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WIRING THE FARM: OPERATIONAL PRACTICES FOR SUSTAINABLE AGRICULTURE

A Group Project submitted in partial satisfaction of the requirements for the degree of Master's of Environmental Science and Management

for the

Donald Bren School of Environmental Science and Management

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The mission of the Donald Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise form scientific or technological decisions.

The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small froups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

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ABSTRACT

Sunnyside Farms, located in Rappahannock County, Virginia, specializes in sustainable agricultural practices. Our project focuses on the design and implementation of an information management system that can help farm managers improve on the previous economic performance of the Farm. The model we have designed is housed in a SQL Server database where data collected daily and weekly for labor, harvest and sales are entered and tracked against the forecasted values for each crop.

The factor that most influenced crops on the Farm this summer was the unusually large amount of rainfall. Of the 19 crops in the model whose season is complete only basil, peaches, and Asian pears met or exceeded their harvest expectations. The Farm's 2003-2004 fiscal year forecast aimed to break even as the first step in becoming profitable. Operating profits were calculated to be $20,027, which is about 18% of their combined revenue. A calorie analysis was conducted that compared the ratio of the amount of fossil fuel energy used to the amount of food calories produced on the Farm. The Farm's ratio was found to be 5:1. Overall the current version of the model is useful as a management tool when considered at the granularity of crop level. However, changes must be made to the model in order to determine the overall economic sustainability of the Farm.

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EXECUTIVE SUMMARY

Since the end of World War II a dominant trend in farming has been to produce a small variety of crops on large parcels of land using synthetic chemicals and a high degree of mechanization. These methods, now standard in conventional agriculture, have resulted in increased crop yields and contributed to the ability of the world to support a growing population.

However, environmental and societal costs are associated with conventional agriculture, and these costs have triggered interest for sustainable farming. Studies of organic farming, closely related to sustainable farming, have shown a decreased dependence on fossil fuels and synthetic inputs while still maintaining comparable yields. Other research has shown organic methods support greater biodiversity, better conserve soil fertility, and have better energy efficiency than conventional methods.

Sunnyside Farms, located in Rappahannock County, Virginia, specializes in sustainable agricultural practices. This is the second year that the Farm has been the subject of a Donald Bren School of Environmental Science and Management Group Project. Last year's group provided an overall accounting of the Farm in terms of the three criteria of sustainability: environmental, economic, and social performance. The group concluded that the Farm performed well according to environmental and social measures but was not profitable and therefore could not be considered a sustainable operation.

Project Scope

Our project focuses on the design and implementation of an information management system that can help farm managers improve on the previous economic performance of the Farm. Our system can be used to assess the Farm's environmental and economic performance and also provides empirical evidence about the consequences of hypothetical changes in production. The model we have designed is housed in a SQL Server database, where data collected daily and weekly for labor, harvest, and sales are entered and tracked against the forecasted values for each crop. The model provides for the management of a complex system of products, labor allocation, and distribution channels. This system of tracking various economic inputs and outputs helps Sunnyside management improve the profitability of the Farm.

During the summer of 2003, two interns worked at the Farm where they designed procedures for data collection by farm employees and gathered data themselves on harvest, labor, and sales activities. Other research included collecting information on historical meteorological conditions and crop yields for Rappahannock and neighboring counties. Data were also collected for past national crop yields, as well as pricing for organic and conventional produce at the national level.

During the fall of 2003, we developed the model in the database through SQL queries in order to retrieve and organize the data so as to be useful for interpretation. Additionally, several analyses were performed including: (1) a comparison of key crop metrics against the projections of the model, (2) a statistical analysis to understand the drivers behind the pricing of organic produce, (3) the use of statistical methods to account

for uncertainty in crop yield, and (4) an estimation of the energy inputs and the energy outputs of the system at Sunnyside. The results identify gaps and opportunities in terms of operating profits, and we make recommendations for more effective processes in terms of data collection, pricing strategy, and crop selection. Further research and analysis are recommended in some cases, and transferability of the model to a larger farm operation is also discussed.

Results

The factor that most influenced crops on the Farm this summer was the unusually large amount of rainfall that caused almost all the crops to fall short of their harvest expectations. It delayed plantings and increased rot and fungal disease. Of the 19 crops in the model whose season is complete, only basil, peaches, and Asian pears met or exceeded their harvest expectations. All other crops fell short.

Although their harvests fell short, most crops commanded a higher price in the market which partially compensated for the lost revenue from the diminished harvest. Of the 22 crops with pricing forecasts, 15 exceeded expectations, many by wide margins. In this regard, the Farm can adjust expected prices upward for several crops for the next fiscal year.

Another factor that helped revenue was that the Farm has improved at selling what it harvests compared to the previous year. Of 33 crops, not all of which are in the model, 21 had sales quantities of over 70% of the amount harvested. Only 6 crops had sales quantities under 50%. The shortfall between what is harvested and what is sold, described by Berry et al. (2003), has been substantially ameliorated this year.

The Farm's 2003-2004 fiscal year forecast aimed to break even as the first step in becoming profitable. The actual labor costs, material costs and revenues have been calculated in the model for the crops that have finished producing for the 2003-2004 fiscal year. Operating profits have been calculated considering labor and material costs only. The overall operating profit for these crops is $20,027, which is about 18% of their combined revenue.

Of the 19 crops whose harvest and sales are currently complete, 12 show an operating profit, meaning their revenue was greater than the sum of their labor and material costs. The three most profitable crops were cherry tomatoes, flowers, and basil, while the three crops that took the biggest losses were peaches, black raspberries, and carrots. The operating profit shown above is encouraging, as it marks an improvement over last year. However, the Farm still has a long way to go to cover the expenses that were not included in the operating profit. The results from next year, assuming that the harvest is closer to average, will give a better idea of the amount of progress that has been made.

An alternative economic performance metric that may be a better measure of individual crop success is per acre profit. The per acre profit ratio is more useful than profit alone because it puts all crops on equal footing by normalizing profit by area. The results are similar to profit alone, except that basil is the top performing crop by this measure, while carrots and eggplant lose the most money per acre.

Harvest Uncertainty

No significant link was found between various meteorological variables and selected crop yields using linear regression. The mean and standard deviation of crop yields reported at the national level were calculated and adjusted to simulate organic yields. The national yields were decreased by 20% from their original value because some research suggests that organic yields are typically about 80% of conventional yields. The Farm yield exceeded the adjusted national yield for cherry tomato production but was below the adjusted national averages for all other crops considered in the analysis. The standard deviations of the arithmetic means can be used as approximations of inter-annual variability of crop yield for specific crops.

Energy Analysis

The metric comparing the ratio of the amount of fossil fuel energy used to the amount of food calories produced on the Farm was calculated and compared to results from previous studies. The input energy measured in the analysis included fuels and electricity, as well as human labor activities. The Farm's ratio of fossil fuel energy consumption to food energy production was 5:1. This ratio is comparable to other ranges quoted by different authors of 3:1 and 10:1 for conventional methods. It was concluded the Farm converts between forms of energy well and the use of unleaded gasoline has the greatest impact on the ratio.

Pricing

A regression analysis of conventional and organic produce prices was done to determine if there was a statistically significant relationship between conventional prices and organic prices, as well as to determine what the actual relationship between these prices is. This relationship represents the price premium organic goods enjoy over conventional ones. At the farm-gate level, the estimated price premiums exceeded 100% for most the Farm's crops. In combination with the regression results, the use of several on-going pricing reports on conventional and organic produce is also recommended to help the farm managers make timely adjustments to pricing.

Model Discussion

Comparing the expected quantities of harvest, labor and sales with the recorded values for these categories shows that discrepancies exist between them. The differences between expected and actual values for the three categories can be explained in part by the meteorological conditions the Farm experienced this year, but improving their accuracy in future years should be a major priority for the Farm.

Adjusted national means of crop yield have been included to help management approximate how much yield to expect for many of Sunnyside's crop. The standard deviations of the adjusted means also provide a measure of year to year variability in crop yields and will allow high and low estimates to be created.

As more annual data are collected the possibility exists that specific trends could become evident about crop specific labor activities or labor activities per acre. Currently the distributions of labor are based solely on the data for this fiscal year, a relatively small dataset, making it difficult to account for the effect of extraneous variables on labor versus production related tasks. There is also an absence of outside information detailing expected labor hours per activity or area, so the best estimates of these parameters are still going to come from Farm managers.

Overall the current version of the model is useful as a management tool when considered at the granularity of crop level. Recording activity and harvest data at the crop level allows for the calculation of per crop or per acre profit for all of the Farm products. Using the per acre profit as the primary measure of economic performance enables managers to determine those crops that should continue to be grown and those that should be eliminated.

Changes should be made to the model in order to determine the overall economic sustainability of the Farm. Some crops produced on the Farm are not incorporated into the profit calculations, so overall operating profits could vary. Additionally, overhead costs are not incorporated into the model, and these must be included to determine the overall profitability of the Farm. Accounting for all crops and costs will make the model a more effective tool for management to guide the Farm to becoming truly sustainable.

1.0 INTRODUCTION

This is the second year that Sunnyside Farms has been the subject of a Donald Bren School of Environmental Science and Management Group Project. Sustainable and organic agricultural practices are incorporated at the Farm. Last year's group provided an overall accounting of the Farm in terms of the three criteria of sustainability: environmental, economic, and social performance. The group concluded that the Farm performed well according to environmental and social measures but was not profitable and therefore could not be considered a sustainable operation. Our project builds upon the analysis begun last year by focusing on an information management system for the Farm. Because of the difficulty of handling complicated, spatially and temporally distributed information, most agricultural operations simplify, either by remaining small or by concentrating on a few crops. Our system keeps track of detailed data. It may be used to assess the Farm's economic and environmental performance, and it provides empirical evidence about the consequences of hypothetical changes. Our analysis leads to conclusions that may be used to improve the profitability of the Farm, helping it become sustainable.

1.1 Significance

Agriculture has changed dramatically over the past century, especially since the end of World War II. Food and fiber productivity have soared because of new technologies, mechanization, increased chemical use, specialization and government policies that favor maximizing production (Feenstra, 1997). The time period after WWII may be thought of as the beginning of modern, industrialized practices in agriculture, involving the production of a small variety of crops on large parcels of land. Synthetic chemicals are used extensively, and a high degree of mechanization is incorporated into farm operations. These agricultural practices, hereafter referred to as conventional farming, have resulted in significant increases in crop yields, contributing to the ability of the world to support a growing population.

These conventional farming practices have become dominant in agriculture because they employ a logical business model. In business, a competitive advantage can be obtained either by delivering the same benefits as competitors but at a lower cost, or by delivering benefits that exceed those of competing products. In the first case, conventional farming practices that specialize in a limited number of crops at high volumes obtain economies of scale and minimize costs. In the second business example, high-quality products are sold at higher margins through the use of many synthetic chemicals that enhance the appearance and longevity of crops. The cost advantage that conventional farming enjoys makes sense from a business standpoint. The sustainability of conventional farming methods, however, remains a disputed issue.

Summing all the various types of energy sources used in the United States for food production, processing, distribution, and preparation results in a use of approximately 423 gallons of oil equivalents per capita per year (Pimentel, 1996). System inputs contribute to the intensive energy use of conventional farms. Synthetic fertilizers and pesticides are used to maintain soil fertility and manage pests, but the chemicals take large amounts of energy to produce. Farm machinery powered by fossil fuel energy is used to till and harvest the crops. Finally the products are prepared, packaged and often shipped long distances, with each step in this chain requiring fossil fuel energy inputs. Conventional farming methods, like those employed in the U.S., result in larger crop yields but also in a greater dependence on fossil fuels.

Conventional practices have led to a decline in the diversity of crops cultivated. Pimentel (1996) estimates that 90 percent of the world's food supply comes from only 15 species of crop plants and 8 species of livestock. More recently the Sustainable Agriculture Network (http://www.sare.org) found that corn, soybeans and wheat account for nearly 80% of the annual crops produced in the U.S. The lack of crop diversity increases risk from a management standpoint because if one particular species of plant or livestock becomes susceptible to a pest, the production loss is enormous.

Conventional methods have had many positive effects and have reduced risk in farming, but there have been significant costs. Prominent among these are topsoil depletion, groundwater contamination, the decline of family farms, neglect of the living and working conditions for farm laborers, increasing costs of production, and the disintegration of economic and social conditions in rural communities (Feenstra, 1997). Because of these negative externalities, there has been a return to more sustainable farming methods in the last two decades. Sustainable agriculture is defined in the 1996 Farm Bill as an integrative system of plant and animal practices having a site-specific application that will, over the long term: satisfy human food and fiber needs; enhance environmental quality and the natural resource base upon which the agricultural economy depends; make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm operations; and enhance the quality of life for farmers and society as a whole (USDA, 1997). Many challenges are inherent to practicing agriculture according to this definition, and therefore it is necessary to understand what has caused this movement to gain momentum.

In comparison with conventional farming, sustainable farming supports the assumption of being the best alternative. Our group project has relied on data collected through studies of organic farming systems because they are closely related to sustainable systems in their operational practices. In one study carried out over a 21-year period on farming systems in Central Europe, organic and conventional farming systems were monitored and data collected on crop yield, inputs, and fertility measures. The study found that although crop yields were 20% lower in organic systems, input of fertilizer and energy was reduced by 34-53% and pesticide input by 97% (Mader et al., 2002). Other research has found that organic farming supports greater biodiversity, better conserves soil fertility and stability, and has lower energy consumption and higher energy efficiency (Stolze et al., 2000). The reduction of inputs like synthetic chemicals leads to less reliance on fossil fuels to produce food.

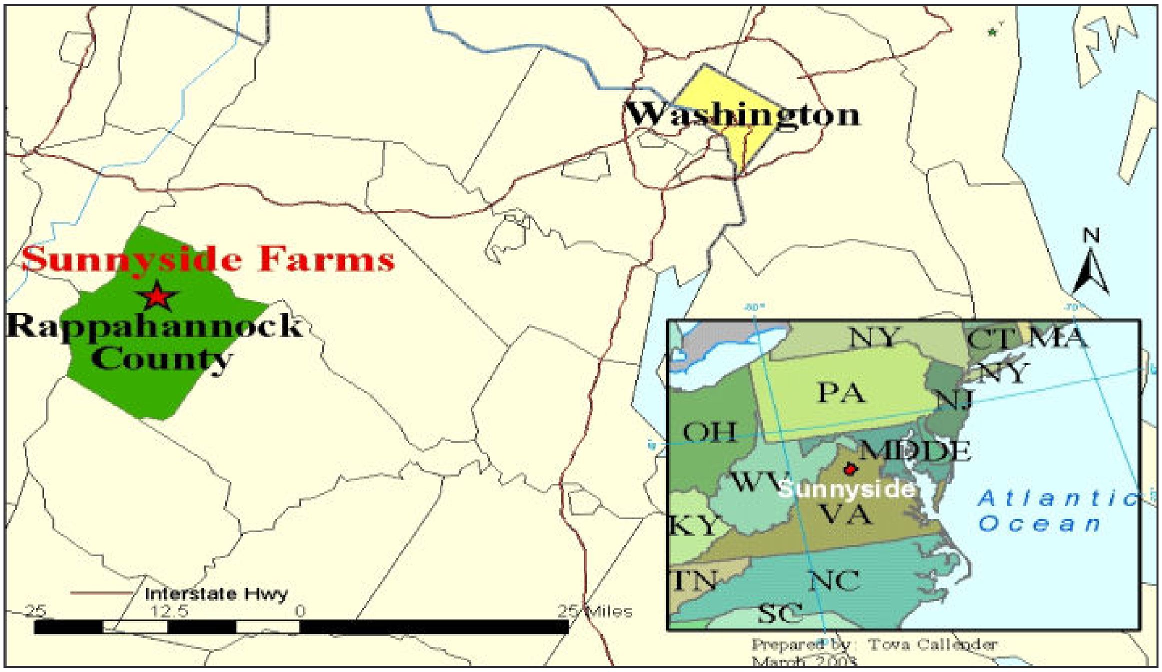
There is more to the increasing trend of organic farming than concerns over sustainability. According to a consumer survey (Hartman Group, 2000), the reasons for consuming organic products are: health and nutrition (66%), taste (38%), environment (26%), and availability (16%). Organic farming methods use less synthetic fertilizers and, therefore, are perceived as producing products that are less threatening to human health.

According to the most recent USDA estimates, U.S. certified organic cropland doubled between 1992 and 1997 to 1.3 million acres. Preliminary estimates for 2001 suggest that certified organic acreage significantly increased between 1997 and 2001. It would seem that many farmers have recognized the market potential of growing organically because over 800 new organic products were introduced in the first half of the year 2000 (Myers and Rorie, 2000). Both trends clearly reflect the growing consumer preference for healthier food, and thus organic foods and natural products continue to gain market share and acceptance.

Environmental factors, risk reduction, and consumer preference alone cannot make the case for larger-scale organic farming without a management system that allows the farm managers to analyze crops, acreage, labor allocation and pricing, as well as to improve the environmental management of the farm. Sunnyside Farms represents a successful departure from conventional farming and is a significant example of what is possible in organic agriculture. The Farm has yet to become profitable, hence this project's goal to develop and implement an information management system that can track the information needed for improved decision making, which will result in a profitable, sustainable agricultural operation.

1.2 Project Setting

Figure 1-1. Location of Sunnyside Farms



Located in Rappahannock County, Virginia, approximately 70 miles west of Washington D.C (Figure 1-1), Sunnyside Farms is in the northern Blue Ridge province, a rugged province with steep slopes, narrow ridges, broad mountains, and high relief (Berry, 2003). A recent survey by the Rappahannock River Basin Authority showed Rappahannock County land use as about 56% rural, 42% in conservation areas and 2% residential, with about 29,000 acres in wetlands. The climate of the area is temperate, with an average annual rainfall of 41.8 inches and an average annual temperature of 52.7°F (11.5 °C) (World Climate, 2004).

Figure 1-2. Detail of Main Farm

The Farm was established in 1747 when the land was deeded by Lord Fairfax under orders from King George to Henry Miller. Descendants of the Millers managed the Farm until 1996 when the remaining 600 acres of land were sold to David and Maggie Cole. The Coles took possession of the land and began its conversion from a conventional agricultural operation to an organic one. Figure 1-2 shows a map of the Farm that has been generated by our project, detailing the current land uses on the Farm. The initials on the map denote the names of the many plots present on the Farm. The tree fruit is located upslope from other perennial crop plots. Livestock grazing areas and water catchments are located at the lower elevations of the Farm. The Coles have worked to transform the land into a productive farm that produces more than 200 varieties of fruits and vegetables, poultry and eggs, cut flowers and livestock. The original buildings on the

Farm, including the main house where the Coles now reside, have been restored, and Sunnyside Farms is striving to become a leading example of a successful organic, sustainable operation. As last year's Group Project illustrated, all of the crops on the Farm are grown organically, and the Farm is environmentally sound. The Farm has yet to become profitable though, so by definition it is not truly sustainable.

1.3 Sunnyside Farms Group Project 2003

The previous Sunnyside Farms Group Project, *Tracking the Way Toward Sustainable Agriculture: Linking Economics and Ecology at Sunnyside Farms* (Berry et al., 2003), assessed the environmental performance of the Farm and made recommendations as to how Sunnyside can become a more sustainable operation. The scope of the project was to analyze the Farm's environmental performance, including energy consumption, nutrient inputs and export, soil quality and erosion levels, and water usage, as well as its economic performance, including harvest, crop profitability and management practices. The project provided a snapshot of the Farm with the goal of establishing baseline data as a precursor to a longer-term assessment.

In order to analyze the economic productivity and environmental impacts of the Farm, the project team developed a whole-farm tracking system that traced all inputs and outputs, including environmental and management categories. Environmental components included soil, water, nutrients, and energy whereas management components included finances, labor, and harvest (Berry et al. 2003).

The conclusions made by the Bren team prompted Farm managers to evaluate their methods and behaviors in light of the information provided by the project. By using this new information in correlation with past management decisions, the managers would be able to improve sales, cut costs, and make better informed decisions in the future. Aside from making recommendations as to how the Farm can improve its economic and environmental performance, the project addressed the overall sustainability of the Farm with respect to the "sustainability triangle," three components are ecological, social and economic performance. The Bren team's conclusions regarding the sustainability of the Farm are:

> "Ecologically, the Farm is capitalizing on the benefits typically associated with organic farming. Soil health is good, nutrient management is efficient, energy use is lower than the national average, water use is within the resources of the watershed, and crop diversity is high." Socially, the Farm strengthens the link between people, their food and the land on which food is grown by selling through local markets and businesses. The Farm also provides a relatively chemical-free environment for its employees. Economically, the Farm has yet to develop into a position where it is profitable and self-sufficient. Specifically, the Farm needs to decrease the disparity between what is grown and what is sold if sustainability is to be achieved in all three areas." (Berry et al., 2003)

2.0 OBJECTIVES

The first objective of our project was to create a database to improve information processing on the Farm. Sunnyside Farms produces a diverse array of products, which include fruit, vegetables, cut flowers, and livestock. Each product has certain characteristics that must be accounted for or tracked. To better illustrate this point, consider the typical tasks associated with growing a potato. The soil where the potatoes are to be grown must first be prepared, which may include activities like weeding or adding organic fertilizers to replenish the nutrients. The seeds need to be planted at a time when the probability of an extreme weather event that may be detrimental to maturation is low. The field needs to be monitored for signs of fungal or pest infestations. The crop then needs to be harvested and prepared for sale. If potatoes were the only crop on the Farm, then the need for a data management system may not be apparent because the managers would only be concerned with one individual crop. This is not the situation at the Farm because of the large variety of products grown. A database system that is capable of storing and presenting information in useful forms is essential for the management of the Farm. Without this mechanism for information storage it would be nearly impossible to account for what is occurring on the farm, and therefore the Farm could not manage labor, track harvests and revenues, or plan for next year's activities.

The second objective of our project was to develop and implement a database model for farm management. The model is housed in the database and tracks expected quantities of harvest, labor hours, prices and sales receipts against the actual values for the current fiscal year. Since this year is the baseline year for the model, our group will need to assess the accuracy of the current predictions. Without a systematic way of forecasting yield, it is difficult to determine how much of which crops to plant, the amount of labor to allocate throughout the year, and how much of each crop that could be sold in the market. The model provides for the successful management of a complex system of products, labor allocation, and distribution channels.

The third objective of our project was to analyze the acreage of the signature crops produced on the Farm, how labor was allocated to care for these crops, and the pricing scheme used to maximize sales at the Farm. Implementing a new system for tracking information requires taking into account current farm practices with regard to crop acreage, labor allocation, and pricing strategy. A new system cannot be recommended without an understanding of how decisions are currently being made and what strategy is behind these decision-making processes. In order to understand the current system, an analysis will be made of crop acreage, labor allocation, and pricing.

The fourth objective of our project was to improve the environmental management at Sunnyside Farms. Accordingly, an analysis of the use and production of energy on the Farm was performed, which uses data stored in the database. A comparison was then made between energy use at Sunnyside Farms and energy use at a conventional farm. The analysis determined the number of calories that the Farm uses to create one calorie of produce and compared this value to the use of calories in production at conventional farms. The comparison is significant in determining the environmental impact of Sunnyside Farms compared to conventional farming in regard to energy use.

3.0 METHODS

3.1 Data Collection

Populating the database with data from the harvest, labor, and sales activities on the Farm requires that they first be recorded accurately. During the summer of 2003, two group members worked at the Farm where they designed procedures for data collection by farm employees, creating logs for both labor activities and harvest. Farm employees complete these logs daily, and the logs are given to Farm mangers to be entered into the database manually. The crop harvest log (Figure 3-1) has been included to show what information the employees must communicate to management. The harvest log includes the crop and variety harvested, the employee who harvested the crop, the plot location, quantity and units of harvest.

Figure 3-1. Crop harvest log

Daily Crop Harvest Log
Filled out by:
Date:

Block/Plot	Person/Crew	Crop	Variety	Quantity Harvested	Units

The daily activity log is similar to the daily harvest log in that employees are responsible for its completion (Figure 3-2). Recorded on this log are the labor hours spent each day per activity. Activities pertinent to the project analysis are classified into five categories: planting, harvest, cleaning and packing, which are crop specific, and infrastructure and general care, which are related to acreage.

Figure 3-2. Activity log

Daily Activity Log
Employee: Date:
Supervisor:

Crop	Activity	Location	Hours

Activity Codes
PL-- Planting GC-- General Care HV-- Harvest CP-- Clean/Pack INF-- Infrastructure OFF-- Off-Farm SA—Sales

Sales data are aggregated weekly instead of being recorded in a daily log and are entered by one of the sales team into the database. In the revenue table of the database, each sale is assigned a unique identification number. Other fields included with each sale are the product, date, category, quantity, price received and units. The category of each sale is defined as either retail, wholesale, cider, or shrink. Cider is applicable only to the tree fruit crops and represents all “value added” products, such as apple or peach cider, apple sauce, and apple butter. Shrink in this context is when produce that has already been sold is returned. The units of each sale may vary depending on the product. Due to the differences of units in some of the sales, a conversion table that gives standard weights for containers used for the Farm’s activities has been included in the database.

Spatial data detailing the land uses on the Farm were collected over the summer using a global positioning receiver (GPS) to record coordinate points of crop and orchard rows, as well as field and building perimeters. This information was appended to the information collected by last year’s project in order to update the maps that were created using ESRI’s ArcView GIS software.

Data were collected for statistical analyses used to achieve the project objectives. These data were collected by the group members using a variety of methods. Historical information about meteorological conditions for Rappahannock and neighboring Virginia counties was retrieved from the National Climatic Data Center website (http://www.ncdc.noaa.gov/oa/ncdc.html). Past crop yields were accessed through the National Agricultural Statistics Service (NASS) website (http://www.usda.gov/nass/). Organic and conventional produce prices were provided by USDA’s National Agricultural Statistics Service (NASS), USDA’s Agricultural Marketing Service (AMS) (http://www.ams.usda.gov/), and Organic Food Business News, a private source of weekly low and high farm-gate prices for selected organic commodities.

3.2 Data Analysis

Two methods were used to analyze the data. The first uses queries written in SQL to retrieve and organize the data in the database into useful information. The second method involves the use of statistical methods to either calculate summary statistics or determine if any significant relationships exist between variables on interest.

The stored data on harvest, labor, and sales are analyzed by writing queries in SQL. The result of a query is a set displayed in the same format as a table. Queries are useful because once they are written, they update automatically with the infusion of new data into the database. The only task a user needs to do to update the query is open its view in the database. Queries provide a way to perform an analysis of the data and present it in a useful form for the management to gauge the performance of the Farm. This method is an improvement over a more traditional method of adding up all the revenues and expenses at the end of the fiscal year to determine whether or not a profit has been achieved. As long as the data in the database are current, the queries will be as well.

A Geographic Information Systems (GIS) has been used to assist in the spatial analysis of the Farm. The data collected using the GPS receiver are stored in tables similar to those of the database. Queries may be written in GIS that return information on land uses and acreages. This helps with the overall analysis of the Farm because patterns may be detected as to how some activities vary spatially. GIS may also be employed as a platform to create visual images of the Farm, complete with building and crop locations.

Additionally, statistical analyses were performed by this year's project. Summary statistics were compiled on crop harvest and labor hours spent per activity. These values were compared with the forecasts included in the predictive portion of the database model. The results show accuracy of the predictions of the Farm management for the fiscal year.

Because of the relative infancy of the Farm and the current approach to data collection, accuracy of harvest, labor, and sales predictions is expected to be somewhat limited. In anticipation of this outcome, regressions were used in an attempt to better predict future outcomes. Regressions were carried out for both harvest quantity and pricing strategy. For harvestable goods, we hypothesized that meteorological variables will have an effect on the quantities produced. Regressions were performed to determine if significant relationships exist between particular annual or seasonal weather variables and quantities of crops produced in a season. Regressions using organic and conventional prices were also carried out. If a significant relationship is found with these variables, it may show a premium the Farm enjoys by growing organically.

The environmental performance of the Farm is in part determined by the energy analysis. The metric of the analysis is a ratio of energy calories used to produce one food calorie on a crop by crop basis. Database queries are used to relate and total the caloric information at the needed scale. Aggregating the ratios over all products determines the total metric for the Farm on an annual basis. This ratio was compared to a similar ratio for conventional farming operations to assess the relative size of the Sunnyside's ecological footprint.

3.3 Database

3.3.1 Purpose and Approach

The primary purpose of using a relational database for this project is to provide the Farm with a system to track daily activities, mainly labor, harvest and sales. It is also used to aid in the reporting and presentation of these data, which will ultimately serve to make farm management decisions. The database is a Microsoft SQL Server database and uses a Microsoft Access interface to view the tables and write the queries. A relational database has the advantage of being able to link together the common aspects of separate datasets, allowing aggregations of the data to bring together information from different datasets.

3.3.2 Contents

The database contains three tables that are updated consistently with new data: harvest, labor activities, and sales. They are all linked together by the crop involved in the recorded transaction. Taking apples as an example, there is an entry in the labor table each time a laborer does work on apples, one in the harvest table each time apples are harvested, and one in the sales table each time a sales transaction occurs involving apples. Additionally, there are several tables that contain the forecasts in the model for the current fiscal year. The remaining tables consist of external datasets that are useful for our analysis, such as national organic and conventional produce prices and information on the amount of calories in various types of produce.

3.3.3 Crop Hierarchy

Because Sunnyside grows so many varieties of produce (close to 200), the crops are grouped into a hierarchy. The product lines, including tree fruit and berries, are at the top of the hierarchy. Some crops are grouped together in smaller categories like herbs. Next is the individual crop level, and lastly the varieties within each crop. This hierarchy allows data to be grouped together at different levels of granularity.

3.3.4 Queries

The raw data only become meaningful when they are aggregated together through queries. Several key queries track the actual harvest, labor, and sales against what was forecasted in the model. They detail a week-by-week comparison, allowing farm managers real-time feedback on how well goals are being met.

3.4 Harvest

The harvest forecast values that are included in our database are based on the farm managers' experience of what has happened previously on the farm. They do not necessarily incorporate climatic uncertainty. To account for the effects that meteorological variables may have on the quantity of harvest, we used an approach similar to that of Sarker (2003) and Kandiannan (2002). Their methods assume a linear relationship between crop yield and weather and use regression techniques to quantify the parameters of the relationship. Our approach begins with a predicted hypothesis:

$$Y_i = \alpha_0 + \alpha_1 X_i + \varepsilon_i$$

This equation assumes the yield for the i^{th} crop, Y_i, is a function of an observed meteorological variable, X_i. The primary variables considered in our approach are monthly values for minimum average temperatures, maximum average temperatures, precipitation, heating degree days and cooling degree days. These were used in step-wise regression with corn yield data of Rappahannock and surrounding counties located near the Farm in Virginia. Corn yield was used because of the availability of historic data that could be compared against historic weather observations. We hypothesized that if a relationship were found between corn yield and weather variables, it may be extrapolated across other crops.

A second approach to improving upon the forecasts of farm management is to collect historic yield data available from the USDA and calculate summary statistics for the datasets, assuming a normal distribution of the yield observations. The arithmetic mean for each crop may then be extrapolated to the Farm by adjusting it accordingly. This approach borrows from a European study that found that organic farm yields were usually about 20% lower than conventional farm yields (Mader et al., 2002). Using the assumption that organic yields will be about 80% of conventional yields provides an initial approximation for the Farm management for crop harvest.

A third approach used the standard deviations of the arithmetic means calculated from national level crop yield data between 1978 and 2001 as estimates for high and low production amounts. Once again our group assumed that the Farm yield would be about 80% of conventional yield. After the adjusted mean was calculated, the percentage value of standard deviation was used to develop high and low estimates of yield for the Farm.

3.5 Pricing

Currently, the Farm has an informal pricing system in which local market conditions are the main criteria to define price levels. This works on a daily basis but has limitations from a longer-term forecasting perspective. In this regard, understanding the price relationship between organic produce and conventional produce, and defining the Farm's pricing position with respect to these two price references, would help the farm managers to have a more accurate prediction of future prices and make adjustments using organic and conventional prices as a benchmark.

Conventional price data are reported by USDA's National Agricultural Statistics Service (NASS) (http://www.usda.gov/nass/) and USDA's Agricultural Marketing Service (AMS) (http://www.ams.usda.gov/) on monthly and daily bases. However, the USDA has not been systematically reporting organic prices. As per USDA Economic Research Service (USDA, 1998), historical data on organic produce prices are only available from *Organic Food Business News,* a private source of weekly low and high farm-gate prices for selected organic commodities. According to the same source, this is the best available data to represent average national prices in fresh organic produce until a regular public program of organic price data collection is established at the federal level. One of the strengths of these organic price data is that they have been reported consistently for the past several years, allowing some analysis of price premiums between organic and conventional produce. USDA-NASS reports US average fresh produce prices for the most common commodities monthly, whereas Organic Food Business News reported on a weekly or semimonthly basis. In the absence of organic production data, which could be used to calculate weighted average prices, a simple monthly average of the low and high prices reported by Organic Food Business News was calculated. The gaps in the time series are indicative of the seasonal supply variability in the market.

Conventional and organic pricing data at the farm-gate level for the years 1998, 1999, 2000, 2001, and 2002 were gathered from USDA-NASS and *Organic Food Business News*. A regression analysis using S-Plus software was done to establish a statistical relationship between conventional and organic prices at the national level. The parameters of the model are:

$$Y_i = \alpha + \beta X_i + \varepsilon_i$$

Y_i is the organic price for the i^{th} commodity, α is the intercept equal to zero, β is the price premium for organic produce, X_i is the conventional price for the i^{th} commodity and ε_i is the residual error.

This model can be used by the farm managers to make timely adjustments to their prices by looking at conventional produce prices published by USDA and adding the premiums for organic produce. In addition, there are two other sources of pricing information that can be used as a reference to make price adjustments. USDA AMS reports daily farmers market prices (with no distinction between conventional and organic) for several areas in the East Coast and since January 2003. The Rodale Institute is offering their Organic Price Index (OPX) (http://www.newfarm.org/opx/index.shtml), which is a comparison of terminal market, other wholesale and selected large-scale retail prices for organic and conventional foods. OPX prices include farm-gate prices, transportation costs, and wholesaler mark-ups, as opposed to our regression analysis, which only considers farm-gate prices.

3.6 Energy Analysis

To help assess the Farm's environmental performance and track the energy consumption/production ratio, the following information has been gathered or calculated for the Farm: caloric data on fossil fuel consumption, electricity consumption, human effort, and calories of produce harvested. No other sources or uses of energy have been taken into account due to limited data availability. Our analysis does not consider the energy required to produce fuels, electricity, or to feed laborers. This calorie analysis will allow farm managers to compare, year to year, the energy in vs. the energy out of the system. It will also allow them to identify potential areas for energy reduction on the consumption side, which will eventually include the use of renewable energy. It will serve as a dashboard of information on energy consumption and production.

$$\text{Ratio of } \frac{\text{energy consumption}}{\text{production}} =$$

$$\frac{\text{Fossil fuel consumption} + \text{Electricity consumption} + \text{Human effort}}{\text{Total energy content in produce harvested}}$$

3.6.1 Energy Consumed: Fossil Fuels

Currently, the Farm utilizes liquid petroleum gasoline (LPG), diesel fuel and unleaded gasoline in Farm vehicles and buildings. The Farm maintains a fuel depot where all cars, trucks, tractors and other farm machinery fill up. Each vehicle has a coded card that is necessary in order to operate the fuel station. When a vehicle fills up, the vehicle code, date, time, fuel used, and quantity are recorded in a computer within the depot. This information is then transferred to the database, where gallons of fuel are converted to calories using the following conversions from the U.S. Department of Energy:

Table 3-1. Energy conversions

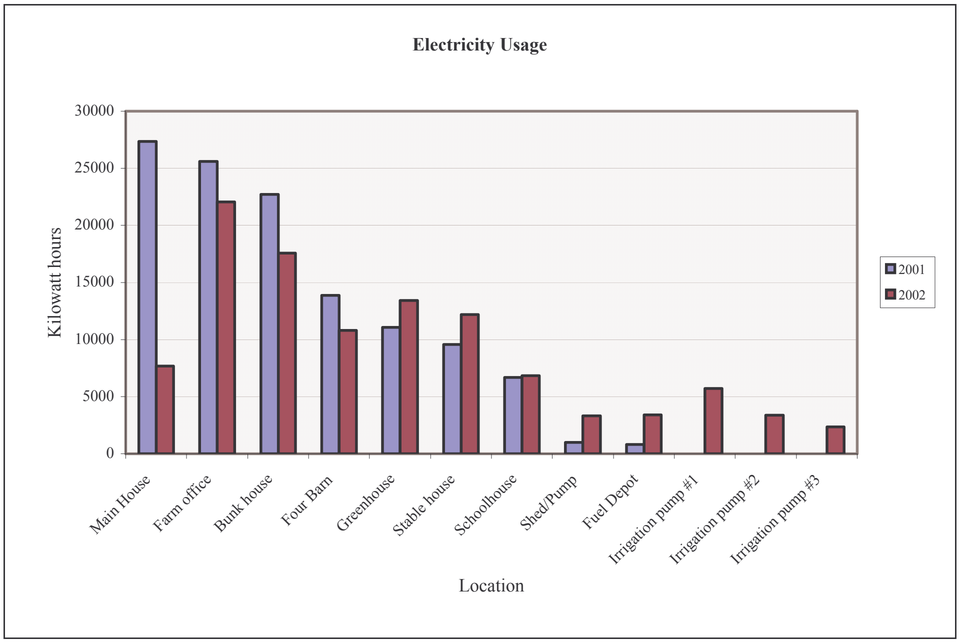
Fuel	kcal/gallon
Unleaded Gasoline	3.13×10^4
Diesel	3.30×10^4
LPG	2.44×10^4

Fuel consumption is then totaled on a per year basis for comparison purposes. Farm operations used a total of 12,034 gallons of petrol-based fuels in 2001, costing $18,131, including necessary annual infrastructure expenses, such as repairs, service and rent (Berry et al., 2003).

3.6.2 Energy Consumed: Electricity

The Farm utilizes electricity from Allegheny Power, located in Virginia. Data for electricity usage were obtained from utility bills, which detail usage in kilowatt-hours (kWh) and entered into the database. Due to incomplete data, electricity usage for billing cycle Jan-Feb 2001 was assumed to be equal to what was used for the same time period in 2002, to allow comparisons to be made. According to data collected in 2001, Farm operations used 118,685 kWh. In 2002, operations decreased slightly to 108,691 kWh. These figures are converted to calories for this analysis using an equivalent of 860 Kilocalories per kWh, estimated by the U.S. Department of Energy (Berry et al. 2003). Figure 3-3 displays electricity consumption at different metered Farm locations by year.

Figure 3-3. Electricity usage by meter



3.6.3 Energy Consumed: Labor Activities

Farm activities are divided into five categories: Planting, Harvesting, General Care, Cleaning and Packaging, and Infrastructure, each demanding different levels of effort from farm workers. The Compendium of Physical Activities (CPA) (Ainsworth et al. 2000), which was developed for use in epidemiologic studies to standardize the assignment of caloric intensities in physical activity questionnaires, was used to assign caloric consumption to each category using the best approximation to similar activities. The source for caloric consumption assigned to the activities in the Compendium is based upon direct calorimetric measurements (movement sensors) on single subjects, or small samples of young, healthy, non-physically impaired adults.

Each farm worker was assigned a standard weight of 70 Kg (154.3 lbs) and caloric consumption by farm workers was estimated to have the following values:

Table 3-2. Calories per labor activity

Activity	CPA Activity	Calories/hr-kg	Calories/hr-worker
Clean/Pack	Wash dishes standing	2.3	161
General Care	Trimming shrubs, trees, manual cutter	4.5	315
Harvest	Picking fruit of trees, picking fruits/vegetables, moderate effort	3.0	210
Infrastructure	Driving tractor	3.0	210
Planting	Planting seedlings, shrubs, and trees	4.5	315

3.6.4 Energy Produced

The total agricultural production of the farm is aggregated per year and the pounds of the different crops produced are converted to calories using the following values estimated by USDA:

Table 3-3. Calories per pound of crop variety

Crop	kcal/lb	Crop	kcal/lb
Apples	266	Kohlrabi	122
Artichokes	213	Leeks	64
Arugula	113	Lettuce	65
Asian pears	190	Melon	154
Asparagus	40	Okra	141
Basil	122	Onions	173
Beets	140	Oregano	1388
Bell peppers	122	Parsley	163
Blackberries	236	Peaches	194
Cabbage	59	Peas	367
Carrots	195	Peppermint	318
Celeriac	56	Potatoes	422
Chard	91	Radicchio	104
Cherry Tomatoes	107	Raspberries	221
Chives	144	Shallots	327
Corn	340	Spinach	104
Cucumbers	54	Strawberries	126
Currants	286	Suckling Pig	1040
Eggplant	128	Summer squash	200
Eggs	680	Sweet Peppers	91
Fennel	44	Sweet potatoes	345
Garlic	676	Thyme	27
Gooseberries	200	Tomatoes	96
Hot peppers	181	Turnips	110
Kale	136	Watermelon	146

4.0 RESULTS AND DISCUSSION

4.1 The Model

The farm model, which forecasts harvest, labor, and revenue for fiscal year 2004 (July 1, 2003 – June 30, 2004), contains estimates for 29 crops. Of these 29 crops, the harvest has been completed at the time of this report for 19 of them. In this section several metrics for the crops will be compared against what was projected by the model. Not all of the crops are included, as this section attempts to highlight the important findings. Furthermore, it should be noted that in the profit calculations two costs categories are considered. The first is the labor cost for the given crop, which sums the total amount of labor hours spent on the crop and is multiplied by the Farm's wage rate of $7.15 per hour. The second is the amount of money spent on material expenses. In the calculation of the actual profit for this fiscal year, only the amount spent on labor that has already occurred is included. More money might be spent on general care labor in the spring for a crop that has already earned all of its revenue for this fiscal year. This additional labor would diminish the operating profit for the crop. The assumption with these calculations is that for the crops whose harvest is complete, most labor costs have already been incurred.

Sometimes labor like general care, which mainly consists of weeding, is applied to multiple crops simultaneously and recorded at the Product Line level. An example would be if a laborer weeded both blackberries and raspberries and the labor was recorded as general care for berries. In the calculations for labor costs, labor attributed to a Product Line was divided among the crops of that Product Line based on their proportion of the total acreage for that Product Line.

Probably the most striking result of the model is that very few crops met their harvest expectations and many fell short by a wide margin. Most of this shortfall was due to the unusually large rainfall experienced on the farm over the summer of 2003, 17.95 inches over the months of June, July, and August (National Climatic Data Center at: http://www.ncdc.noaa.gov/oa/ncdc.html). This compares to a historical average of only 12.72 inches over the same three months with a standard deviation of 4.22 inches, putting the summer of 2003 in the 89th percentile of rainfall (National Climatic Data Center at: http://www.ncdc.noaa.gov/oa/ncdc.html). The rain affected almost every crop (except flowers and basil) albeit to varying degrees. Crops with a soft exterior like berries, tomatoes, and peppers were actually physically damaged by the force of the rain. All crops experienced much greater incidences of either rot or fungal disease. However, an even bigger problem was that the rain caused plantings to be either delayed or canceled because the soil was too wet. Some crops like tomatoes and peppers can have multiple plantings and harvests in a season. Last summer the second pepper planting and the fourth tomato planting were delayed three weeks. The second melon planting never made it into the ground. These events explain a large part of the harvest deficiency in some of the following crops.

4.1.1 Cherry Tomatoes

Cherry tomatoes were one of the largest revenue generators this year for Sunnyside, as well as having the second highest profit per acre. They were also one of the most successful crops in terms of meeting the model's expectations. Currently, cherry tomatoes are grown on 0.25 acres. Table 4-1 is an aggregate of several performance metrics.

Table 4-1. Forecasted vs. actual values for cherry tomatoes

Cherry Tomatoes	Forecast	Actual	Difference	Unit
Harvest	900	679	-221	flat
Harvest Per Acre	3,600	2,716	-884	flat/acre
Labor Total	575	460	-115	hour
Revenue (Retail)	$8,100	$10,178	$2,078	
Revenue (Wholesale)	$4,500	$3,888	-$612	
Revenue (Total)	$12,600	$14,066	$1,466	
Operating Profit	$6,588	$9,001	$2,413	
Profit per Acre	$26,353	$36,005	$9,653	.25 acres
Pricing (Retail)	$18.00	$30.00	$12.00	$/flat
Pricing (Wholesale)	$10.00	$19.44	$9.44	$/flat
Distribution (Retail)	50%	63%	13%	
Distribution (Wholesale)	50%	37%	-13%	

Though the harvest for cherry tomatoes fell short of expectations, about 75% of the forecast, they compensated in other areas to exceed revenue and profit expectations. Most notably, fewer hours were spent on labor than predicted and higher prices were commanded from the market. Additionally, a greater percentage was sold through higher-priced retail channels than forecasted. Out of the 679 flats that were harvested, 539 or 79.4% were sold. This is a very good sold-to-harvested ratio considering that cherry tomatoes are perishable and must be sold fairly soon after harvest. The harvest most likely failed to meet expectations because of the rain experienced on the Farm this summer, which either physically damaged them or caused them to rot on the vine.

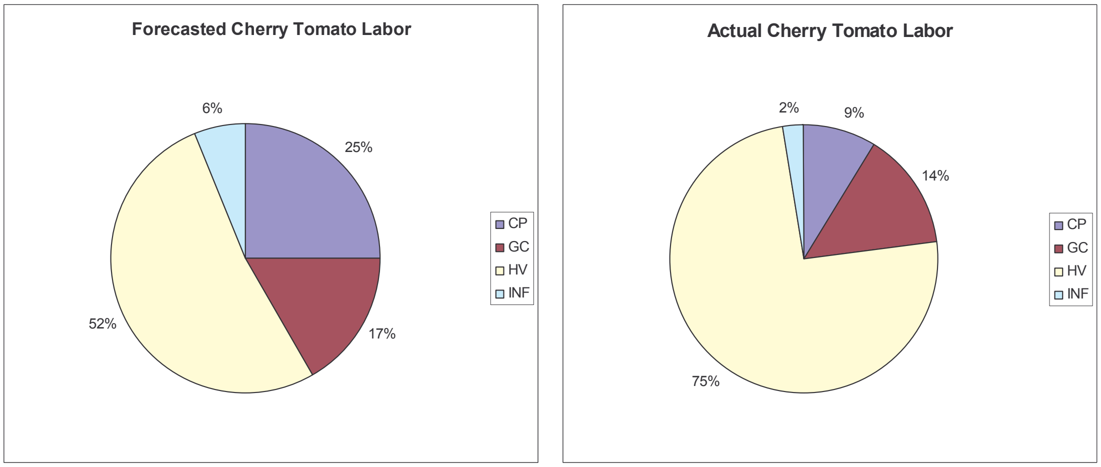
Labor Comparison

Table 4-2 and Figure 4-1 display a further breakdown of the distribution of labor, as well as a comparison to the forecasted labor for each category. A higher percentage of labor was spent harvesting than forecasted, though the actual harvest labor exceeded the predicted by only about 40 hours or 14%. Less time was spent on the other three categories than was expected. For cleaning and packing, this was most likely due to the fact that cherry tomatoes can be packed into flats as they are harvested leading to a lower expenditure of labor on this activity.

Table 4-2. Forecasted vs. actual labor for cherry tomatoes

Cherry Tomatoes	Forecast Hours	Actual Hours	Difference
Clean & Pack	144	41	-103
General Care	96	66	-30
Harvest	300	342	42
Infrastructure	35	11	-24
Labor Total	575	460	-115

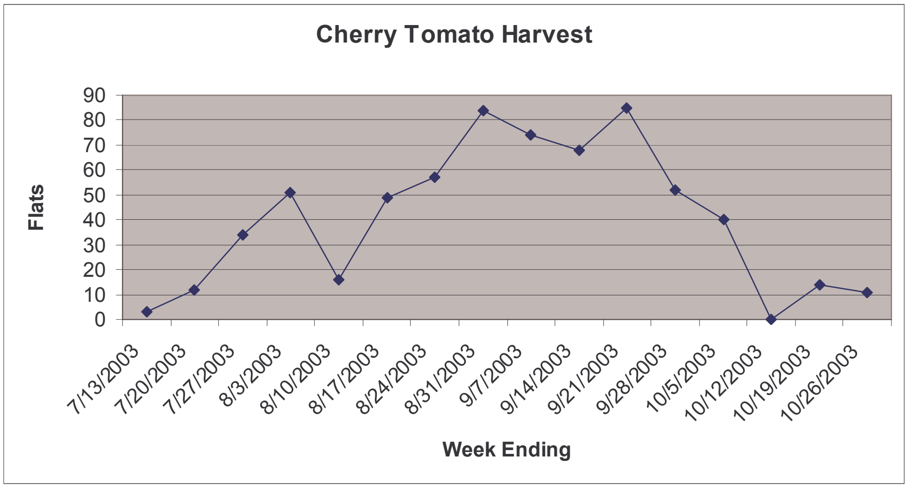
Figure 4-1. Forecasted vs. actual labor for cherry tomatoes



Timing of Harvest

The harvest season for cherry tomatoes was predicted to last from 7/21/2003 to 10/12/2003. As Figure 4-2 shows, the actual season correlated closely to the one in the model, exceeding it by a week or two on each end. The harvest also shows a peak over the month of September.

Figure 4-2. Seasonal progression of cherry tomato harvest



4.1.2 Apples

Apples are one of the most important crops at Sunnyside with over twenty different varieties growing on about 14 acres. Apples had the single largest revenue forecast of any crop, indicating high expectations for their success this year. However, apples have fallen far short of their revenue goals. This shortfall is mainly the result of a higher percentage of apples than expected being sold through lower priced wholesale channels. Wholesale channels were expected to account for 14% of sales but instead made up 85%. Additionally, the average price received through wholesale channels was only $12.42 per bushel compared to the predicted price of $33 per bushel, indicating that the Farm had to unload large quantities of apples at low prices. On the more positive side, of 2,157 bushels of apples harvested 1,184 bushels have been sold, about 55%. This percentage of harvest sold marks the second consecutive improvement for the sales rate of apples. The largest gap in sales expectations is in the cider category. Since apples keep well and are still currently being sold as cider, it is likely that more cider will be sold, increasing the profit made on apples. Cider and retail distribution channels enjoyed a higher than expected price with both doubling expectations. This discrepancy is a bit misleading since apples sold through retail and cider channels were sold by units much smaller than bushels and customers did not receive a bulk discount. In fact, $76.28 per bushel translates into about $1.53 per pound, which is a reasonable retail price.

Table 4-3. Forecasted vs. actual values for apples

Apples	Forecast	Actual	Difference	Unit
Harvest	2,925	2,157	-768	bushel
Harvest Per Acre	216	159	-57	bushel/acre
Labor Total	1,230	1,098	-132	Hour
Revenue (Cider)	$22,919	$5,052	-$17,868	
Revenue (Retail)	$8,950	$4,767	-$4,182	
Revenue (Wholesale)	$13,424	$12,499	-$925	
Revenue (Total)	$45,293	$22,318	-$22,976	
Operating Profit	$23,584	$1,557	-$22,027	
Profit per Acre	$1,740	$115	-$1,625	13.6 acres
Pricing (Cider)	$18.00	$43.86	$25.86	$/bushel
Pricing (Retail)	$33.00	$76.28	$43.28	$/bushel
Pricing (Wholesale)	$33.00	$12.42	-$20.58	$/bushel
Distribution (Cider)	75%	9.7%	-65.3%	
Distribution (Retail)	11%	5.3%	-5.7%	
Distribution (Wholesale)	14%	85%	71%	

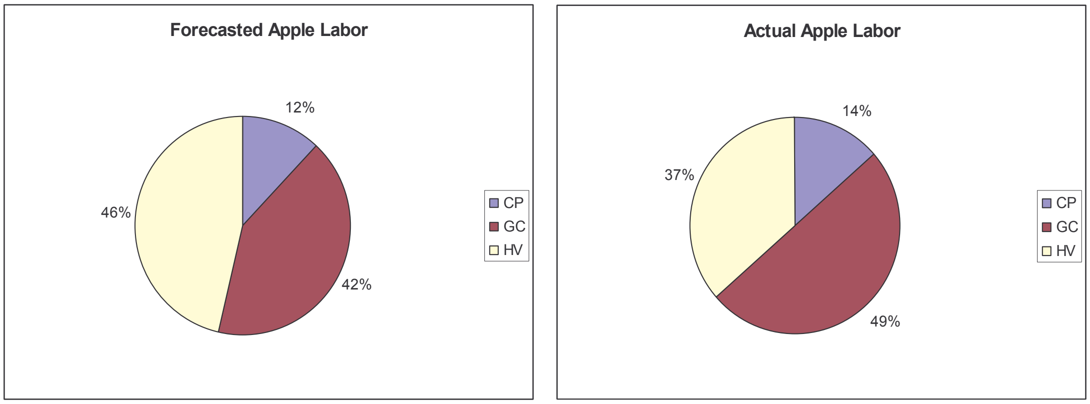
Labor Comparison

As can be seen in the table and charts below, the apple labor correlated fairly well with the predictions of the model except that less labor was spent on the harvest than expected. However, actual harvest was only about 74% of expected and actual harvest labor was 67% of expected, so it appears that the actual labor for harvest correlates well with what was actually harvested.

Table 4-4. Forecasted vs. actual labor for apples

Apples	Forecast Labor	Actual Labor	Difference
Clean & Pack	147	141	-6
General Care	512	517	5
Harvest	571	382	-190
Total	1,230	1,098	-132

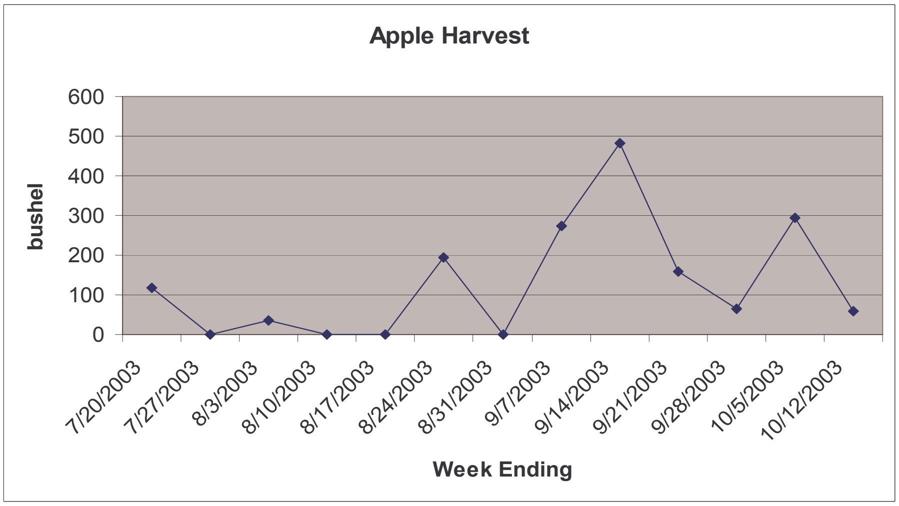
Figure 4-3. Forecasted vs. actual labor for apples



Timing of Harvest

For apples the harvest season was supposed to run from 7/15/2003 to 11/8/2003. It started at about the right time, but finished about a month early. The apple harvest appears erratic and does not follow much of a pattern, though it does peak in mid-September. Given that there are over 20 varieties of apples on the Farm, this is not surprising.

Figure 4-4. Seasonal progression of the apple harvest



4.1.3 Blackberries

Berries are a major crop at Sunnyside, and blackberries are a large component of the berries product line. They are currently grown on 1.5 acres and were projected to take in $24,000 in revenue. Blackberries seriously underperformed in 2003 as Table 4-5 indicates.

Table 4-5. Forecasted vs. actual values for blackberries

Blackberries	Forecast	Actual	Difference	Unit
Harvest	950	484	-466	flat

Harvest Per Acre	633	323	-310	flat/acre
Labor Total	1,534	991	-543	hour
Revenue (Retail)	$13,680	$4,004	-$9,676	
Revenue (Wholesale)	$10,336	$7,554	-$2,782	
Revenue (Total)	$24,016	$11,558	-$12,458	
Operating Profit	$11,046	$2,473	-$8,573	
Profit per Acre	$7,364	$1,649	-$5,715	1.5 acres
Pricing (Retail)	$36.00	$36.00	$0.00	$/flat
Pricing (Wholesale)	$27.20	$19.32	-$7.88	$/flat
Distribution (Retail)	40%	22.1%	-17.9%	
Distribution (Wholesale)	40%	77.9%	37.9%	

The underperformance of blackberries as compared to the model's forecast mostly stems from the shortfall of the harvest, which was only about half of what was expected. As previously mentioned, rainfall near the time of peak harvest caused the blackberries on the vine to rot and physically destroyed much of the crop. Their performance was further hurt by the failure to meet pricing expectations for the wholesale category, which received on average $19.32 per flat instead of $27.20 per flat. Additionally, more of the crop was sold through wholesale channels than anticipated, thereby receiving a lower average price. More positive news was that shrink, the difference between what was harvested and sold, was low. Almost everything that was harvested was sold even though blackberries perish quickly.

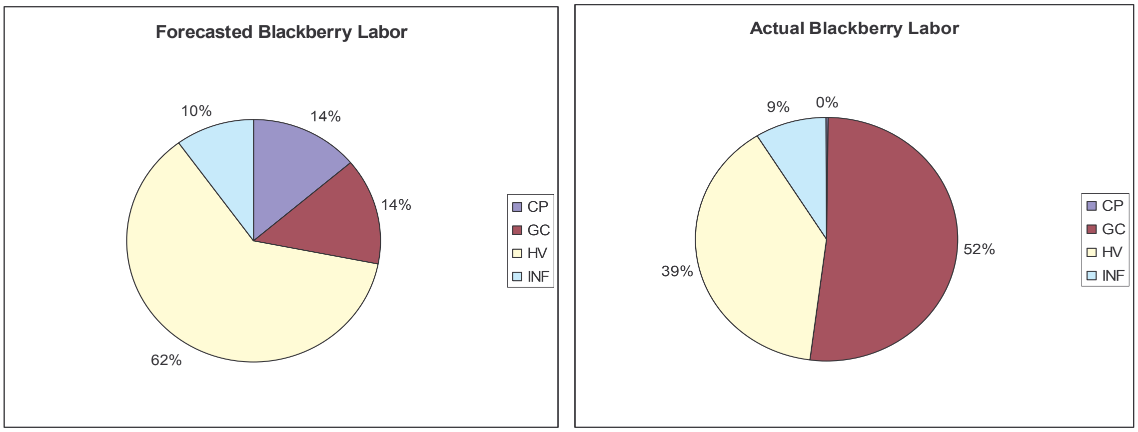
Labor Comparison

Data for the actual labor hours spent on blackberries vary from the forecasted data for each category. Overall, only about 65% as many hours were spent on labor as predicted. The extra hours spent on general care can be attributed to the new acreages of blackberries that were put in this year, which will not produce berries until next year. The actual harvest number is lower than predicted and the actual time spent cleaning and packing is negligible. The actual harvest labor is so much lower than predicted because a lower percentage of the crop was suitable to be picked because of the rain. The near non-existent value for cleaning and packing most likely results from a recording error on the activity logs. Blackberries are often packed in the field and put directly into pints or half pints. The flat is made up of a number of pints or half pints. In this system the cleaning and packing hours get recorded as harvest hours. The berries do not require cleaning as other crops do, because they come directly off the shrub. The accumulated hours for actual and forecasted labor are shown in the table below. The percentages are shown in the charts that follow.

Table 4-6. Forecasted vs. actual labor for blackberries

Blackberries	Forecast Hours	Actual Hours	Difference
Clean & Pack	215	3	-211
General Care	215	513	298
Harvest	950	387	-563
Infrastructure	155	88	-67
Total	1,534	991	-543

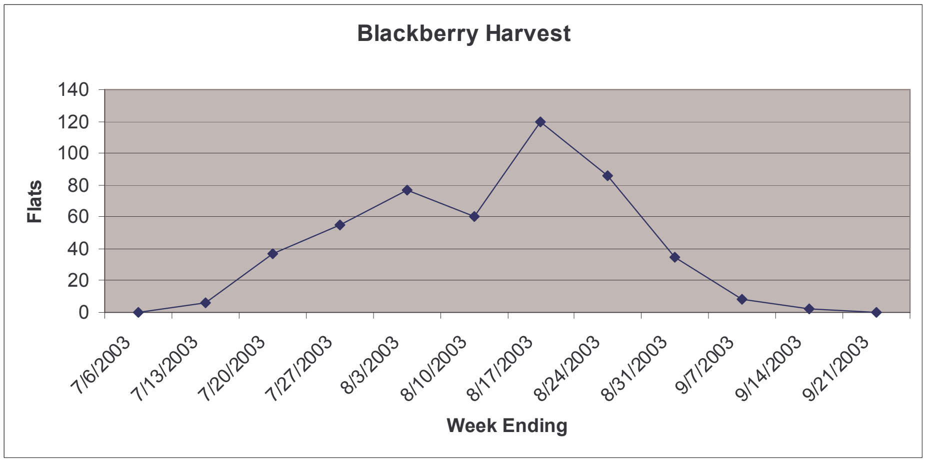
Figure 4-5. Forecasted vs. actual labor for blackberries



Timing of Harvest

The harvest season for blackberries was predicted to last from 7/21/2003 to 10/12/2003. The beginning of the blackberry season correlated well with the model, but the season ended a month earlier than expected (Figure 4-6). The harvest over the season loosely resembles a bell curve, peaking in the middle of August.

Figure 4-6. Seasonal progression of the blackberry harvest



4.1.4 Potatoes

Table 4-7 shows comparisons over the past season for potatoes, which are grown on 1/3 of an acre on the Farm. Harvest fell far short at only 60% of the forecasted value. Potatoes were relatively unaffected by the rain except that the muddy conditions made weed control difficult. Much of the lost revenue on the diminished amount of crop was compensated by potatoes receiving a higher wholesale price than expected, $1.59 per pound as opposed to $0.50 per pound. Additionally, potatoes had a fairly low shrink rate. Of the 3,877 lbs. that were harvested, 3,055 lbs were sold, about 79%. Overall labor hours were less than anticipated which cut costs.

Table 4-7. Forecasted vs. actual values for potatoes

Potatoes	Forecast	Actual	Difference	Unit
Harvest	6,500	3,877	-2,623	lb
Harvest Per Acre	19,500	11,631	-7,869	lb/acre
Labor Total	255	155	-100	hour
Revenue (Retail)	$4,063	$1,933	-$2,130	
Revenue (Wholesale)	$1,625	$2,495	$870	
Revenue (Total)	$5,688	$4,429	-$1,259	
Operating Profit	$2,342	$2,283	-$59	
Profit per Acre	$7,027	$6,848	-$179	.33 acres
Pricing (Retail)	$1.25	$1.35	$0.10	$/lb
Pricing (Wholesale)	$0.50	$1.59	$1.09	$/lb
Distribution (Retail)	50%	48.5%	-1.5%	
Distribution(Wholesale)	50%	51.5%	1.5%	

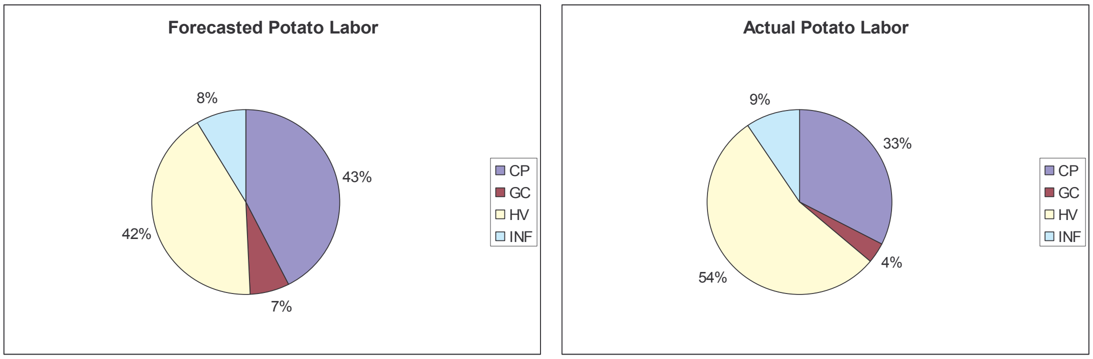
Labor Comparison

Though actual labor was less than forecasted, the percentage breakdowns by category were similar (Table 4-8 and Figure 4-7). Given that fewer potatoes were harvested than expected, it makes sense that less time was spent actually harvesting than forecasted. The following table and charts illustrate the other comparisons.

Table 4-8. Forecasted vs. actual labor for potatoes

Potatoes	Forecast Labor	Actual Labor	Difference
Cleaning & Packing	108	50	-58
General Care	17	6	-11
Harvest	108	84	-24
Infrastructure	22	15	-7
Total	255	155	-100

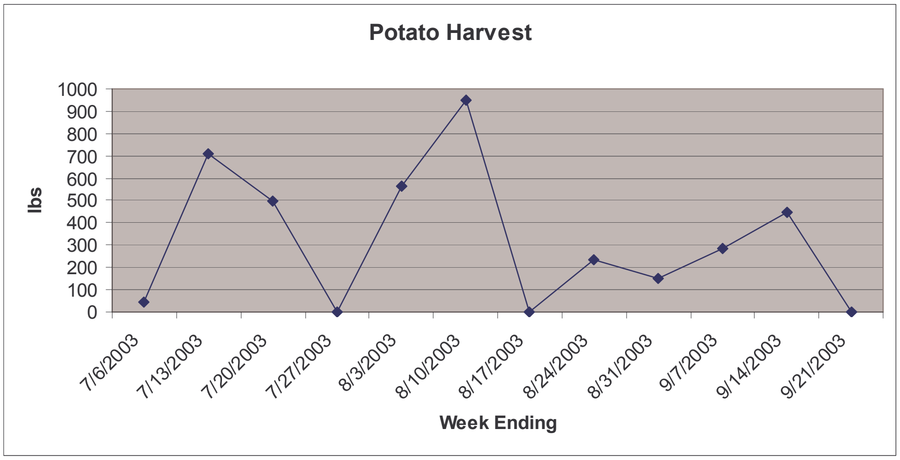
Figure 4-7. Forecasted vs. actual labor for potatoes



Timing of Harvest

The harvest for potatoes was predicted to run from 7/7/2003 to 10/5/2003. The beginning of the harvest season was correct, but it ended a few weeks short of the expected date. The distribution of the harvest for potatoes is fairly erratic, but this can be attributed to the fact that there are several varieties that have their own harvest periods.

Figure 4-8. Seasonal progression of the potato harvest



4.1.5 Basil

In addition to growing many varieties of fruit and vegetables, the Farm also grows several herbs. Basil is the most prominent of the herb crops and was the overall most successful crop in 2003 in terms of profit per acre. Basil exceeded expectations in almost every performance metric. More was harvested than predicted, less time was spent on labor, and more revenue was taken in. Actual prices received for both retail and wholesale categories came close to expectations. Additionally, revenue totals benefited from the fact that more basil was sold through higher priced retail channels than forecasted. Basil has such a high profit per acre in part because it is grown on a small amount of land. It is only grown on 1/30 of an acre inside a hoop house, a structure that is similar to a greenhouse. The hoop house effectively sheltered the basil from the heavy summer rainfall, and this protection from the rain doubtlessly contributed to the basil's success.

Table 4-9. Forecasted vs. actual values for basil

Basil	Forecast	Actual	Difference	Unit
Harvest	750	780	30	lb
Harvest Per Acre	22,500	23,391	891	lb/acre
Labor Total	215	126	-89	hour
Revenue (Retail)	$2,046	$2,636	$590	
Revenue (Wholesale)	$1,667	$1,477	-$190	
Revenue (Total)	$3,713	$4,113	$400	
Operating Profit	$2,089	$3,130	$1,041	
Profit per Acre	$62,680	$93,892	$31,212	1/30 acre
Pricing (Retail)	$6.00	$5.89	-$0.11	$/lb
Pricing (Wholesale)	$4.00	$4.45	$0.45	$/lb
Distribution (Retail)	45%	57.4%	12.4%	
Distribution (Wholesale)	55%	42.6%	-12.4%	

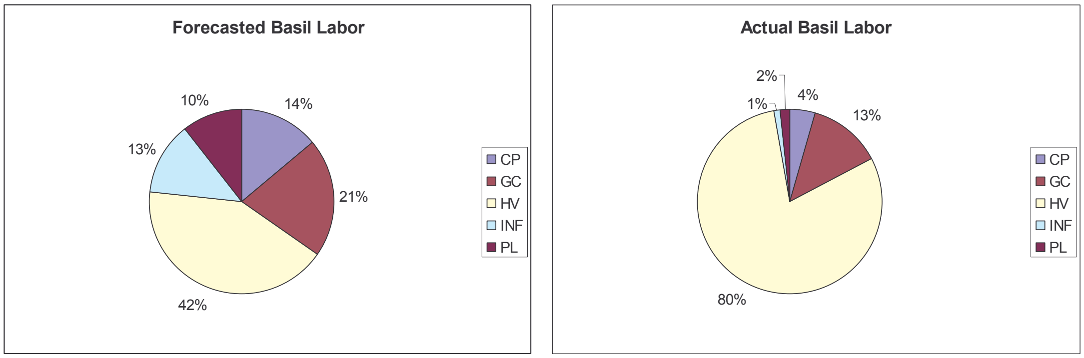
Labor Comparison

Labor spent on basil was dominated by the harvest (Table 4-10 and Figure 4-9). The harvest consumed 80% of the actual labor as opposed to only 42% of the forecasted labor and was the only category to go over its projected amount, though it did so by only 12%. All other labor categories did not require as much time as expected.

Table 4-10. Forecasted vs. actual labor for basil

Basil	**Forecast Labor**	**Actual Labor**	**Difference**
Cleaning & Packing	30	6	-24
General Care	45	16	-29
Harvest	90	101	11
Infrastructure	28	1	-27
Planting	23	2	-21
Total	215	126	-89

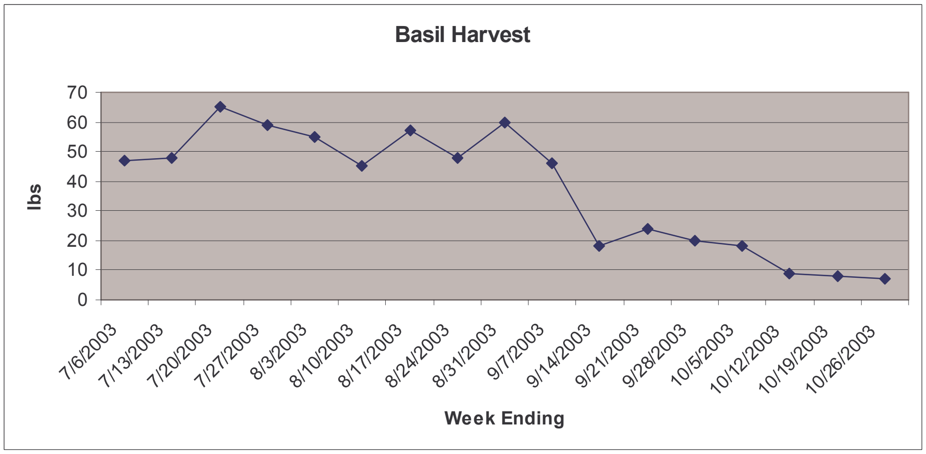
Figure 4-9. Forecasted vs. actual labor for basil



Timing of Harvest

The basil harvest was supposed to last from 7/1/2003 to 10/13/2003. As Figure 4-10 shows, the actual harvest correlates closely to these dates but exceeds the end of the season by about two weeks.

Figure 4-10. Seasonal progression of the basil harvest



4.1.6 Flowers

Flowers are the only crop at Sunnyside that is not edible, but are still significant in terms of acreage and revenue. Flowers performed well this year, having the third highest operating profit and sixth largest profit per acre. Their harvest was about 75% of expected, as were total labor hours, which cut costs. The wholesale price was about a dollar more than forecasted, though a slightly higher than predicted percentage was sold through this lower priced channel. Table 4-11 shows the comparisons.

Table 4-11. Forecasted vs. actual values for flowers

Flowers	Forecast	Actual	Difference	Unit
Harvest	1,500	1,121	-379	bunch
Harvest Per Acre	1,200	897	-303	bunch/acre
Labor Total	900	671	-229	hour
Revenue (Retail)	$13,500	$9,148	-$4,352	
Revenue (Wholesale)	$450	$851	$401	
Revenue (Total)	$13,950	$9,999	-$3,951	
Operating Profit	$7,023	$4,712	-$2,311	
Profit per Acre	$5,618	$3,769	-$1,849	1.25 acres
Pricing (Retail)	$10.00	$10.00	$0	$/bunch
Pricing (Wholesale)	$3.00	$4.09	$1.09	$/bunch
Distribution (Retail)	90%	81.5%	-8.5%	
Distribution (Wholesale)	10%	18.5%	8.5%	

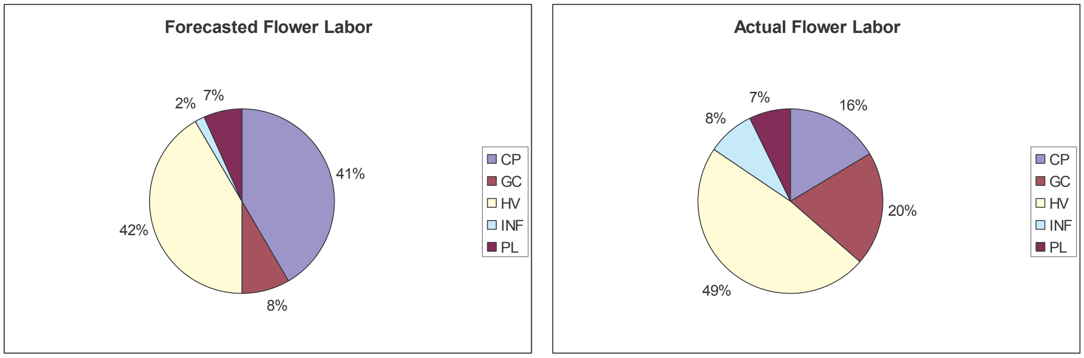
Labor Comparison

Labor spent on flowers was dominated by the harvest (Table 4-12 and Figure 4-11). The forecasted percentage breakdown was fairly accurate with the exception of cleaning and packing. The overestimation of this category alone accounts for the overall difference between forecasted and actual labor. The cleaning and packing process must be more efficient than was thought.

Table 4-12. Forecasted vs. actual labor for flowers

Flowers	Forecast Labor	Actual Labor	Difference
Cleaning & Packing	375	110	-265
General Care	75	133	58
Harvest	375	323	-52
Infrastructure	15	56	41
Planting	60	48	-12
Total	900	671	-229

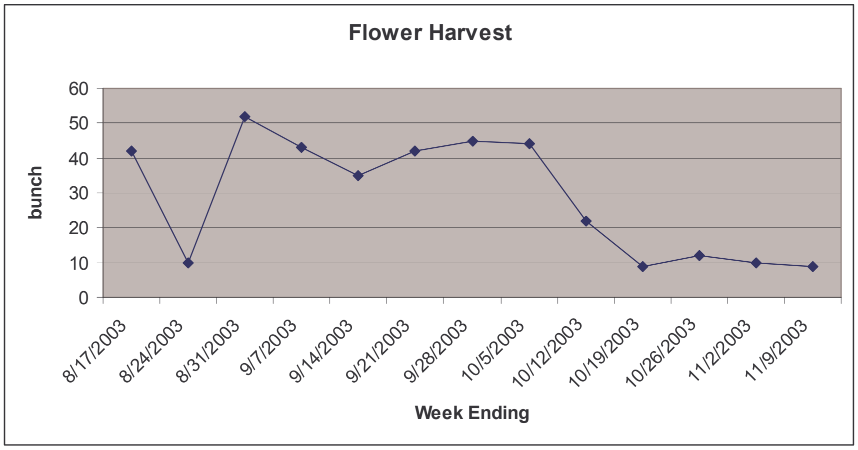
Figure 4-11. Forecasted vs. actual labor for flowers



Timing of Harvest

The flower season was supposed to go from 7/2/2003 to 10/14/2003. As Figure 4-12 shows, the actual season started and ended considerably later than predicted. The peak of the harvest occurred over the month of September.

Figure 4-12. Seasonal progression of the flower harvest



4.2 Relevant Comparisons with Data from Previous Years

4.2.1 Product Line Harvest

Table 4-13 shows the total harvest for berries and tree fruit over the past three years. The berry harvest for 2003 was less than half of that harvested in 2002. Most of this decline was caused by the heavy rainfall on the farm over the summer of 2003. The rain caused the berries to rot while they were still on the bush. In fact, both the blackberry and raspberry harvest for 2003 were about half of what was forecasted. The tree fruit harvest on the other hand nearly doubled. This large increase can be attributed to the maturing trees in orchards that were planted in 1998 or 1999.

Table 4-13. Berry and tree fruit harvest, 2001-2003

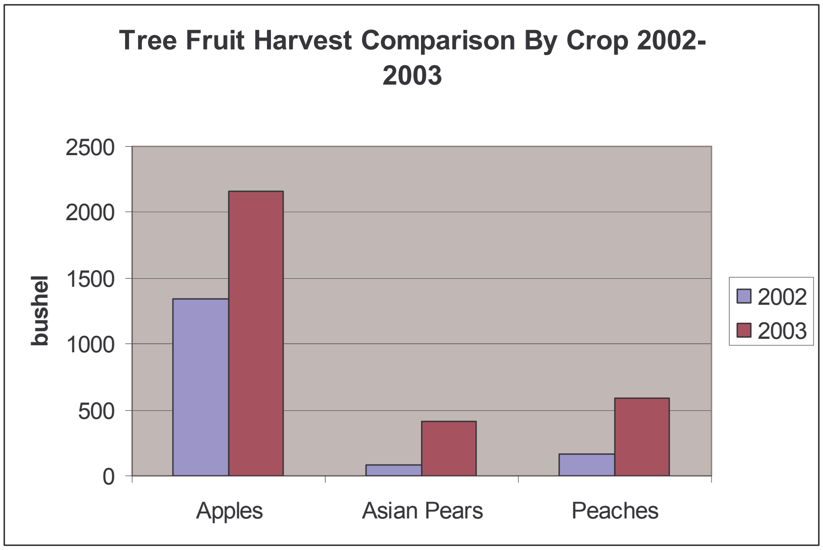
Product Line	2003 Harvest	2002 Harvest	2001 Harvest
	(lb)	(lb)	(lb)
Berries	4,386	9,948	16,548

Tree Fruit	158,157	80,954	75,796

4.2.2 *Tree Fruit*

Figure 4-13 compares tree fruit harvest between 2002 and 2003. The harvest of each crop increased substantially, especially for the Asian Pears which increased fivefold and the peaches which more than tripled. The apples increased by 60%.

Figure 4-13. Tree fruit harvest comparison, 2002-2003



4.2.3 *Percent of Harvest Sold*

Figure 4-14 shows the percentage of the amount harvested that was sold by product line for the past three years. Berries have steadily improved each year, and this past year close to the entire harvest was sold, which seems a little unrealistic given that berries perish easily. The discrepancy probably results from the fact that the quantity of sale at farmers' markets is an estimation. Regardless of any minor errors, it is clear that the percentage of harvested berries sold is at an excellent level. Eggs remained at about the same level for 2003 as they were at in 2002. Tree fruit continued to improve this year reaching 47%, up from 34% in 2002. If more apples continue to be sold as cider, then this percentage will further increase. Given that last year's project listed increasing the percentage of harvested tree fruit that is sold as the best way to make the tree fruit product line more profitable, the Farm appears to be on the right track (Berry et al., 2003). Considering the appearance of much of the fruit was marred by fungal disease, tree fruit seems poised to continue to make improvement next year if this problem can be controlled. If the appearance improved, more could be sold through higher priced retail channels as well.

Figure 4-14. Percent of harvest sold by product line, 2001-2003

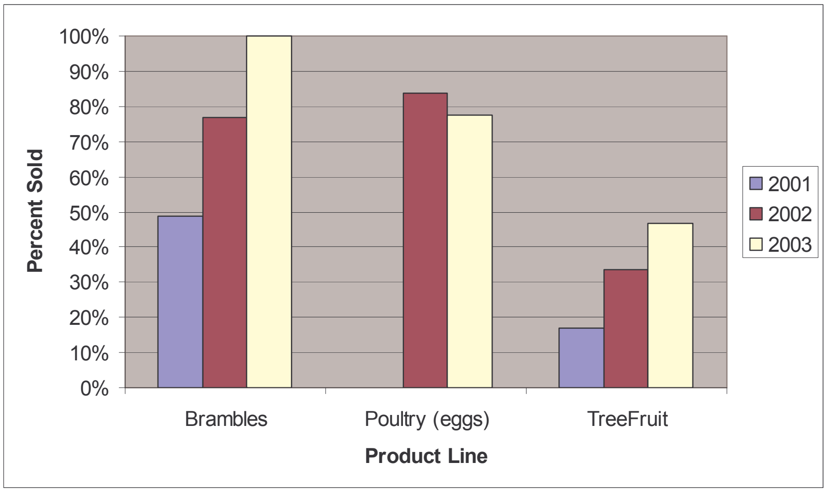


Figure 4-15. Fraction of harvest sold, by crop, 2001-2003

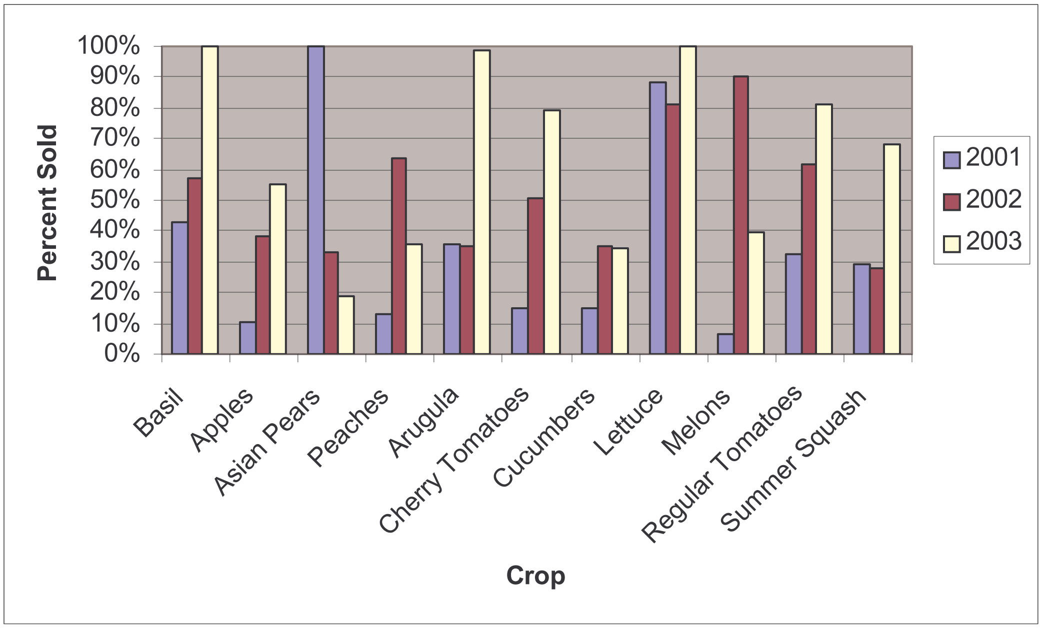


Figure 4-15 shows the percentage of harvest sold for 11 selected crops for which information is available. The trends are mixed. Basil, apples, arugula, cherry tomatoes, lettuce, regular tomatoes, and summer squash all had a much higher percentage of their harvest sold than in the two previous years. Cucumbers were about the same as last year while tree fruit other than apples and melons did worse than last year. The upward trend for the various vegetable crops and apples is encouraging, while the other tree fruit decline is disappointing.

Discussion of Model Results

One of the major observations from the actual performance of the crops in comparison to the model is that only three crops met or exceeded their harvest expectations: peaches, Asian pears, and basil. All other crops for which the harvest is now complete underperformed. See Table A-4 in the appendix for a complete listing of harvest results. The question that arises is what can be done to protect against the potential damage of a rainy summer, such as the one experienced in 2003. It appears that not much can be done. Crops grown in greenhouses or hoop houses will be more protected, but the acreage that can be grown under these structures is very limited. A plastic covering can be put over some crops during early stages of development, but this protection seems minimal. The Farm does make use of fungicides approved for organic farming to curb the outbreak of fungal disease. However, these organic fungicides are not as powerful as conventional ones and do not offer as much protection. The conclusion that can be drawn from the harsh weather of the previous summer is that certain risks are inherent in agriculture and if they affect almost all crops, then they cannot be fully protected against.

The second major result of the model is that the Farm seems to have improved at selling what it harvests, compared to the previous year. Of 33 crops, not all of which are in the model, 21 had sales quantities of over 70% of the amount harvested. Only 6 crops had sales quantities under 50%. The shortfall between what is harvested and what is sold, described by Berry et al. (2003), has been substantially ameliorated. See Table A-5 in the appendix for a complete listing of quantities harvested versus quantities sold.

Most of the crops in the model received higher prices from both their wholesale and retail channels than expected. The higher prices partially compensated for the generally lackluster harvest. Of the 22 crops with pricing forecasts, 15 exceeded expectations, many by wide margins. For example, peppers were forecasted to sell at a retail price of $20 per case, but they actually sold at $45 per case. However, $45 per case converts to about $3 per lb., which seems like a reasonable farmers' market price. In fact, the three Washington D.C. area farmers' markets are the only retail channel for Sunnyside. The model forecasted the retail prices mostly in the larger wholesale units. For example the retail unit for apples was "bushel" and for peppers was "case," even though both are sold by the pound at farmers' markets. Since they were sold by smaller units, there was no bulk discount that is expected with a larger unit of sale. This is the major reason why higher prices were commanded, at least for retail transactions. A complete record of prices by category can be found in Table A-3 of the appendix.

4.3 Pricing

As mentioned in the Methods section (3.0), conventional and organic pricing data at the farm-gate level for the years 1998, 1999, 2000, 2001, 2002 were gathered from USDA-NASS and *Organic Food Business News*. The farm-gate price is literally the price the farmer receives on the farm without any markup. These data on pricing were used in a regression analysis to determine if there is a statistically significant relationship between conventional prices (independent variable) and organic prices (dependent variable) at the national level, as well as to determine what the actual relationship between these prices is. This relationship represents the price premium organic goods enjoy over conventional ones. All prices were converted to dollars per pound and individual regressions were run for apples, asparagus, cantaloupes, carrots, cucumbers, onions, peaches, and tomatoes, which were the commodities that matched more closely between the two sets of data (i.e. commodities with no more than three varieties listed and with units given in terms of weight as opposed to volume). Also, a general regression including all the data for the commodities mentioned was run to determine a general price premium for organic produce. The parameters of the model are:

$$Y_i = \alpha + \beta X_i + \varepsilon_i$$

Y_i is the organic price for the i^{th} commodity, α is the intercept equal to zero, β is the price premium for organic produce, X_i is the conventional price for the i^{th} commodity and ε_i is the residual error.

Table 4-14 shows the regression results and the premiums for organic produce:

Table 4-14. Regression results for organic pricing

Crop	Coefficient	Multiple R^2	*p*-value	Conventional-Organic Multiplier (Premium)
ALL	2.20	0.81	0.0000	2.20x
Apples	2.65	0.93	0.0000	2.65x
Asparagus	1.97	0.88	0.0000	1.97x
Cantaloupe	2.15	0.96	0.0001	2.15x
Carrots	3.15	0.95	0.0000	3.15x
Cucumbers	3.99	0.64	0.0000	3.99x
Onions	2.26	0.88	0.0000	2.26x
Peaches	2.66	0.86	0.0000	2.66x
Tomatoes	2.77	0.93	0.0000	2.77x

Conventional price was chosen as the only regressor to estimate price premiums of organic produce, as it was the only relevant variable expected to explain the relationship. *P*-values of the parameters are below 0.05 in all the cases, meaning that there is a statistically significant relationship between organic and conventional prices. With the exception of cucumbers, R^2 values are above 0.80, meaning that the model explains 80% or more of the variation. The intercept is assumed to equal zero in all the cases because if the price of a conventional good is zero, then the corresponding price of the organic good should not be greater than zero.

At the farm-gate level, the price premiums of organic produce over conventional produce are higher than at the retail level because organic farmers sell most of their production direct to consumers while conventional farmers go through a longer distribution chain, which include several mark-ups. The premiums listed in the table 4-12 exceed 100% in most cases, which is explained by the use of farm-gate prices in our analysis. On the other hand, a study by the Colorado Department of Agriculture concluded that organic premiums should not be higher than 33% at the retail level (Sparling, 1993).

The table below shows a comparison of 2003 average prices for peaches originally forecasted by the Farm, the prices at which the peaches were actually sold, conventional prices at the national level, fitted prices using the regression results for peaches (conventional price × 2.65), and fitted prices using the regression results for all the crops (conventional price × 2.20).

Table 4-15. Price comparison between regression and actual values

	$/lb				
	Forecast	Actual	Conventional price	Fitted (Crop)	Fitted (General)
Peaches	0.50	0.63	0.27	0.72	0.59

For peaches, the fitted price resulted in a price $0.22 higher than the price forecasted by the Farm and $0.09 higher than the actual sale price. Actually, there are several market variables that could drive the Farm managers to price their produce at different levels than the ones based on the regression results. However, pricing more than 40 crops simultaneously can be challenging and these regression models can certainly be used as a reference. Also, as mentioned in the Methods section, USDA AMS reports daily farmers' market prices for several areas on the East Coast, and the Rodale Institute has been reporting national organic prices since January 2003. These two sources could be combined as well with the results from the regression analysis to make timely price adjustments.

4.4 Profitability

The Farm's 2003-2004 fiscal year forecast aimed to break even as the first step in becoming profitable. The actual labor costs, material costs and revenues have been calculated in the model for the crops that have finished producing for the 2003-2004 fiscal year. It must be kept in mind that the Farm may still incur labor costs for these crops later in the year even though they are finished producing. Operating profits have been calculated considering labor and material costs only. The profits for specific crops thus far in the current fiscal year are listed below in Table 4-16, which also show each crop's costs and revenues as well as its profit per acre. As can be seen from this table, the operating profit for these crops is $20,027, which is about 18% of their combined revenue. Other crops are produced on the Farm that are not incorporated into these profit calculations, thus operating profits may vary. There are also overhead costs that are not incorporated into the model. These costs must be included in order to determine the overall profitability of the Farm.

Out of the 19 crops whose harvest and sales are currently complete, 12 show an operating profit, meaning their revenue was greater than the sum of their labor and material costs. The three most profitable crops were cherry tomatoes, flowers, and basil with profits of $9,001, $4,712, and $3,130 respectively. The three crops that took the biggest losses were peaches, black raspberries, and carrots with losses of $5,620, $1,748 and $488 respectively. The operating profit shown above is encouraging, as it marks an improvement over last year. However, the Farm still has a long way to go to cover the expenses that were not included in the operating profit. The results from next year, assuming that the harvest is closer to average, will give a better idea of the amount of progress that has been made.

Profit per acre is a better measure of individual crop success than profit alone because it puts all crops on equal footing. The crops grown on larger acreage have no advantage because profit per acre is standardized by area. The results are similar to profit alone, except that basil is the top performing crop by this measure, while carrots and eggplant lose the most money per acre.

Table 4-16. Operating profit for FY 2004

Crop	Labor Costs	Material Costs	Revenue	Operating Profit	OP per Acre
Apples	$7,848	$12,913	$22,318	$1,557	$115
Asian Pears	$991	$1,905	$3,135	$239	$120
Beets	$61	$395	$19	($437)	($8,743)
Blackberries	$7,084	$2,000	$11,558	$2,473	$1,649
Black Raspberries	$2,207	$667	$1,125	($1,748)	($3,497)
Basil	$899	$84	$4,113	$3,130	$93,892
Carrots	$501	$550	$563	($488)	($5,858)
Cherry Tomatoes	$3,289	$1,776	$14,066	$9,001	$36,005
Eggplant	$265	$483	$376	($372)	($4,466)
Flowers	$4,796	$492	$9,999	$4,712	$3,769
Heirloom Tomatoes	$3,013	$850	$6,092	$2,229	$4,459
Melons	$454	$366	$452	($368)	($1,104)
Onions	$1,770	$480	$3,132	$882	$2,646
Peaches	$4,664	$7,144	$6,394	($5,414)	($722)
Peppers	$739	$700	$1,573	$134	$1,074
Potatoes	$1,106	$1,100	$4,489	$2,283	$6,848
Red Raspberries	$10,300	$3,333	$13,972	$338	$135
Tomatoes	$2,879	$850	$5,957	$2,228	$4,456
Winter Squash	$488	$390	$526	($353)	($705)
TOTAL	**$53,354**	**$36,478**	**$109,859**	**$20,027**	

4.5 Harvest

4.5.1 Harvest Forecast

Unlike Sarker (2003) and Kandiannan (2002), our group did not find a significant relationship between historic corn yields in selected Virginia counties with chosen meteorological variables. There are many explanations as to why no relationship was found, including the possibility that the relationship between corn yield and weather is not linear. The productivity of agricultural plants is limited by sunlight, water, nutrients, temperature, and animal or plant pests. It is likely all of these factors had significant influences on crop yields over time. Unfortunately, our approach was limited to only those factors related to temperature and precipitation. Not accounting for the other variables may have also contributed to the inability to find a significant relationship.

Figure 4-16 shows the comparison of summary statistics of national averages to Sunnyside Farm's yield per acre. The national averages were decreased by 20% to simulate organic yield.

Figure 4-16. Comparison of yield

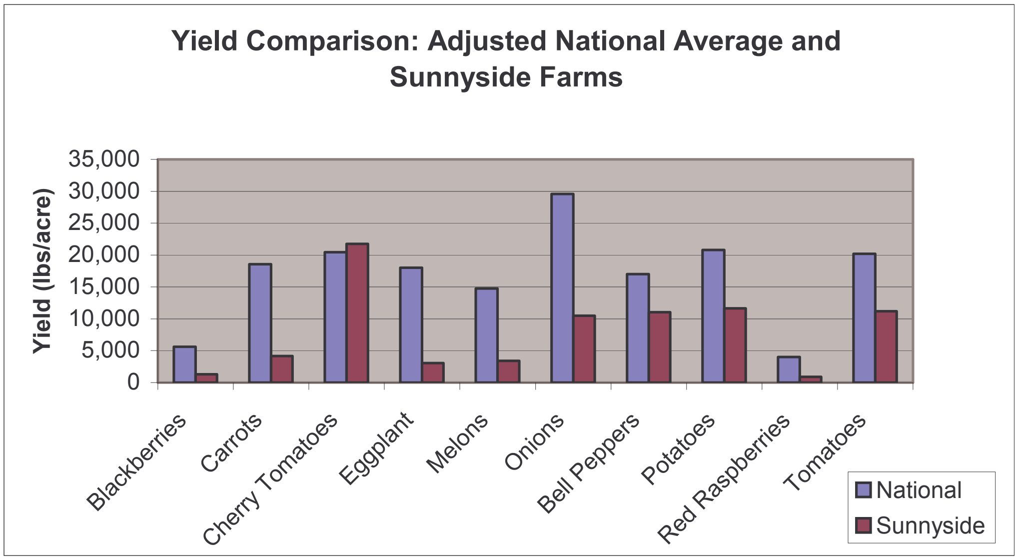


Table 4-17 summarizes values of the graph in Figure 4-16. From the graph and the table it is evident that cherry tomatoes were the only crop to match the adjusted national average. The next closest crops were bell peppers, tomatoes, and potatoes, which were 65%, 56% and 55% of the adjusted national average respectively. These crops were chosen for this portion of the analysis because their growth, harvest, and sales were complete for the season.

Table 4-17. Yield Comparison: National average and Sunnyside Farms

Crop	80% of National Yield (lbs/acre)	Sunnyside Yield (lbs/acre)	Percentage of National Yield
Cherry Tomatoes	20,000	21,728	109%
Bell Peppers	17,000	11,052	65%
Tomatoes	20,000	11,211	56%
Potatoes	21,000	11,632	55%
Onions	30,000	10,515	35%
Melons	15,000	3,399	23%
Red Raspberries	4,000	901	23%
Carrots	19,000	4,192	22%
Blackberries	6,000	1,291	22%
Eggplant	18,000	3,084	17%

4.5.2 Harvest Uncertainty

The standard deviation of the arithmetic mean has been calculated and expressed both as an integer and as a percentage to account for uncertainty in harvest (Table 4-18). The same crops have been used in the analysis to determine levels of yield the Farm may experience during production.

Table 4-18. Descriptive statistics of selected national crop yields

Crop	Mean	Standard deviation	Stdev as a percentage of mean	80% of mean	Standard deviation	High yield	Low yield
Blackberries	7,028	915	13%	5,623	732	6,355	4,891
Carrots	23,675	6,305	27%	18,940	5,044	23,984	13,896
Cherry Tomatoes	25,565	7,642	30%	20,452	6,114	26,566	14,338
Eggplant	20,317	5,371	26%	16,254	4,297	20,551	11,957
Onion	37,317	3,630	10%	29,854	2,904	32,757	26,950
Peppers	27,447	4,415	16%	21,957	3,532	25,489	18,426
Potatoes	25,926	2,504	10%	20,741	2,003	22,744	18,738
Red Raspberries	5,076	709	14%	4,061	567	4,628	3,494
Tomatoes	25,663	2,803	11%	20,530	2,242	22,773	18,288
Melons	18,761	2,745	14%	15,009	2,155	16,960	13,058

***All yields given in lbs/acre**

These calculated statistics are meant to give an approximation of the annual variability of crop yields the Farm may experience. The lowest standard deviation as a percentage of the mean reported on the table is 10% while the highest is 30%. These values reflect the uncertainty agricultural operations experience from year to year. While the forecasts made for the Farm may improve through time, they are still subject to the inter-annual uncertainty that is inherent in agriculture.

The range of yields calculated above can be compared to the yields the Farm realized this growing season. As Table 4-19 shows, most of the yields reported at the Farm this year do not fall into the calculated high to low yield range. The primary reason for the diminished yields is the heavy rainfall the Farm received during the growing and harvesting season in 2003.

Table 4-19. Comparison of adjusted national and Sunnyside yields

Crop	80% of mean	High yield	Low yield	Sunnyside Yield
Blackberries	5,623	6,355	4,891	1,291
Carrots	18,940	23,984	13,896	4,192
Cherry Tomatoes	20,452	26,566	14,338	21,728
Eggplant	16,254	20,551	11,957	3,084
Onions	29,854	32,757	26,950	10,515
Peppers	21,957	25,489	18,426	11,052
Potatoes	20,741	22,744	18,738	11,632
Red Raspberries	4,061	4,628	3,494	901
Tomatoes	20,530	22,773	18,288	11,211
Melons	15,009	16,960	13,058	3,399

***All yields given in lbs/acre**

The appendix contains a table of descriptive statistics for other crops available through the USDA website (Table A-6). The list has been included as a reference for

Farm managers on possible yield variability should they decide to grow a crop that has not been included here.

4.6 Energy Analysis

The metric comparing the ratio of the amount of fossil fuel energy used to produce food energy on the Farm has been calculated and is compared to the metric given by Pimentel (1996). Another way of interpreting the metric is as the efficiency of converting energy from one form to another.

Table 4-20 and Table 4-21 summarize the calculations used in our analysis. Our group has made the assumption that fossil fuel and electricity usage are the same as reported by last year's project due to the absence of data for this year. This analysis also takes a narrow view of the energy expenditures per calorie produced metric. Only the activities taking place on the Farm property directly related to crop production were considered for the fossil fuel kilocalorie consumption. If the analysis were to expand the system boundaries, other energy expenditures could be considered. Examples may include counting the kilocalories used to produce the materials used to create the Farm machinery. Other possible inputs are to quantify the amount of energy required to build the road system the Farm employees use to deliver products. Our analysis is not purposely narrow to improve the ratio of energy consumption to production on the Farm. Instead, it is meant to simplify the accounting process.

Table 4-20. Fossil fuel consumed, 2002 (kilocalories)

Power Source	Conversion (kcal/unit)	Unit	Units Consumed	Total (1,000 kcal)
Diesel	3.30×10^4	gal	2.76×10^3	9.11×10^4
Unleaded Gasoline	3.13×10^4	gal	8.04×10^3	2.52×10^5
Electricity	860	kWh	1.13×10^5	9.72×10^4
Total				4.40×10^5

Table 4-21. Food kilocalories produced by product, 2003

Crop	Total produced (1,000 kcal)	Crop	Total produced (1,000 kcal)
Apples	41,300	Leeks	28.1
Artichoke	8.7	Lettuce	733
Arugula	69.6	Melon	244
Asian Pears	758	Okra	15.2
Asparagus	11.8	Onions	954
Basil	102	Oregano	18.2
Beets	189	Parsley	91.7
Bell peppers	178	Peaches	6,450
Blackberries	588	Pears Asian	3,330
Cabbage	3.4	Peas	190
Carrots	118	Peppermint	2.1
Celeriac	3.7	Potatoes	2,520
Chard	58.7	Radicchio	4.9
Cherry tomatoes	930	Raspberries	625
Chives	8.8	Shallots	65.3
Corn	211	Spinach	42.4
Cucumbers	203	Strawberries	0.9
Currants	47.2	Suckling pig	865
Eggplant	129	Summer squash	1,490
Eggs	20,700	Sweet peppers	91.6
Fennel	8.4	Sweet potatoes	120
Garlic	130	Thyme	0.7
Gooseberries	6	Tomatoes	408
Hot peppers	83.6	Turnips	109
Kale	11.4	Watermelon	271
Kohlrabi	38.5	Winter squash	218
Total (1,000 kcal) produced, 2003		**84,800**	

From the data in the tables above, it can be calculated that the Farm experiences a 5:1 ratio of fossil fuel consumption to food production. This metric is in the range quoted by different authors of 3:1 (Pimentel, 1996) and 10:1 (Kimbrell, 2002) of conventional farming methods. From this metric it is shown the Farm does well in converting fossil fuel energy into food energy, although it is not as efficient as Pimentel's estimate.

Table 4-22 shows the energy expended for human labor activities. A total of about 12,200 hours were spent during 2003 to perform the production-related tasks for the Farm. The consumed calorie total for these activities is substantially lower than the consumed fossil fuel calories. This does not mean the Farm should switch to only human labor to increase the efficiency of energy conversion. Fossil fuels power the machinery used in crop production. Electricity is used for irrigation pumps and the heating of greenhouses. The overall effect on the ratio of discontinuing these practices to improve conversion efficiency is not immediately clear because there would be a corresponding decrease in food production. The magnitude of each reduction would determine whether or not the ratio improved.

Table 4-22. Labor hours and energy expenditures per activity, 2003

Activity	Hours	Energy spent (1,000 kcal)
Clean & Pack	1,362	219
General Care	6,601	2,080
Harvest	3,269	687
Infrastructure	288	60.5
Planting	673	212
Total	12,193	3,260

If the spent calories of fossil fuel use and human labor are added together, the overall consumption to production metric still is 5:1, illustrating the influence fossil fuel consumption has on the overall conversion ratio. Improving the ratio would require the Farm to adopt practices less dependent of fossil fuel energy while still maintaining a similar level of food production, or increasing the level of food production at constant fossil fuel and electricity consumption levels.

5.0 LIMITATIONS

As our group worked to complete the objectives for our project at Sunnyside Farms we encountered some limitations regarding the creation and use of the database and the model. There were also limitations in incorporating uncertainty in harvest, conducting the calorie analysis and determining a pricing strategy for the Farm.

5.1 The Database

The database is designed to store and organize data regarding labor, harvest and sales at the Farm. The labor and harvest data are collected using logs that are filled out daily by farm managers. This is a new system and there are limits to how accurately information is recorded. The managers are responsible for much more than managing the farm activities: they plant, harvest, and care for crops as well as organize the labor force. Thus the probability exists that some of the data entered into the database are flawed. This is a process that will grow to be more accurate as managers become more accustomed to filling out the logs.

Due to the short length of this project and the Farm's use of the 2004 fiscal year, July 2003 through June 2004, we are limited in the data used to make our analysis. The data for the 2004 fiscal year are incomplete, and there are some crops that have not been fully harvested or sold. Furthermore, some of the labor costs that should be included in the revenue/cost calculations may not yet have been recorded because they occur in the later part of the fiscal year.

5.2 The Model

The model is constrained by certain factors. The farm parameters—harvest, labor and sales—used in the model are variable from year to year. Some of the variability depends on factors such as environmental conditions like weather, soil moisture and pests, and market opportunity. Thus, one year may not be an accurate indicator of future years. The model needs to be calibrated over multiple years in order to reflect an average year. The data collected this year will serve as a baseline for future years but will not be able to accurately predict next year's labor needs, harvest and sales. Only after several years of accurate data can annual uncertainties and variations be effectively captured and reflected in the model.

The model includes labor and material costs, which are the most significant variable costs of the Farm and thus have the greatest impact on profits. There are, however, other costs that Sunnyside incurs that are not incorporated into the model. These costs include the salaries of farm managers and office employees as well as specific overhead costs such as electricity, water, gas, phone, insurance, leases, fuel for automobiles, and benefits for the farm crew. Capital expenditures are also not included in the model. These include general farm maintenance and infrastructure as well as new farm equipment. Although the model provides extensive information on labor and material costs, which can assist in cost reduction, it does not provide information on the total costs of the Farm.

5.3 Harvest

The methods used to incorporate annual variability of crop yield into the model relied on statistics of conventional crops aggregated at the national level. Extrapolating the standard deviations of national datasets to the Farm provided an initial approximation of variability, which may be improved with data actually collected from the Farm. As mentioned earlier, collecting site specific data over several years will help to improve the accuracy of expected harvest quantities.

5.4 Pricing

Price analysis was limited by data availability on organic prices. The USDA has not been providing consistent organic pricing data for the past several years, and our analysis relies on data supplied by *Organic Food Business News*, a private source of prices for selected organic commodities at the national level. The USDA has recognized this limitation and is currently working on a regular public program of organic price data collection (USDA, 1998). Besides *Organic Food Business News* not being a federal source of information, their data are aggregated at the national level, which may not reflect the market reality of the Farm.

The pricing analysis itself does not include an estimation of the demand curve for the Farm's product, thus it is not possible to determine price elasticity and assess the responsiveness of demand to changes in price. Results from the analysis can be used as a reference to make pricing adjustments but will not provide information on how consumers would react to them. The analysis is based on input information that is available at the same moment that decisions need to be taken (e.g. conventional prices). In this regard, it provides a reference for just in time price changes but it cannot be used to predict prices in advance.

5.5 Energy Analysis

There are certain limitations associated with the energy analysis that are acknowledged and may be improved upon in future studies. These include the accuracy of the calorie information on specific crops and the inputs used in the analysis. The calorie information for the selected crops came from the USDA. They were not compared to another source. The crops themselves were separated into different categories by the USDA. For example, potatoes were separated into skin and flesh and lettuce was separated by several varieties. For the purposes of this project, only one of the lettuce types was selected and the calorie number for the potato flesh was used. Thus, there may be some inaccuracy in the numbers as compared to actual calorie counts of Sunnyside's fresh vegetables.

The inputs used to conduct the energy analysis may not fully represent total inputs for the selected crops. The fiscal year does not end until July 2004, and therefore we are limited to data for only half of the fiscal year. There may be some inputs that have not been recorded and are not included in the analysis.

Our analysis includes only end of the line inputs. These include the fuel used by vehicles on the farm, electricity and manual labor. The calories consumed by the employees are not included in the analysis. In terms of outputs, the analysis only considers the calories from the produce harvested. It does not include the energy content of what is not picked.

6.0 RECOMMENDATIONS

The recommendations section contains suggestions to improve Farm operations. These suggestions do not necessarily mean the particular aspect of production or business operations needs to be changed, rather they are meant to help make the jobs of management easier, improve the efficiency of job related tasks, or to help calibrate model expectations for future years.

6.1 Database and Data Collection

Currently, the data collection and entry system relies on the use of a paper-based system. The employees and managers are responsible for the completion and accuracy of the logs. The information recorded on the logs is entered manually into the computer on a daily or weekly basis. The opportunity cost of the current system is employee resources being diverted from production related tasks in order to complete the logs. A more efficient system would incorporate the use of PDAs (Personal Digital Assistants) to record daily harvest and activity data. One advantage a PDA affords is the collected data would not have to be entered manually into the database. Instead, it would be downloaded directly from the PDA into the database saving a lot of time for the office personnel. The problem of falling weeks behind on data entry would be eliminated. The ease of data entry would lead to daily updates of the database, keeping the harvest information up to date, shortening the time lag that may exist in communication between the Farm and sales managers.

One potential disadvantage of incorporating a PDA-based data collection and entry system on the Farm is the initial capital investment that would be required for the software and hardware. The needed investment capital would depend on how many devices are purchased and how often the software must be updated. Another disadvantage from a digital system would be costs to productivity because the employees would need to be trained in their operation. This loss to productivity may be incurred once, but it is more likely to occur annually because of employee turnover. It might be possible to only have managers use PDAs which would reduce the amount of time needed for training of new employees, but this approach would only redistribute the responsibility for activity and harvest log entry into the database. Field workers would still need to complete daily paperwork and submit it to their managers who would then need to enter it into the PDA to be linked to the database.

Some kinks still exist in the data collection system on the Farm. For example, the recorded labor hours spent on general care for cherry and heirloom tomatoes were minimal. Further investigation revealed that the general care hours for regular tomatoes were nearly double the projected amount, and it was inferred that when general care was performed on any of these three crops the labor was almost always attributed to regular tomatoes. Perhaps the general care, which is primarily weeding, was usually done simultaneously for the three tomato crops making accurate reporting impossible under the current system in which one labor activity is only attributable to one crop. The current system presents a problem because the Farm needs accurate labor hour accounting at the crop level. One solution would be to carefully review the forecasted versus actual numbers for labor hours and search for large differences or discrepancies that do not make sense. The farm managers could clarify these potential accounting errors. A more preventative solution would attempt to identify some of these potential ambiguities at the beginning of the season so that the correct information could be extracted at the end. A better workaround might be to adjust the crop hierarchy so that there is a category that includes all the types of tomatoes, and then any labor attributed to this category would be divided among the three crops based on acreage. Adjusting these labor hours significantly improved the performance of regular tomatoes, as their labor costs were almost cut in half. The performance of cherry and heirloom tomatoes diminished slightly. There were a few other cases where discrepancies were clarified after careful study of the data.

6.2 The Model

Comparing the expected quantities for harvest, labor, and sales with the recorded values shows that discrepancies exist between them. The differences can be explained in part by the meteorological conditions experienced by the Farm this year. These inaccuracies in the model should be expected since this fiscal year is the first time that a model was designed and used on the Farm. However, the inaccuracies limit the usefulness of the model to the Farm's management, and improving upon its future accuracy should be a priority.

Adjusted national means of crop yield were calculated to help management approximate how much yield to expect for many of Sunnyside's crops. Additionally, the standard deviations of these means provide a measure of the year to year variability in crop yields. Understanding the variability allows for high and low estimates to be created, which would lead to the formulation of best and worst case scenarios for the Farm, helping the managers plan according to revenue expectations.

Another method of improving harvest forecasts is to link them with variables such as weather, soil moisture, or soil nutrient content. These three parameters certainly impact harvest quality and quantity. Gathering information on them would require the use of more technical instruments that were not available to this project, though many research articles discuss how these variables are used to forecast harvest. The diversity of crops grown at Sunnyside presents a challenge to this approach because a different growth model would be needed for each one, as research suggests that variables that influence one crop may not influence another.

As more data are collected annually the possibility exists that specific trends could become evident about crop specific labor activities or labor activities per acre. The distributions of labor that have been calculated thus far are based on a relatively small dataset, making it difficult to account for the effect of extraneous variables on labor allocation versus production related tasks. There is also an absence of research detailing expected labor time per activity or area, so the best estimates of these variables are still going to be from Farm management.

The database is currently set up to query stored data entered by Farm employees. Human error may be a factor in the accuracy of the data collected, and the timing of data entry varies according to the seasonal time demands placed on Farm managers. Lags still might exist between the actual harvest and the recording of the harvest in the database. In some cases a lag would prevent a member of the sales team from using the database as a tool to plan the timing and quantity of goods sold. The harvest information is transferred person to person, not in the real-time form that would make the database a better tool.

The current version of the model is useful as a management tool when considered at the granularity of the crop level. Recording activity and harvest data at the crop level allows for the calculation of metrics like per acre profit for all Farm crops. Using the per acre profit as the primary measure of performance enables the managers to determine those crops that should continue to be grown and those that should be reduced in area, or eliminated completely.

The model is also somewhat misleading with respect to the overall economic sustainability of the Farm. Some crops produced on the Farm are not included in the profit calculations, so overall operating profits could vary. Overhead costs are not incorporated in the model either, and these must be included to determine the overall profitability of the Farm. Accounting for all the production and costs will make the model a more effective tool for management to guide the Farm to becoming truly sustainable.

6.3 Harvest

The recording of harvest quantities into the database should continue. Building a large dataset of annual harvest quantities will be an asset to farm management when it is time to forecast the expected amount of future harvest. Additionally, having data specific to the Farm will improve the accuracy of anticipated year to year variability of crop production. One way to improve the accuracy of harvest data is to standardize the units of certain crops when they are harvested and the size of the buckets used to harvest some crops. Currently, there is a significant amount of guesswork that goes into calculating the actual harvest of specific crops and comparing it to sales data.

6.4 Pricing

The regression model, Organic prices = Premium × Conventional Prices, can be used as a reference tool to adjust prices in a more systematic way. Farm managers should revise their previously forecasted prices on a monthly basis using the regression model, and adjust the results taking into account the actual conditions of the markets in which the Farm is competing. This process will require that Farm managers search for conventional prices published monthly by USDA NASS at: http://usda.mannlib.cornell.edu/reports/nassr/price/pap-bb/. Farm managers can also fine-tune prices on a weekly basis by looking at:

i) Farmers Market prices reported daily by USDA AMS at: http://www.ams.usda.gov/fv/mncs/fvwires.htm, and

ii) Rodale Institute’s daily Organic Price Index (OPX) at: http://www.newfarm.org/opx/.

USDA AMS prices include transportation to the Farmers Market and do not distinguish between organic and conventional produce. OPX prices include farm-gate prices, transportation costs, and wholesaler mark-ups.

6.5 Crops

Recommending which crops to continue to grow and possibly expand and which ones to abandon after a season's worth of data is a difficult prospect, especially after a year like the previous one where weather ruined much of the yield. Harvest yields might be quite different in a more normal year. However, some crops stand out and others like tree fruit are already committed for the long-term. Based on its performance, basil is a crop that should be expanded, as it had the highest profit per acre. Since basil is grown in greenhouses or hoop houses, it is largely protected from adverse weather. The Farm is currently undertaking a project to build several new heated greenhouses, so there would be available area to grow additional basil. Almost all the basil that was harvested was sold indicating that there is further demand for the herb in the market.

Currently, cherry tomatoes are only grown on ¼ of an acre, and their acreage should be expanded as well. Cherry tomatoes outperformed many similar crops, including other types of tomatoes, in terms of harvest expectations and revenue generation. Bringing in $14,066 they generated far more revenue in absolute terms than heirloom tomatoes or regular tomatoes, even though both of the latter are grown on double the acreage of cherry tomatoes. They exceeded price expectations for both retail and wholesale channels, bringing in $30 per flat instead of $18 per flat for retail and $19 per flat instead of $10 per flat for wholesale. 80% of what was harvested was sold, which is good for a crop that does not keep well. Perhaps the bad weather was a relative advantage for cherry tomatoes, but their performance would likely improve under better conditions, though maybe not to the extent of some other crops.

Tree fruit appears to be improving which is a positive sign since this represents a return on the initial investment made by the management at Sunnyside. Apples, Asian pears, and peaches combined lost about $3,600, though harvest was fairly well in line with expectations. However, this loss is significantly smaller than the year before, and apples continue to be sold as cider, so the overall loss could be eliminated. The percentage of apples harvested that were sold increased from 38% to 55%. Peaches and Asian pears did not perform as well, selling 35% and 15% of their harvests respectively. Even though the trees are maturing and producing more fruit, the quality of the fruit is apparently lacking. Perhaps this year it was related to increased fungal disease caused by the excessive rain. Even though a fairly high percentage of apples were sold, 85% of what was sold went through lower priced wholesale channels. An effort should be made to determine if anything can be done to improve the sale of tree fruit. Is the problem the quality of the fruit or is there not a market for it?

The farm should consider eliminating some crops. Black raspberries are already being eliminated for next year, which is a good decision as they had one of the highest losses per acre of any crop. Eggplant and carrots also performed poorly, and eliminating them should be considered. Their performance could improve next year under different conditions, so giving them another chance and making an assessment after next year is also a possibility.

6.6 Transferability

The potential to transfer the data collection, storage and retrieval system established on the Farm to other organizations exists. Our group suggests using a similar system at the Maui Land and Pineapple Company, but PDAs should be introduced at the same time as the establishment of the database. Doing so will allow for the recruitment of workers who are interested in using this type of technology to facilitate the manner in which data are collected. If Sunnyside were to begin the use of PDAs, the employees would need to be trained in their use. Initially this would result in some lost productivity as the staff learned how the devices worked. There may also be some employee resistance to the new system, although our group cannot confirm this with any empirical evidence. Additionally, a database administrator would need to be hired to maintain the database and write any queries necessary for analysis. A much larger farm could more easily afford hiring such a person, whose salary would be a considerable expense. However, on a large farm it would be a much lower percentage of total costs, making the hiring more feasible.

APPENDICES

A-1. Conversion Table

Table A-1. Conversions from English units to metric equivalents

English unit	Metric equivalent
1 acre (ac)	0.40 hectare (ha)
1 inch (in)	25.4 millimeter (mm)
1 pound (lb)	0.45 kilogram (kg)
1 gallon (gal)	3.79 liter (L)

A-2. Additional Crop Statistics

Table A-2. Model sales distribution percentage breakdown comparison

Crop	Category	Quantity	Forecast	Actual	Unit
Apples	Cider	57	75%	10%	bushel
Apples	Retail	63	11%	5%	bushel
Apples	Wholesale	182	14%	85%	bushel
Arugula	Retail	17	45%	82%	case
Arugula	Wholesale	4	55%	18%	case
Asian Pears	Retail	14	18%	18%	bushel
Asian Pears	Wholesale	51	25%	67%	bushel
Basil	Retail	447	45%	57%	lb
Basil	Wholesale	332	55%	43%	lb
Beets	Wholesale	0	80%	100%	case
Black Raspberries	Retail	2	40%	4%	flat
Black Raspberries	Wholesale	55	40%	97%	flat
Blackberries	Retail	111	40%	22%	flat
Blackberries	Wholesale	391	40%	78%	flat
Carrots	Retail	12	35%	87%	case
Carrots	Wholesale	2	65%	13%	case
Cherry Tomato	Retail	339	50%	63%	flat
Cherry Tomato	Wholesale	200	50%	37%	flat
Eggplant	Retail	14	20%	82%	case
Eggplant	Wholesale	3	80%	18%	case
Eggs	Retail	212	70%	21%	case
Eggs	Wholesale	786	30%	79%	case
Flowers	Retail	914	90%	82%	bunch
Flowers	Wholesale	208	10%	19%	bunch
Heirloom Tomato	Retail	151	40%	74%	case
Heirloom Tomato	Wholesale	53	60%	26%	case
Lettuce	Retail	127	20%	55%	case
Lettuce	Wholesale	106	80%	46%	case
Melons	Retail	452	80%	100%	lb
Onions	Retail	60	30%	51%	case

Crop	Category	Quantity	Forecast	Actual	Unit
Onions	Wholesale	58	70%	49%	case
Peaches	Retail	13	35%	6%	bushel
Peaches	Wholesale	201	15%	95%	bushel
Peppers	Retail	22	20%	53%	case
Peppers	Wholesale	19	80%	47%	case
Potatoes	Retail	1,481	50%	49%	lb
Potatoes	Wholesale	1,574	50%	52%	lb
Red Raspberries	Retail	158	40%	29%	flat
Red Raspberries	Wholesale	387	40%	71%	flat
Summer Squash	Retail	724	50%	37%	lb
Summer Squash	Wholesale	1,243	50%	63%	lb
Tomato-Standard	Retail	87	60%	48%	case
Tomato-Standard	Wholesale	95	40%	52%	case
Winter Squash	Retail	321	50%	46%	lb
Winter Squash	Wholesale	384	50%	54%	lb

Table A-3. Model price comparison by crop

Crop	Category	Forecast	Actual	Unit
Apples	Cider	$18.00	$43.86	bushel
Apples	Retail	$33.00	$76.28	bushel
Apples	Wholesale	$33.00	$12.42	bushel
Arugula	Retail	$22.00	$75.00	case
Arugula	Wholesale	$14.00	$46.58	case
Asian Pears	Retail	$20.00	$100.07	bushel
Asian Pears	Wholesale	$20.00	$33.59	bushel
Beets	Wholesale	$9.00	$95.00	case
Blackberries	Retail	$36.00	$36.02	flat
Blackberries	Wholesale	$27.20	$19.32	flat
Black Raspberries	Retail	$36.00	$36.00	flat
Black Raspberries	Wholesale	$27.20	$19.32	flat
Basil	Retail	$6.00	$5.89	lb
Basil	Wholesale	$4.00	$4.45	lb
Carrots	Retail	$13.00	$40.00	case
Carrots	Wholesale	$9.00	$35.53	case
Cherry Tomato	Retail	$18.00	$30.00	flat
Cherry Tomato	Wholesale	$10.00	$19.44	flat
Eggs	Retail	$29.00	$43.43	case
Eggs	Wholesale	$23.50	$18.21	case
Eggplant	Retail	$21.00	$24.00	case
Eggplant	Wholesale	$12.00	$16.80	case
Flowers	Retail	$10.00	$10.01	bunch
Flowers	Wholesale	$3.00	$4.09	bunch
Heirloom Tomato	Retail	$18.00	$30.00	case
Heirloom Tomato	Wholesale	$10.00	$29.36	case

Crop	Category	Forecast	Actual	Unit
Lettuce	Retail	$34.00	$23.39	case
Lettuce	Wholesale	$28.90	$19.42	case
Melons	Retail	$1.00	$1.00	lb
Onions	Retail	$14.00	$33.64	case
Onions	Wholesale	$8.00	$19.64	case
Peaches	Retail	$20.00	$100.00	bushel
Peaches	Wholesale	$20.00	$25.29	bushel
Peppers	Retail	$20.00	$44.93	case
Peppers	Wholesale	$13.00	$30.83	case
Potatoes	Retail	$1.25	$1.35	lb
Potatoes	Wholesale	$0.50	$1.59	lb
Red Raspberries	Retail	$36.00	$35.99	flat
Red Raspberries	Wholesale	$27.20	$21.45	flat
Summer Squash	Retail	$2.00	$2.00	lb
Summer Squash	Wholesale	$1.50	$0.58	lb
Tomato-Standard	Retail	$22.00	$51.25	case
Tomato-Standard	Wholesale	$14.00	$16.02	case
Winter Squash	Retail	$0.50	$0.86	lb
Winter Squash	Wholesale	$0.08	$0.65	lb

Table A-4. Model harvest comparison by crop

Crop	Forecast	Actual	Diff	Percentage	Unit
Apples	2,925	2,157	-768	74%	bushel
Asian Pears	275	418	143	152%	bushel
Beets	1,800	0	-1,800	0%	case
Blackberries	950	484	-466	51%	flat
Basil	750	638	-112	85%	lb
Carrots	400	13	-387	3%	case
Cherry Tomato	900	679	-221	75%	flat
Eggs	190	1,353	1,163	712%	case
Eggplant	330	21	-309	7%	case
Endive	250	0	-250	0%	case
Flowers	1,500	375	-1,125	25%	bunch
Heirloom Tomato	720	308	-412	43%	case
Melons	3,375	1,133	-2,242	34%	lb
Onions	325	234	-91	72%	case
Peaches	390	457	67	117%	bushel
Peppers	455	92	-363	20%	case
Potatoes	6,500	3,877	-2,623	60%	lb
Radicchio	162	0	-162	0%	case
Red Raspberries	1,075	563	-512	52%	flat
Tomato-Standard	480	224	-256	47%	case
Winter Squash	12,000	1,088	-10,912	9%	lb

Table A-5. Harvested vs. sold by crop

Handle	Harvested	Sold	Percentage	Unit
Apples	2,157	1,184.01	54.89%	bushel
Artichoke	41	14.14	34.49%	lb
Asian Pears	417.67	77.93	18.66%	bushel
Blackberries	484	502.15	103.75%	flat
Basil	637.75	779.71	122.26%	lb
Carrots	13.1	14.29	109.06%	case
Chard	76.5	62.5	81.70%	lb
Cherry Tomato	679	539.22	79.41%	flat
Chives	14.5	12.1	83.45%	lb
Celeriac	66	52.16	79.03%	lb
Cucumbers	588	200.69	34.13%	lb
Eggs	1,353.43	1,404.48	103.77%	case
Eggplant	21.42	16.54	77.24%	case
Fennel	20	20	100.00%	lb
Heirloom Tomato	308.1	204.2	66.28%	case
Leeks	308	168	54.55%	lb
Lettuce	226.30	278.26	122.96%	case
Melons	1,133	452	39.89%	lb
Onions	233.67	117.04	50.09%	case
Peaches	588.08	211.16	35.91%	bushel
Peppers	92.1	41.12	44.64%	case
Suckling Pig	48	48	100.00%	count
Potatoes	3,877.25	3,054.8	78.79%	lb
Parsley	26	20.2	77.69%	lb
Red Raspberries	563	544.58	96.73%	flat
Summer Squash	2,891	1,966.88	68.03%	lb
Thyme	7	5.5	78.57%	lb
Tomato-Standard	224.21	181.27	80.85%	case
Turnips	353	302	85.55%	lb
Winter Squash	1,088	705.32	64.83%	lb

A-3. Unadjusted Yields

Table A-6. Unadjusted national yields for selected crops

Crop	Mean	Standard deviation	Standard deviation as percentage of mean
Anise	18,783	5,099	27%
Artichokes	10,299	1,979	19%
Asparagus	1,472	341	23%
Baby vegetables	1,523	240	16%
Bell peppers	21,264	7,484	35%
Broccoli	8,949	3,085	34%
Brussels sprouts	15,855	1,937	12%
Cabbage	29,479	4,184	14%
Cantaloupe	18,715	3,612	19%
Cauliflower	10,447	3,252	31%
Celery	58,906	7,587	13%
Cilantro	15,223	2,240	15%
Cucumbers	16,858	3,637	22%
Endive	15,583	2,590	17%
Escarole	15,787	4,413	28%
Garlic	15,597	2,054	13%
Honeydews	17,623	1,364	8%
Horseradish	4,941	163	3%
Kale	16,799	3,885	23%
Leeks	21,979	10,792	49%
Lettuce	30,917	3,655	12%
Parsley	18,767	6,060	32%
Romaine	25,056	1,337	5%
Shallots	25,477	7,817	31%
Snow peas	5,095	657	13%
Spinach	11,642	2,776	24%
Squash	33,765	12,379	37%
Strawberries	29,033	6,971	24%
Sweet corn	9,002	1,186	13%
Swiss chard	12,797	768	6%
Watermelon	19,068	4,956	26%

*Yields given in lb/acre

A-4. Leaf Sampling

Leaf samples were taken from various tree fruit crops and berries in order to determine what nutrients are getting into the plants. Samples were collected from the peach orchard, several apple orchards, pears, and cherries as well as from several raspberry and blackberry plots. For the tree fruit, five leaves were collected from ten trees in a given plot in as random a fashion as possible. For the berries, six leaves were collected from ten bushes in each plot. The nutrients that were analyzed were nitrogen, phosphorous, potassium, calcium, magnesium, manganese, iron, copper, boron, and zinc. The results were recorded by %DW (dry weight) and PPM DW (part per million of dry weight) as well as by the categories deficient, low, normal, high, and excessive. The results will help determine what action needs to be taken in which plots for which crops. While soil sampling shows what levels of different nutrients are in the soil, leaf sampling shows what levels of different nutrients actually get into the plant or tree, and therefore reveals the health of the crop. The results of the leaf sampling are shown in the two tables below. The first table shows results for nitrogen, phosphorous, potassium, calcium, and magnesium. The second table shows manganese, iron, copper, boron, and zinc. The results for nitrogen and phosphorous, which are particularly important to plant health, are shown in the graph below. The identification numbers found in parenthesis next to each crop in the graph represent the farm plot where that crop can be found. The various plots are shown in Figure 1-2 in section 1.2 of this document.

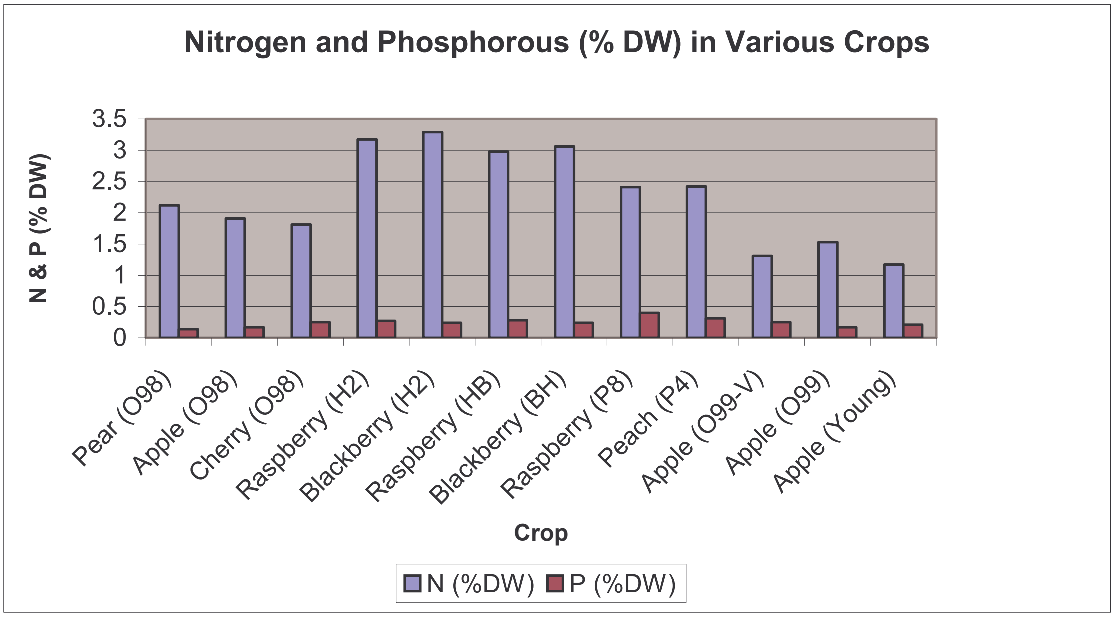
Table A-7. Nutrient content of leaf samples by percentage Dry Weight

Crop	**N** (%DW)	**P** (%DW)	**K** (%DW)	**Ca** (%DW)	**Mg** (%DW)
Pear (O98)	Normal	Deficient/ Low	Normal	Normal	Low/Normal
Apple (O98)	Normal	Normal	Normal	Normal	Normal
Cherry (O98)	Deficient	Normal	Excessive	Low/Normal	Low/Normal
Raspberry (H2)	High	Normal	Low/Normal	Normal	Normal
Blackberry (H2)	High	Low	Low/Normal	Normal	Normal
Raspberry (HB)	Normal	Normal	Deficient	Normal	Normal
Blackberry (HB)	High	Low	Low/Normal	Low/Normal	Normal
Raspberry (P8)	Normal	Normal	Deficient	Normal	Normal
Peach (P4)	Low	Normal	Normal	Normal	Normal
Apple (O99-V)	Deficient	Normal	Normal	Normal	Normal
Apple (O99)	Deficient/Low	Normal	Normal	Normal	Normal
Apple (Young)	Deficient	Normal	Normal	Low/Normal	Normal

Table A-8. Nutrient content of leaf samples, cont.

Crop	Mn (PPM-DW)	Fe (PPM-DW)	Cu (PPM-DW)	B (PPM-DW)	Zn (PPM-DW)
Pear (O98)	Normal	Low/Normal	Normal	Low	Low/Normal
Apple (O98)	Normal	Normal	Normal	Low	Low/Normal
Cherry (O98)	Normal	Low/Normal	Low/Normal	Normal	Low/Normal
Raspberry (H2)	Normal	High	Normal	High	Low/Normal
Blackberry (H2)	Normal	Normal	Normal	Normal	Normal
Raspberry (HB)	Normal	Normal	Normal	Excessive	Normal
Blackberry (HB)	Normal	High	Normal	Excessive	Normal
Raspberry (P8)	Normal	High	Low/Normal	High	Normal
Peach (P4)	Low/Normal	Normal	Normal	Normal	Low/Normal
Apple (O99-V)	Low/Normal	Normal	Low/Normal	Low	Low
Apple (O99)	Normal	Normal	Low/Normal	Low	Low
Apple (Young)	Low/Normal	High	Normal	Low/Normal	Low

Figure A-1. Nitrogen and phosphorous content of leaf samples by percentage Dry Weight



REFERENCES

Ainsworth, B., Haskell, W., Whitt, M., Irwin, M., Swartz, A., Strath, S., O'Brien, W., Bassett, D., Schmitz, K., Emplaincourt P., Jacobs D., and Leon A. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise, 32*, S498-S516.

Baker, J.M. (2001). Introduction to crop modeling papers from Eastern Europe and the former Soviet Union. *Agronomy Journal, 93*, 650-653.

Berry, L., Callender, T., Chang, A., Gabriel, D., Henson, B., and Turner, A. (2003). Tracking the way towards sustainable agriculture: Linking economics and ecology at Sunnyside Farms. Group Project Report, *Bren School of Environmental Science and Management, Santa Barbara, University of California*.

Bouman, B.A.M., Van Keulen, H., and Rabbinge, R. (1996). The 'School of de Wit' crop growth simulation models: A pedigree and historical overview. *Agricultural Systems, 52,* 171-198.

Feenstra, G., Ingels, C. and Campbell, D. (1991). What is Sustainable Agriculture? Davis, California: *University of California Sustainable Agriculture Research and Education Program.*

Hoogenboom, G. (2000). Contribution of agrometeorology to the simulation of crop production and its applications. *Agricultural and Forest Meteorology, 103,* 137-157.

Kandiannan, K., Chandaragiri, K., Sankaran, N., Balasubramanian, T., and Kailasam, C. (2002). Crop-weather model for turmeric yield forecasting for Coimbatore district, Tamil Nadu, India. *Agricultural and Forest Meteorology, 112,* 133-137.

Kimbrell, Andrew (2002). *The Fatal Harvest Reader: The Tragedy of Industrial Agriculture*. New York: Island Press.

Jacquet, F. and Pluvinage, J. (1997). Climatic uncertainty and farm policy: A discrete stochastic programming model for cereal-livestock farms in Algeria. *Agricultural Systems, 53,* 387-407.

Lentz, W. (1998). Model applications in horticulture: a review. *Scientia Horticlturae, 74,* 151-174.

Mader, P., Fliebach, A., Dubois, D., Gunst, L., Fried, P., and Niggli1, U. (2002). Soil fertility and biodiversity in organic farming. *Science, 296,* 1694-1697.

Myers, S. and Rorie, S. (2000). Facts and Stats: The Year in Review. *Organic and Natural News* at: http://www.organicandnaturalnews.com/articles/0c1feat1.html.

National Climatic Data Center Webpage (NCDC), NOAA Satellites and Information, accessed September 10, 2003, at http://www.ncdc.noaa.gov/oa/ncdc.html.

Pimentel, D. and Pimentel, M. (1996). *Food, energy and society*. Niwot, CO. University of Colorado Press.

Pirog, R., and Benjamin, A. (2003). Checking the food odometer: Comparing food miles for local versus conventional produce sales to Iowa institutions. Paper, *The Leopold Center for Sustainable Agriculture.*

Sarker, A. and Erskine, W., and Singh, M. (2003). Regression models for lentil seed and straw yields in Near East. *Agricultural and Forest Meteorology, 116,* 61-72.

Sparling, E., Wilken, K, and McKenzi, J. (1993). Marketing fresh organic produce in Colorado supermarkets. Colorado Department of Agriculture/USDA

Stafne, E., Brown, J., and Shine, J. (2001). A relational database for agronomic and genealogical sugarcane data: An adaptable prototype. *Agronomy Journal, 93,* 923-928.

Stolze, M., Piorr, A., Haring, A. and Dabberttolze, S. (2000). *Environmental and Resource Use Impacts of Organic Farming in Europe.* Stuttgart-Hohenheim, University of Hohenheim.

The Hartman Group. (2000). *The Organic Consumer Profile*. Bellevue, WA.

USDA. (1998). Workshop: Organic Farming and Marketing Research - New Partnerships and Priorities. Washington D.C.

Yang, C., Perterson, C., Shropshire, G., and Otawa, T. (1998). Spatial variability of field topography and wheat yield in the Palouse region of the Pacific Northwest. *Transactions of the ASAE, 4101*, 17.