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TRACKING THE WAY TOWARD SUSTAINABLE AGRICULTURE: LINKING ECONOMICS AND ECOLOGY AT SUNNYSIDE FARMS

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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EXECUTIVE SUMMARY

At the 2002 World Summit on Sustainable Development in Johannesburg, South Africa, the International Federation of Organic Movements (IFOAM) presented a paper arguing that organic agriculture is "sustainability put into practice."[1] Organic agricultural systems, they asserted, offer the most comprehensive response to the sustainability problems facing the global food production system and the world environment. At the same time that world leaders were discussing the benefits of organic agriculture, this group of Master's students from UC Santa Barbara had begun to work on a project with similar implications at Sunnyside Farms, an organic farm in Virginia. The focus of this project is to assess the economic performance and environmental implications of Sunnyside Farms (the "Farm") as a means of determining the feasibility of organic farming. The project goal is to use these findings to make recommendations that will increase the sustainability of the Farm and to add to the knowledge base for sustainable agriculture.

Significance

Scientists have studied the environmental implications and problems associated with conventional agriculture extensively for several decades, particularly since Rachel Carson detailed the effects of the pesticide DDT in *Silent Spring,*[2] the book generally credited with helping launch the environmental movement. Documented problems associated with agricultural practices include: decreasing biodiversity within agro-ecosystems and in surrounding environments, soil degradation and erosion leading to declining yields, inefficient use and degradation of natural resources such as water and fossil fuels, environmental problems caused by pesticides and agro-chemicals, and pollution caused by manure from large-scale animal husbandry operations. Less studied, however, is the potential for organic farming to offer a more environmentally and economically sustainable alternative to conventional, "factory farm" production. Although it has been shown that organic farming, as a less chemical-intensive and more holistic production system, can avoid some of the environmental problems associated with conventional systems, only recently have scientists begun to study the feasibility of organic farming as a means of larger-scale sustainable food production.

For organic agriculture to replace industrialized systems as the primary means of national food production, organic farms must be environmentally sustainable, sufficiently productive, and economically profitable. While demand for organic goods is growing in the U.S. and the world, organic food remains a niche market. Additionally, the few studies that have compared organic to conventional systems have not conclusively determined that organic systems are as productive, in the sustainable sense, as more chemical-intensive systems, which generally produce higher yields but at the expense of greater energy inputs. In order for scientists and economists to assess the sustainability and viability of organic agriculture, it will become increasingly important to study the short- and long-term costs and benefits of organic farming to both the farmer and society. It is within this context that this project was formulated and carried out. The overarching goal of our project analyses is to provide Farm managers with tools to make informed decisions that will improve performance, both economically and environmentally. This information may be of value to other farms that have made, or are considering making, the transition to organic food production.

Project Scope

The scope of the project is 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. This information will be essential for Farm managers to assess the overall viability of the Farm. While the bulk of the analysis is specific to the Farm, the findings will be of use to individuals in both the organic and conventional sectors of agriculture. By comparing Farm data with national averages, the reader can gain a perspective of the Farm's performance. Although *sustainability* implies a long-term analysis, this project provides a snapshot of the Farm in order to establish baseline data as a precursor to a longer-term assessment. Also, it does not include the impacts of market fluctuations or an assessment of the human health implications of organic products.

Approach

To analyze the economic productivity and environmental impacts of the Farm, a whole-farm tracking system was developed. The tracking system traces all inputs and outputs of the Farm, which have been broadly categorized as aspects of the Farm's environmental and management practices. Environmental components include soil, water, nutrients, and energy, whereas management components include finances, labor and harvest. The data that make up each of these components are housed in a relational database management system (DBMS), which has been married to a geographical information system (GIS). The GIS is used to spatially analyze and display the information. During the summer of 2002, two interns worked at the Farm gathering data, which were then entered into the DBMS. Examples of the types of information gathered include accounting records, activity logs (allocations of farm labor to various activities), physical data (such as water and soil samples), and harvest data. They also spent time observing farm management practices and interviewing farm employees.

During the fall of 2002, the DBMS/GIS was utilized to analyze the Farm's economic productivity and environmental impacts. The analyses performed generally fall into two categories: (1) tracking Farm harvest, labor, expenses and revenues; and (2) quantifying Farm inputs and outputs, and their impacts. The results of the various analyses were used to identify financial and environmental inefficiencies and make recommendations for more sustainable alternatives, or in some cases to recommend further research and analysis.

Overall Conclusions and Recommendations

The value of the tracking system, though limited by the accuracy and completeness of the Activity, Harvest and Treatment logs, could provide useful information for Farm managers. These conclusions should prompt Farm managers to evaluate their methods and behaviors in light of the information provided. Correlating past management decisions with these data has the potential to improve sales, cut costs, and better inform decisions in the future. These conclusions keep in mind the Farm's goal of increasing efficiency, profitability and yield.

With respect to harvest, significant revenue is lost when products are left unsold and when ripe fruits or vegetables are not picked. This presents a significant loss to the Farm, not only in forfeited revenues, but also in the loss of utility from the necessary inputs, including labor, seed, irrigation, energy and nutrient treatments.

Labor represents a considerable Farm expense, consuming roughly 14% of all operating expenses. A large portion of labor hours is comprised of maintenance activities; roughly 54% of labor activities between mid-March and mid-August were maintenance and landscaping. Labor tracked by month and product line suggests that labor allocation and planning were insufficient for the summer harvest of 2002. For example, Brambles dominated labor hours in August, and while Vegetable harvest peaked in this month, harvests of both Brambles and Vegetables were less than the previous year. Labor allocation decisions need to be driven more by what is profitable, and need to be timed in such a way that harvest is not lost.

Revenues and expenses are at the crux of the economic viability of the Farm. The Farm did not earn a profit in 2001 and 2002 due to high operating and capital expenses relative to revenue. In terms of product lines for 2002, Tree Fruit lost the least amount of money by acre relative to other product lines.

Increasing the percentage of harvest that is sold, and decreasing the difference between harvest and yield will have direct, positive effects on the net profitability of Tree Fruit, but not Brambles, Poultry, Vegetables or Herbs. Tree Fruit, which has the highest cull rate, consequently has the highest potential profit of all of the product lines. With a cull rate of 15% and an increase in harvest of 30%, Tree Fruit appears to have the greatest revenue-generating potential, followed by Brambles, Vegetables and Herbs. The product line with the lowest cull percentage was the Poultry product line at 16%. The product line with the highest cull percentage was the Tree Fruit product line with a cull percentage of 64%.

In an effort to maximize productivity, energy inputs should be utilized efficiently. While conventional systems typically rely on energy inputs derived from fossil fuels, the Farm is more labor-intensive. Labor costs, therefore, are higher, but petrol-based fuels represent only 1.6% of Farm expenses, compared to the national average of 4%. As a result, environmental externalities, such as air pollutants and greenhouse gas emissions, are ameliorated.

In terms of nutrient use, compost created mostly from animal manure and bedding provides the majority of nutrients that the Farm applies to its crops. This is beneficial to the Farm because compost is essentially a free byproduct of raising animals. Nutrient budget calculations showed, in general, a surplus of nutrients applied to crops versus what is lost through harvest. Soil organic matter levels, which are generally stable or increasing throughout most of the Farm, indicate that excess nutrients are stored in the soil and probably not washed away in surface water, though we were unable to calculate this loss. Chicken manure provides an important source of nitrogen to the Farm, but the current way that chickens are managed may result in significant losses of nitrogen to the air. Chicken manure nitrogen might be better utilized if it could be captured. It is recommended that the Farm consider using absorptive bedding, like hay, to capture this nutrient more effectively.

On the Farm, slope is the largest factor contributing to soil loss from water erosion. According to the Revised Universal Soil Loss Equation, soil erosion on the Farm is potentially 3.1 tons/acre/year. Current management practices are, in most cases, effective at keeping erosion values as low as possible, given the gradient. Soil organic matter content (SOM) is higher for all blocks (4.3%) than the value recorded in neighboring Appomattox county (1.5%). Vegetable plots show moderate organic matter content whose levels are increasing over time. Tree Fruit blocks also have moderate organic matter content, and levels are stable. The area of greatest concern is the peach orchard, which is most susceptible to erosion and therefore SOM loss because it has the highest slope gradient. Blocks where livestock graze are among the areas with the highest SOM levels.

The calculated water budget for the Farm informs management of the expected irrigation requirements for different levels of precipitation. It will be able to give a reliable, real time calculation of the required irrigation application by plot, if the recommended data are collected at a fine level of resolution. This will maximize the efficiency of water use at Sunnyside Farms. An automated system could be implemented which would accurately distribute the required water to each crop, enhancing the environmental sustainability of irrigation at the Farm.

Sustainability Conclusions

Although many of the conclusions and recommendations made in our analyses pertain directly to the Farm's operations, and are intended mainly to improve the financial and environmental performance of the Farm's day-to-day operations, it is also important to examine the Farm in light of its long-term goal of increased sustainability. Using the three components of the "sustainability triangle," generalizations can be made with respect to the Farm's ecological, social and economic performances. 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.

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1 PROJECT BACKGROUND AND GOALS

1.1 Project Background

Sunnyside Farms (the "Farm") is a 600-acre certified organic Farm owned by David and Maggie Cole, located in Washington, Virginia just 70 miles west of Washington, D.C. The Cole family purchased the Farm in 1996 from the Miller family, which had owned the Farm since 1747 when King George deeded it to Henry Miller. Currently, Sunnyside Farms grows over 300 varieties of fruits, vegetables, cut flowers and herbs, and also produces organic eggs and livestock. The Cole family is interested in seeing the expansion of organic farming as a viable means of sustainable food production across the U.S. The Farm prides itself on being a leader in this area, and is striving to reduce the impact it has on the regional and global environment. At the same time, the Farm must be profitable as a business. Therefore, Sunnyside Farms is searching for ways to make its management and Farm practices more sustainable.

A holistic and comprehensive definition, although ambiguous, is proposed by the Alliance for Sustainability: sustainable agriculture is "ecologically sound, economically viable, socially just and humane."[3] Although these principles present an ambitious agenda, there are incremental steps that the Farm can take to not only move closer to sustainability, but also to discover and evaluate management practices that are more efficient and cost-effective.

Before substantial sustainability assessments and improvements can be made at the Farm, we must have a clear idea of the economic viability and environmental impacts of the Farm in its present form. Therefore a tracking system must be developed that quantifies inputs, outputs and activities on the Farm in order to analyze its economic and environmental sustainability. The Sunnyside Farms group, consisting of six Master's Students from the Donald Bren School of Environmental Science and Management at the University of California, Santa Barbara, was charged with assisting in this effort.

1.2 Mission Statement

To develop a nutrient, water, energy and economic tracking system to assess the performance of the Farm in terms of profitability and environmental impact.

1.3 Project Objectives

As presented in the project Mission Statement, the main goal of the group project is to develop a comprehensive tracking system that models major inputs, outputs and activities on the Farm, so that management questions about economic performance and environmental impacts on the Farm can be addressed.

The tracking system has the following purposes:

1. Analyzing financial performance as it relates to labor and products.

2. Performing ecological/environmental assessments in order to identify areas of inefficient natural resource use and negative environmental impact.
3. Making recommendations based on the economic and environmental analyses that suggest more sustainable alternatives.
4. Comparing results to conventional farming (based on national averages).
5. Developing a Farm Manual, separate from this document, explaining the tracking system so that it can be utilized in the future.

1.4 Significance

There are several reasons why this project is significant to Sunnyside Farms and to the organic farming community as a whole.

1. The tracking system identifies important economic interplays on the Farm that can help managers make more informed decisions about the Farm that affect its profitability.
2. The tracking system highlights the ecological and economic linkages on the Farm. It can help managers to think of the Farm as an integrated economic and ecological system.
3. The tracking system is critical in determining the environmental impact of the Farm in terms of its goal of sustainability.
4. The project will add to the body of knowledge for those interested in learning more about organic farming specifically, and sustainable agriculture in general.

The project will allow the Farm to establish a reference point for broad-based comparisons between the Farm and national average statistics for agriculture in the U.S. It is essential to understand the costs and benefits of sustainable farming practices – economically, environmentally and socially – relative to conventional practices.

1.5 Approach

Developing the tracking system was the crux of the group project and entailed:

1. Obtaining the following information from the Farm:
   (a) Labor activity data;
   (b) Financial data;
   (c) Physical environment data.
2. Constructing a relational database management system (SQL Server) linked to a Geographical Information System (ArcGIS).

The tracking system was then used to:

3. Break down the data into major categories for analysis. These categories are: water, energy, soil, nutrients, harvest, labor, revenues and expenses.

4. Analyze and draw conclusions in order to make recommendations based on categorical analyses and syntheses of various analyses, including:
   (a) Quantification of the physical inputs and expenses required to produce various crops and products;
   (b) Quantification of the physical outputs and revenues;
   (c) Evaluation of the magnitude of environmental externalities associated with the Farm's various activities.
5. Compare the results of various Sunnyside-specific analyses to conventional farm information (using national averages).

1.6 Project Setting

Sunnyside Farms is located in Rappahannock County's Harris Hollow, a valley just north of Washington, Virginia and east of Massie's Mountain. The town of Washington is situated at the base of the Blue Ridge Mountains, part of the larger Shenandoah range, at 38.7°N 78.2°W. The Farm is located in the northern Blue Ridge province, which is characterized as a rugged province with steep slopes, narrow ridges, broad mountains, and high relief (elevation typically ranges from 1,500-4,200 ft. above mean sea level). 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 in Washington, Virginia is classified as temperate. The average rainfall is 41.3 inches per year.[4]

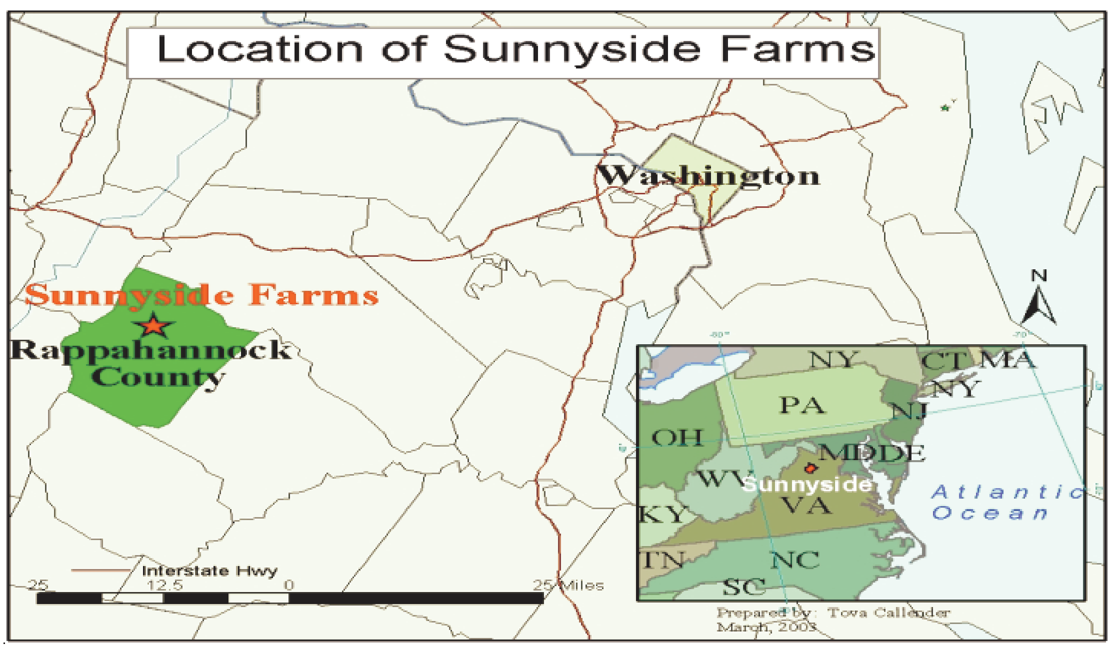


Figure 1 Location of Sunnyside Farms

1.7 Overview of Products and Management Practices

In addition to the unique history and beautiful setting of Sunnyside Farms, the diverse combination of crops grown and techniques used to manage the Farm also contributes to its distinctive character. The following section aims to provide an overview of what is grown and raised on the Farm, as well as outline management practices in order to provide a context for the analyses that follow.

1.7.1 Products

Product lines grown or raised on the Farm include Vegetables, Herbs, Cut Flowers and Potted Plants (Flowers), Grains, Tree Fruit, Brambles, Livestock and Poultry (Eggs). Products were divided into these product lines for ease of tracking harvest, labor and financial data. Approximately 11.2 acres are used for Vegetables, Herbs and Flowers, 21.5 acres for Tree Fruit and 4.4 acres for Brambles. Approximate locations and varieties for the product lines are illustrated in Figure 2.

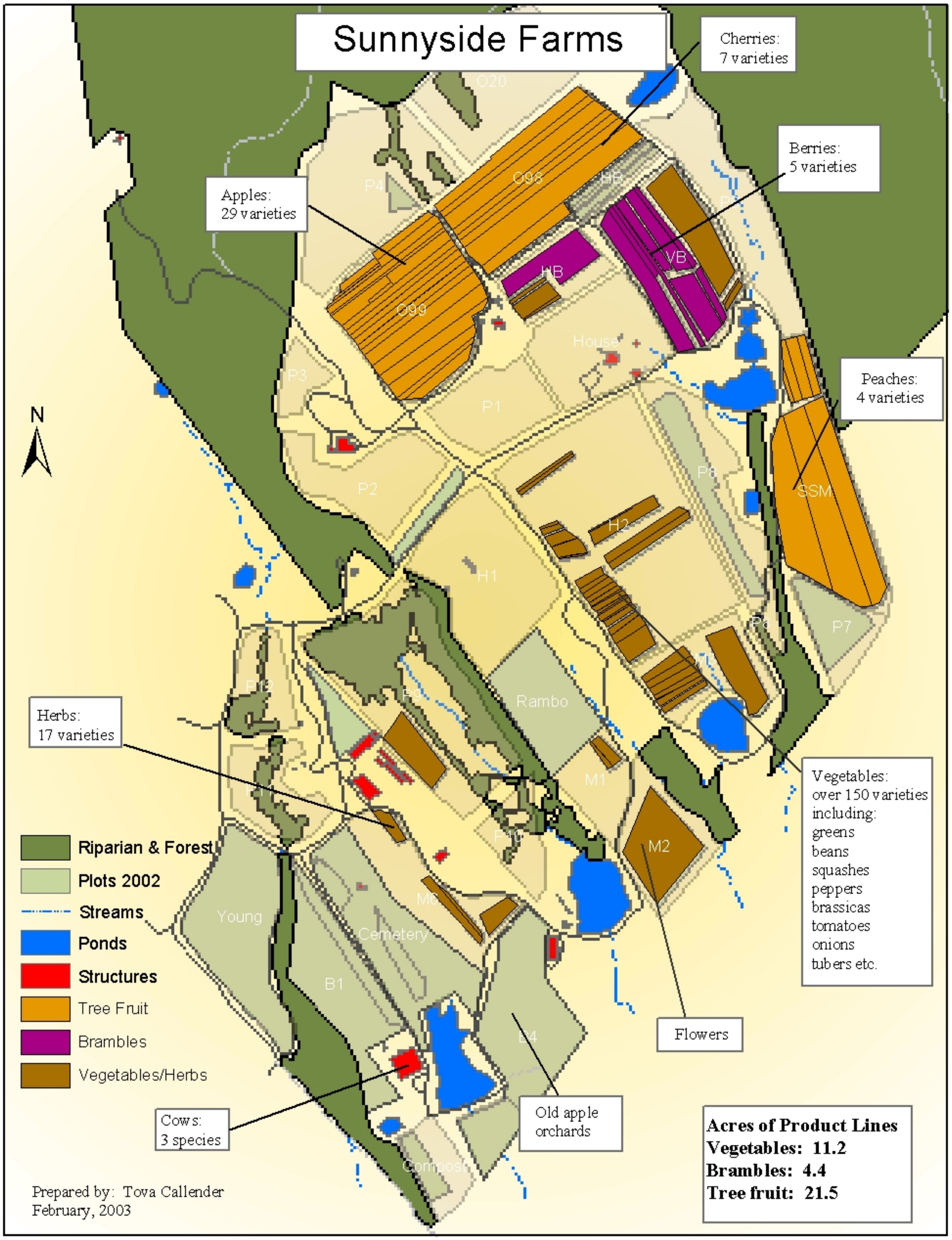


Figure 2 Locations of Product Lines at Sunnyside Farms
Plots for 2002 not assigned to a product line are old orchards that were not harvested, or orchards and Brambles which were too young to harvest in 2002.

Figure 3 'Elvis' the Llama Guards the Sheep that Keep Grass Short and Fertilize Soil

The Farm is unique in that a wide range of Vegetables and Herbs are grown, including the heirloom varieties of many plants. Vegetables fall under the categories of greens, brassicas, roots and tubers, squash, and tomatoes, and represent over 150 varieties. Herbs are all culinary, of which there are seventeen varieties. There are five varieties of Brambles, four types of peaches, seven cherry varieties and 29 varieties of apples. The Farm also has a cut flower program.

There are three commercial categories of animals on the Farm. Layers (chickens) are used for egg production, cattle are raised for beef and, occasionally, pork is sold. The three types of beef are Wagyu, Angus and a hybrid of the two called Wangus. Typically there are around 20 pigs on the Farm, 1,500 layers and 275 heads of cattle. Other animals that live on the Farm include a llama that is used to herd the flock of sheep, five horses and numerous field dogs.

1.7.2 Practices

The Farm currently grows over 300 species of plants and raises three types of livestock, and thus requires diverse management practices. Some measures are necessary for compliance with the National Organic Standards while others are farm-based decisions. The following section outlines the current management regime for the Farm in terms of fertilization, pest and weed control, livestock management, natural resource conservation and harvest practices.

Fertilization

The choice of fertilizer a farm uses can have a considerable impact on cost, energy intensity and pollution potential. The Farm relies mostly on organic compost, which is supplemented with more specific products where appropriate.

Maintaining healthy compost is critical in organic farming as it allows nutrients from waste to be recycled and reduces reliance on costly commercial fertilizers. The compost at the Farm is made up of livestock bedding materials, manure and crop residue. Compost is turned once or twice a week with a tractor-powered turner. The temperature is measured using a probe thermometer. It is speculated that due to the relatively low nitrogen content of cow manure, the

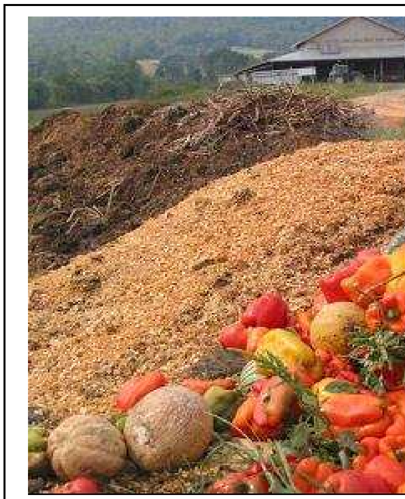


Figure 4 Compost – Mostly Cattle Bedding and Manure, with a Small Portion of Culled Produce

compost has not been able to maintain the required temperatures of between 130-170°F, and must therefore be treated as manure under the Organic Standards Act. Under this Act, manure is required to stand for 4 months prior to application on crops with an edible portion in the ground.

A pond catches compost runoff. Due to the basin-like shape of the compost area, this management strategy seems to work well, as during heavy rain, a dark compost solution can be seen draining almost exclusively into the pond. On the lower banks of the pond, an experimental mycofiltration (mushroom) plot was planted in an attempt to stop any overflow from the pond from entering the nearby stream. By late August 2002, the experiment appeared unsuccessful, likely due to drought conditions.

Figure 5 Compost Turner Attaches to Tractor

Plots of land to be planted with annuals are amended with compost prior to planting. For fruit trees, fertilization decisions are based on soil analysis for the block, and tissue samples (taken in early July) indicate what nutrients are actually being taken up. Compost and sprays are typically applied in early spring, depending on conditions. Cherries also receive compost tea (a solution of compost added to the irrigation water).

Pest Management and Weed Control

Given the life cycle differences associated with each product line, pest management practices are outlined separately for each of the following product lines.

Vegetables

Figure 6 Weeds Overtaking Herbs

Several approaches are taken in managing insects and mites; these approaches include introducing beneficial insects, planting resistant varieties, timing cultivation to reduce damage, employing crop rotation, and utilizing sanitization measures. The major insect pests are aphids, flea beetles, potato beetles, cabbageworms, corn earworms, cucumber beetles, squash bugs, onion maggots, thrips and leafhoppers. Pest populations are monitored through trapping and field scouting conducted by the head vegetable grower.

Diseases are managed by removing diseased plants, managing water appropriately, planting resistant varieties, utilizing sanitation methods and rotating crops. The major disease problems are tomato early blight, powdery mildew, bacterial wilt and botryitis (in the

Figure 7 Field Dogs Protect Fruit Trees From Deer and Bears

greenhouse). Monitoring of disease is conducted by scouting. Physical tactics employed to protect against disease are trellising and control of insect vectors with crop covers. In the case of tomatoes, crops are planted three times per year to ensure tomato availability despite each crop eventually being overtaken by tomato blight.

Weeds are managed mechanically using plastic mulch, cover crops, organic mulches and sanitation. The most predominant weeds on the Farm are lamb's quarter, pigweed, horse nettle, various grasses and, occasionally, bed flaming. Weeds are not managed in those areas where their presence does not hinder the growth of the crop. In addition to the physical measures to control pests outlined above, chemical measures are also taken when necessary with substances approved for organic farming.

Tree Fruit

One pest management approach unique to fruit trees is the use of traps to capture pest insects, followed by the use of pheromone disruptors at critical times to prevent establishment of pest populations. These disruptors resemble thick twist ties and are attached to the trees at the required density. The release of species-specific pheromones serves to confuse the insects, disabling them from finding a mating partner, thereby keeping population levels low.

Figure 8 A Trap in an Apple Tree Facilitates Pest Monitoring

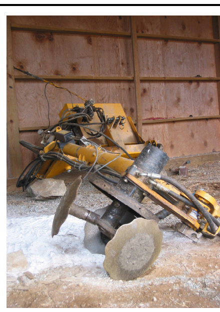


Figure 9 Weed Badger Mulches Leaves Between Orchard Rows

To control weeds, mowing takes place about once a month, and a weed badger is employed (a mechanical tool for getting into small spaces and turning over the soil). Some areas with steep slopes must be hand weeded. Limbs and fruit are removed periodically to stop the spread of fire blight.

A range of animal pests affects the Farm. Those requiring management efforts are deer, ground hogs, rabbits and mice. Physical measures taken to exclude these pests are electric fencing, dogs, hunting and trapping.

To increase the size of the fruit and decrease pest damage, trees are hand thinned in early June. In older orchards (such as apple orchards) where the crop will be used only for processing, hand thinning is not cost effective, so the fruit remain small in size and run a greater risk of infestation by lepidoptera (a member of the worm family). To improve fertilization rates, beehives are brought by contractors during the spring.

Figure 10 Mobile Chicken Units Allow Hens to Fertilize Soil and Control Larvae in Varying Blocks

To manage pests that may over-winter, fallen leaves are mechanically piled in the middle rows and mulched with the weed badger after harvest (Figure 8). The middle of the rows is then seeded with orchard grass, clover (for nitrogen fixing) and/or wild flowers that may attract beneficial insects.

Livestock Management Practices

Beef

Several types of records are kept on the cattle so that each animal can be tracked throughout its life. This ensures that the health and genealogy of each cow is documented.

The cow barn is open on one side and has a translucent roof to allow light to enter. Bedding is certified organic straw. Cows are periodically cleaned and massaged to ensure they are content and free from physical ailments. The barn is cleaned a minimum of once a month depending on how many cows have been occupying the barn. In the spring, summer and fall, animals are outdoors for 12 hours a day, and in the winter, 8 hours.

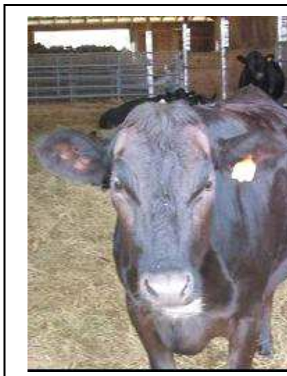


Figure 11 Cows are Massaged and Cleaned to Ensure a High-Quality Life

Cattle (called feeder cows) reach a phase in their life cycle when they need to gain weight at a prescribed rate. At this time they are confined to the barn. There are approximately 12-15 of these cows in the barn at any given time. In addition to pasturing, the feeder cows are fed grain in the summer at a rate of 31 lbs. of grain and hay per day. In the winter, depending on the weight and age of the animal, a cow eats between 12-15 lbs. of hay and 3-20 lbs. of grain per day. All cows are also fed a mineral mix to help maintain the health of the herd. Physical alternations performed on the cattle include castration and dehorning.

Not all of the cows belonging to the Farm reside in the main Farm area. Some are pastured on a lot closer to town and others are in the mid-west. Most cows are kept at the Farm until they reach a weight of about 500 - 700 lbs. For the remainder of their growth, they are shipped 17 hours away to Promised Land Livestock, a certified cattle-raising company. Promised Land continues to house and feed the cows until they reach a harvestable weight and age.

Figure 12 One Side of the Barn is Open to Allow Ample Circulation

Chickens

Chickens are an important part of Farm operations, not only for their role in egg production, but also because of their role in pest control and soil enrichment. Hens are housed in portable coops called mobile chicken units (MCUs), which are circulated around the Farm according to the need and appropriateness of chicken driven pest control (hens are effective larvae predators). Hens graze during daylight and return to the coop at night. Chickens are restocked when they are no longer producing at high enough rates, which is generally after two to three years.

In addition to grazing in the fields, hens are fed organic grain, which is consumed at a rate of 25 lbs of mash grain per 100 birds per day. There are approximately 1,500 chickens on the Farm.

Pigs

Pigs graze year-round in open plots. They are moved to another plot with sufficiently stable fencing about once a month. Pigs are not being re-stocked as they have not been slaughtered in the recent past. Animal rotation through all plots for the fertilizing and tilling benefits has not been practical over short time frames, as pigs (and sheep which are kept strictly to fertilize and cut the grass) require sturdier fencing that could not feasibly be moved around every few weeks. In addition to being fed leftover crops, pigs also receive organic feed. On average, the pigs eat five pounds of feed per head per day.

Figure 13 Pigs Consume Leftover Produce and Work Soil

Natural Resource Conservation

Reducing the impact of the Farm on the natural environment underlies many management decisions. For example, in the interest of conserving soil, vetch and clover are used in some areas as winter cover crops.

Other portions of the Farm are left undisturbed to maintain wildlife habitats, protect riparian zones and conserve water. Riparian areas can be seen on the Farm map in Figure 2.

Figure 14 Riparian Area Preserved in Natural Shade

Harvest and Post Harvest Handling

All crops are harvested manually. Crops that require washing are washed in sinks by hand. The water is changed after each case lot. Those crops that do not require washing are wiped with a cloth before being sorted and packed. Crops requiring refrigeration are kept in a walk-in refrigerator, while others are stored in a greenhouse covered in black plastic. Delivery and transport occur in Sunnyside trucks, which are only used for organic crops.

Irrigation

There is a network of permanent irrigation lines on the Farm, which service Tree Fruit and Brambles. Vegetable plots rely on portable pumps and irrigation lines as they occupy different blocks in different years. Water is drawn from two sources subject to availability, namely irrigation ponds and the well. Pond water is filtered and applied through use of drip irrigation and micro-sprinklers depending on the crop. The pumps used for the permanent irrigation lines are powered by electricity, while those that are moved to accommodate rotated crops, such as the Vegetables, are powered by gasoline. While currently there are no meters measuring water outflow, it has been proposed that they be installed at the pipe entrance to each block. In the event that water levels in the ponds become too low for irrigation, water from farm wells is pumped and used for irrigation. Various water tests are preformed on these water sources to ensure they are safe for use on plants.

Figure 15 Drip irrigation Lines Suspended Above the Ground for Ease of Weeding. Small Holes allow Efficient Water Delivery, but are Subject to Clogging Over Time.

Figure 16 Gas Powered Irrigation Pumps Allow Rotating Annuals to be Watered.

2 DATA MANAGEMENT INFRASTRUCTURE FOR SUNNYSIDE FARMS

2.1 The Tracking System: Science and Management at Sunnyside

Figure 17 represents a conceptual model of the tracking system that was used to quantify the inputs, outputs and activities on the Farm. The two-headed arrows represent features that are *both* inputs and outputs (e.g. water, nutrients, soil, energy, and expenses/revenues), while the one-headed arrows represent features that are *either* inputs or outputs (e.g. labor and harvest).

A rough division can be made between those inputs, outputs and activities that are related to science, and those that are related to management. The organization of the subsequent sections of this document follows this natural division between science and management at Sunnyside Farms. The inputs, outputs and activities relevant to the management aspects of the Farm include harvest, labor, revenue and expenses, while those related to the ecology of the Farm include energy, nutrients, soil and water.

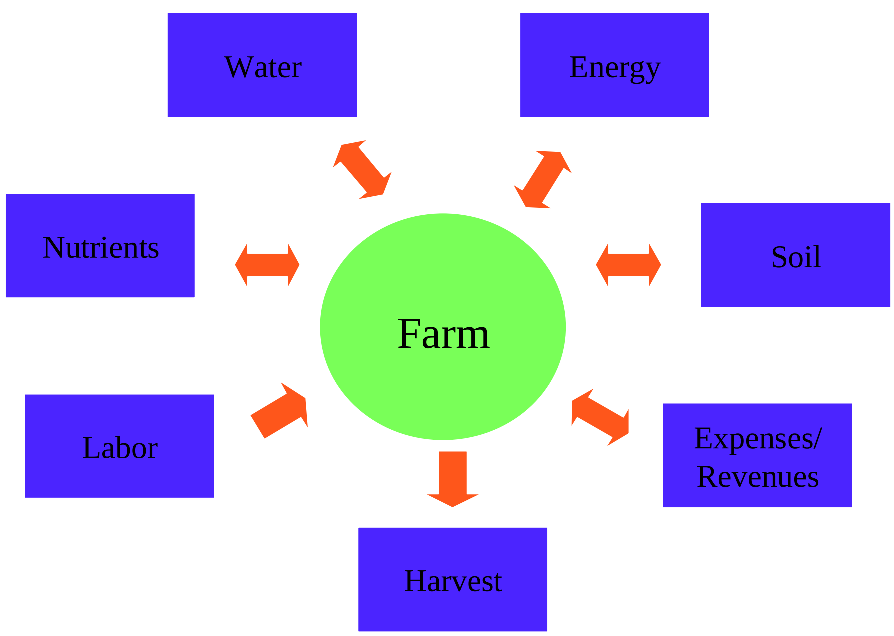


Figure 17: Conceptual Model of the Tracking System

Section 2.2 describes the database management system and geographical information system that were used to make this conceptual model a reality. Subsequent sections discuss each input, output and activity in detail. The document then concludes with sections integrating the issues related to science and management. This integration is vital to understanding the economic and ecological linkages on the Farm.

2.2 Database Management System

2.2.1 Purpose and Approach

The purpose of the database management system (DBMS) is to provide a means of tracking the inputs and outputs of nutrients, energy, labor and water, and to track expenditures and revenues on the Farm. The power of a relational database is that relationships can be established between data sets that enforce data integrity and provide rapid calculations based on the defined relationships. The DBMS was created so that when new information is added to the database, the results presented in this document are automatically updated to reflect the new data. The DBMS has been married to a geographical information system (GIS) in order to incorporate a geographical reference to the major components of the database.

2.2.2 Design

The database is largely based on a hierarchical structure. The four primary hierarchies that provide the structure for the major tables in the database are: Products, Activities, Blocks and Plots, and Expense Categories. Relationships between data tables were established to enforce data integrity, thus ensuring the accuracy of the analyses based on the data.

2.2.3 Hierarchies

Product Hierarchy

The products produced on the Farm are differentiated into a series of product lines, crops and varieties (Figure 18). The product lines consist of Tree Fruit, Livestock, Poultry, Brambles, Flowers and Live Plants, Grains, Herbs, and Vegetables. Each product line is composed of crops and each crop, where applicable, has a series of varieties. The database is constructed such that a unique, three-letter code is assigned to each product. For example, a "Gold Rush" has a product identification of GDR: thus, if sorted by variety, the database will show "Gold Rush;" if sorted by crop it will show "Apple;" or if sorted by product line it will show "Tree Fruit." This hierarchy allows us to analyze information on four levels based on varieties, crops, product lines and a whole farm scale. The product hierarchy is found in the expenditure, revenue, labor, and harvest tables in order to link the tables together and provide a detailed analysis of the total costs and revenues generated by each product.

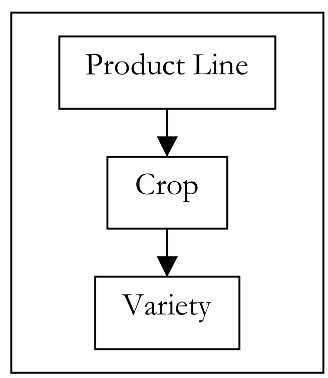


Figure 18 Product Hierarchy

"Whole Farm" is a designation associated with expenses that cannot be attributed to a specific product line, but rather can only be related to the Farm as a whole. While it is not a product line in the same vein as Brambles, Vegetables, etc., it is included in product line expense analyses.

Activity Hierarchy

The Activity hierarchy was established based on a list of various activity categories that Farm workers perform in their day-to-day duties. The main activity categories are: administration, capital expenditures, driving, harvesting, maintenance, marketing, planting, and treatment. Each activity category has a list of activities under it to further differentiate between tasks.

Block/Plot Hierarchy

The Farm is divided into blocks, which are subdivided into sub-blocks and plots. The blocks and sub-blocks were based on existing Farm categories, whereas the plots within the sub-blocks were based upon what was growing in the plot. The plots for the Brambles and Tree Fruit will remain static over time, but the plots where annuals are planted can change multiple times in a year, as well as from year to year.

Expense Category Hierarchy

Expenses were broken down into categories that are similar to the categories used by the Farm accountant. Expenses were also separated into capital expenditures and profit and loss expenses. The Expense hierarchy, like the other hierarchies, allows manipulation of the data at each level of the hierarchy.

2.2.4 Major Components

Tables

The major tables and their components are illustrated in Table 96 on page 196 in the GIS/DBMS Appendix. The tables contain data that range both temporally and spatially, and provide the base of all analysis for the project. The primary tables in the database are the MasterHarvest, ActivityLogbyDate, Expense, Revenue, and RawWeather tables. These tables are the foundation of the tracking system. All of the other tables are either hierarchies or complimentary tables.

Queries

Queries, which extract data from the tables by relevant characteristics, provide information for the bulk of the analysis for this project. Most queries apply to the Activity log, Harvest, Weather, Revenue and Expense tables, and were used to delineate the data by date and hierarchy. The power of a relational database is that many tables can be brought together to link information. For example, the Payrollsalary table was queried to get an hourly cost associated with each laborer, which was then related to the Activity log in order to calculate the total labor cost for each activity and product line.

2.3 Geographical Information System

2.3.1 Purpose and Approach

The geographical information system (GIS) contains information on the Farm infrastructure and major planting blocks. Spatial data were collected and integrated into the GIS during the summer utilizing GPS technology. The bulk of spatial data collected include:

- Vegetable plots;
- Tree rows;
- Irrigation infrastructure;
- Soil tests;
- Water tests.

There are several primary purposes for integrating a GIS with the database. The first is that a large portion of the data has a spatial component. For example, plots have an area and irrigation lines have a specific location. The second is that GIS software can perform rapid calculations (such as plot areas) and graphically display this information. The GIS also provided information for other analyses such as slopes and aspects for soil loss and water balance calculations.

3 HARVEST LOG ANALYSIS

3.1 Significance

Jeff Dozier, the project advisor, developed a paper harvest log in collaboration with Farm managers prior to the beginning of this project. The purpose of the log is to track harvest events, which indicate what was harvested, when it was harvested, where it was harvested from, how much was harvested, and which employee completed the activity. Accurate harvest data can provide valuable information on nutrient cycling (quantity of product being removed from a certain location), and the productivity of the product lines through time and space. These logs also constitute an information base that managers can use for a variety of purposes, including determination of labor requirements over time, estimates of crop profitability, return on investment and crop health.

3.2 Approach

The Farm managers fill out the paper logs weekly. Two project members, while interning at the Farm, entered the logs into the database. The harvest data were then related to other data in order to calculate unit conversions and harvest per acre.

3.3 Results and Discussion

The harvest logs filled out by the Farm managers track Brambles, Vegetables, Herbs, Poultry (eggs), and Tree Fruit, but exclude Livestock, Flowers and Potted Plants. This analysis focuses on the crops and product lines tracked by the logs. The units that are used in tracking harvest are dependent upon the product line. For comparability within a product line that has more than one unit of harvest measurement, as well as across product lines, harvest units were converted to pounds where appropriate. Pounds were chosen as the common unit of measure because of its frequent use on the Farm.

3.3.1 Total Harvest

Total harvest for 2001 and 2002 is displayed in Table 1. In terms of pounds, Tree Fruit overwhelmingly makes up the majority of the harvest. However, comparisons are difficult to make due to the differences in weight of the various crops. A graphical representation of total harvest in pounds is illustrated in Figure 19. A comparison of the 2001 and 2002 harvest indicates that production increased in 2002 for Herbs, Vegetables and Tree Fruit, but decreased for Brambles. Aggregating the total pounds harvested of Tree Fruit, Brambles, Vegetables, and Herbs shows that the Farm increased the total pounds harvested in 2002 by 1.6% over 2001. A more relevant representation of harvest is presented by the actual harvest units. A more detailed description of the product lines is presented in the following sections.

Table 1 Harvest and Harvest Difference for 2001 and 2002 by Product Line

Product Line	2002 Harvest in Pounds	2001 Harvest in Pounds	2002 - 2001 Harvest
Brambles	9,948	16,548	-6,600
Herbs	1,842	874	968
Tree Fruit	80,954	75,796	5,158
Vegetables	50,064	43,326	6,738

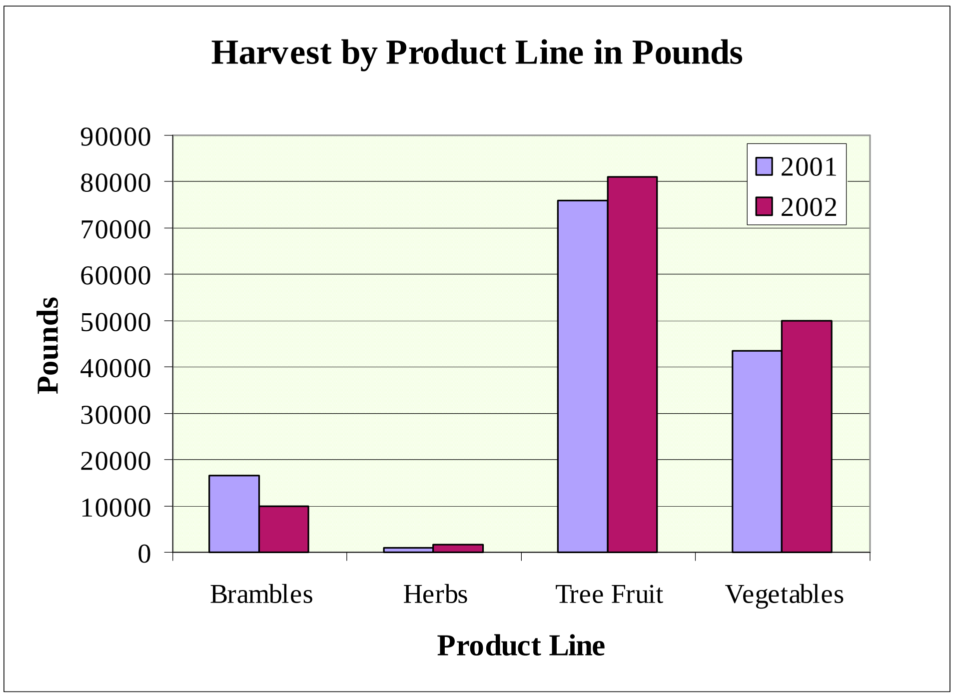


Figure 19 Harvest by Product Line in Pounds for 2001 and 2002

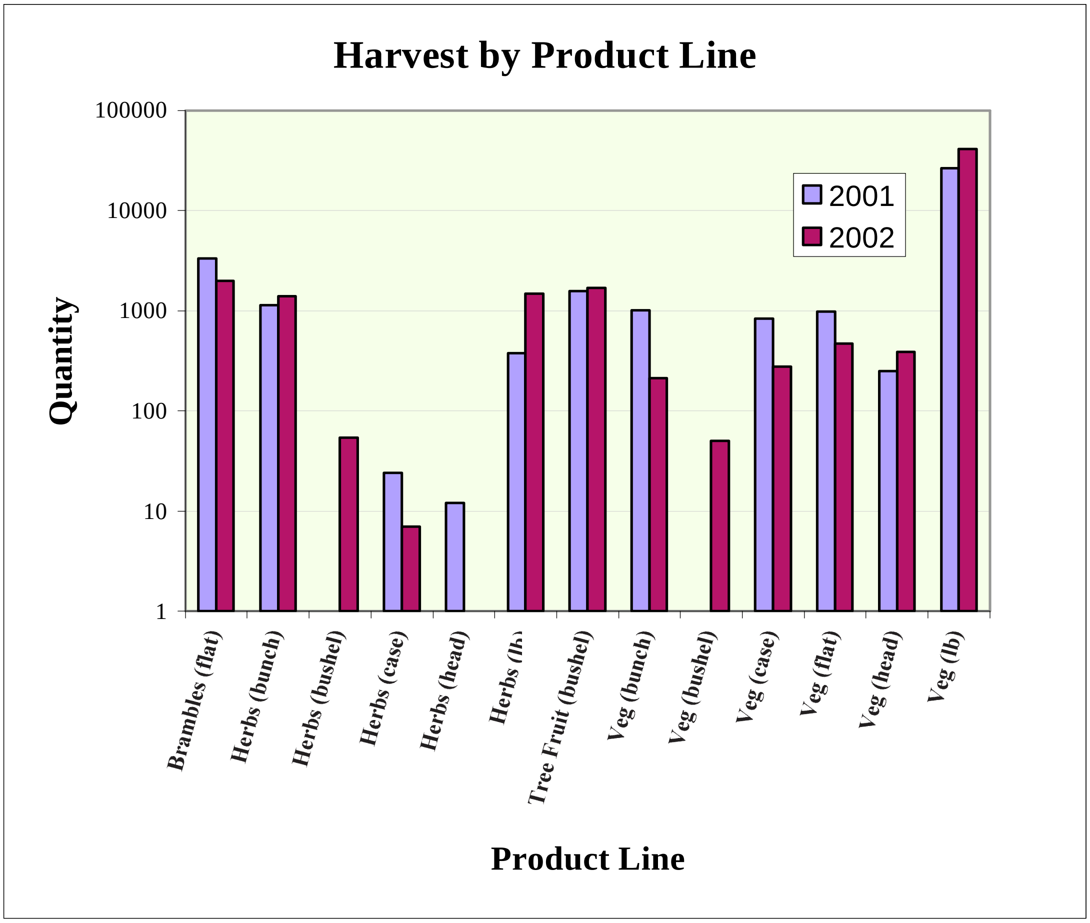


Figure 20 Harvest by Product Line in Harvested Units for 2001 and 2002

3.3.2 Tree Fruit Harvest

The fruit trees at the Farm were predominantly planted in 1998 and 1999. As the trees mature, it is expected that harvest will increase. However, the 2002 harvest of Tree Fruit was only 20 bushels more than the 2001 harvest. The harvest by crop and variety are illustrated in Figure 21. For most of the crops the 2002 harvest was greater than the 2001 harvest, with the major exceptions being York and Golden apples. It was indicated by Farm managers that several apple harvest logs from September 2002 were missing. Both York and Golden apples, which constituted the largest harvest in 2001, were harvested in September of 2001. If these were the missing logs were for these varieties, then it is reasonable to assume that the total Tree Fruit harvest for 2002 would be on the order of 900 bushels greater than 2001.

Tree Fruit harvest can be further distinguished by the harvest timing of each variety. Figure 22 shows the harvest by month for both years. In 2002, the increase in harvest in June, July and August is due to more crops and varieties being harvested, rather than a harvest increase of any one variety. The decrease in the September harvest is likely an artifact of the missing logs.

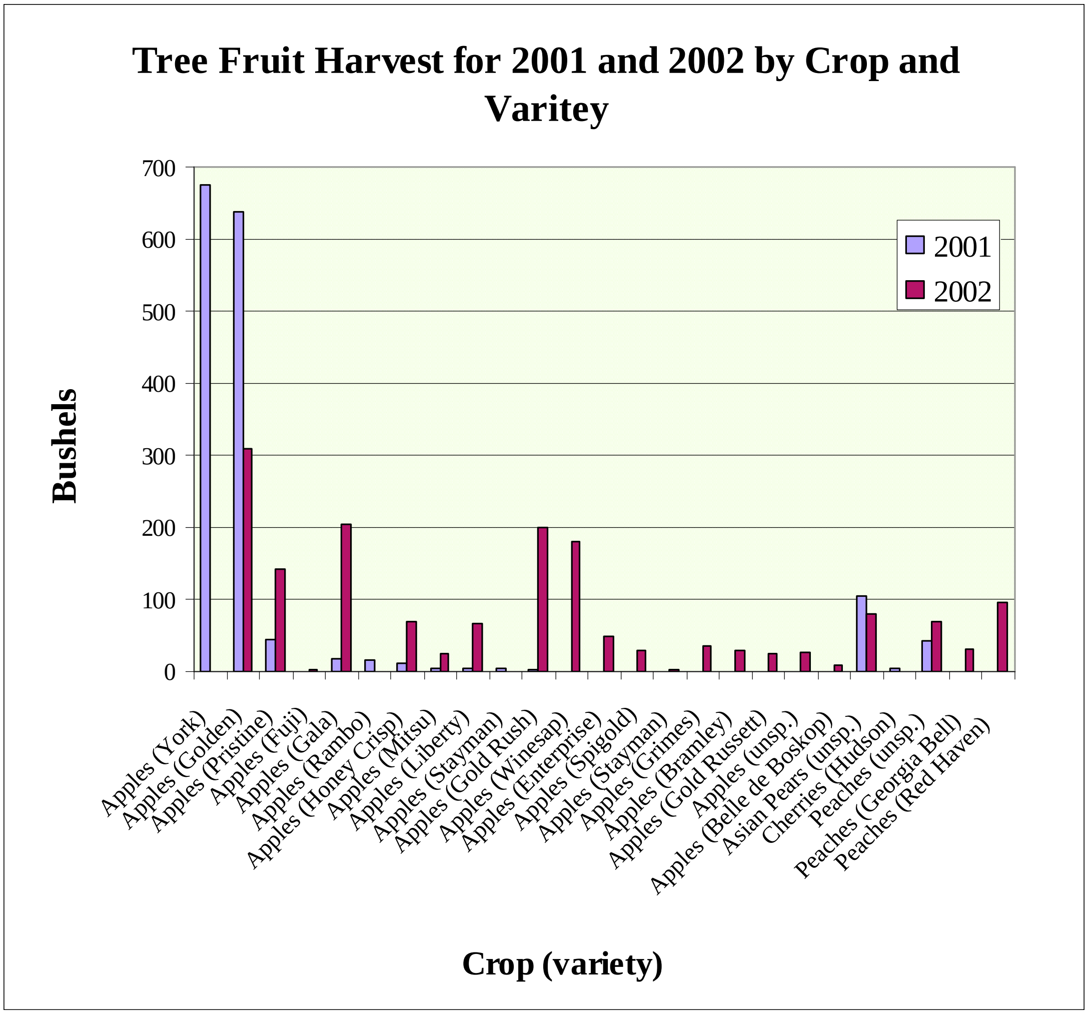


Figure 21 Tree Fruit harvest in bushels by crop and variety for 2001 and 2002

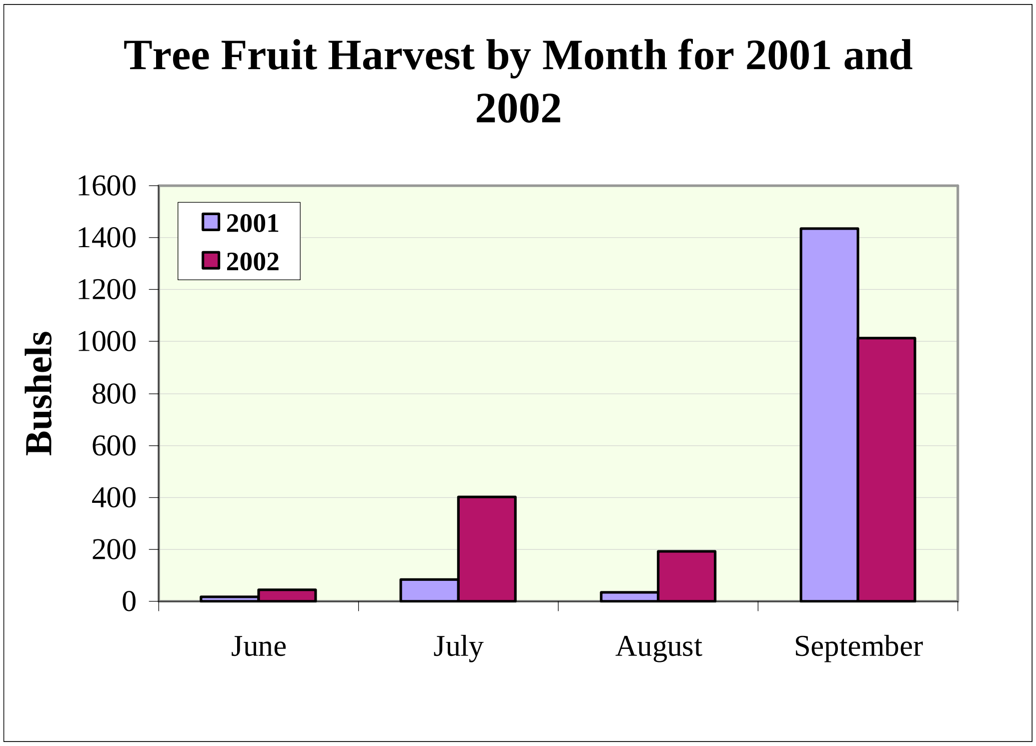


Figure 22 Total Tree Fruit Harvest in Bushels by Month for 2001 and 2002

3.3.3 Bramble Harvest

Blackberries dominate Bramble harvest at the Farm. Figure 23 shows the Bramble harvest by crop for 2001 and 2002. An unspecified Bramble crop is the principle crop harvested in 2002. Though the harvest logs did not differentiate the type of crop harvested in most instances, it is likely that the unspecified crops are predominantly blackberries, as they constitute the largest acreage. Direct observations of harvest events also support this assumption. Bramble harvest in 2001 peaked in July, whereas in 2002 the peak was in August.

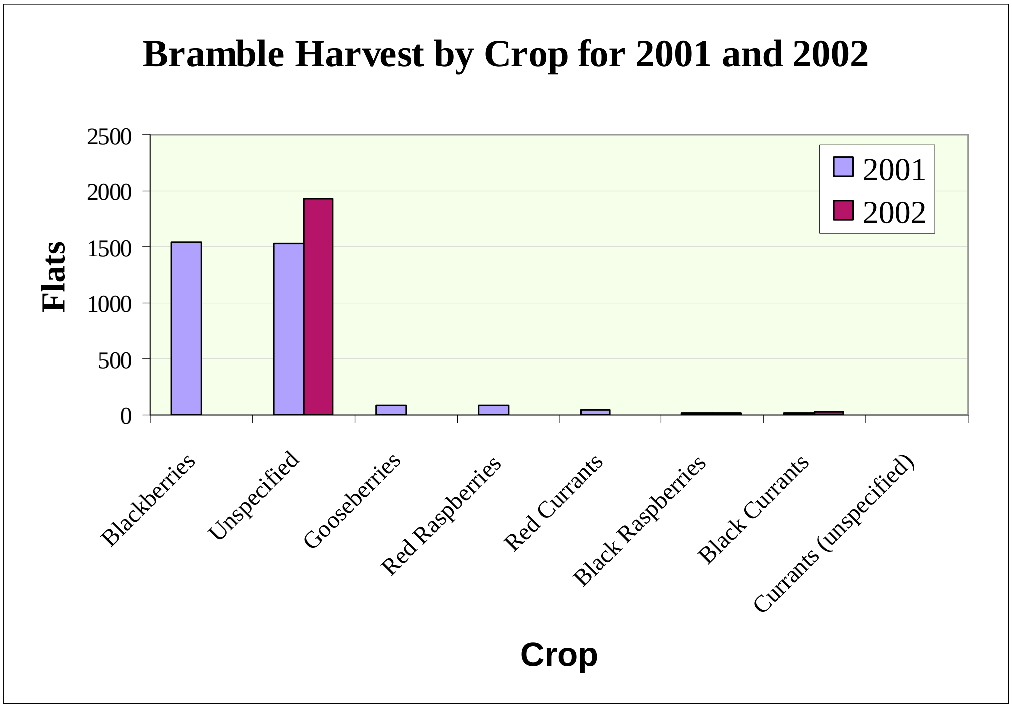


Figure 23 Bramble Harvest in Total Flats by Crop for 2001 and 2002

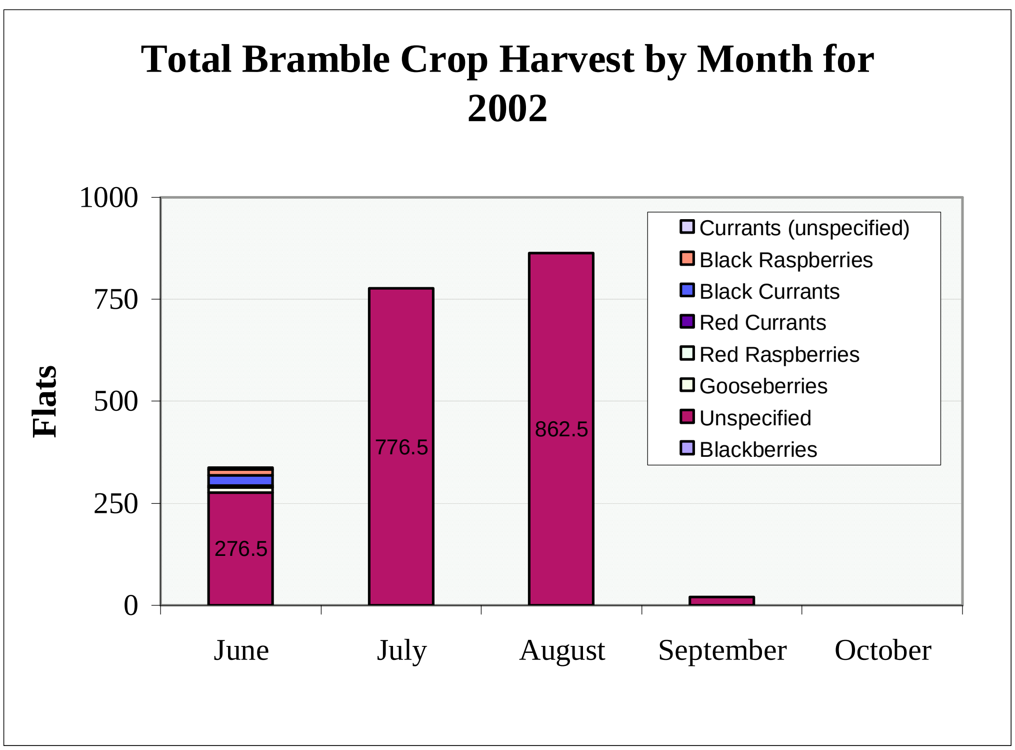


Figure 24 Total Bramble Harvest by Month for 2002

Approximately 1,320 more flats were harvested in 2001 than in 2002. This is a decrease in harvest of 40% between 2001 and 2002. Figure 25 illustrates the difference in harvest between 2001 and 2002 based on each harvest event. It is suspected that since the peak harvest of Brambles occurred in August in 2002 instead of July, the Bramble harvest conflicted with the peak Vegetable harvest, which occurred in August for both years. This could either be due to the Brambles not ripening until late July or August, a decrease in yield between the two years, or management error in harvest labor allocation. Since the decrease in harvest was so large, Farm managers should consider the possible causes of the decrease, as a 40% decline in harvest constitutes a significant portion of revenues.

3.3.4 Vegetable Harvest

Over 150 vegetable varieties are harvested at the Farm. As with the Herb harvest, recorded units of harvest vary between crops and varieties. Varying harvest units are also used for the same variety. To compare across crops and varieties, all units have been converted to pounds. Figure 26 shows total pounds harvested by crop for 2001 and 2002, and indicates that there are a wide variety of harvest quantities.

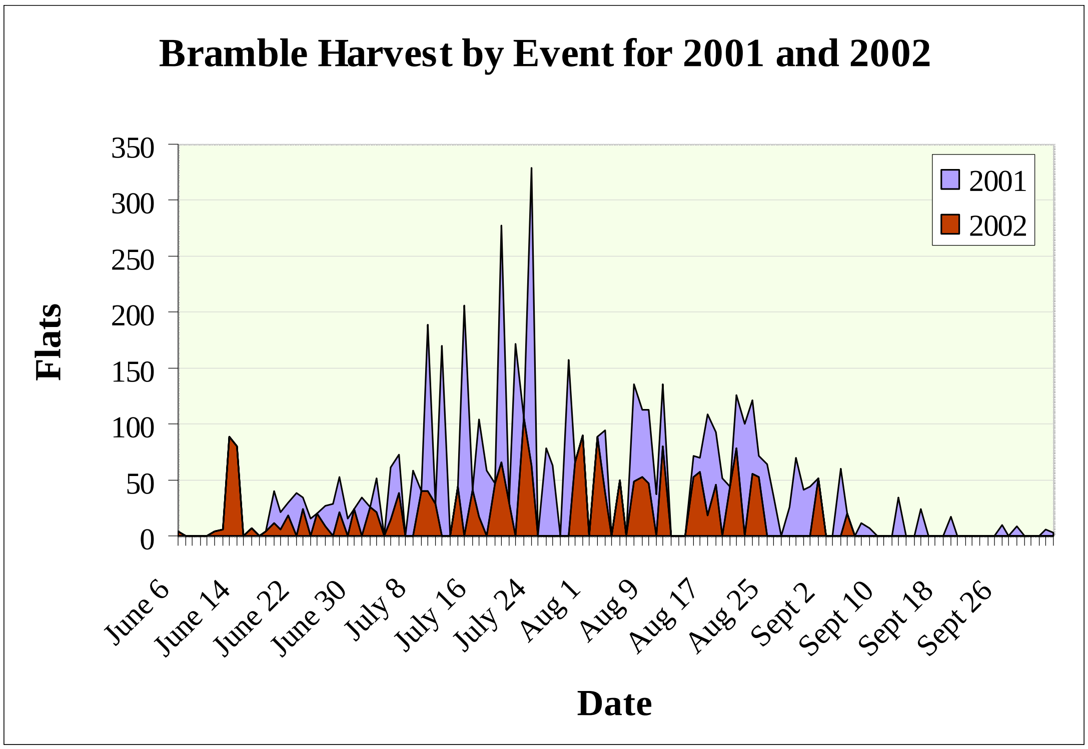


Figure 25 Bramble harvest by event for 2001 and 2002

A comparison of the total monthly harvest for 2001 and 2002 is illustrated in Figure 148 in the Harvest Appendix. From January until August, more Vegetables, in terms of pounds, were harvested in 2002 than in 2001. However, the months of August and September had a greater harvest in 2001 than 2002. It was indicated by Farm managers that over 20 weeks of Vegetable harvest logs from the latter half of 2002 were lost. Some of these logs could have been from late August and September, thus skewing the harvest graphs. In addition, there are no data for the first three months in 2001. Whether or not Vegetables were harvested or data were not collected is unknown.

Figure 27 illustrates the top five harvested crops. In 2002 there was an increase in regular tomatoes, summer squash and lettuce, but a decrease in potatoes and cherry tomatoes by approximately half of the quantity harvested in 2001.

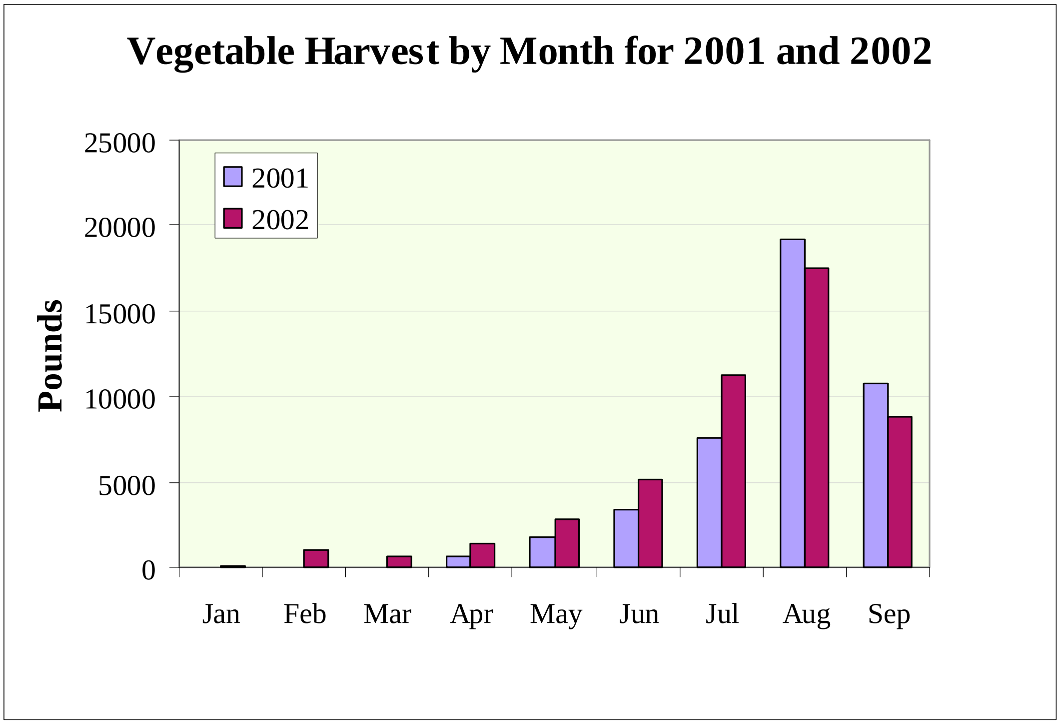


Figure 26 Vegetable harvest by month for 2001 and 2002

3.3.5 Herb Harvest

Herb harvest increased 52% by weight from 2001 to 2002 (Figure 28). The most significant increases were seen in basil, cilantro and chives, all of which had a harvest increase of over 60% from 2001. Figure 29 shows the harvest by month for 2001 and 2002. Harvest for 2002 was greater than 2001 in every month.

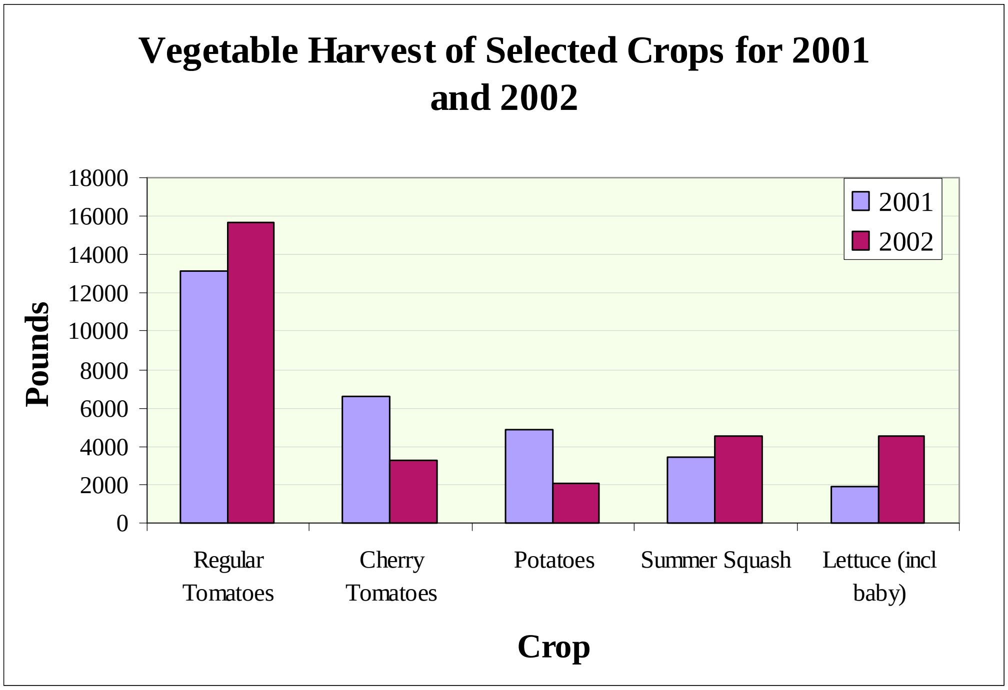


Figure 27 Vegetable Harvest of Selected Crops for 2001 and 2002

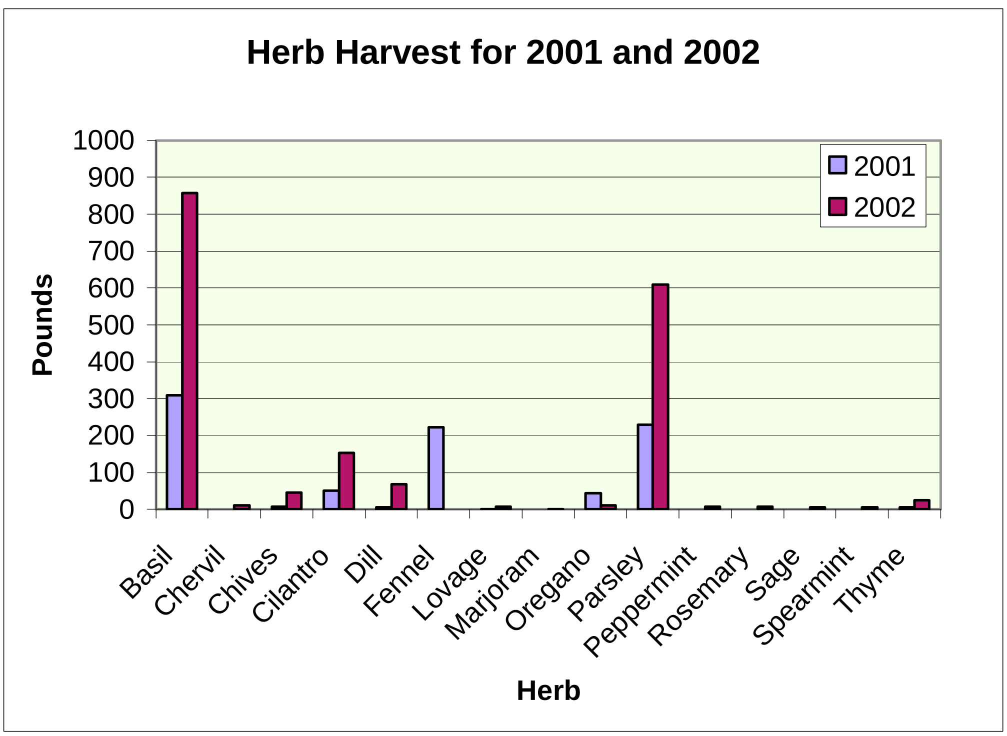


Figure 28 Herb Harvest for 2001 and 2002

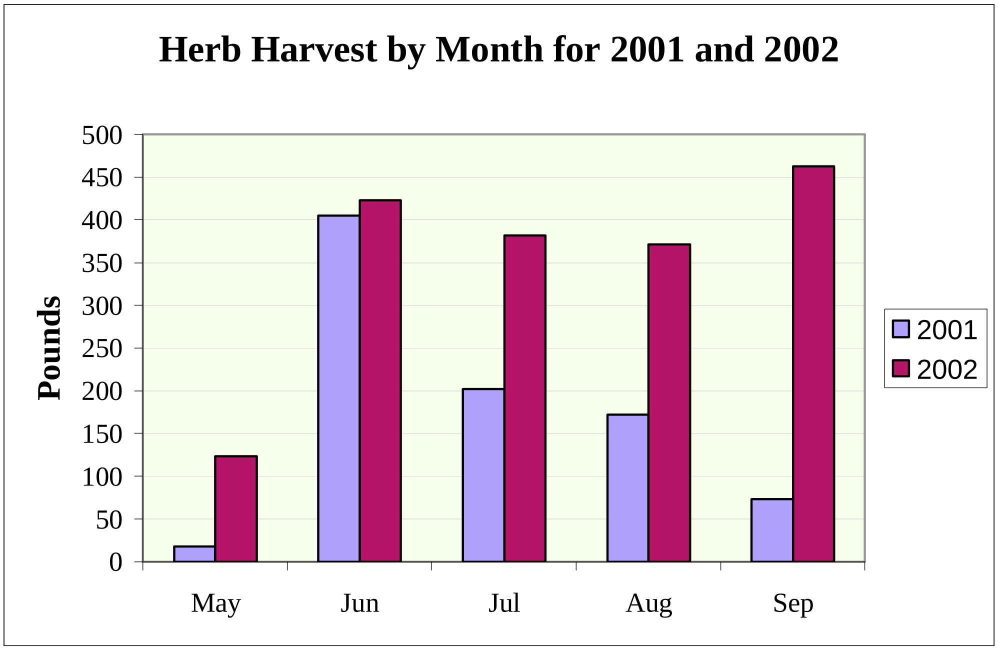


Figure 29 Herb Harvest by Month for 2001 and 2002

3.3.6 Poultry (Egg) Harvest

The Poultry (egg) harvest is the most complete of all harvest data with only four months of missing data. In 2001, the numbers of culls were not recorded. Figure 30 shows the results of the egg harvest for 2001 and 2002 by month, and indicates that there is variability in both the quantity of eggs harvested and the timing of the harvest. This cyclical pattern becomes more evident when the harvest data are plotted by event (Figure 31). The large gaps in the graph are due to missing data. The logs were either not completed or were misplaced for these timeframes. In 2001, there is a general upward trend, but there is a high degree of variability between the events. This is most evident from mid-March to mid-July 2001, when there is a significant decline in the harvest.

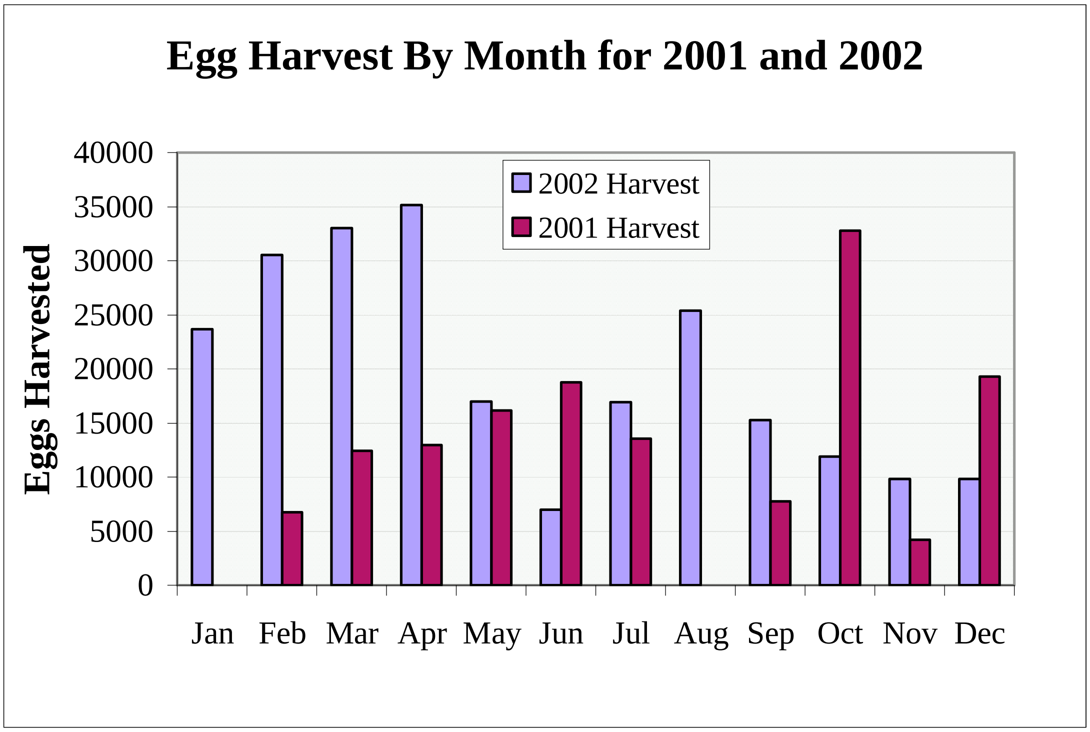
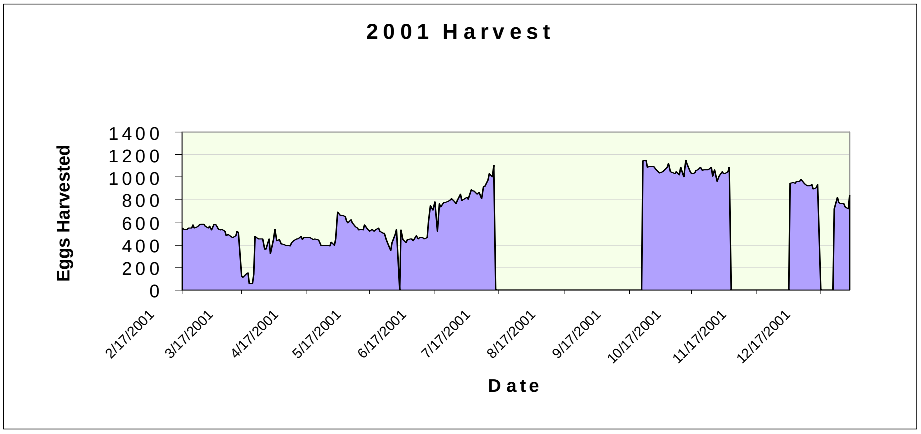


Figure 30 Egg Harvest by month for 2001 and 2002

3.3.7 Chicken Flock Analysis

According to the 2002 harvest logs, four different flocks of layers (chickens) were producing eggs at the Farm. These data were not recorded until October of 2002. Figure 32 illustrates the harvest by flock. As should be expected, the overall pattern of harvest by flock mirrors the harvest by month and event for 2002. This graph further illustrates that in 2002 there was a drastic decline in the egg harvest beginning in May and continuing into July. Although some variation in flock harvest over time is expected, the variation shown in Figure 32 was unexpected. Direct Farm observations, in this case, did not provide any insight that would explain the high variation. During the summer months, all layers were in one area. Clear flock delineation was not recognized. The mixing of the flocks could possibly explain some of the variation. For example, in the latter months of 2001 only flocks 1, 2 and 3 were recorded. This convention was held until mid-February of 2002, when a fourth flock was added to the harvest logs. Based on the data, it could be possible that flocks 1 and 3 are, in reality, the same flock. This would explain why flock 1 had such a small harvest during the first half of the year and why flock 3 had a small harvest during the latter half.



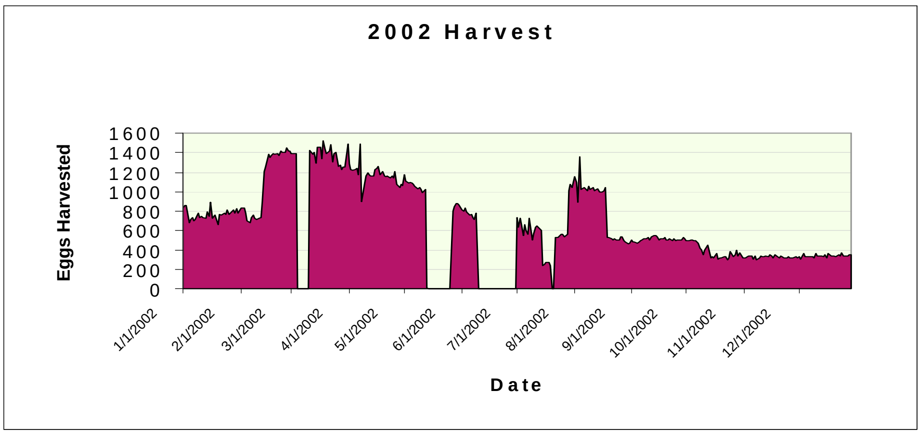


Figure 31 Poultry (Egg) Harvest by Event for 2001 and 2002

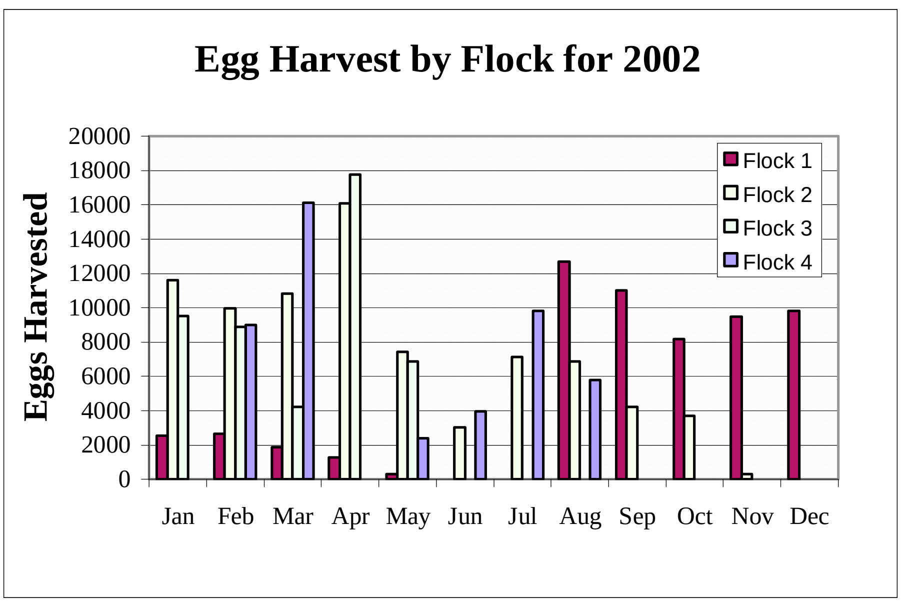


Figure 32 (Poultry) Egg Harvest by Flock and Month for 2002

3.3.8 Harvest Culls

Harvest culls are the harvested crops that are damaged or otherwise unsuitable for sale. Culls are tracked at harvest for the Bramble and Poultry (egg) product lines, but cull data are often missing. In addition, discrepancies exist between the quantity picked and quantity packed. For example, several weeks of Bramble harvest data had larger quantities of packed than picked, indicating that more brambles were picked than were recorded. Discrepancies of this nature can be problematic with respect to the accuracy of Farm records and organic reporting guidelines. When the Farm managers were asked about this apparent problem, one suggested that the size of the containers differed (the collection containers contain more berries, thus more containers would be needed to pack the berries), while another indicated that the columns just needed to be switched. Cull analysis will be limited to the egg harvest because of the unreliability of the Bramble data.

In comparing the quantities harvested and sold for eggs in 2001, the magnitude of the missing harvest data becomes apparent. Nearly 22,000 more eggs were sold than were recorded as harvested. An analysis of the harvest by month for 2001 suggests that if harvest for the two missing months of data for 2001 were similar to the months before and after, then the quantity of eggs harvested would exceed the quantity sold. In 2002, approximately 37,000 more eggs were harvested than sold. These data are summarized in

Table 2 and Figure 33. The highest cull percentage was in April of 2002. This correlates with the decrease in harvest at the beginning of April illustrated in Figure 31.

Table 2 Culls and Percent Culled Eggs for 2001 and 2002

Year	Harvested	Sold	Culled	Harvested-Sold	Percent Culled
2001	144,704	166,585	0	-21,881	0%
2002	235,589	198,530	12,374	37,059	21%

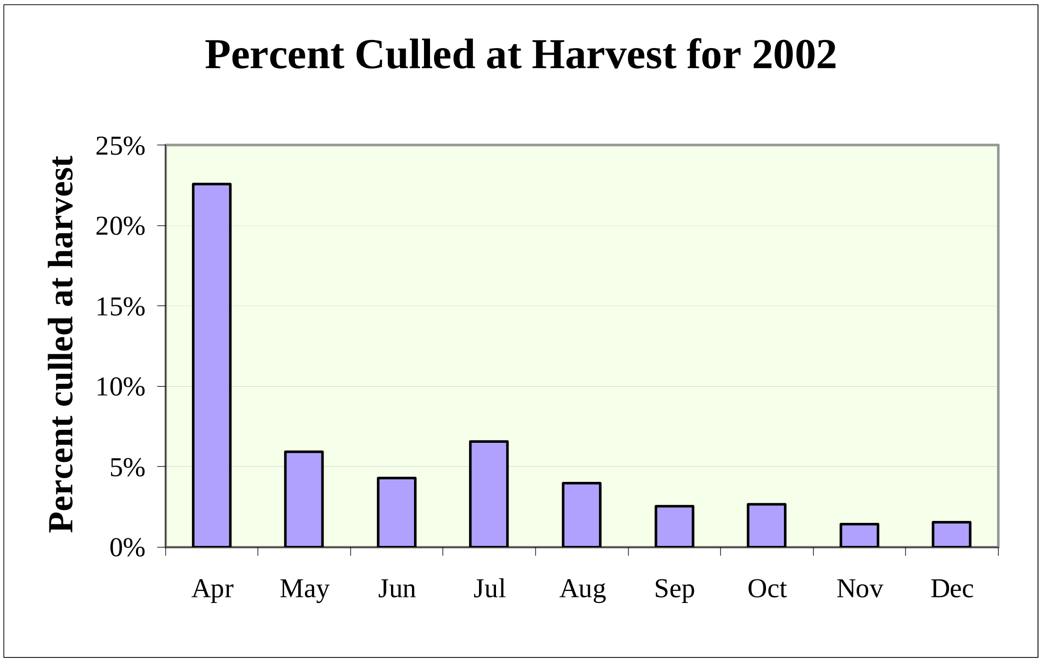


Figure 33 Egg Cull Percentage of Harvest by Month for 2002

3.3.9 Harvest Timing

The timing of expected labor requirements for each product line is of concern to Farm managers. Figure 34 and Figure 35 show the percent of harvest for each product line relative to that product line by month for 2001 and 2002, respectively. In both years, the months of July, August and September had the largest percentage harvested. September was dominated by Tree Fruit harvest in both 2001 and 2002. Over 75% of the Bramble harvest occurred in July and August in both years. Vegetable harvest peaked in August with a percentage of over 35% for both years. Herb harvest in 2002 remained relatively stable for June, July and August; however, in 2001 it peaked in June then declined in the following months. Egg harvest declined during the summer months for both years, yet remained relatively stable throughout the rest of the year.

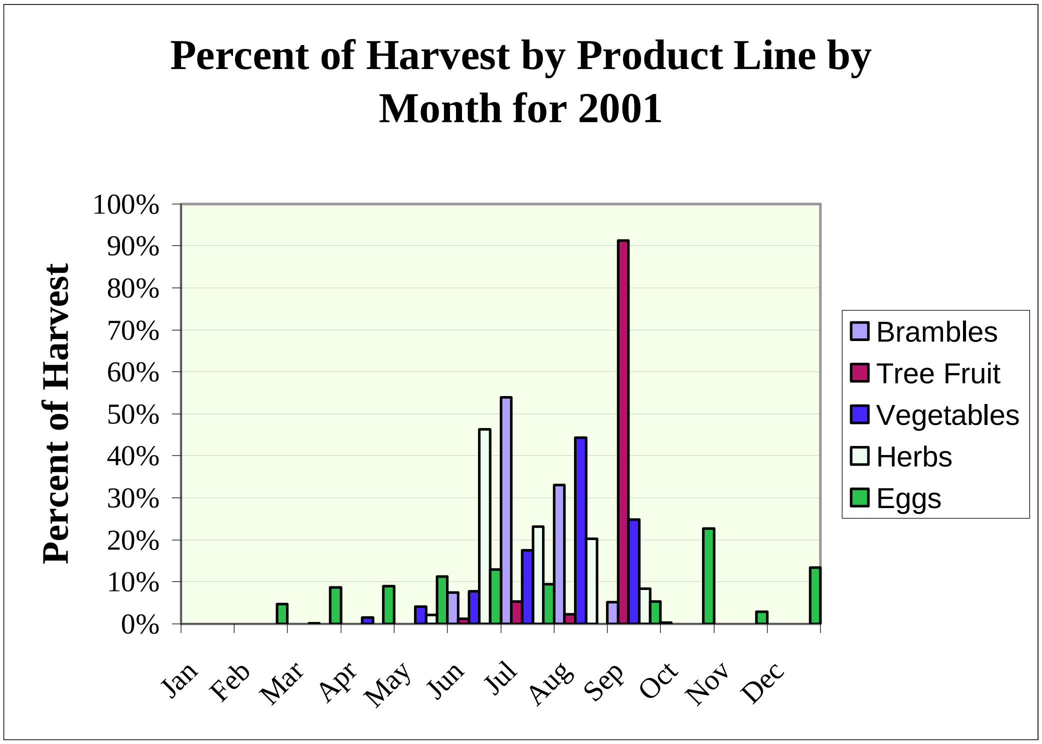


Figure 34 Percent of Harvest by Product Line and by Month for 2001

Figure 36 and Figure 37 show the total harvest in pounds for 2001 and 2002. These figures show the relative harvest requirements, though since they are based on pounds, they should only be used as an estimate of peak harvest. For example, apples weigh much more than a bunch of basil, but the time required to harvest them might be approximately the same. These two graphs do not capture this information. What can be determined from them is the peak harvest by product line. In 2001, Brambles peaked in July, Vegetables peaked in August and Tree Fruit peaked in September. In 2002, both Brambles and Vegetables peaked in August, and Tree Fruit peaked in September but had a significant harvest in July.

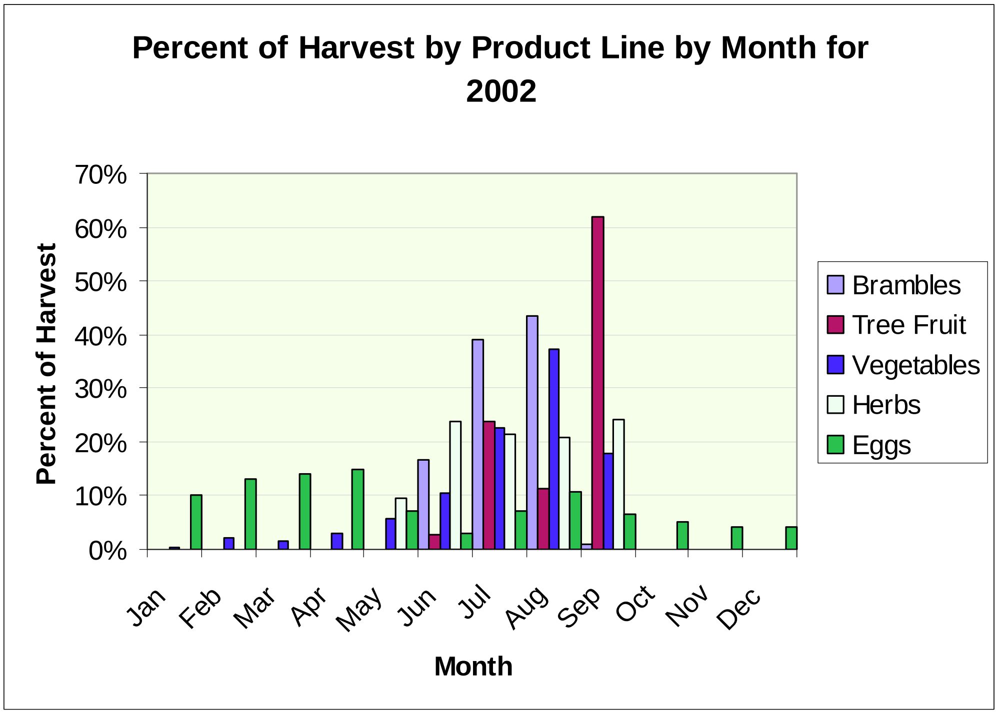


Figure 35 Percent of Harvest by Product Line and Month for 2002

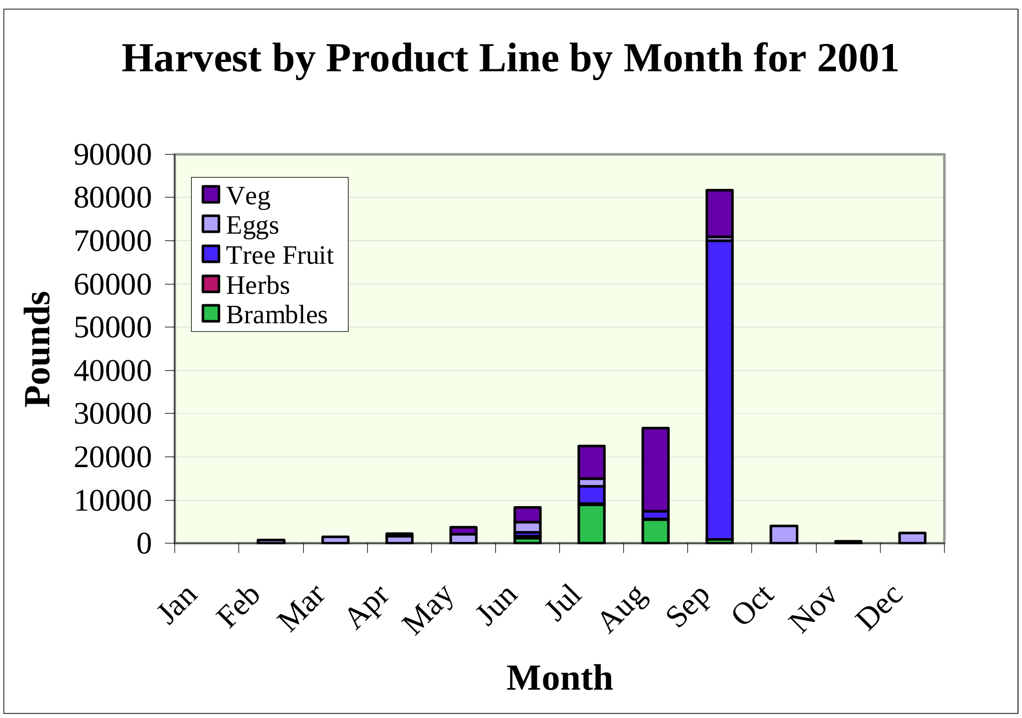


Figure 36 Total Harvest by Product Line and Month for 2001

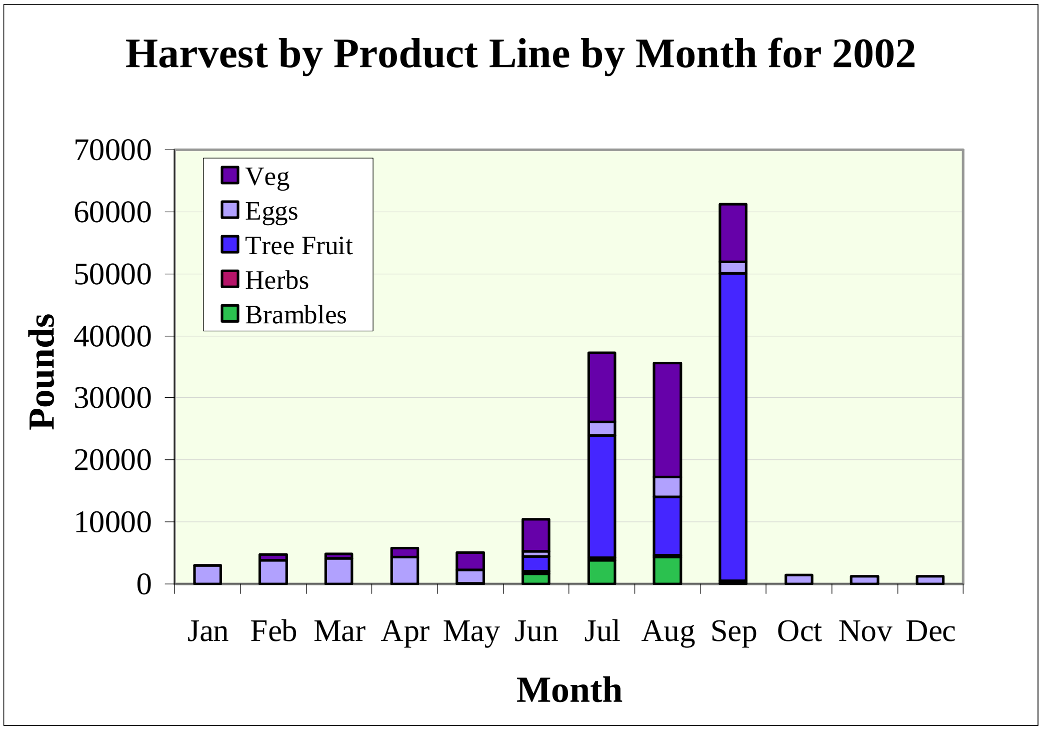


Figure 37 Total Harvest by Product Line and Month for 2002

3.4 Harvest per Acre

The harvest per acre in pounds for 2001 and 2002 is illustrated in Figure 38. Vegetables and Herbs were combined because they are often grown in the same areas. For this analysis the acreages in Table 3 were used. These acreages were determined by taking GPS coordinates of the specific plots that were planted and then by utilizing GIS. In the case of Brambles and Tree Fruit, the acreages only reflect the producing acreages of the Farm (Figure 147). The difference in Brambles between the two years is due to the removal of a small section of Brambles in 2002.

Table 3 Harvested Acreage by Product Line for 2001 and 2002

	Acres	
Product Line	**2002**	**2001**
Tree Fruit (not including Cherries)	21.51	21.51
Vegetables and Herbs	11.22	11.22
Brambles	4.42	3.20

3.4.1 Comparison to state and national averages

Although comparing harvest per acre between years is valuable for the evaluation of management practices, comparing the harvest per acre with national and state averages also gives an indication of the relative ability of the Farm to produce food. This analysis will focus on Brambles and Tree Fruit.

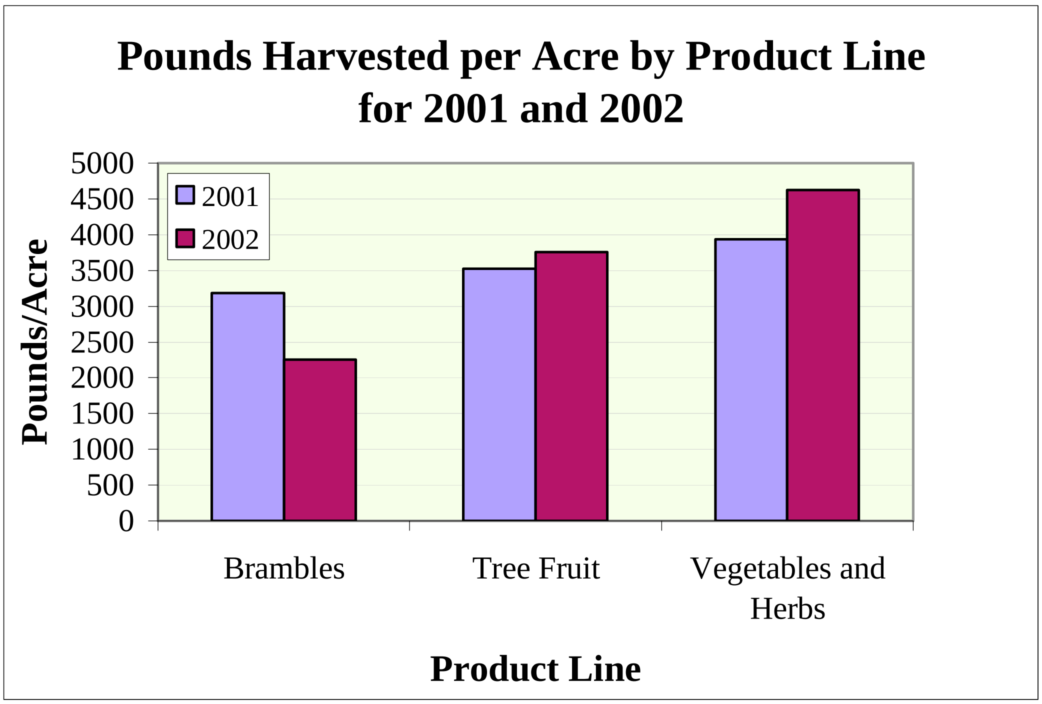


Figure 38 Harvest per Acre by Product Line in Pounds for 2001 and 2002

Tree Fruit

In 2002, approximately 1,400 bushels of apples and 195 bushels of peaches were harvested. This results in 95 bushels per acre for apples, and 14 bushels per acre for peaches. It has been estimated that commercial producers of apples in Virginia produce approximately 700 bushels per acre of apples, or 29,000 pounds per acre.[5] The apple production per acre at the Farm is 14% of the state average. Peach production statistics were not found for Virginia; however, per acre production in pounds for Georgia and South Carolina are 6,760 (130 bushels) and 9,090 (175 bushels), respectively.[6] The Farm produces 10% of the Georgia average and 8% of the South Carolina Average.

Brambles

In 2002, 9,950 pounds of Brambles were harvested, resulting in 2,250 pounds per acre. For comparison to average production, we assume that blackberries constitute the bulk of Bramble production on the Farm. Blackberry yield per acre is dependent upon region and blackberry type.[7] Blackberry production statistics were not found for Virginia; however production statistics for the nation as well as Kentucky will be used. In 2001, the US harvest per acre was 5,050 pounds, and Kentucky's harvest per acre was 1,200 pounds. The Farm is producing 180% of the Kentucky average, and 45% of the national average. This variation is likely due to regional and cultivation differences.

3.5 Harvest Conclusions

Relative to 2001, the 2002 harvest increased for Vegetables, Herbs, Poultry (eggs) and Tree Fruit but decreased for Brambles. There was an increase in the types of Tree Fruit being harvested as well as the quantity. The increase in quantity and variety of Tree Fruit is also reflected in the timing of harvest. The wider variety of apples that were harvested account for the increase in Tree Fruit harvest in July of 2002. The Vegetable harvest began early in the year in 2002. Harvest events occurred in January, February and March in 2002, but not 2001. Apple harvest per acre is approximately 14% and peach harvest per acre is 8-10% of an average commercial grower. Bramble harvest per acre is approximately 50% of the national average, but greater than the average of a neighboring state.

3.6 Harvest Recommendations

Harvest managers should focus on spreading out the harvest as much as possible to avoid conflicting labor requirements. There are two primary ways to achieve this objective. The first is to use the above data to anticipate when the harvest peaks will occur and structure labor requirements as necessary. In 2002, harvest for Brambles and Vegetables peaked at the same time. This resulted in a reduction in harvest for both product lines by roughly 1,000 pounds from the previous year. As a result, Bramble harvest should be focused on in July in order to reduce the conflict in labor requirements in August. The second method of avoiding conflicting labor requirements is to plant more of the crops that arrive earlier in the season. Since peak harvest for most of the product lines is in June through September, an increase in spring, winter and fall crops will reduce the peak labor demands as well as increase revenues throughout the year.

3.6.1 Harvest Log Recording

Accurate data recording is necessary if meaningful analyses are to be made. There is doubt regarding the accuracy of the information provided by the harvest logs. A large source of potential error is the ambiguous recording of product lines in the harvest logs. For example, a large portion of the Bramble harvest logs simply had the product line recorded and not the specific crop or variety. That is, instead of recording what was harvested (blackberries, raspberries, etc.) all that was recorded was 'berries.'

When this occurs, significant information is lost as to what was actually harvested. In addition to this, care must be taken in recording how much is picked and how much is packed so that accurate cull records can be kept.

3.6.2 Harvest Log Storage

The process of recording and storing the Harvest, Activity and Treatment logs was not seen to be a high priority. It is suspected that the logs are not regularly filled out, but are rather occasionally filled out several days after the event or at the end of the week. If this is the case there is potential for significant error in the results of the analysis. Retrieving the logs has also been a constant source of struggle, as there is currently no central storage place for the logs. It was reported by Farm managers that over 20 weeks of Vegetable harvest and several weeks of Tree Fruit harvest were lost from August of 2002 through the end of the year. Organization of the paper logs, or direct electronic input of the data, is crucial for future Farm analyses.

4 LABOR

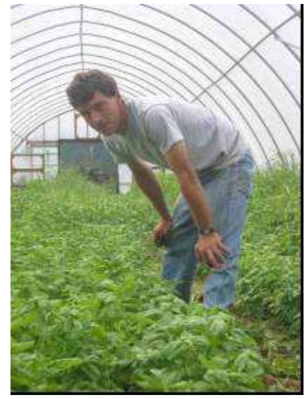


Figure 39 A Farm Manager Assessing Basil Growth

Because labor costs represent a significant proportion of the operating expenses each year, appropriate allocation of labor is crucial. The following analysis pertains to hourly wage labor. Salaried labor is treated separately from hourly labor, as salaried workers do not record activities in logs. Salaries are therefore designated to product lines and included in profit and loss (P & L) calculations.

4.1 Labor Tracking

Labor is tracked through the use of an "Activity Log." While this log was only used from mid-March through mid-August 2002, preliminary observations related to the cost and use of labor can be made. This log recorded the date, duration, place and nature of an activity in which a worker is engaged. Hours of work were assigned to a product line or crop by Farm managers and were entered into the database by interns. Labor information was analyzed on the basis of activity, product/product line, location, total number of hours, cost, date, and employee.

Managers filled out labor logs during the week for all hourly laborers. For payroll purposes, workers were also responsible for punching in and out each day, and hours worked were assigned to a general category. This information is used for parts of the analysis where a time period longer than March to August was required, since logs were not kept up through the fall, despite the fact that the data from the Activity logs are more detailed.

To allow the total cost of hourly labor to be included in the analysis, payroll information was used. In addition to the hourly wage, employer contribution was also added to reflect the true cost of each labor hour. Employer contribution included Federal Unemployment, Medicare, and Social Security. Total contributions from January to August 2002 for each employee were divided out by the number of total hours worked in the same period to gain the cost added to each labor hour through contributions. This value was used to calculate the real cost of hourly labor.

It should be noted that the Vegetable manager Brian Cramer, Farm manager Rito Garcia, maintenance personnel Wayne Jenkins and marketing director Tamara Waldo do not record their activities in the logs. For accounting expenses, Wayne and Tamara are included as a Whole Farm expense and Brian as a Vegetable expense. Rito's salary is divided equally between Livestock, Brambles, Tree Fruit and Whole Farm. This omission of hours in this analysis can be misleading as to the total number of hours spent on a category of activity. For example, labor hours spent on Herbs cost about $800, but Brian spends time harvesting Herbs for restaurant orders, so this amount could be larger.

In addition, as the total cost of labor is calculated based on hours recorded on Activity logs and not hours submitted to payroll, cost represents the minimum amount, not the actual total. Due to the increased level of granularity of detail included in activities performed, activity logs are still useful for examining labor breakdown on the Farm despite the systematic understatement of total cost.

4.2 Results

4.2.1 Total

Total hours worked by month based on payroll data suggest that labor requirements per month vary greatly with season (Figure 40). Labor requirements at the Farm are low during winter months, increase in the spring and summer, and decrease in the winter.

4.2.2 Activity

Farm activities are divided into categories, followed by subset activities. The broader categories are administration, maintenance, capital expenditures, harvest, treatment, planting and market activities. For example, feeding the dogs is a part of maintenance, and is under the Tree Fruit product line since dogs act as orchard deer-control. A complete list of activity subsets can be viewed in Table 97 in the Labor Appendix. This section is based strictly on Activity Log data.

While activities are divided into categories, comparing the top ten activity subsets (Figure 41) provides an overview of the most labor-intensive activities. Of the 55 possible activity areas, landscaping incurs the largest expense, followed by picking, weeding and Livestock maintenance. Maintaining the horses (8th highest labor expense) is of note because it is a personal, rather than a Farm expense.

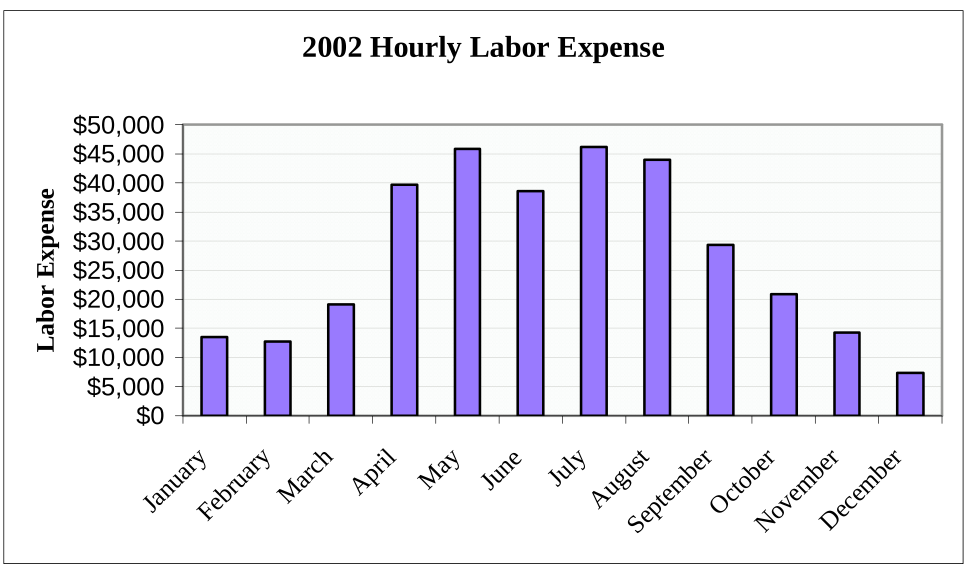


Figure 40 Total Labor Cost by Month. Values are taken from payroll information.

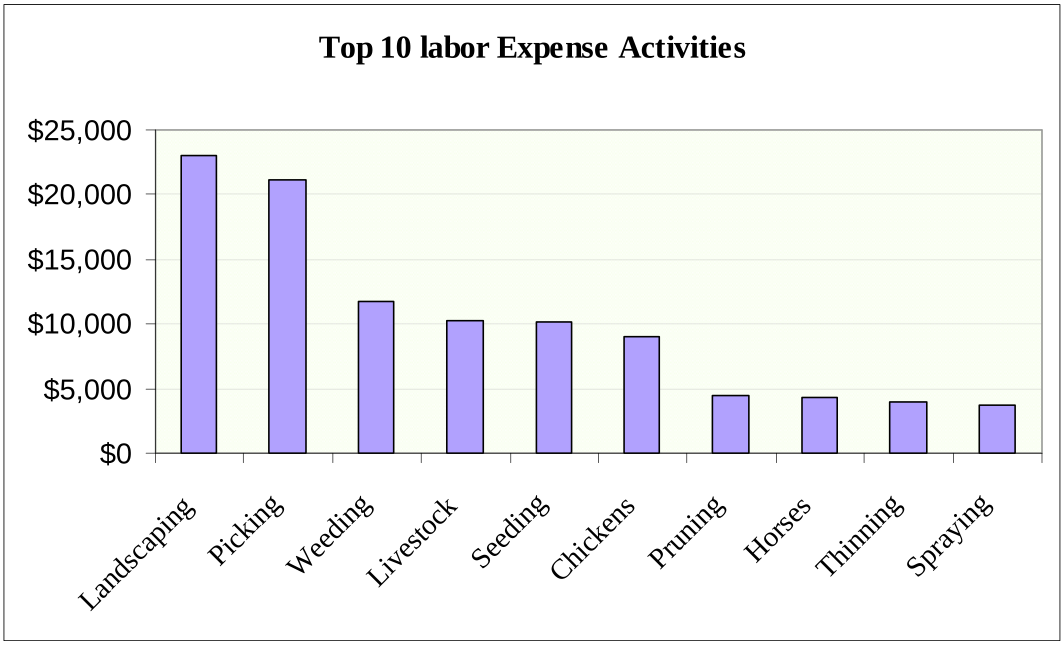


Figure 41 Top 10 Labor Expense Activities.

Of the 55 possible labor categories, the ten shown here incurred the greatest labor expense for a period from mid March to mid August. Landscaping includes mowing.

In examining the distribution of activities in each month by the main categories (Figure 42), it is apparent that the largest portion of labor hours is allocated to maintenance activities, followed by treatments and harvest activities. This is not surprising, as the greatest numbers of activities are categorized as maintenance.

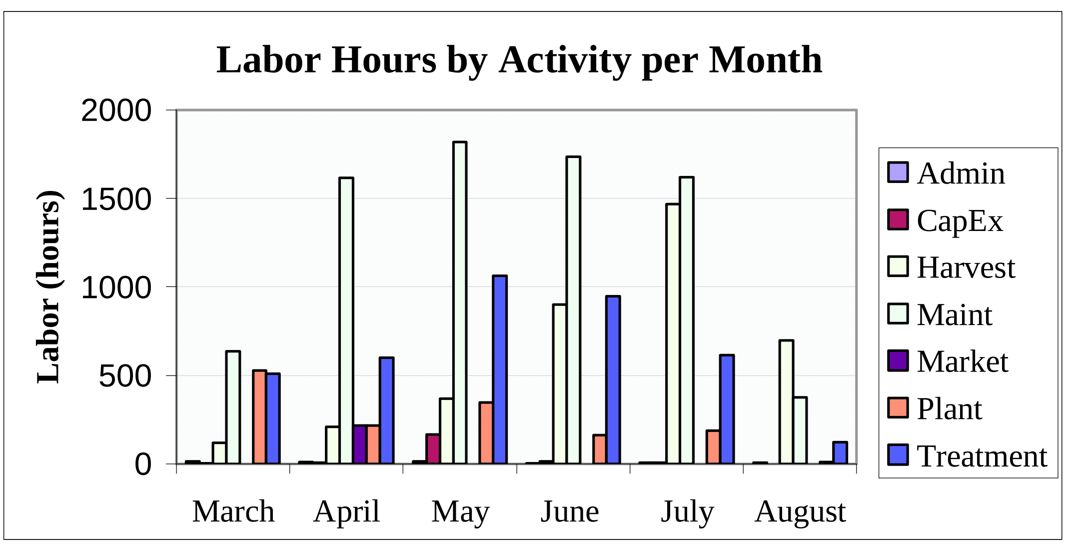


Figure 42 Labor Hours by Activity per Month
Note that March and August are partial months.

As illustrated in Figure 43, maintenance makes up approximately 41% of all labor, followed by treatments at 22%, and harvesting at 20%. Direct revenue-generating activities such as harvesting and marketing only make up 26% of total labor expense from mid-March to mid-August 2002. This percentage would be larger if the Activity logs had captured the peak harvest in August and September.

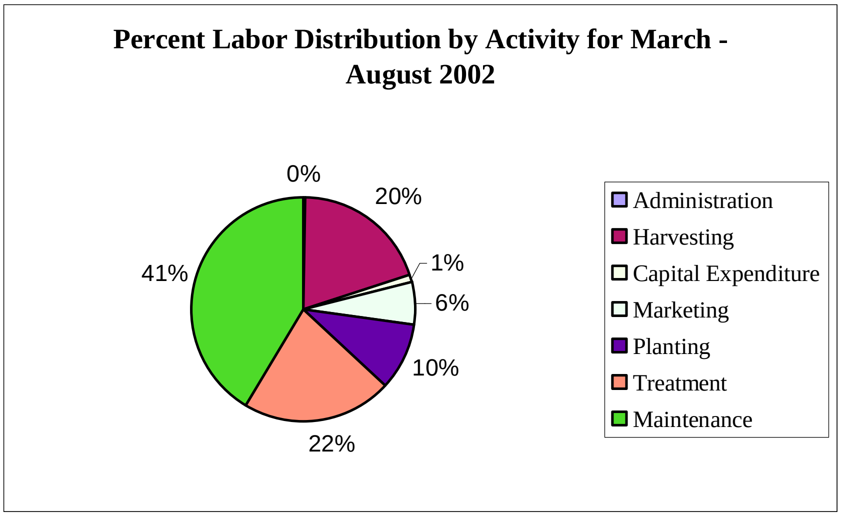


Figure 43 Percent Labor Distribution by Activity

Breaking down maintenance activities (Figure 44) shows that a broad range of activities from landscaping and Livestock maintenance to painting, field observations and repairing are included in this category.

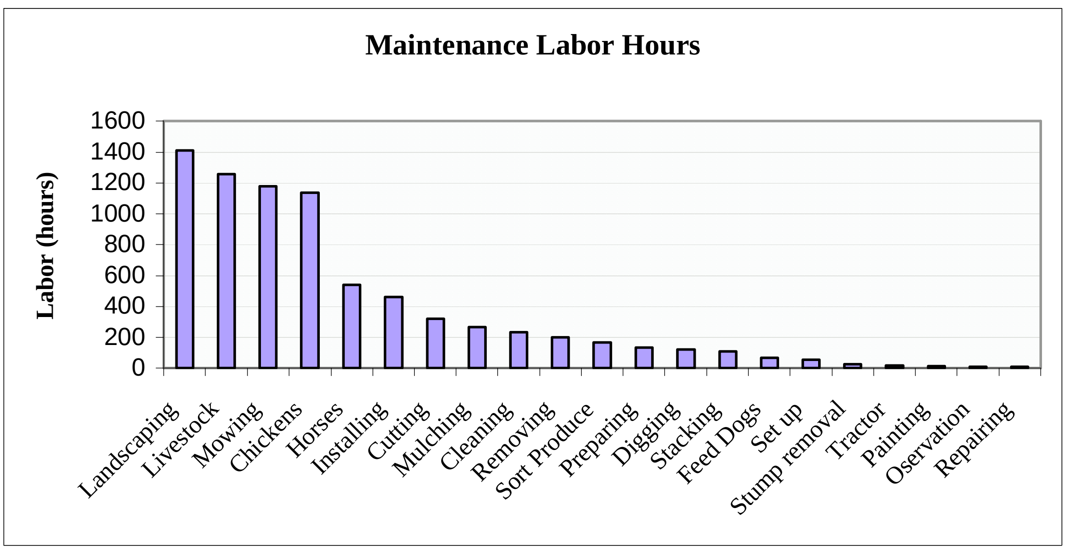


Figure 44 Activity Log Maintenance Hours
The majority of maintenance hours are spent on landscaping, Livestock, mowing, and chickens.

Maintenance activities as a percentage of total maintenance (Figure 45) show that the largest percentage of maintenance labor goes to landscaping. Landscaping and mowing combined represent 34% of all maintenance labor. As maintenance makes up 41% of all labor hours, 14% of total labor expenditures are devoted to maintaining Sunnyside's grounds.

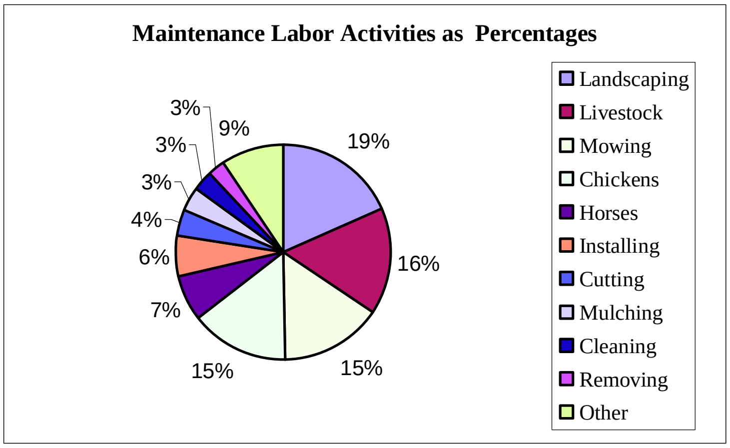


Figure 45 Maintenance Subset Activities by Percent

Treatment activities, which consumed the second largest amount of labor hours at 22%, are broken down further into subset activities below (Figure 46). Treatment labor requirements are of particular interest in an organic Farm since heavy application of pesticides and fertilizers is often offset by increased labor. In the case of the Farm, this appears to be valid, as 40% of labor treatment costs are consumed by weeding, while activities such as applying, fertilizing and pest control make up the smallest labor use at approximately one percent each.

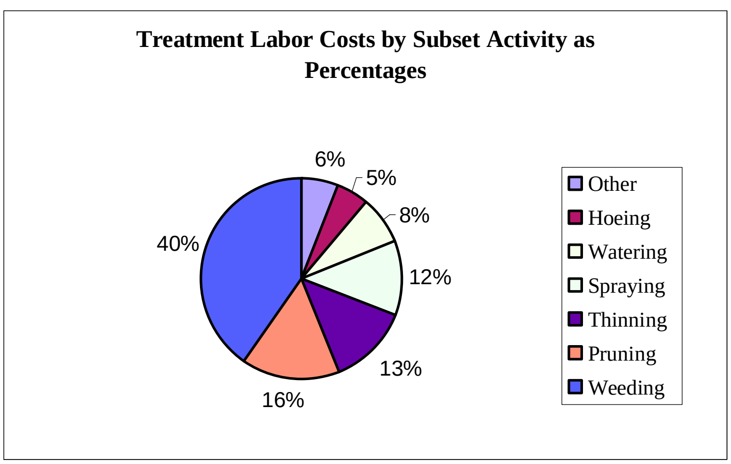


Figure 46 Treatment Labor Costs by Subset Activity as Percentages

4.2.3 Product Line

In addition to categorizing labor on the basis of activities, labor can also be differentiated by product lines. Product lines represent what was grown or raised on the Farm with the exception of the "Whole Farm" designation, which refers to all activities or expenses that cannot be divided into a distinct product line. That is, Farm overhead operations in general are captured by the Whole Farm term. As seen below (Figure 47), Vegetables represent the largest fraction of labor expenses, followed by Whole Farm and Tree Fruit labor expenses. While Grain is also a product line, it has been omitted from the figure as it represents an insignificantly small amount of labor and revenue.

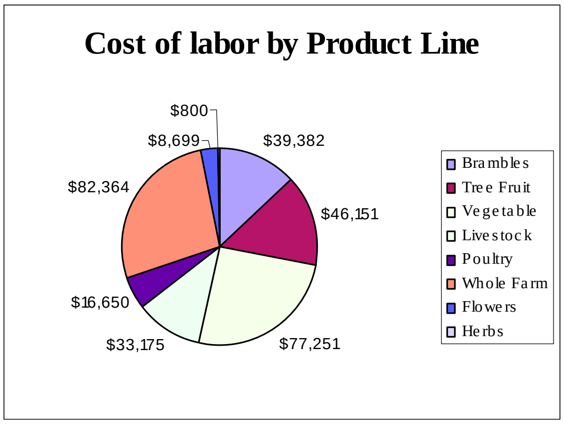


Figure 47 Labor Expense by Product Line. Values are based on payroll information.

Labor expenses by product line by month (Figure 48) show that Whole Farm and Vegetable labor are consistently the highest, where Whole Farm peaks in May and Vegetable labor peaks in September. Both Poultry and Livestock require low levels of sustained labor throughout the year.

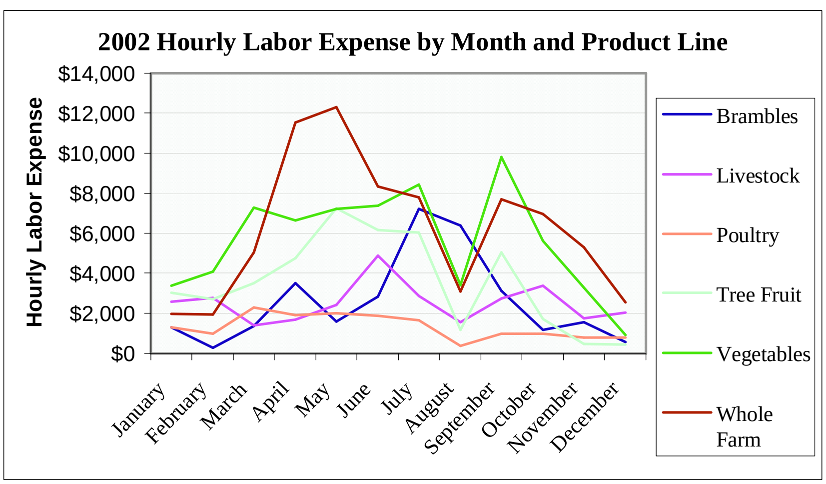


Figure 48 Cost of Labor by Product Line by Month

Values are based on payroll information.

4.2.4 Product

In the case of Tree Fruit, activities were recorded in the Activity Log to the level of detail that included crop (Figure 49). The majority of Tree Fruit labor hours are spent maintaining the product line in general. This is to be expected, as most treatments, fertilizing, pruning etc., are necessary for all fruit trees, while only a few treatments are specific to the various crops of fruit. Labor hours by fruit are greatest for peaches at 24%, followed by apples at 13%, and Asian pears and cherries at 3% and 2%, respectively. It should be noted that, as these data represent March to August only, it is likely that apples, many of which are harvested in the fall, would greatly increase the proportion of Tree Fruit labor allocated to apples.

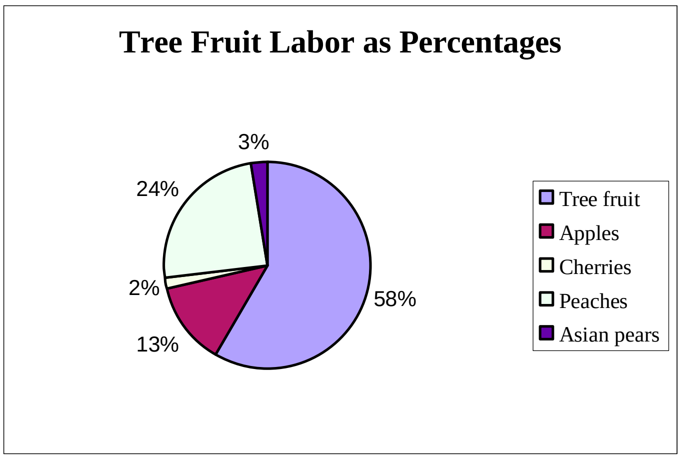


Figure 49 Tree Fruit Labor as Percentages

Based on Activity log data for March 15 – August 10, 2002.

4.2.5 Comparison of Activity Logs and Payroll Labor Tracking

Due to the limited tracking of labor activities in the Activity Log, which provides a high level of detail, labor breakdown tracked on the pay cards of hourly labor was also used to supplement some parts of labor analysis. While the Activity logs used the six Farm product line designations outlined earlier to categorize labor hours, payroll information used slightly different designations. Payroll labor tracking omitted Herb and Flower product lines, and included an "overhead/administration" category. To allow compatibility with product line designations, the payroll "overhead" category was treated as "Whole Farm," and Activity Log Vegetable and Herb labor was combined with Vegetables to reflect the level of tracking used in payroll information. In order to understand the relationship between these two methods of tracking, comparisons are necessary.

Figure 50 shows that the number of hours recorded in the Activity logs is consistently lower than that on the time cards. This is likely because transport, set-up and break time have not been recorded in the logs, but make up part of every workday. It is also likely that, while many tasks may be performed in a day, all hours are credited to one product line for simplicity. Figure 50 also suggests that in March when Activity logs were first implemented, recording was more accurate than later on when it was completely dropped in August.

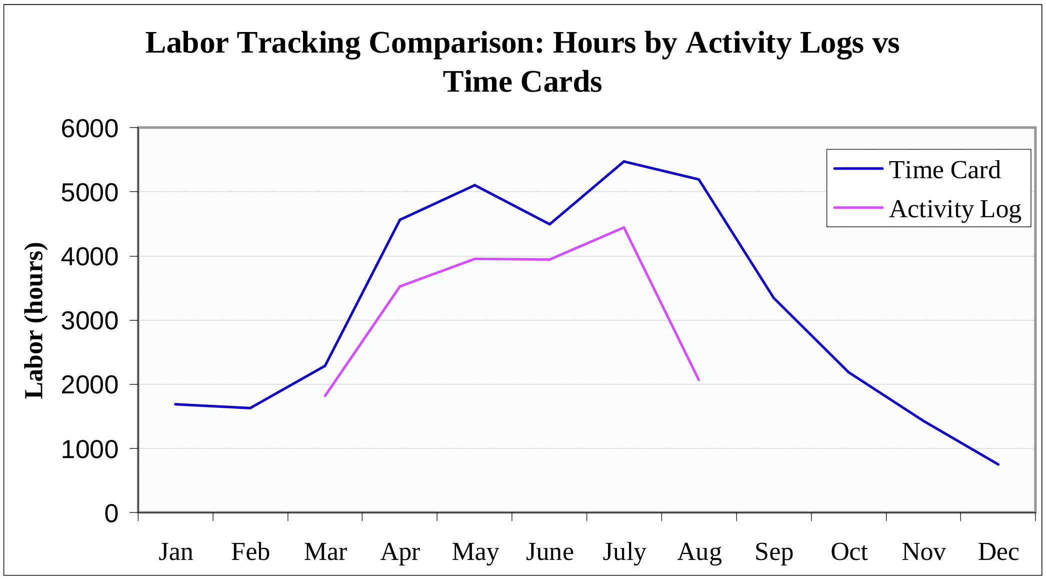


Figure 50 Total Labor Hours Recorded by Activity Logs vs. Time Cards

Graphing the difference in hours recorded by the two methods during the overlap period (Figure 51) shows the variations in how labor was assigned to product lines. That is, by subtracting hours recorded in Activity logs from those recorded on time cards, the discrepancy in the tracking of labor by product line can be assessed. The negative values in some months for Livestock, Poultry and Brambles indicate that managers completing Activity logs designated hours to those categories when the employee/manager filling out time cards did not.

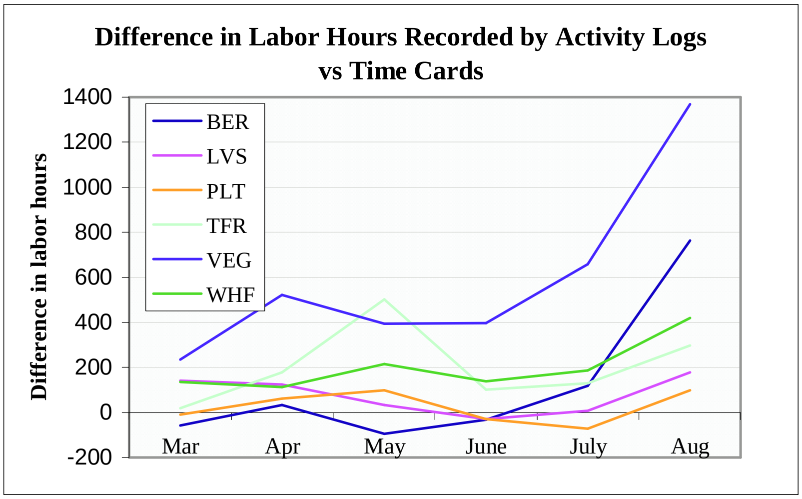


Figure 51 Difference in Hours Recorded in Time Cards vs. Activity Logs

4.2.6 Labor Expenses in Relation to Revenues and Expenses

Labor breakdown is meaningful not only in terms of the hours used for varying activities and product lines, but also in terms of revenues and expenses for each product line, and for the Farm as a whole.

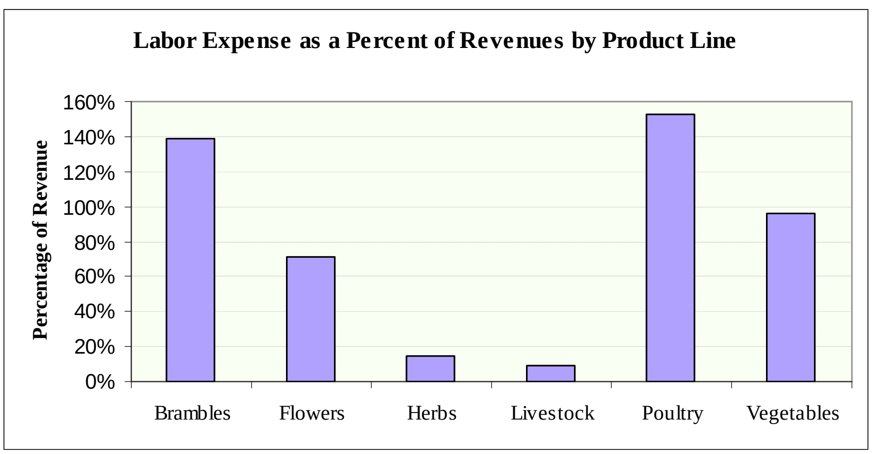


Figure 52 Labor Expense by Product Line as a Percentage of Revenue for 2002

Based on time card information, Tree Fruit consumes the largest amount of labor relative to revenue at 159% of revenue, followed by Vegetables at 114% of revenue. Bramble and Poultry labor inputs are also high relative to revenues at 91% and 72%. Livestock requires by far the lowest amount of labor inputs relative to revenue at 3%.

To gain an understanding of which product lines are input intensive and which are labor intensive, expenditures for labor are compared to those for annual operating expenses. Operating expenses on the Farm include the cost of items such as seeds, soil amendments, staking materials, and feed. A great deal of variation can be seen between product lines (Figure 53). Livestock was not included in the figure as there was an order of magnitude difference in operating expenses. Livestock requires annual expenses of roughly $1.4 million relative to labor expenses of $33,000. As cattle and chickens require organic feed, bedding and health care inputs, both Poultry and Livestock have higher operating expenses than produce. Vegetables have much higher labor operating costs than any other product line, but relatively low operating inputs. Flowers and Potted Plants have the lowest labor and P&L expenses, in part because these activities and expenses are often captured under Vegetable expenses, given that they are planted in common plots, and represent a relatively small amount of area.

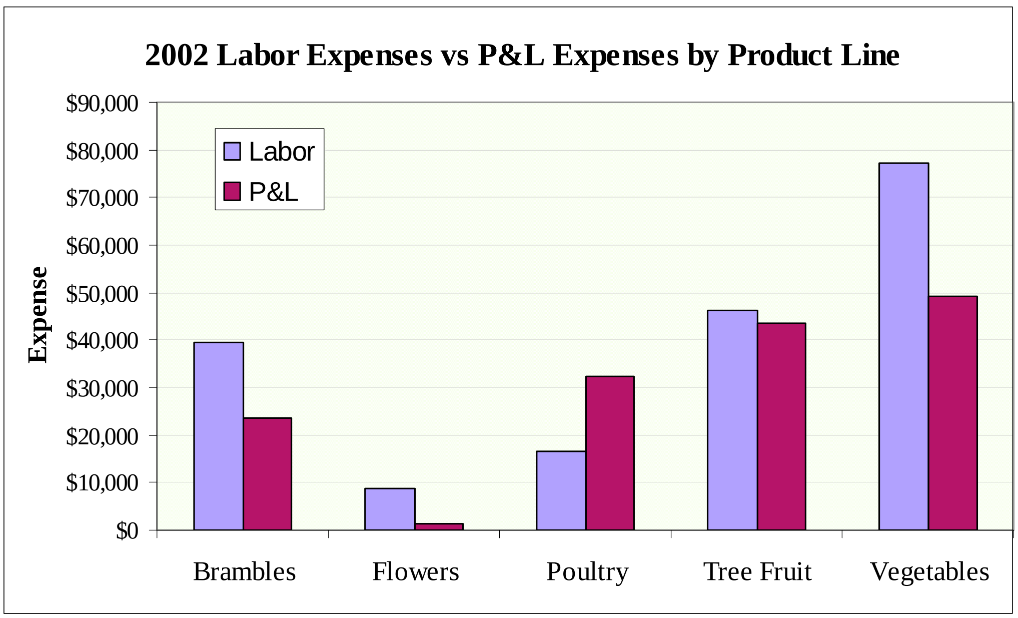


Figure 53 Labor Expenses Relative to P&L Expenses by Product Line

4.3 Comparisons to National Average

To understand what some of the labor components mean relative to other farms in the country, USDA data from the National Agricultural Statistics Service (NASS) were used. Values were available for field worker wages at the state and national levels, and for average national percentage of expenses devoted to labor.

The average wage at the Farm was calculated based on the hourly wages provided by the Farm accountant. Averages were taken for each year for all field laborers. USDA rates include only wages. Housing and other benefits supplied at many farms (including Sunnyside) are not included. Table 4 shows that the average wage at the Farm is below both the national and state averages. However, NASS wages do not include other benefits such as housing, health care, etc., whereas Sunnyside provides a range of benefits to workers, including housing, produce, health care, unemployment insurance and special accommodation of family members.

Table 4 Comparison of Average Farm Worker Wages

State and national values are based on the National Agricultural Statistics Service. Farm averages are based on payroll information.

	2001	2002
National Average Wage for farm worker	$8.01	$8.30
VA Average Wage for farm worker	$7.44	$ 7.71
Sunnyside Farm Average Wage for farm worker	$6.82	$7.16

Comparisons of percent of total operating expenses show that the Farm is above the national average of 11.2% at 13.8%. This is not surprising, as organic farms theoretically have higher labor intensity than conventional farms, which make up the bulk of the national average data. Since this comparison is based on percentages, it is necessary to compare total production expenses to ascertain if these values are indeed comparable.

Table 5 Labor as a Percentage of Production Expenses

	Labor as a percent of total production expenditures
National Average[8]	11.2% (2001)
Sunnyside Farms	13.8% (2002)

4.4 Conclusions

Labor represented 13.8% of all operating expenses on the Farm in 2002, which, while higher than the national average, does not represent a very high percentage of expenses. Therefore, in considering future planting regimes, labor should not be weighted as heavily in the decision as other factors such as annual operating costs for some product lines. This is particularly true of Livestock and Poultry, which have very low labor requirements.

Nonetheless, labor is an important component of Farm inputs to analyze, as it allows labor needs and trends to be identified, and is the component of Farm management most easily adjusted. In general, the following observations can be made about labor usage on the Farm. There are substantial differences in labor usage by season, where usage peaks in the summer and drops off in the winter. Maintenance activities consume the largest proportion of labor of any activity category at 40%. Of all activities, 14% of labor is used for mowing and landscaping, which, while important for public relations purposes, could be cut if labor expenses needed reducing. Overall, Whole Farm consumes the most labor in 2002 at $82,400, followed by Vegetables labor at $77,250. Management decisions at the product line level need to consider both labor and operating expenses, as failing to consider one could lead to erroneous conclusions about potential profitability.

Allocation of labor by month (Figure 48) can help inform labor-planning decisions. This figure clearly shows that in August, almost all labor was taken off of other product lines to assist with Brambles harvest. While Tree Fruit may not have suffered because of later harvest dates, the interns noted that many Vegetables were left un-harvested in this month due to insufficient labor. Better anticipation of this picking rush, or greater incentives for workers to work more quickly might have been helpful.

While labor does form a small proportion of total operating expenses, in the case of Tree Fruit and Vegetables, this labor expense exceeded revenue. For Brambles, labor amounts to 95% of revenue.

4.5 Recommendations for Future Labor Tracking

While the five months of Activity Log records that were maintained are very useful in understanding the distribution of labor on the Farm, a longer time frame that included the major harvest period would have been even more useful. To fully understand labor on the Farm, records should be kept year round. If it is deemed important in the future to track labor, upper management should consider offering incentives to managers, and explaining the merits in order to increase employee buy-in. For all records being kept on the Farm, it seems absolutely essential that a system be established to physically keep track of the documents. As with other logs, Activity records are currently left on desks in the Farm center, and are therefore subject to misplacement and are not accessible to other parties interested in the content. The Activity Log form created by Jeff Dozier in 2002 captures all relevant information, and should be put back into use.

5 EXPENSES AND REVENUES

5.1 Significance

An important goal of the project is to assess the profitability of Sunnyside Farms in terms of the Farm as a whole, as well as at finer scales such as by product line or activity. Thus, an analysis of the expenses and revenues of the Farm was conducted at different levels in order to appraise the Farm's productivity, and to make appropriate recommendations.

5.2 Approach

5.2.1 Data Collection Method

The expense data were obtained from the Farm's accountant in the form of Microsoft Excel versions of the Farm's general ledger for 2001 and 2002. In cases where the general ledger lacked sufficient detail for the purposes of the analyses, supplemental information was derived from additional sources of expense information, such as bills and invoices.

The revenue data were also obtained from the Farm's accountant. This accounting information was comprised of Microsoft Excel documents, downloaded from accounting software used by the Farm, which detailed Farm revenue.

5.2.2 Details of the Analysis

Expenses

In order to conduct the expense analysis for the Farm, the following issues were addressed:

- The Farm businesses include Black Bear Gallery, Sunnyside Farm Market (SSFM), and Green Circle. Since the objective was to assess the profitability of the Farm in and of itself, all expenses associated with these other three entities were disregarded. For example, all expenses related to Black Bear Gallery in the general ledger were not incorporated into the Farm database.
- The Expense table does not track all the pertinent expenses for the Farm. Specifically, the table does not include labor, salary or electricity expenses. These three components were separated out from the Expense table because other information besides expenses was also being tracked. In order to capture the labor, salary, and electricity expenses in the analysis, the Activity, Payroll, and Electricity tables were utilized. See section 2.2.4 for more detail on database tables.
- Currently, there is no information for 2001 labor expenses on a product line or month level; the information only exists as a sum for the year. Thus, 2001 and 2002 expenses were only directly compared at the "total expenses" level, not at the product line or month level.

- The labor expense data for 2002 are derived from the Activity logs kept by Farm managers. However, the Activity dataset presently only covers the time period from March 16 to August 10, 2002. Thus, in order to obtain more complete 2002 labor expense information, employee time cards were utilized for January to December 2002. We used this time card dataset in total Farm expense analyses.
- The granularity of this timecard dataset with regards to product line information is coarser than the data obtained from the Activity table. Therefore, in order to take advantage of both the Activity table's greater amount of detail and the time cards' greater date range, the two datasets were combined. In this way, we obtained a comprehensive labor expense dataset that ranged from January to December 2002. Due to its greater amount of product line detail, this comprehensive dataset was used in product line expense analyses.
- Expenses that are associated with the Whole Farm designation are those that cannot be attributed to a specific product line, but rather can only be related to the Farm as a whole. The "Whole Farm" Analysis will discuss the expenditures associated with the Whole Farm designation in more detail.

Revenues

The following issues comprised the framework of our revenue analysis:

- The Farm generates revenue by selling its products to restaurants, Bed & Breakfasts and Farmers' markets (namely Clarendon, 211, and Dupont), as well as wholesale (directly and through dealers such as Green Circle and Wholefoods). When the Farm sells through Green Circle, it receives 75% of the revenue.
- The Farm "does business as" Black Bear Gallery, Sunnyside Farm Market (SSFM), and Green Circle. Since the objective was to assess the profitability of the Farm in and of itself, all revenue associated with these other three entities was disregarded.
- Currently, the revenue data range in date from January 2001 to December 2002. As this dataset is complete, the revenue analysis is completely derived from the Revenue table (see section 2.2.4 for more detail on tables).
- Non-sales revenue is not included in the revenue analysis since it is predominantly comprised of revenue from rental properties, which is not considered part of Farm revenue.
- There is no revenue associated with the Whole Farm designation.

5.3 Results and Conclusions

5.3.1 Expenses

The expense results shown below are broken down into the following main analysis categories:

- Capital vs. P&L expenses: expenses were divided into capital expenditures (Capex) and profit and loss (P&L) expenses based on generally accepted accounting principles
- Total expenses: these include both Capex and P&L expenses
- Product Lines: these identify the expenditure and where it falls in the Product hierarchy (see the Product Hierarchy section for more detail on the Product hierarchy)
- Expense Categories: these categorize the expenditure and identify where it falls in the Expense Category hierarchy (see the Expense Category Hierarchy for more detail on the Expense Category hierarchy)

Summary of Total and P&L Expenses for 2001 and 2002

Table 6 summarizes the Farm's total and P&L expenses for 2001 and 2002. As the table shows, total expenses decreased from 2001 to 2002, while P&L expenses increased during the same time period. As will be discussed in the Capital expenses in 2001 and 2002 section, these trends can be explained by the fact that capital expenditures decreased from 2001 to 2002.

Table 6 Total and P&L Expenses for 2001 and 2002

	2001	2002
Total Expenses (includes Capex and P&L)	$2,774,386	$2,466,614
P&L Expenses	$1,590,701	$2,453,566

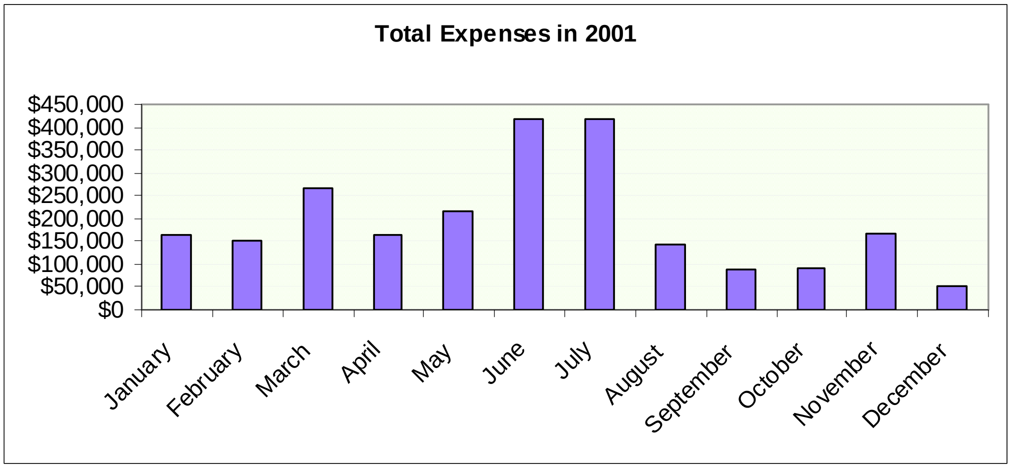


Figure 54 Total Expenses in 2001

Does not include labor expenses.

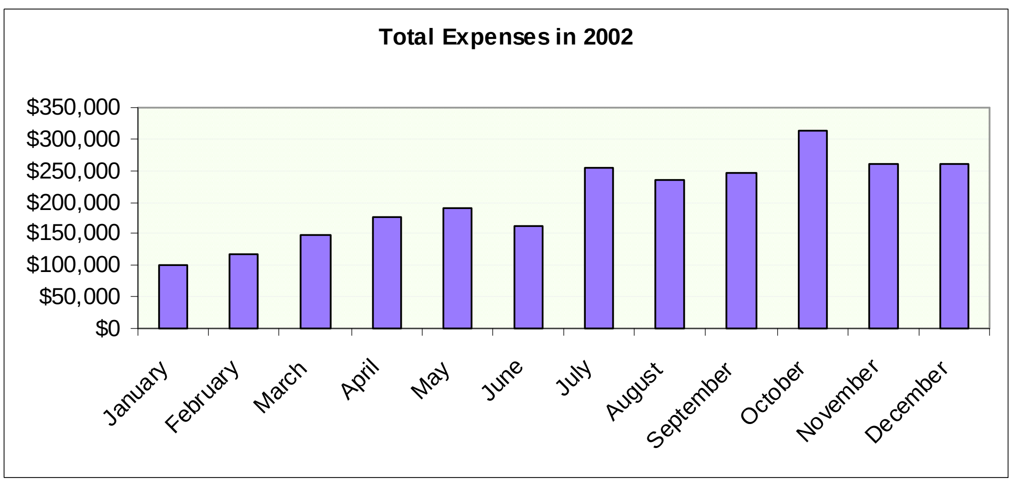


Figure 55 Total Expenses in 2002

Figure 54 shows total expenses in 2001 by month, while Figure 55 shows total expenses in 2002 by month. Because 2001 labor expenses cannot be expressed by month, Figure 54 does not include labor expenses, while Figure 55 does. Although the two graphs cannot be directly compared, they do provide a useful snapshot of total expenses for the Farm. Subsequent analyses will further breakdown total expenses in order to more rigorously analyze Farm expenditures.

Capital expenses in 2001 and 2002

Figure 56 and Figure 57 show the Farm's capital expenditures for 2001 and 2002 by month. As illustrated by the two graphs, capital expenditures were higher overall in 2001 compared with 2002. Subsequent analyses will show the product lines and expense categories associated with these capital expenditures.

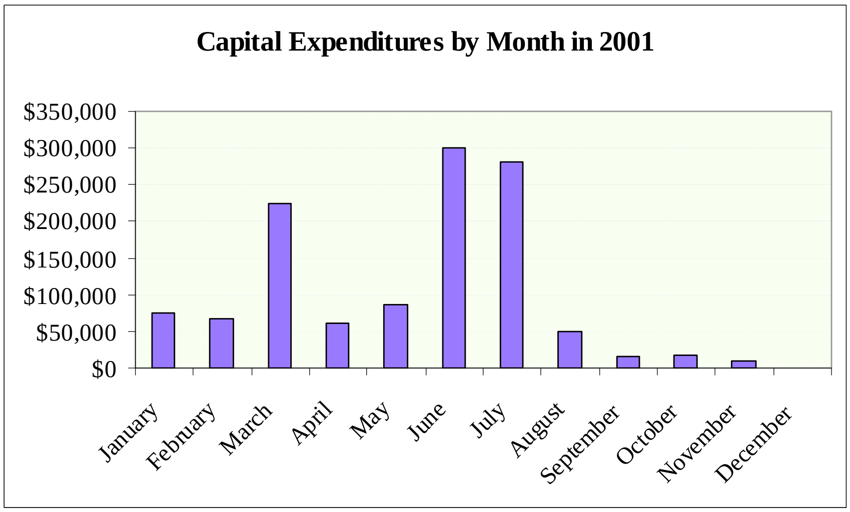


Figure 56 Capex in 2001 by Month

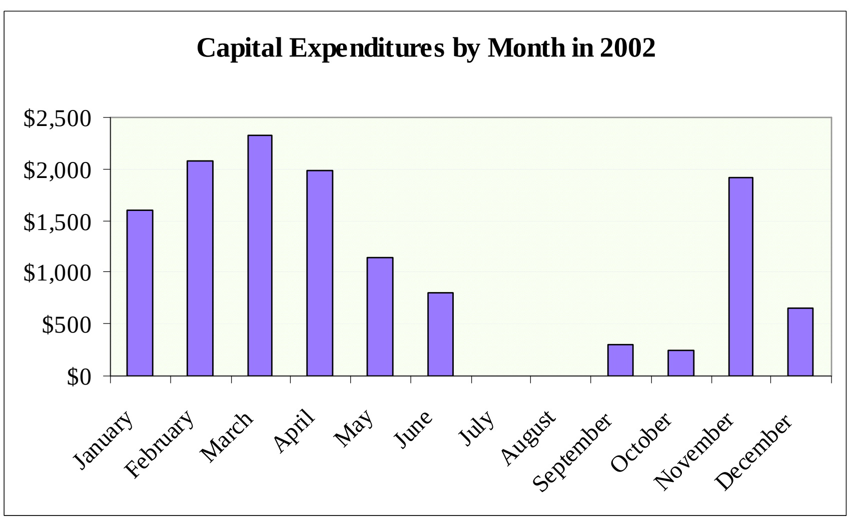


Figure 57 Capex in 2002 by Month

P&L Expenses in 2001 and 2002

Figure 58 shows P&L expenses for 2001 and 2002 by month, not including labor expenses. Overall, 2002 P&L expenses were higher than 2001 P&L expenses, particularly in the months from June through December. Figure 59 shows P&L expenses by month in 2002, including labor expenses.

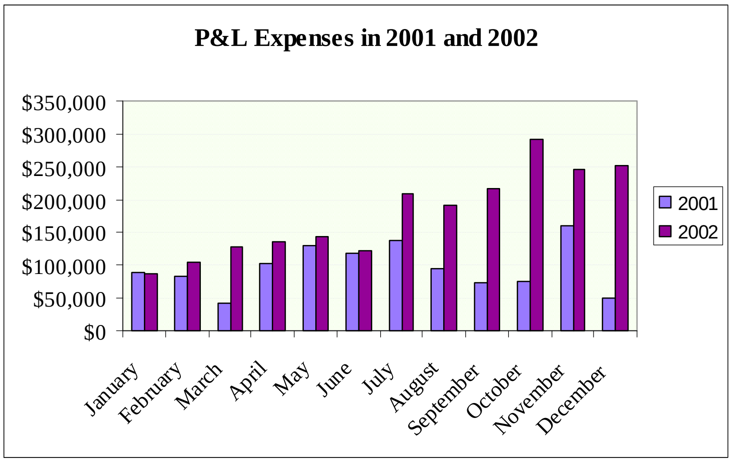


Figure 58 P&L Expenses in 2001 and 2002 by Month

Does not include labor expenses.

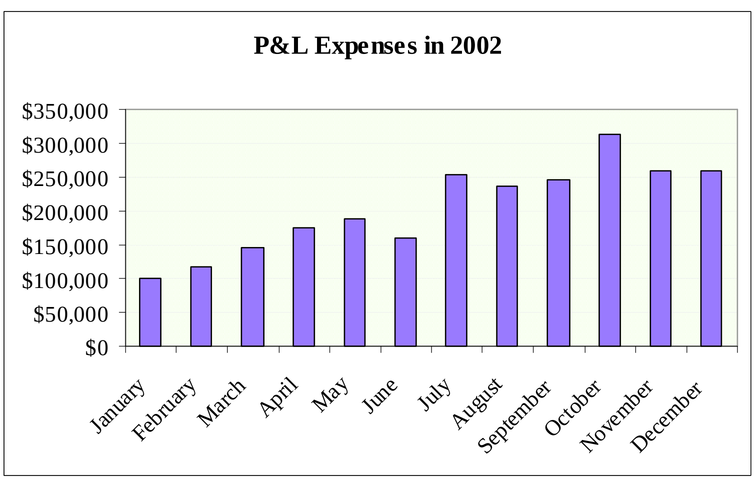


Figure 59 P&L Expenses in 2002 by Month.

Includes labor expenses.

Capex by Product Line in 2001 and 2002

Capital Expenditures were then broken down by product line. Figure 60 and Figure 61 above show the highest Capex by product line in 2001 and 2002. The 2001 graph does not include the Whole Farm designation in order to more clearly show the product lines. As Figure 61 shows, there was only one product line in addition to the Whole Farm designation that was associated with capital expenditure spending in 2002.

In 2001, Tree Fruit had approximately $33,000 in Capex, while in 2002, Capex for this product line had declined to approximately $3,800. In both years, the Whole Farm designation had the highest capital expenditures compared to all other product lines. The "Whole Farm" Analysis section discusses in more detail the expenditures associated with the Whole Farm designation.

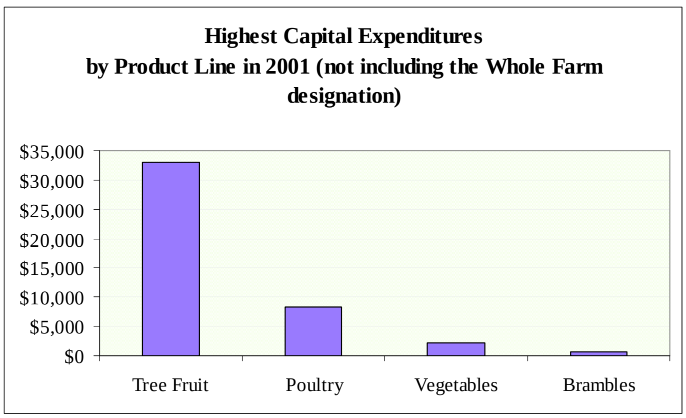


Figure 60 Highest Capex by Product Line in 2001

Does not include Whole Farm, which had a Capex exceeding $1M.

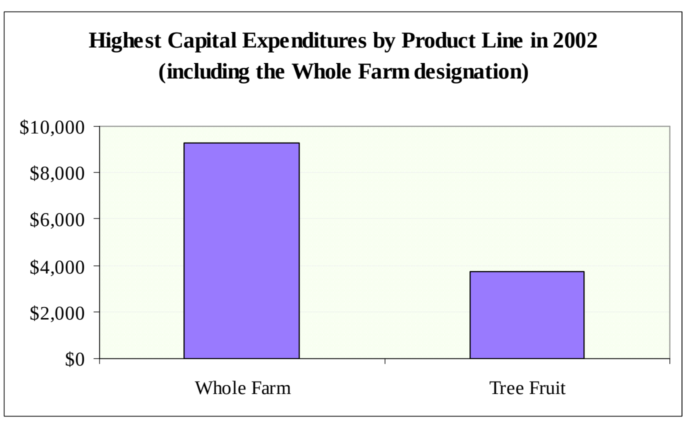


Figure 61 Highest Capex by Product Line in 2002

This year, there was only one product line (Tree Fruit) in addition to the Whole Farm designation that was associated with Capex spending.

P&L Expenses by Product Line in 2001 and 2002

P&L Expenses were also broken down by product line. Figure 62 and Figure 63 show the highest P&L expenses by product line in 2001 and 2002. The 2001 graph does not include labor expenses, while the 2002 graph does include labor expenses. In both years, the Livestock product line and Whole Farm designation were associated with the highest P&L expenses.

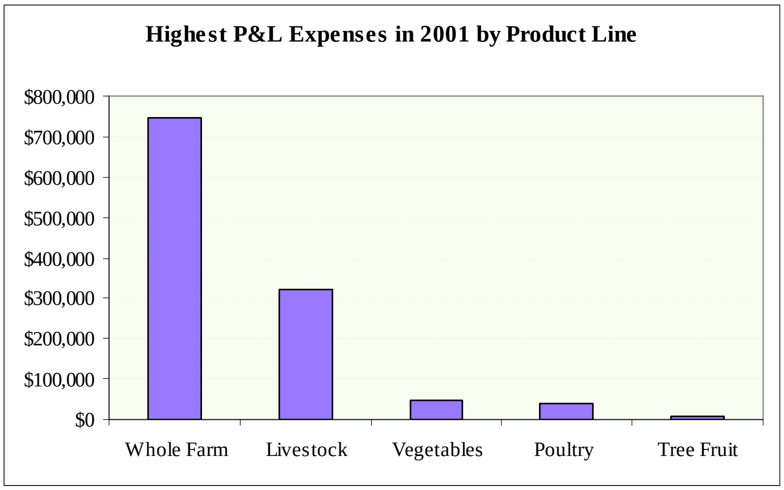


Figure 62 Highest P&L Expenses in 2001 by Product Line

Does not include labor expenses.

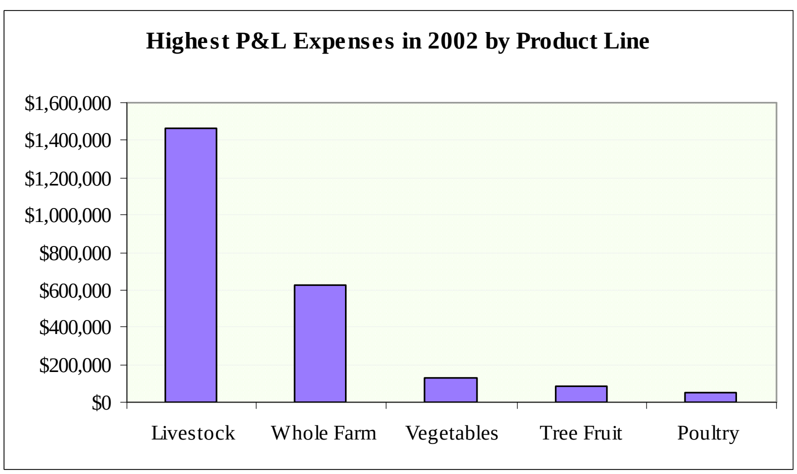


Figure 63 Highest P&L Expenses in 2002 by Product Line

Capex by Expense Category in 2001 and 2002

Capital Expenditures were then broken down into expense categories. The 2001 graph does not show Clopton, as it dominated the graph. In 2001 (Figure 64), Clopton was the highest capital expenditure, while in 2002 (Figure 65), Orchard was the highest.

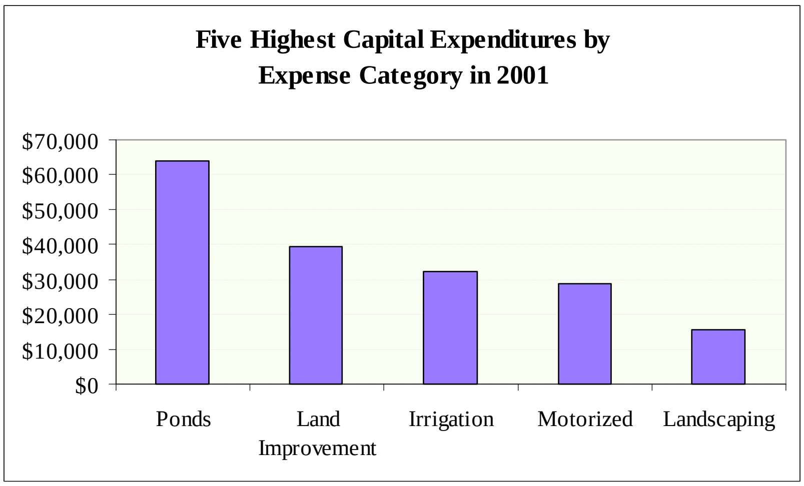


Figure 64 Five Highest Capex by Expense Category in 2001

Does not include Clopton, the highest Capex at nearly $1M.

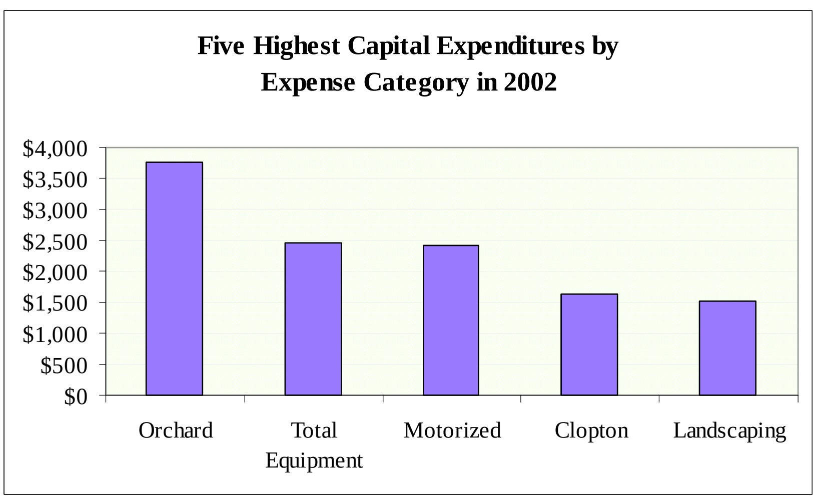


Figure 65 Five Highest Capex by Expense Category in 2002

P&L Expenses by Expense Category in 2001 and 2002

P&L expenses were also broken down by expense category. Because this analysis was based on the Expense table, it does not include salary, electricity or labor expenses. In 2001 (Figure 66), Hay Purchases constituted the highest P&L expense, while Feed Purchases constituted the highest P&L expense in 2002 (Figure 67).

Figure 66 Five Highest P&L Expenses by Expense Category in 2001

Does not include salary, electricity, or labor expenses.

Figure 67 Five Highest P&L Expenses by Category in 2002

Does not include salary, electricity, or labor expenses.

5.3.2 Revenue

The revenue results shown below are broken down into the following main analysis categories:

- Total revenue
- Buyers: this identifies the buyer associated with the transaction
- Product Lines: this identifies the product which generated the revenue and where it falls in the Product hierarchy

Revenue in 2001 and 2002

In 2001, the Farm's revenue totaled $296,130, while in 2002 it had increased to $1,306,186. The analysis of product line profitability in the Net Profit for 2001 and 2002 section examines reasons for this increase. Figure 68 shows revenue by month in 2001 and 2002. A large increase in revenue can be seen in the months of October through December, year on year.

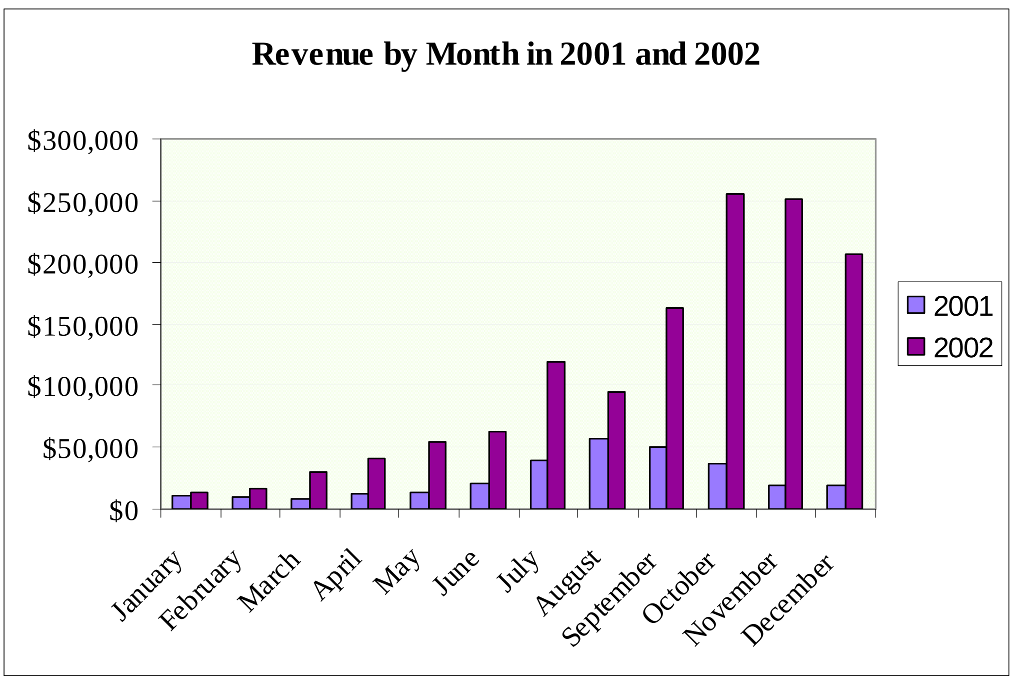


Figure 68 Revenue by Month in 2001 and 2002

Revenue by Product Line in 2001 and 2002

Figure 69 and Figure 70 show revenue broken down by product line in 2001 and 2002. The 2002 graph does not show Livestock ($1,105,855) because it dominated the graph. The highest revenue-generating product line in 2001 and 2002 was Livestock.

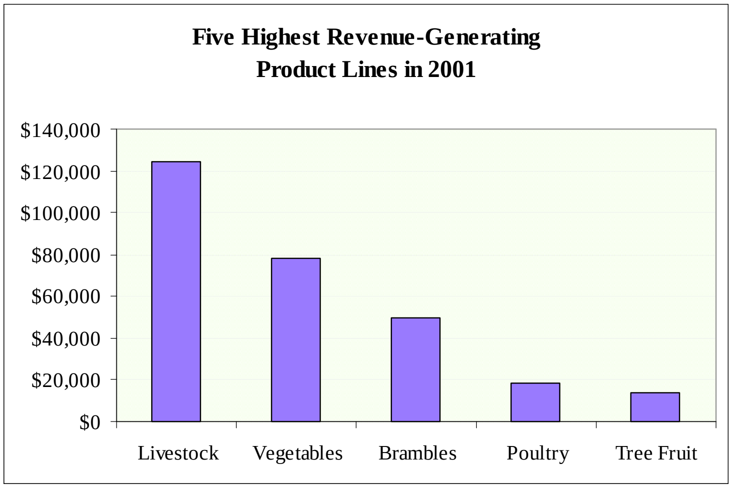


Figure 69 Five Highest Revenue-Generating Product Lines in 2001

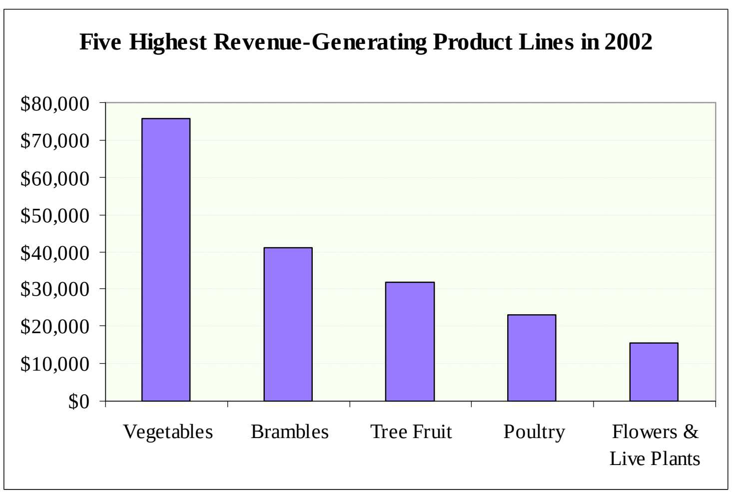


Figure 70 Five Highest Revenue-Generating Product Lines in 2002

Does not include Livestock, the highest revenue-generating product line: $1,105,855.

Revenue by Sales Avenue in 2001 and 2002

Figure 71 and Figure 72 show the top five sales avenues in 2001 by revenue amount and percentage of revenue. As the graphs show, the top sales avenue in 2001 was Dupont Market.

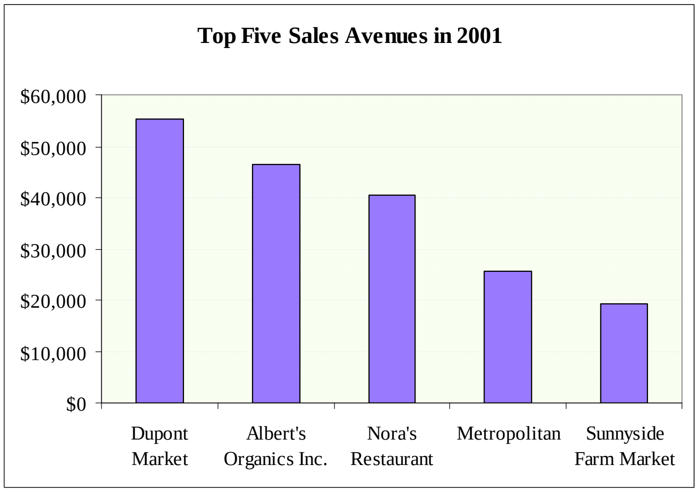


Figure 71 Top Five Sales Avenues in 2001

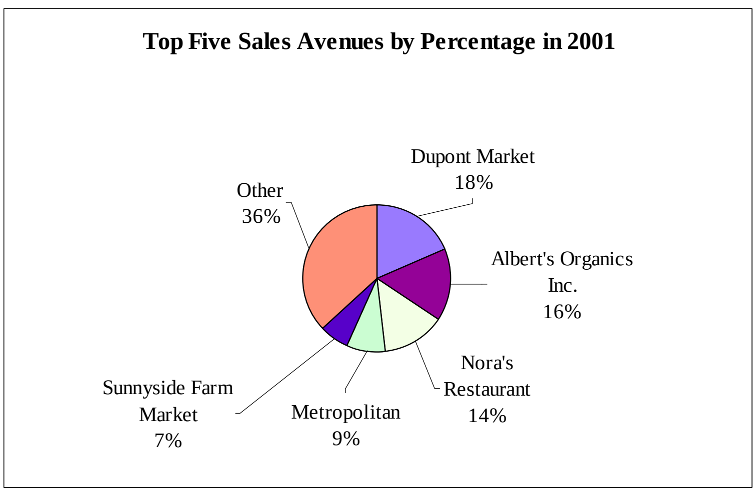


Figure 72 Top Five Sales Avenues by Percentage in 2001

Figure 73 and Figure 74 show revenue by sales avenue in 2002 by revenue amount and percentage of revenue. Figure 73 does not show Green Circle ($712,154) because inclusion of it dominated the graph. As the graphs show, the top sales avenue in 2002 was Green Circle.

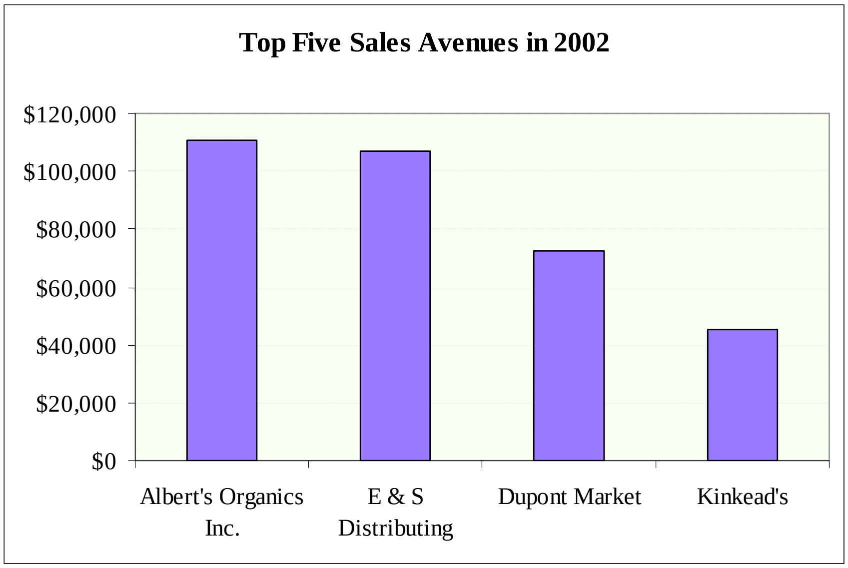


Figure 73 Top Five Sales Avenues in 2002

Does not include Green Circle, the top sales avenue: $712,154.

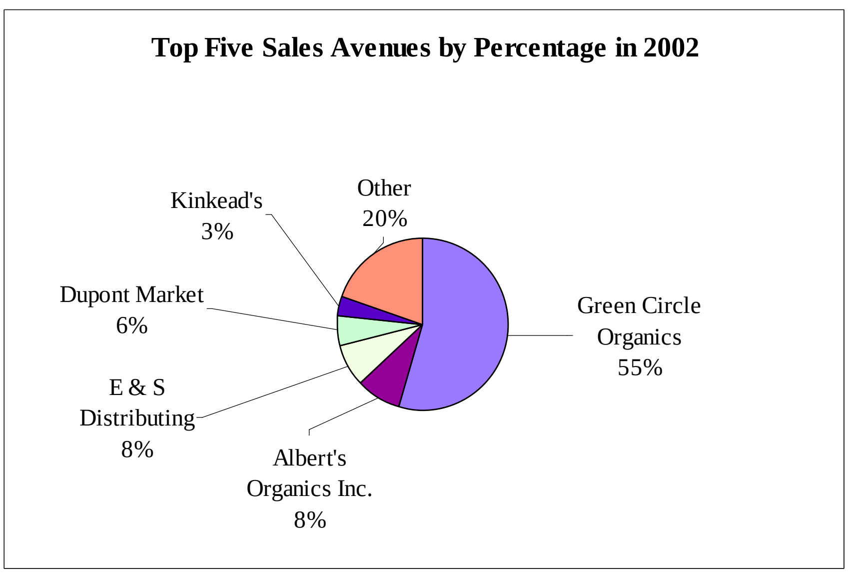


Figure 74 Top Five Sales Avenues by Percentage in 2002

Figure 75 and Figure 76 show the breakdown of sales avenues in 2001 and 2002 into market (including 211, Clarendon, and Dupont) and Green Circle categories. In 2001, markets constituted a larger portion of Farm revenue in 2001 than 2002, while Green Circle was a larger portion of Farm revenue in 2002 than 2001. Green Circle did not purchase Farm products in 2001 because the business did not exist as a produce distributor that year.

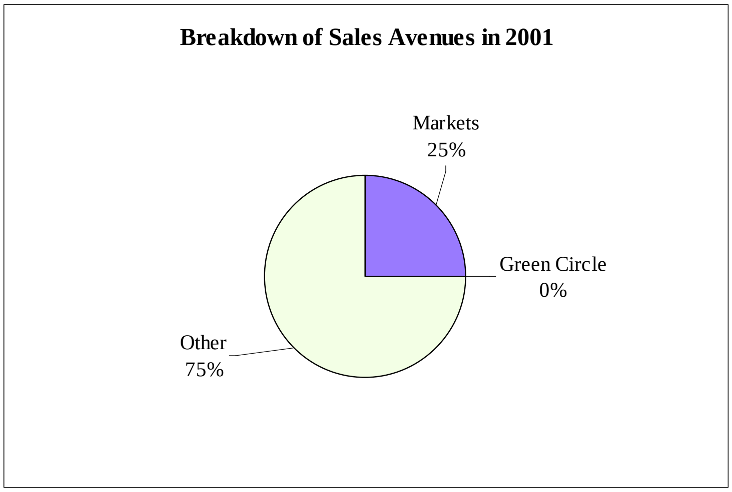


Figure 75 Breakdown of Sales Avenues in 2001

Markets include 211, Clarendon, and Dupont.

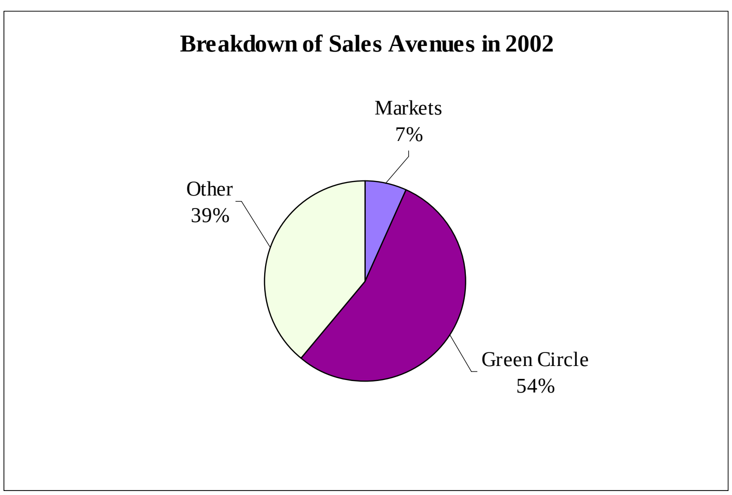


Figure 76 Breakdown of Sales Avenues in 2002

Markets include 211, Clarendon, and Dupont.

5.4 Comparison to National Averages

One of the purposes of analyzing Sunnyside Farms' expenses is to compare the results to national averages, which are mainly composed of data related to conventional farms. Table 7 compares data taken from the USDA's National Agricultural Statistics Service (NASS) with P&L expenses for Sunnyside Farms. The categories used by the NASS that are relevant to Sunnyside Farms are Average Farm, Farms with Sales $250,000 and Over, and Farms in the Appalachian Region. The expense averages vary widely, namely from $45,546 to $740,751 in 2000 and from $45,583 to $749,682 in 2001, depending on the category used for comparison. As the table shows, Sunnyside Farms' expenses are on the higher side relative to national averages. No national averages with respect to revenue were found.

Table 7 Comparison of Farm P&L Expenses to US Averages

	2000	2001	2002
Sunnyside Farms	No data	$1,590,701	$2,453,566
Average Farm	$87,543	$91,547	No data
Farms with Sales $250,000 and Over	$740,751	$749,682	No data
Farms in the Appalachian Region	$45,546	$45,583	No data

5.5 Recommendations

5.5.1 Data Specifications for the Future

The Farm Group carried out labor- and time-intensive data manipulations in order for the expenses and revenues to be related to product line information and a detailed categorical breakdown. To avoid this in the future, the Farm should integrate the tracking system with accounting software.

With regards to revenue, more accurate recording of sales at the farmers' markets would improve the quality of observations that could be made. This would in turn improve the quality of the analyses that depend on these observations. Currently, market sales are recorded in general terms on the product line level – records of what is sold at finer scales, e.g. by variety, would be more useful. Moreover, information regarding amounts sold is only estimated, since no product inventory is taken before or after products are sold at the markets. More accurate information regarding the amounts sold would be extremely valuable.

With regards to expenses, more care should be taken to record expenses with the correct accounting category. Expenses tracked as "other" may lose valuable information.

5.5.2 Sunnyside Farms' Profitability

A combined expense and revenue analysis was undertaken in order to determine the net profitability of the Farm by product line and make recommendations based on the results.

Net Profit for 2001 and 2002

Table 8 Net Profit Summary for 2001 and 2002

	2001	2002
P&L Expenses	$1,590,701	$2,453,566
Revenue	$296,130	$1,306,186
Net Profit	**-$1,294,571**	**-$1,147,380**

Table 8 shows the net profit summary for 2001 and 2002. Capital expenditures have not been included in the profit/loss calculations. As the table shows, the Farm had a net loss of $1,294,571 in 2001 and a net loss of $1,147,380 in 2002. Comparing the two years, the table shows that the Farm lost less money in 2002 than in 2001, primarily due to a higher increase in revenue from 2001 to 2002 versus the increase in P&L expenses during the same time period.

Net Profit by Product Line

Table 9 Net Profit by Product Line in 2001 and 2002

Does not include Capex or labor expenses.

	2001 Profit/Loss (no Capex)	2002 Profit/Loss (no Capex)
Whole Farm	-$744,087	-$539,433
Tree Fruit	$7,099	-$11,525
Poultry	-$19,152	-$9,568
Vegetables	$33,143	$26,311
Brambles	$49,199	$17,500
Livestock	-$196,415	-$326,290
Herbs	-$453	$12,873
Flowers	$7,831	$14,201
Grains	$155	$0
Herbs/Flowers/Veg	$40,521	$53,385

Table 10 Net Profit by Product Line in 2002

Does not include Capex, but includes labor expenses.

	2002 Profit/Loss (no Capex)
Whole Farm	-$621,797
Tree Fruit	-$57,676
Poultry	-$26,217
Vegetables	-$50,940
Brambles	-$21,882
Livestock	-$359,465
Herbs	$12,073
Flowers	$5,502
Grains	-$55
Herbs/Flowers/Veg	-$33,365

Table 9 shows the Farm's net profit broken down by product lines for 2001 and 2002, not including labor expenses. Table 10 shows the Farm's net profit broken down by product line for 2002, including labor expenses. Capital expenditures have not been included in the calculations. In addition, the Herbs, Flowers, and Vegetables product lines are shown combined in the last line in order to create a more accurate statement of their profitability, since expenses applicable to all three product lines are frequently applied to only the Vegetable product line.

Both tables show that the Whole Farm designation lost the most amount of money. This is not surprising, since Whole Farm is not revenue-generating and represents only expenses. However, there are expenses associated with each of the product lines that are captured by the Whole Farm designation.

In this context, Table 10 shows that Brambles and Herbs/Flowers/Veg lost the least amount of money relative to the other product lines. Table 9, which does not include labor expenses for 2001 or 2002, allows us to compare significant trends in net profit across the two years. Due to the fact that labor expenses are not included in these results, the trends that are observed should only be used for comparison across the two years, rather than as an indication of net profitability.

- Livestock: the loss increased from -$196,415 in 2001 to -$309,916 in 2002
  - The Farm receives only 8% of the contract fees from beef growers
  - P&L expenses (not including labor expenses) related to Livestock increased by approximately $1,000,000 from 2001 to 2002
- Poultry: the loss decreased from -$19,152 in 2001 to -$9,568 in 2002
  - The Farm purchased feed in 2001 and used it in both 2001 and 2002, thus decreasing its expenses
  - More eggs were harvested

- Brambles: the profit in 2001 ($49,199) decreased in 2002 ($33,874)
  - The loss could be related to the fact that approximately 1,300 flats were not harvested in 2001
- Tree Fruit: the profit in 2001 ($7,099) decreased in 2002 ($4,850)
- Vegetables/Herbs/Flowers: It is difficult to draw any conclusions regarding these product lines because, as was stated earlier, expenses applicable to all three product lines are frequently applied to the Vegetable product line
  - Vegetables: the profit in 2001 ($33,143) increased in 2002 ($40,027)
  - Herbs: the loss in 2001 (-$453) turned into a profit in 2002 ($12,873)
    - The Farm sold approximately 500 more pounds in 2002 than in 2001
    - The Farm had 7 more varieties in 2002 than in 2001
  - Flowers: the profit in 2001 ($7,831) increased in 2002 ($14,201)
- Grains: Grains were not harvested in 2002

The two charts below show similar results in graphical form. Again, the 2001 graph does not include labor expenses, while the 2002 graph does.

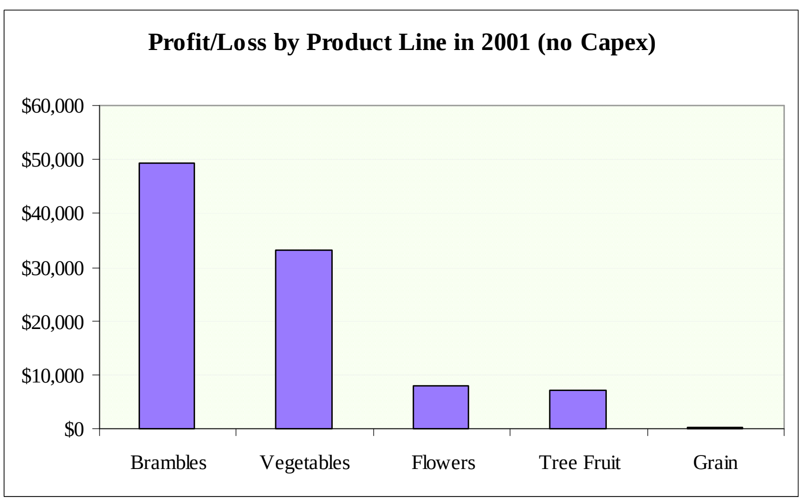


Figure 77 Profit/Loss by Product Line in 2001

Labor expenses not included.

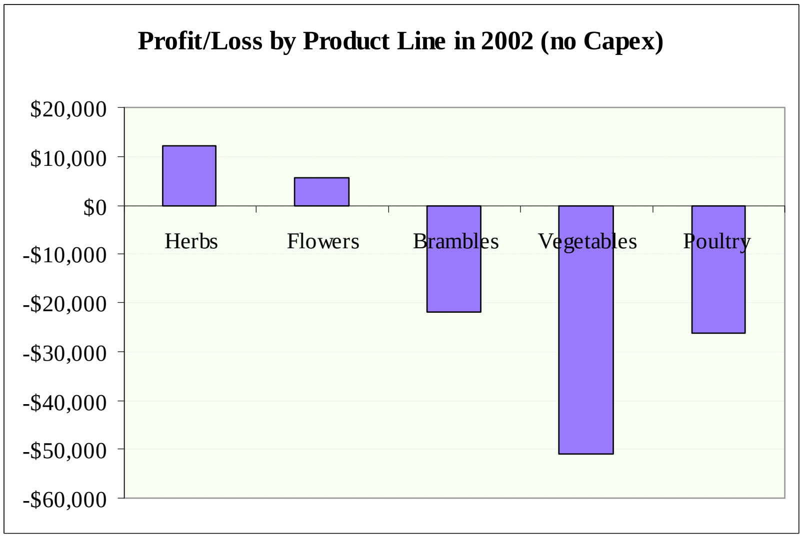


Figure 78 Profit/Loss by Product Line in 2002

Labor expenses included.

"Whole Farm" Analysis

As the previous section demonstrated, Whole Farm plays an important role in detracting from the profitability of the Farm. Thus, a more rigorous analysis was undertaken with respect to the Whole Farm designation in order to examine the elements that it incorporates. This was done using the Expense Category information in the Expense table.

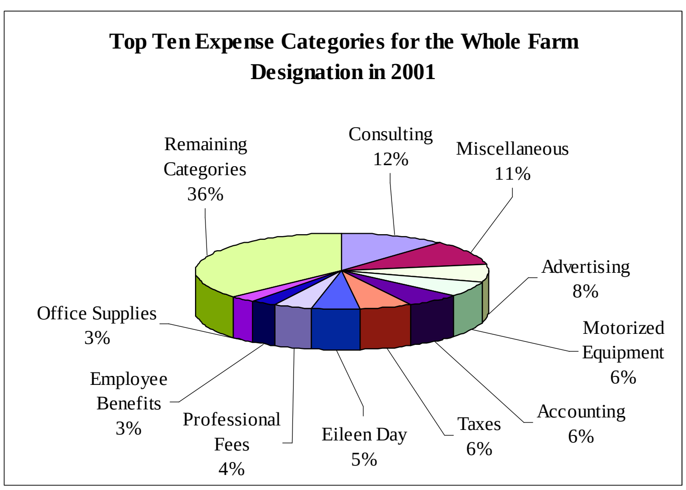


Figure 79 Top Ten Expense Categories for the Whole Farm Designation in 2001

Does not include labor, electricity, or salary expenses.

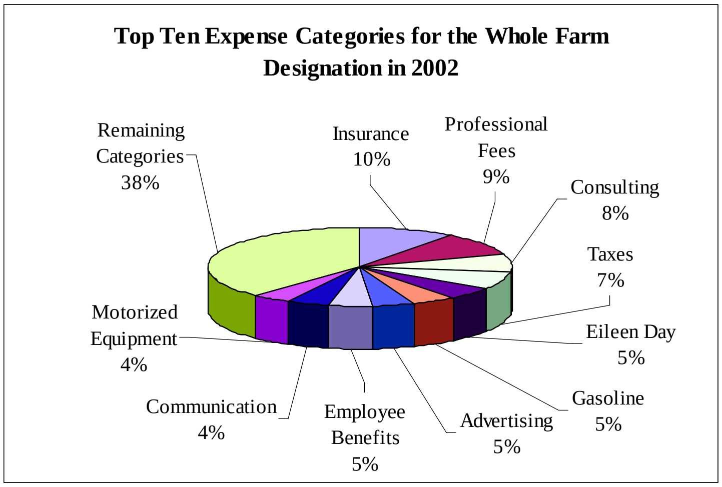


Figure 80 Top Ten Expense Categories for the Whole Farm Designation in 2002

Does not include salary, electricity, or labor expenses.

Figure 79 and Figure 80 show the top expense categories for Whole Farm in 2001 and 2002, not including salary, electricity, or labor expenses. In 2001, Consulting represented the largest expense category, while in 2002, Insurance was the largest category.

Revenue and Total Expenses in 2001 and 2002

Figure 81 and Figure 82 show revenue and total expenses in 2001 and 2002. The 2001 graph does not include labor expenses, while the 2002 graph does.

Figure 81 shows that expenses were much higher than revenue in 2001, while Figure 82 shows that revenue and expenses began to be more comparable from September to December 2002.

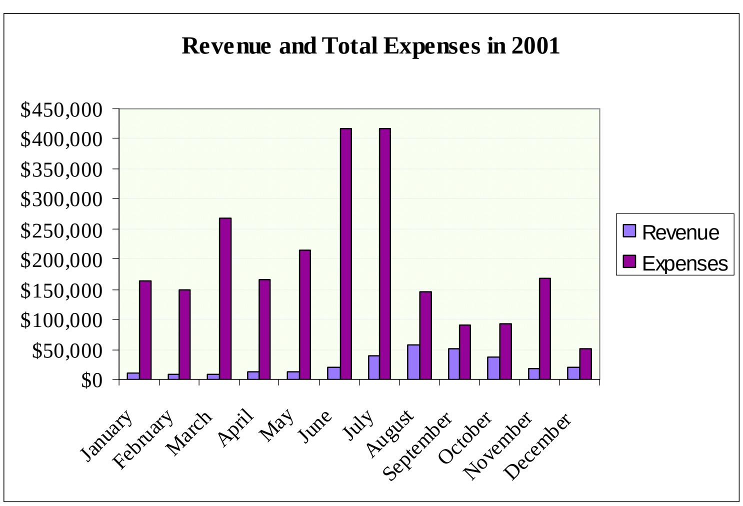


Figure 81 Revenue and Total Expenses in 2001. Does not include labor expenses.

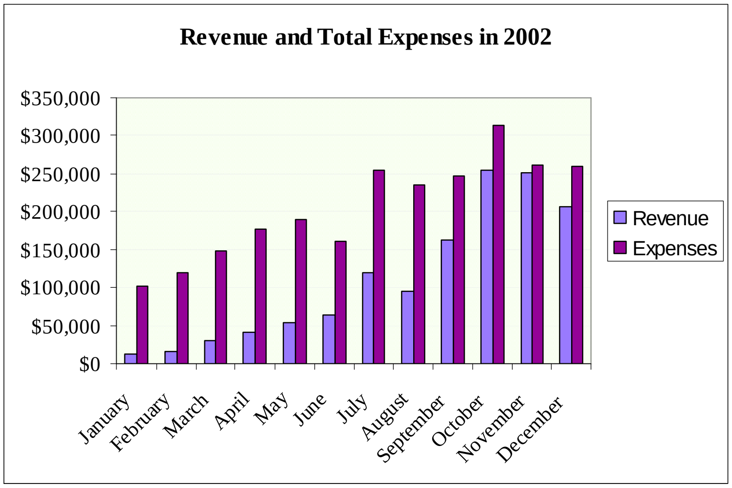


Figure 82 Revenue and Total Expenses in 2002

Revenue and P&L Expenses in 2001 and 2002

Figure 83 and Figure 84 show revenue and P&L expenses in 2001 and 2002. The 2001 graph does not include labor expenses, while the 2002 graph does.

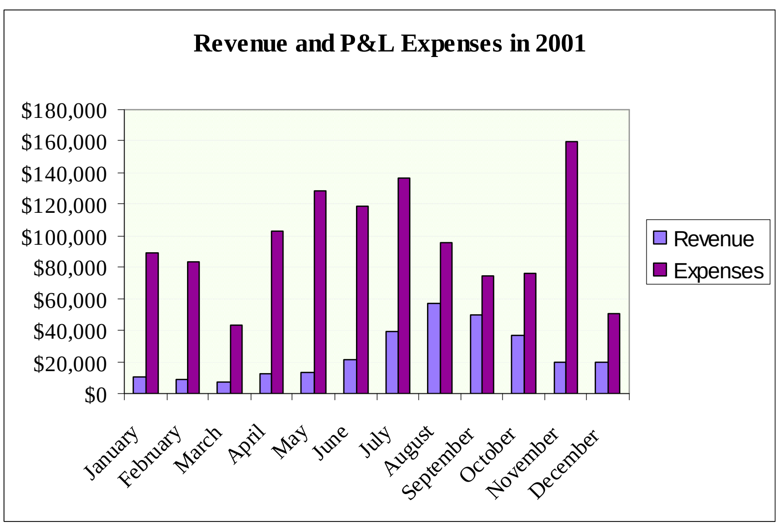


Figure 83 Revenue and P&L Expenses in 2001

Does not include labor expenses.

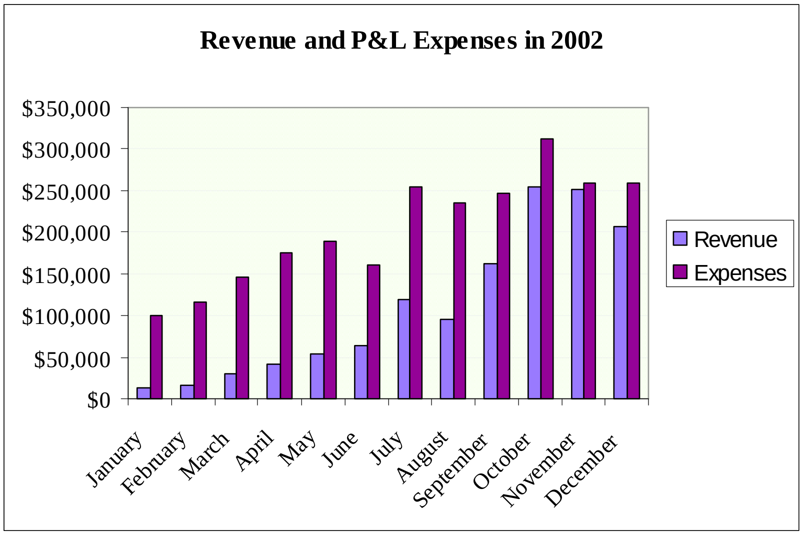


Figure 84 Revenue and P&L Expenses in 2002

Net Profit by Product Line per acre in 2001 and 2002

Table 11 Net Profit by Product Line per Acre in 2001 and 2002

Labor expenses are not included for 2001 but are included for 2002.

Product Line	Acres Planted in 2002	Profit/Loss per Product Line (not including Capex) in 2001	Profit/Loss per Product Line (not including Capex) in 2002	Profit/Loss by Acre in 2001	Profit/Loss by Acre in 2002
Tree Fruit	21.51	$7,098.80	-$57,676.08	$330.02	-$2,681.36
Veg/Herbs/Flowers	11.22	$40,520.85	-$33,364.84	$3,611.48	-$2,973.69
Brambles	4.42	$49,199.30	-$21,882.39	$11,131.06	-$4,950.77

Table 12 Net Profit by Product Line per Acre in 2001 and 2002

Does not include labor expenses.

Product Line	Acres Planted in 2002	Profit/Loss per Product Line (not including Capex) in 2001	Profit/Loss per Product Line (not including Capex) in 2002	Profit/Loss by Acre in 2001	Profit/Loss by Acre in 2002
Tree Fruit	21.51	$7,098.80	-$11,524.92	$330.02	-$535.79
Veg/Herbs/Flowers	11.22	$40,520.85	$53,385.07	$3,611.48	$4,758.03
Brambles	4.42	$49,199.30	$17,499.57	$11,131.06	$3,959.18

Table 11 shows the Farm's net profit by product line per acre in 2001 and 2002, with labor expenses not included for 2001 but included for 2002. Table 12 shows the Farm's net profit by product line per acre in 2001 and 2002, with no labor expenses included. This table allows us to compare the Farm's net profit by acre over the two years. Using this table, it can be seen that the Brambles and Veg/Herbs/Flowers product lines are the most profitable product line per acre in both years, although Brambles declined in profitability from 2001 to 2002. Table 11 shows that no product line is profitable by acre in 2002.

This analysis can also be used as a rough benchmark for the Farm's projected profit/loss in 2003, since the new crops for 2003 fall under the Tree Fruit, Veg/Herbs/Flowers, and Brambles product lines. Such an analysis would assume the same amount of acres planted in 2003.

6 ANALYSIS OF MANAGEMENT PRACTICES AND PROFITABILITY

6.1 Significance

A primary focus of this study is the assessment of the profitability of each product line. It is important for Farm managers to not only have an understanding of what happened in the past, but what could happen in the future. Section 3 discussed the quantities of crops harvested, Section 4 highlighted the labor requirements by product line, and Section 5 provided an overview of the expenses and revenues associated with each product line. The synthesis of these sections can provide insight as to how each product line can become more profitable, and how management practices can influence profitability and productivity.

6.2 Approach

First, trends of expenses and revenues are examined to identify the strongest factors affecting each product line. Next, scenarios involving the incorporation of cull and pricing information are used to evaluate how each product line might be more profitable. Several scenarios were constructed in order to perform a sensitivity analysis of the various losses due to differences in yield, harvest and sales.

6.3 Results and Conclusions

6.3.1 Product Line Profitability in 2002

In assessing the productivity of product lines, it is useful to compare labor and P&L expenses against revenue over time to help inform how a given line of products may be made more profitable. This section aims to identify which components of given product line are most impeding profitability. It should be noted that this product line analysis ignores expenses that are incurred to the whole farm operation in general. That is, even if P&L and labor expenses were less than revenue by product line, the general farm expenses may still exceed current revenues. Thus, if profitability is to be achieved, Whole Farm expenses must also be addressed.

Table 13 Summary of Product Line Finances for 2002

	Labor	P&L	Revenue	Net Loss	% of Revenue Consumed by Labor and P&L
Brambles	$39,382	$23,741	$41,240	($21,883)	153%
Poultry	$16,650	$32,481	$22,913	($26,218)	214%
Tree fruit	$46,151	$43,408	$31,883	($57,676)	281%
Vegetables/Herbs/Flowers	$86,750	$50,834	$104,218	($33,366)	132%

Despite high Bramble sales in summer months (Figure 85), the revenues of this product line fail to exceed the combined labor and P&L expenses for 2002. Brambles require steady labor sustained through the year and moderate operating expenses, which combined comprise 153% of revenues. The close relationship between labor and revenue suggests that picking more berries alone will not make Brambles very profitable. In order to offset expenses, marketing channels need to be in place to sell a greater number of Brambles during peak months (reduce culls), or a higher price must be received by selling through channels with greater returns (such as the farmer's markets).

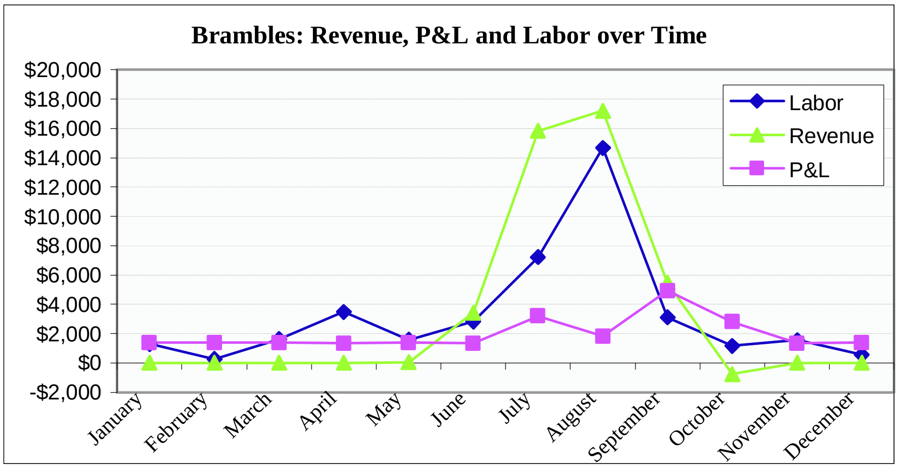


Figure 85 Brambles: Comparison of Revenue, P&L and Labor Expense Over Time

Examining the Poultry product line, which is composed only of eggs (Figure 86), illustrates that operating costs are significantly higher than revenues generated. Labor expenses follow Poultry (egg) revenues closely, while generally remaining slightly below it. As a result of periodic feed purchases, P&L expenses are distributed in peaks throughout the year. When total annual P&L and labor expenses for 2002 are combined, they compose 214% of revenues, suggesting profitability is seriously undermined. Given that labor devoted to Poultry (egg) production and revenues are directly related, and given the high operating costs, it is likely that in order for Poultry (eggs) to be profitable, they must be sold for a higher unit price. A loss from the Poultry operation, partly offset by egg sales, may be justified because of the chickens' role in preparing the soil for planting.

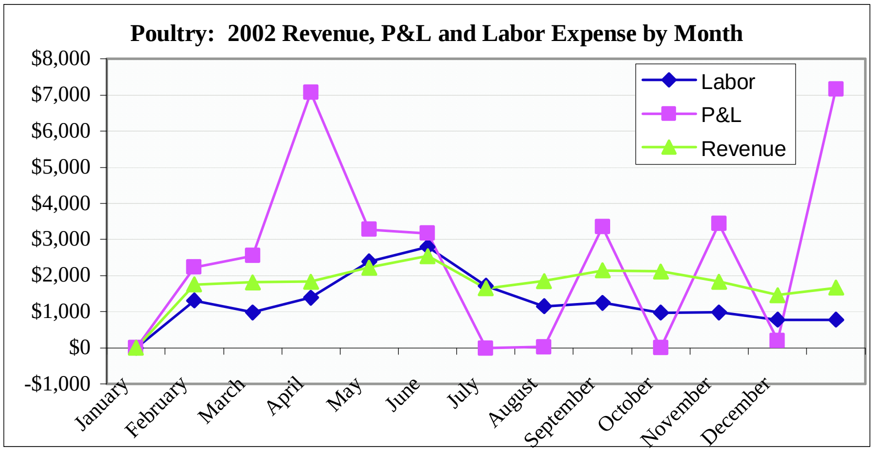


Figure 86 Poultry: Comparison of Revenue, P&L and Labor Expense Over Time

The Tree Fruit product line currently represents the greatest challenge in terms of turning a yearly profit (Figure 87). Labor expenses alone are equal to 144% of revenues. If operating costs are included in expenses, together they make up 281% of revenues. This is the only product line where revenues are generated months after labor is invested. As some of the orchards are still relatively young, future increased yields may help to offset this difference. In addition, some of the labor expenses can be attributed to one-time tasks necessary for young orchards, such as staking and trellising. Nevertheless, it is necessary that a greater amount of Tree Fruit be sold. This relates to the need for distribution channels to be in place for perfect and second grade fruit, and the necessity that cull rates be reduced in Tree Fruit (see the Percent of Harvest Sold section).

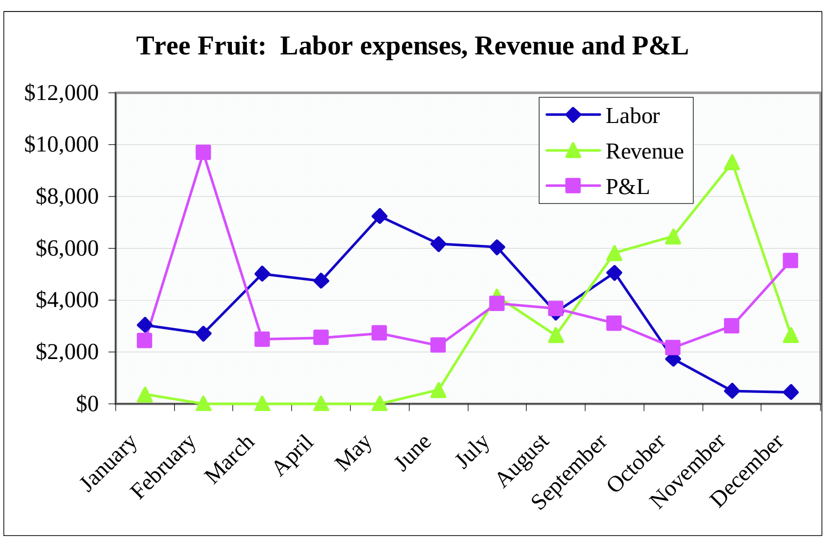


Figure 87 Tree Fruit: Comparison of Revenue, P&L and Labor Expense Over Time

Vegetables also present management challenges, as labor expenses exceed revenues for most of the year (Figure 88), given that the majority of P&L costs are salary expenses for the head vegetable grower. P&L and labor expenses represent 132% of revenues. Operating costs are relatively low all year if the salary expense is removed, and therefore are not a significant concern. As with Tree Fruit and Brambles, greater quantities or higher priced produce must be sold to offset the high labor investment. The summer interns also noted that in some vegetable plots, a notable amount of produce was not harvested. This suggests that distribution channels and labor management could be improved to allow more of the Vegetables grown to reach the market.

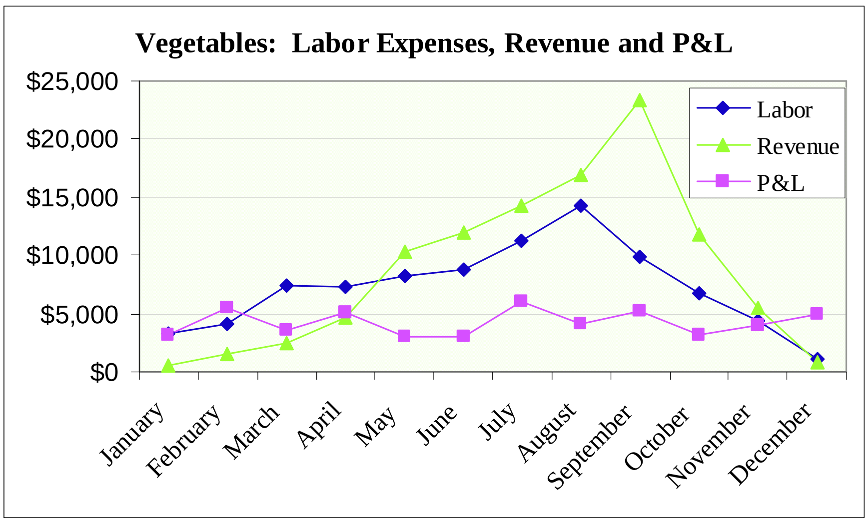


Figure 88 Vegetables/Herbs/Flowers: Comparison of Revenue, P&L and Labor Expense Over Time

6.3.2 Percent of Harvest Sold

One indication of how well farm managers have been able to connect farm products with markets is the percent of harvested crops that were sold. Though there is a portion of harvested material that is not appropriate for sales due to bruising or other standards, knowing the percentage sold can allow managers to correlate past marketing strategies with the quantities of harvested crops. Since Harvest logs were missing after September 29, 2002, the quantities sold from that date on were added to the total harvest as a minimum, thus making the percentages more realistic. It was assumed that the harvest information for 2001 was complete, though data were only collected from April through September. These percentages should not be considered to be exact because they are based on harvest data that are both incomplete and imprecise. Based on the assumption that harvest data are relatively complete, the estimates of percentage of harvested material that was sold are likely to be overestimates. Figure 89 shows the percent of harvested crops that were sold for 2001 and 2002. Several important aspects of both quantities harvested and sold stand out in this graph. The first is that in 2001 it appears that 100% of harvested Herbs and Eggs were sold. Since it is not possible to sell more than was harvested, it is clear that there are missing harvest data for the 2001 Herb and Poultry (egg) harvests. For Brambles, the overall quantity of harvest decreased from 2001 to 2002. Vegetables decreased in percentage sold in 2002, though the harvest increased over 2001. The most notable result is the Tree Fruit harvest. Though the percent of harvest doubled from 2001 to 2002, the percent of harvest that is sold is still below 35%. Percentages sold for various crops can be seen in Figure 90.

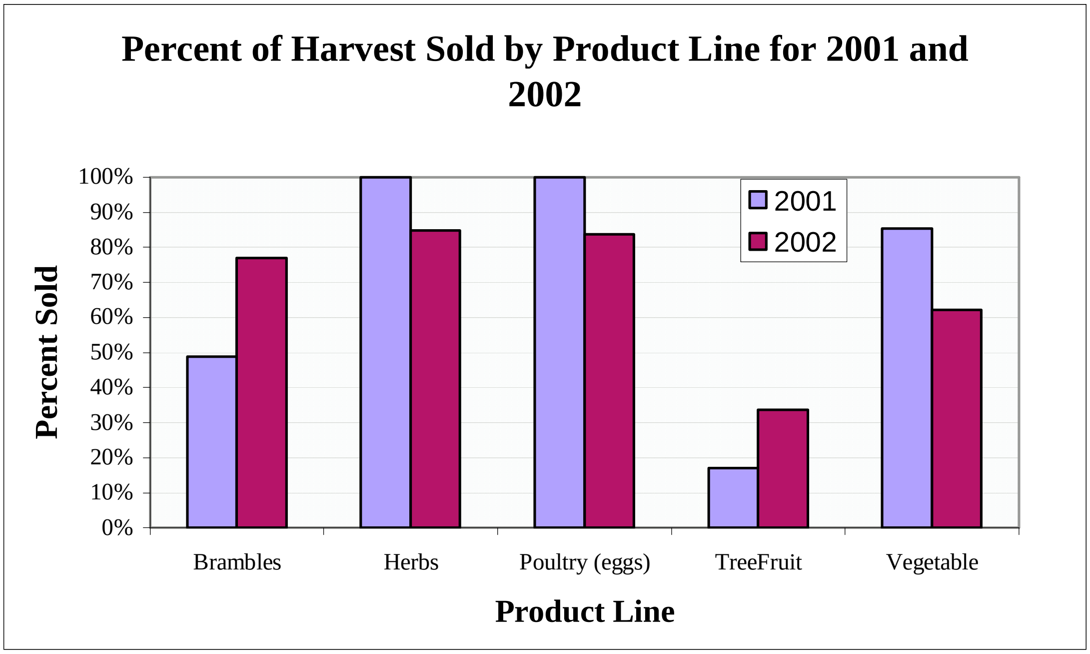


Figure 89 Percentage of Harvested Material that was Sold, by Product Line, in 2001 and 2002

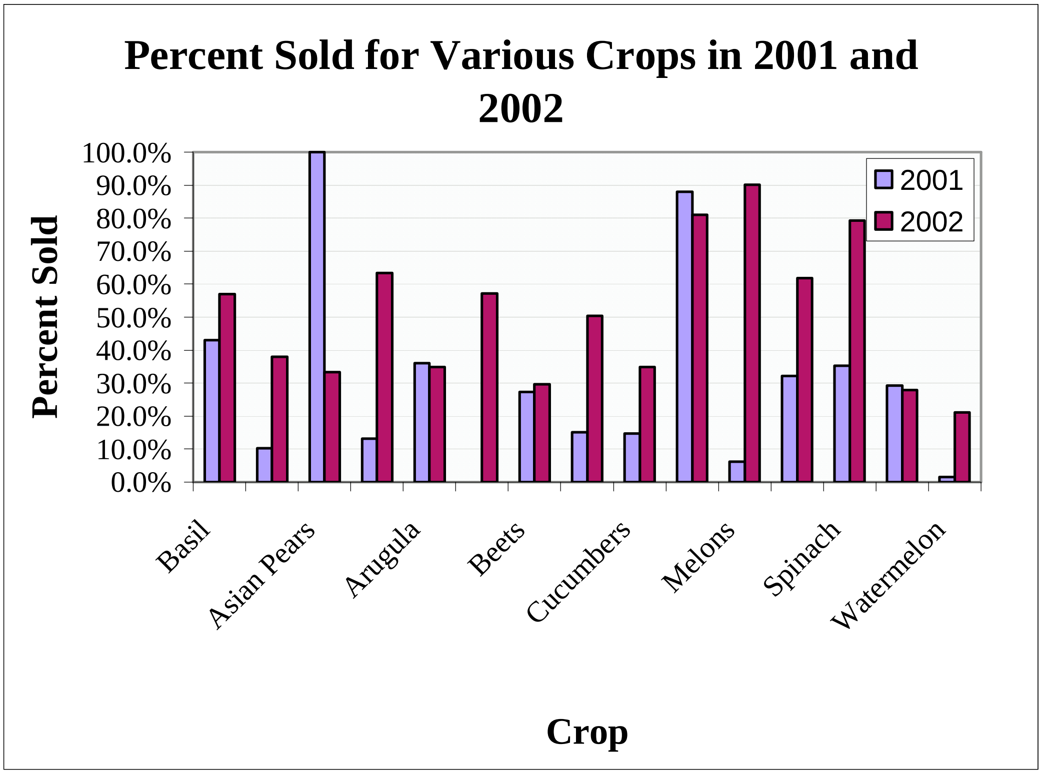


Figure 90 Percent of Harvest Sold for Various Crops for 2001 and 2002

6.3.3 Yield vs. Harvest

Revenue is lost when products are left unsold. Revenue is also lost when products are produced but not picked. If the crops are not picked, the costs associated with planting, irrigating and tending the crops cannot be recovered. Though the percent of the yield that was harvested is difficult to quantify, it is estimated that for Vegetables, Brambles, and Herbs, the cull percentage ranges between 10-40% depending upon the crop. Management practices for Tree Fruit include a complete harvest of all fruit that is yielded. Direct observations indicated that at times significant portions of certain crops were not harvested. These observations form the basis for the percentages lost between yield and harvest.

6.3.4 Revenue Generating Potential

There are five ways to increase the profitability of each product line: (1) reduce labor cost, (2) reduce P&L costs, (3) increase the unit price, (4) increase the percent of harvest that is sold, and (5) decrease the difference between harvest and yield. This analysis focuses primarily on the latter two options and their potential impact on revenues. Combining the profitability and percent of harvest sold provides for a useful analysis of revenues that were lost to the difference between what was harvested and what was sold. Since most of the labor and P&L expenses are incurred in the growing and harvesting phases of production, it is assumed that these costs remain fixed. Based on the quantities harvested, the percent of the harvest that was sold and revenues for 2002, the maximum revenue by product line was calculated (Table 14). This number reflects the potential revenues that could have been generated had all of the produce that was harvested been sold. As these numbers are based on incomplete harvest data, it is likely that they are slightly underestimated. A weighted average was used for the Vegetable/Herb percent sold combination. It was assumed that 25% of Rito Garcias' salary could be designated to both the Bramble and Tree Fruit product lines. 100% of Brian Cramer's salary was attributed to Vegetables and Herbs. This analysis does not include "whole farm" costs mentioned in other sections, but rather gives a minimum value (in terms of cost) for each product line.

Table 14 Product Line Revenue Potential Based on 100% Sales of Harvested Crops

	Labor Cost	P&L Expenses	Total Cost	Revenue	Percent Sold 2002	Maximum Potential Revenue (100% sales, current harvest)
Brambles	$39,382	$23,740	$63,122	$41,240	77.0%	$53,567
Poultry (Eggs)	$16,526	$32,481	$49,007	$22,913	83.7%	$27,369
Tree Fruit	$50,666	$43,408	$94,073	$31,883	33.6%	$94,822
Vegetables/Herbs	$101,088	$50,834	$151,922	$88,528	66.1%	$133,930

Though it is not realistic to assume that 100% of a harvest can be sold, it can provide insight into how to make each product line more profitable. Each product line is discussed in more detail below.

6.3.5 Decreasing the Difference Between Harvest and Sales

Brambles

Figure 91 illustrates the relationship between percent of harvest sold and profitability for Brambles. Even if 100% of harvested Brambles were sold, Brambles would still cost approximately $9,500 more than is generated.

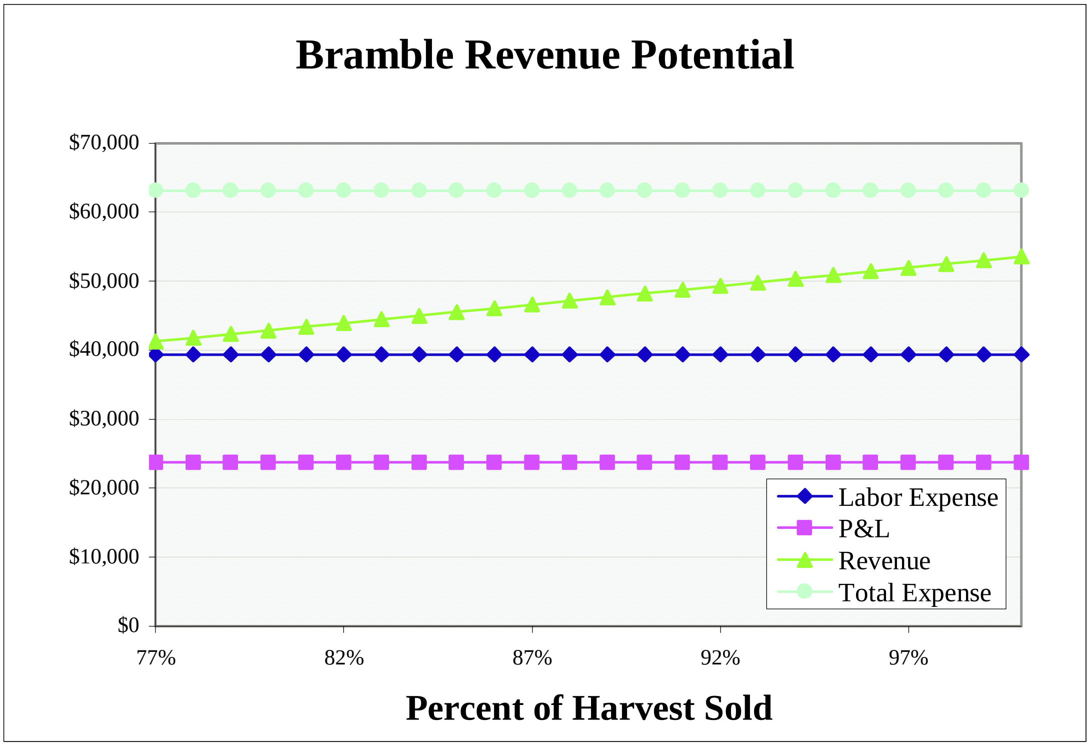


Figure 91 Bramble Profitability as a Function of Percent of Harvest Sold

Eggs

Figure 92 illustrates the relationship between percent of harvest sold and profitability for Eggs. It is evident that Poultry (egg) revenues were not sufficient to cover the P&L costs of production, even if 100% of the harvest was sold. At 100% sales of the 2002 harvest, Poultry (egg) cost $21,600 more than they generated.

Tree Fruit

The revenues generated by the Tree Fruit product line are sufficient to cover P&L expenses or labor expenses at approximately 54% sales of harvest, but not both. For Tree Fruit to have broken even in 2002, 100% of the harvest would have had to be sold (Figure 93). This represents an increase in sales by approximately 76%.

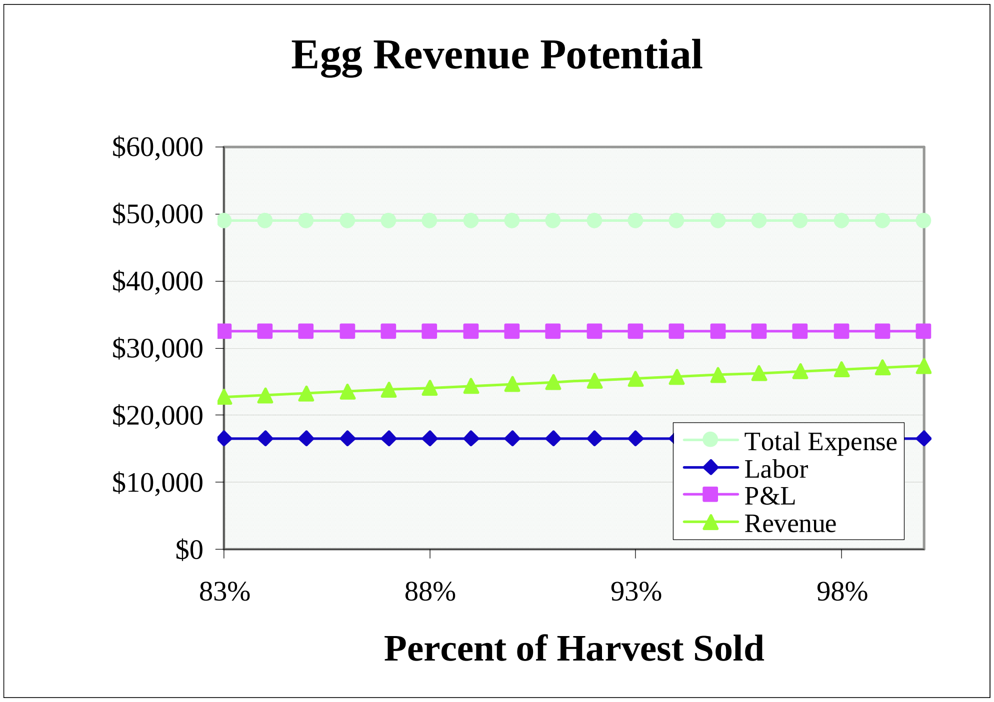


Figure 92 Poultry (Egg) Profitability as a Function of Percent of Harvest Sold

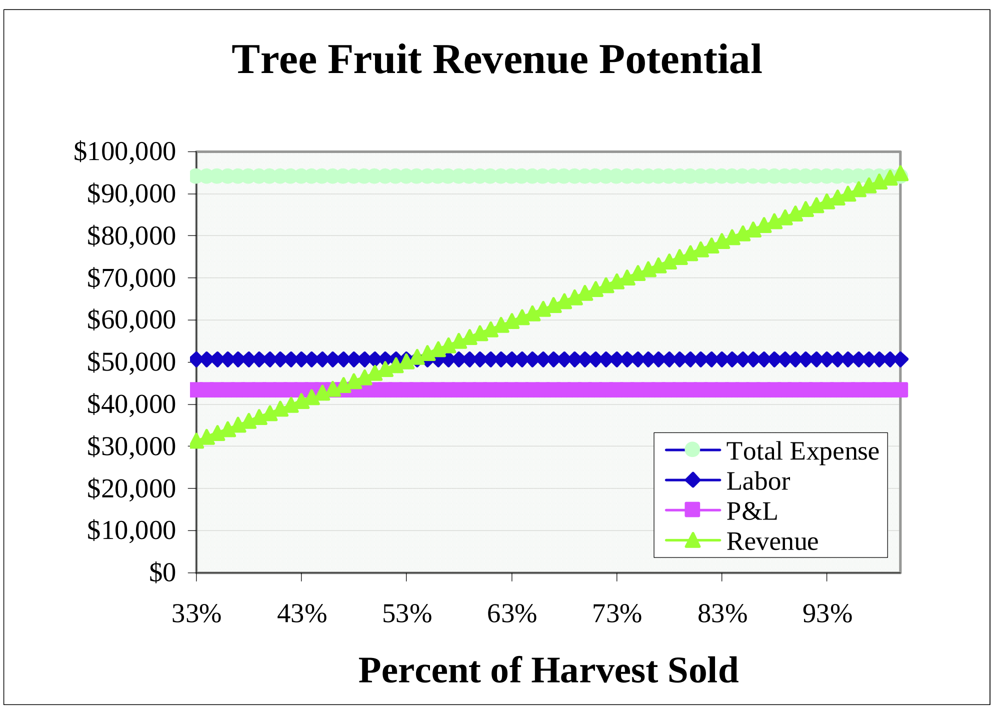


Figure 93 Tree Fruit Profitability as a Function of Percent of Harvest Sold

Vegetables and Herbs

The Vegetable and Herb product lines were combined in this analysis because harvest data are not relevant (and was not recorded) for the Flowers and Live Plant product line, and revenues for Vegetables and Herbs were not differentiated. Figure 94 illustrates the relationship between percent of harvest sold and profitability for Vegetables and Herbs. At 100% sales, Vegetables and Herbs could not cover the direct costs associated with the product lines. Even if all of the harvested crops were sold, Vegetables and Herbs would cost approximately $18,000 more than they generate.

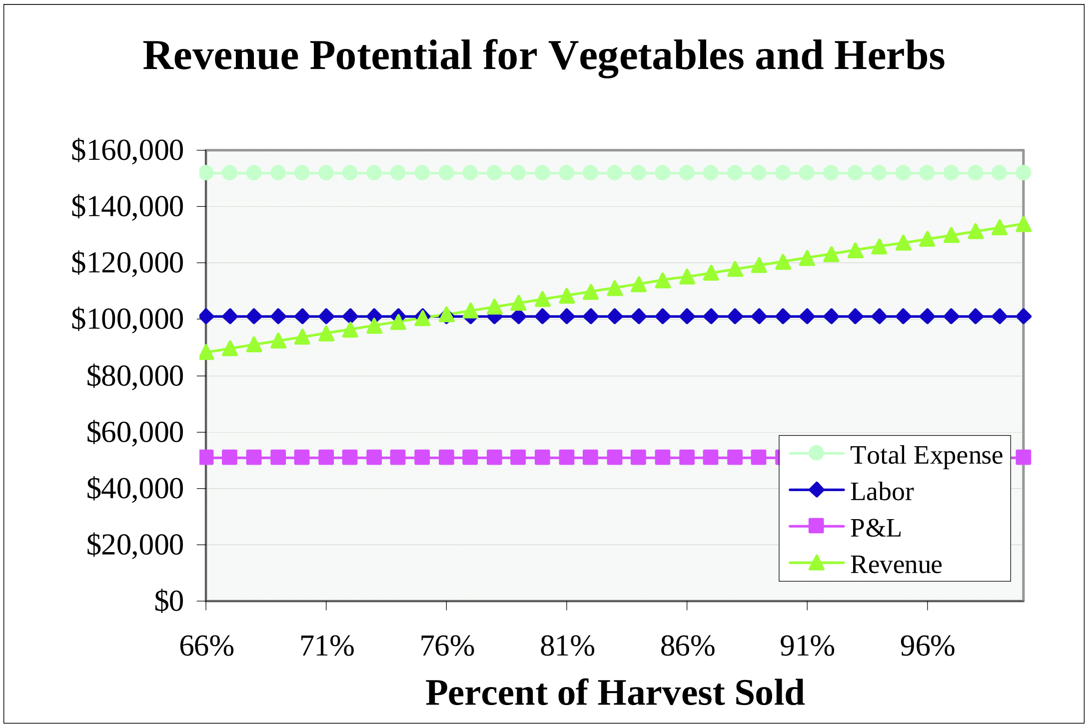


Figure 94 Vegetable/Herb Profitability as a Function of Percent of Harvest Sold

6.3.6 Decreasing the Difference Between Harvest and Yield

As mentioned earlier, revenue is lost when crops are left unpicked. An exploration in potential revenues as a result of decreasing the difference between yield and harvest can provide a first order approximation of both the potential profitability and necessary harvest to break even for each product line. A summary of three potential harvest scenarios is illustrated in Table 15. This analysis is most relevant to the Bramble and Vegetable/Herb product lines because these product lines most likely have the largest difference between harvest and yield. A sale percentage of 85% of all harvested produce was assumed for each product line.

Table 15 Product Line Revenue Potential with an Increase in Harvest

	Total Cost	Maximum Potential Revenue (85% Sales)	Maximum Potential Revenue (85% sales, 10% harvest increase)	Maximum Potential Revenue (85% sales, 20% harvest increase)	Maximum Potential Revenue (85% sales, 30% harvest increase)
Brambles	$63,122	$45,532	$50,085	$54,639	$59,192
Eggs	$49,007	$23,264	$25,590	$27,916	$30,243
Tree Fruit	$94,073	$80,599	$88,659	$96,718	$104,778
Vegetables/Herbs	$151,922	$113,841	$125,225	$136,609	$147,993

Brambles

With an increase in the percent of harvest sold by 8%, and an increase in harvest by 30%, Brambles would cost approximately $4,000 more than they generate (Figure 95). This number would likely be even greater due to the labor and P&L costs associated with a larger harvest.

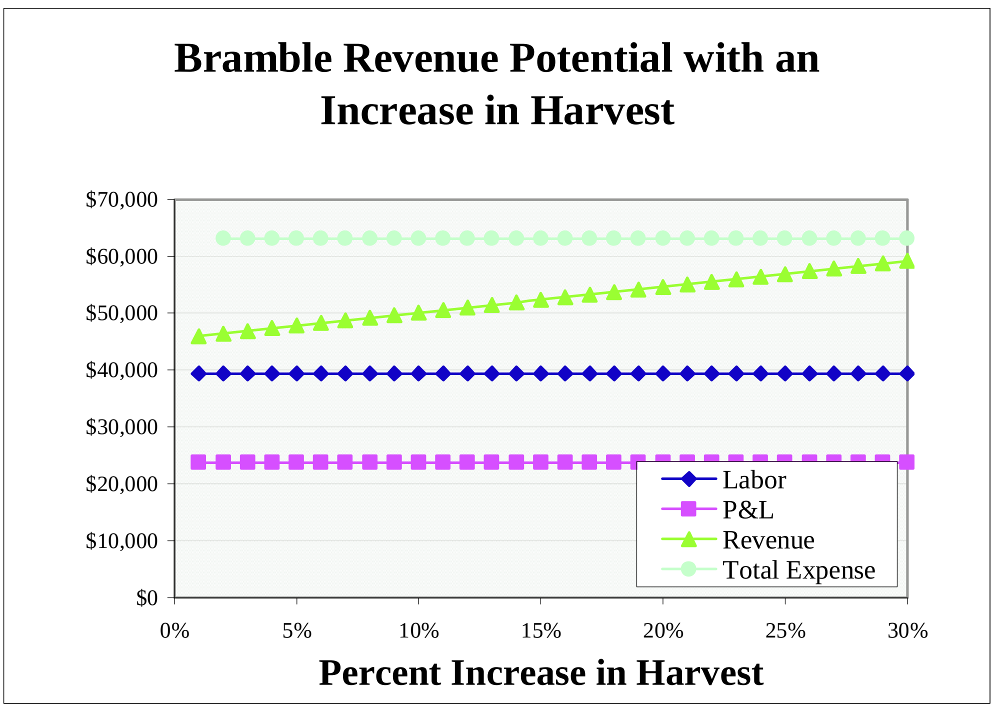


Figure 95 Bramble Profitability Potential as a Function of Increasing Harvest

Eggs

With an increase in the percent of harvest sold by 1.3%, and an increase in harvest by 30%, the revenues generated by Poultry (eggs), is not sufficient to cover P&L expenses. The Poultry (eggs) profitability potential as a function of increasing harvest is illustrated in Figure 96. Under this scenario, Poultry (eggs) is not profitable, and would cost approximately $18,000 more than they generate.

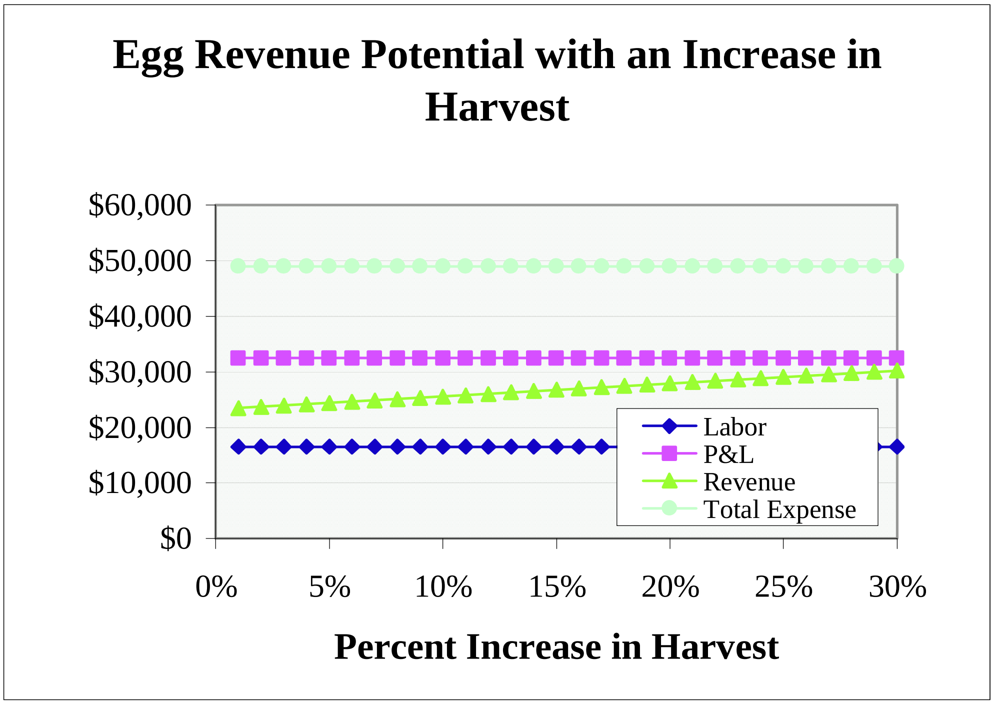


Figure 96 Egg Profitability Potential as a Function of Increasing Harvest

Tree Fruit

With an increase in the percent of harvest sold by 51% and an increase in harvest by 17%, the revenues generated by Tree Fruit are sufficient to cover P&L and labor expenses. With a 30% increase in harvest, Tree Fruit would generate a net profit of $10,000.

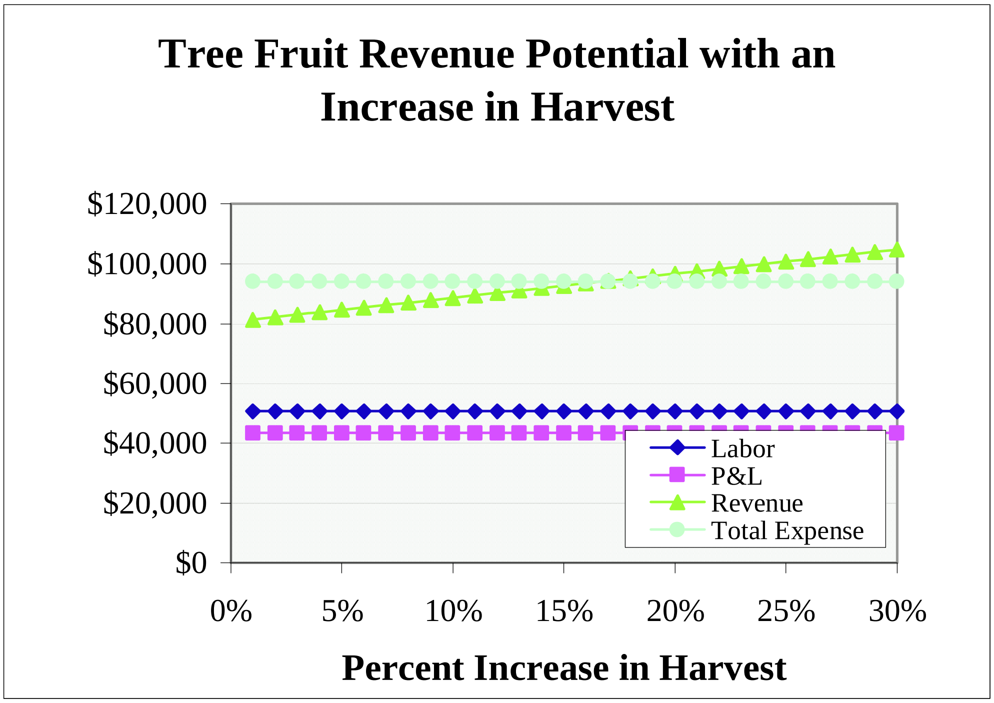


Figure 97 Tree Fruit Profitability Potential as a Function of Increasing Harvest

Vegetables and Herbs

With an increase in the percent of harvest sold by 19% and a harvest increase of 30%, Vegetables and Herbs do not generate sufficient revenues to cover P&L and labor expenses. Even with these increases, Vegetables and Herbs would cost approximately $4,000 more than they generate.

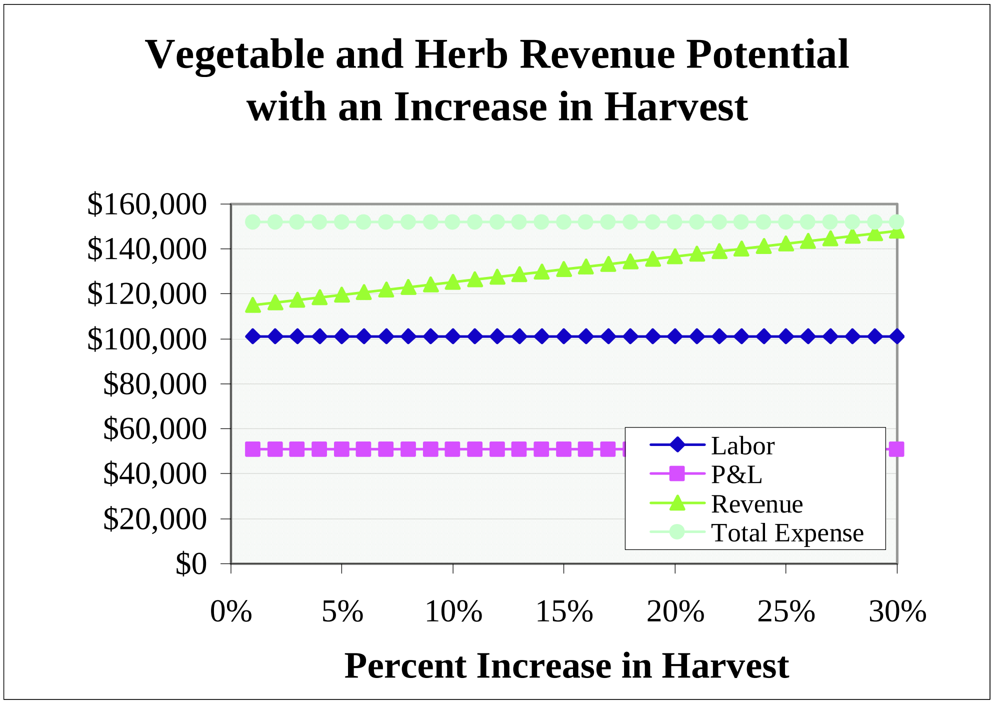


Figure 98 Vegetable and Herb Profitability Potential as a Function of Increasing Harvest

6.3.7 Sales Distribution Analysis

The previous analysis of potential revenues from reducing culls and increasing harvest assumes that sales distribution channels are static. In the interest of better understanding which sales channels are most profitable, sales via the farmer's market verses other distribution channels are analyzed for 2002. For these analyses, beef sales were omitted, both because beef is largely not sold at the markets, and because the sales channels for Livestock are very different from other product lines (revenues are largely a percent of professional fees, rather than direct sales).

With Livestock revenues removed, revenues for 2002 are greatly reduced from $2.4 million to $1.3 million. To allow a basis for comparison by market and non-market sales, total pounds sold by product line were calculated. When considered as a percent of revenues generated, it was found that in total, 24.4% of pounds sold were at the three markets, generating 80% of 2002 revenues (Figure 99). Conversely, the remaining 75.6% of pounds of produce sold through non-farmer's market distribution channels only generated 20% of revenues for 2002. This suggests that there are much higher returns on goods sold through the markets relative to other distribution channels.

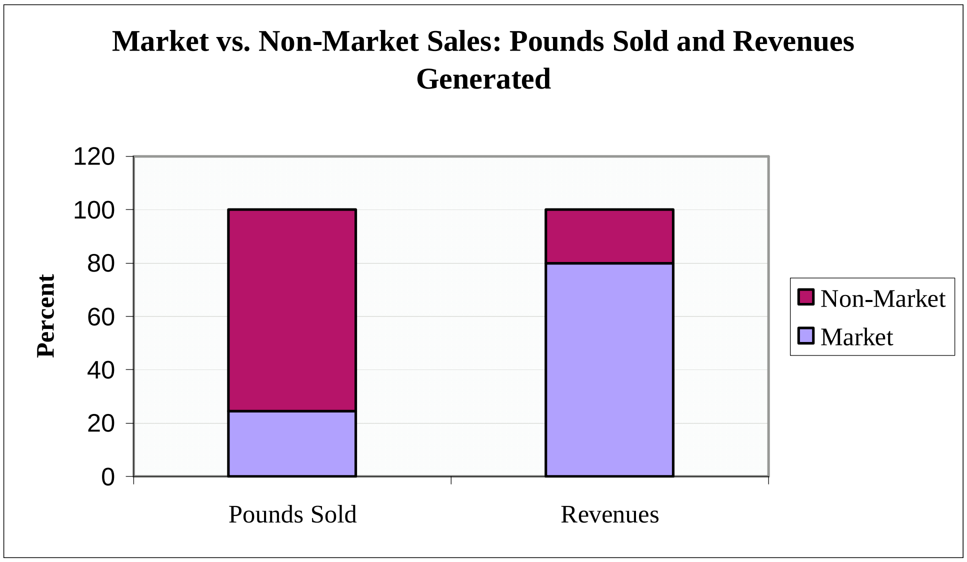


Figure 99 Farmers' markets vs. other sales

Beef sales are omitted.

Contributing factors to this difference could be that the head farm marketing person was not assigned to the job until mid-summer. Another contributing factor could be inadequate communication between managers about the availability of crops. It is interesting to note that of the produce sold at the markets, 49% were Vegetables and 37% were Herbs, which are grown by Brian Cramer, versus 9% of total pounds of Tree Fruit and 11% of total pounds of Brambles (Figure 100). He is also responsible for preparing for and attending the largest market of the week. Communication between the interns and the marketing manager in the summer suggested that Cramer might not have been accurately communicating the availability of Vegetables. At current volumes of sales it is more profitable to sell produce and eggs at the farmer's markets, but if the wholesale and restaurant sales distribution channels could increase in volume, economies of scale could eventually be realized.

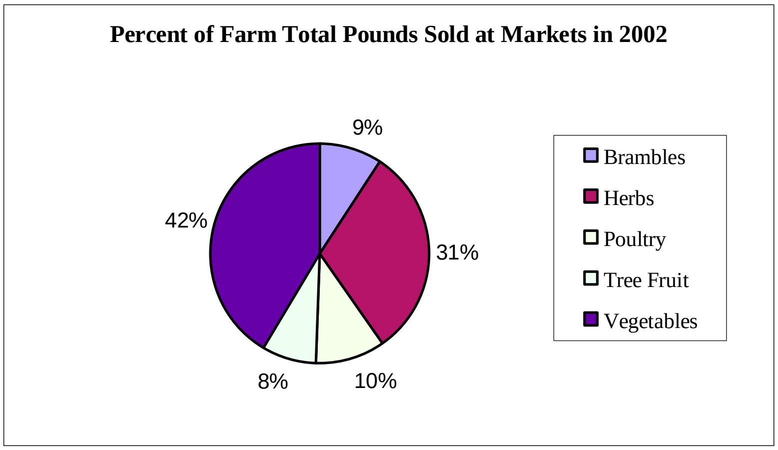


Figure 100 Percent of Total Pounds Sold in 2002 at Farmers' Markets

Beef sales are omitted.

In conclusion, sales via farmer's markets should not be reduced unless other distribution channels are available where goods can be sold at high enough prices or volumes to equal the high return possible at the market. Therefore, in addition to improving the percentage of crops harvested and sold, managers must consider which combination of sales distribution channels will increase profitability.

6.4 Results and Conclusions (Including Whole Farm Expenses)

6.4.1 Whole Farm Expense Designation

Whole Farm expenses, or the expenses that either apply to multiple product lines or expenses that do not apply specifically to one product line, were incorporated into the following analysis in order to better determine the profitability of the product lines. The whole Farm expenses were divided into product lines based on the acreage used by each product line. The rationale behind this is that the top whole farm expenses (taxes and insurance) are essentially based on the acreage of the farm. The land use designations are seen in Table 16, which were based on the land usage on the Main Farm. Tamara Waldo's salary was subtracted from the whole farm expense and equally added to the salary expenses of Livestock, Tree Fruit, Poultry, Brambles, and Vegetables/Herbs/Flowers. The Whole Farm expense ($572,591) was then multiplied by the percent of land use for each product line and added to the P&L Expenses. The expenses and revenues by product line with the whole Farm expenses can be seen in Table 17.

Table 16 Land Use on the Main Farm

Land Use	Acres	Percent of Total
Forest/Riparian	211	51%
Non Use	124	30%
Livestock	26	6%
Tree Fruit (Harvested)	22	5%
Vegetables and Herbs (Harvested)	11	3%
Tree Fruit (Not Harvested)	7	2%
Chickens	5	1%
Berries (Not Harvested)	5	1%
Berries (Harvested)	4	1%
Total	415	100%

Table 17 Expenses and Revenues by Product Line with Whole Farm Expenses Included

	P&L Exp with WHF	Labor	Salary with WHF	Total Expenses	Revenue
Tree Fruit	$67,114.69	$46,151.15	$26,215.79	$93,330.48	$31,882.94
Poultry	$38,206.84	$16,649.72	$9,841.26	$48,048.10	$22,913.31
Brambles	$18,817.72	$39,381.96	$26,215.79	$45,033.50	$41,240.00
Veg/Herbs/Flowers	$31,993.62	$86,749.91	$45,858.80	$77,852.42	$104,218.50
Total	$156,132.87	$188,932.75	$108,131.63	$264,264.50	$200,254.75

6.4.2 Product Line Analyses

The following criteria were used to analyze the profitability of each product line: the percent of total expenses that is required by each product line, the percent of revenue generated by each product line, the percent of revenues that are required to pay for P&L expenses, the percent of revenues that are required to pay for labor expenses (not including salary), and the cull rates. These criteria and their results (Table 18) can be used to highlight the major inefficiencies associated with each product line. These criteria are discussed in more detail in the following sections.

Table 18 Product Line Performance

	% Exp by Product Line	% Rev by Product Line	Labor as % of Total Expenses	P&L Expenses/ Revenue	Labor Expenses/ Revenue	Cull Rates
Tree Fruit	31%	16%	33%	211%	145%	66%
Poultry	14%	11%	26%	167%	73%	16%
Brambles	19%	21%	47%	46%	95%	23%
Veg/Herbs/Flowers	36%	52%	53%	31%	83%	34%

6.4.3 Poultry Analysis

The major inefficiency associated with the poultry product line is that P&L expenses account for 167% of the revenues. The primary expense associated with this product line is the cost of feed, which accounted for approximately $27,700 in 2002. The cost of feed alone accounts for 121% of the revenues. As revenues are not sufficient to cover operating costs for this product line, increasing the price of the eggs and/or decreasing the costs associated with feed is necessary to improve profitability. A brief analysis of egg pricing and feed reduction is displayed in Table 19and Table 20. The current price per egg is an average number based on the revenues and quantities sold.

Table 19 Current Price per Egg and Break Even Price per Egg

Total Expenses	Current Price/ Egg	Number Eggs Sold	Total Expenses/Number of Eggs Sold = Price/Egg Needed to Cover Expenses	Price/Egg Increase Required	Percent Increase in the Price of Eggs
$64,697.82	$0.12	235,589	$0.27	$0.15	129%

Table 20 Price Increase/P&L Decrease Scenarios for Poultry

New Price/Dozen	New Price per Egg	New Revenue	Profit/Loss Under New Price	P&L Expenses	Break Even P&L Expenses	Percent Reduction in P&L Expenses
$2.50	$0.21	$49,081.04	-$15,616.78	$38,206.84	$22,590.06	-41%
$3.00	$0.25	$58,897.25	-$5,800.57	$38,206.84	$32,406.27	-15%

6.4.4 Bramble Analysis

The major inefficiency associated with the Bramble product line is the cost of labor, which accounts for 95% of revenues. A brief analysis of the price per pound was performed in order to determine the break-even price under current conditions (Table 21). In addition, two pricing scenarios were explored in order to determine how much labor would have to be reduced in order to break even under scenarios of increases in per pound prices by 25% and 50% (Table 22).

Table 21 Current Price per Pound and Break Even Price per Pound for Brambles

Total Expenses	Current Price/Pound	Number Pounds Sold	Total Expenses/Number of Pounds Sold = Price/Pound Needed to Cover Expenses	Need to Raise Price/Pound by	Percent Increase
$84,415.47	$5.11	8,073	$10.46	$5.35	105%

Table 22 Price per Pound Increase/Labor Decrease Scenarios for Brambles

Price Increase	New Price per Pound	New Revenue	Profit/Loss Under New Price	Labor Expenses	Break Even Labor Expenses	Percent Reduction in Labor Expenses
25%	$6.39	$51,566.29	-$32,849.18	$39,381.96	$6,532.78	-83%
50%	$7.67	$61,879.55	-$22,535.92	$39,381.96	$16,846.04	-57%

6.4.5 Tree Fruit Analysis

The major inefficiency associated with the Tree Fruit product line is the high cull rate (66% in 2002). Table 23 shows the price increase per pound necessary to break even with current cull rates, labor and P&L expenses. A more realistic and effective step towards profitability would be to focus efforts on reducing the high cull rates. Since it is likely that harvest will continue to increase because the trees at the Farm have not yet reached maturity, an increase in harvest and a decrease in culls can have dramatic effects on profitability. Several scenarios were explored to see the effect on reducing culls and increasing harvest on the other criteria, namely the percent of revenues that are required to pay for P&L expenses and the percent of revenues that are required to pay for labor expenses (Table 24). It is evident that even though reducing culls cut both of these percentages in half, labor would still require greater than 80% of revenues and P&L expenses would be greater than 116% of revenues.

Table 23 Current Price per Pound and Break Even Price per Pound for Tree Fruit

Total Expenses	Current Price/Pound	Number Pounds Sold	Total Expenses/Number of Pounds sold = Price/Pound Needed to Cover Expenses	Need to Raise Price/Pound by	Percent Increase
$139,482	$0.95	33727	$4.14	$3.19	335%

Table 24 Decreases in Cull Rates/Increase in Harvest Scenarios for Tree Fruit

Original Revenue	Cull Rates	Increase in Harvest	Total Revenue	P&L as a % of Revenues	Labor as a % of Revenues
$31,883	15%	20%	$57,772	116%	80%
$31,883	20%	15%	$53,531	125%	86%
$31,883	15%	15%	$55,365	121%	83%
$31,883	30%	15%	$49,865	135%	93%

6.4.6 Vegetable/Herb/Flower Analysis

Vegetables, Herbs and Flowers were combined in this analysis because the current accounting structure does not differentiate between these product lines when tracking revenues. The major inefficiencies associated with the Vegetable/Herb/Flower product lines are the high labor costs (83% of revenues) and the relatively high cull rates (greater than 34%). The break even per pound price can be seen in Table 25. The effect of increasing the price on labor expenses can be seen in Table 26.

Table 25 Current Price per Pound and Break Even Price per Pound for Vegetables/Herbs/Flowers

Total Expenses	Current Price/Pound	Number Pounds Sold	Total Expenses/Number of Pounds sold = Price/Pound Needed to Cover Expenses	Need to Raise Price/Pound by	Percent Increase
$164,602	$2.73	38193	$4.31	$1.58	58%

Table 26 Price per Pound Increase/Labor Decrease Scenarios for Vegetables/Herbs/Flowers

Price Increase	New Price/ pound	New Revenue	Profit/Loss Under New Price	Labor Expenses	Break Even Labor Expenses	Percent Reduction in Labor Expenses
25%	$3.41	$130,334	-$34,269	$86,750	$52,481	-40%
50%	$4.10	$156,400	-$8,202	$86,750	$78,548	-9%

6.5 Recommendations

Management should focus on strategies that would increase sales of harvested crops, and estimate the field quantities available for sale that are in the field. Each manager that is involved in the sale of the crops should have a clear understanding of the yields in order to minimize the difference between harvest and yield.

Increasing the percentage of harvest that is sold and decreasing the difference between harvest and yield will have direct, positive effects on the profitability of Tree Fruit, but not Brambles, Poultry and Vegetables and Herbs. At 100% of sales of the current harvest, none of the product lines made a profit. With an increase in harvest of 30% and an 85% sale of harvest, only the Tree Fruit product line is profitable. Under this scenario Tree Fruit generated $10,000, Brambles cost $4,000, Vegetables and Herbs cost $4,000, and Poultry cost $18,000. Since the majority of P&L costs for Poultry (eggs) are feed costs, the only way for Poultry (eggs) to become profitable is for the price to increase. Tree Fruit appears to have the greatest revenue generating potential, followed by Brambles and Vegetables and Herbs.

Produce should continue to be sold via the farmer's markets and sales distributed through other channels must be at volumes high enough where economies of scale can be realized.

More complete harvest and revenue data that track quantities and sale prices would allow these same analyses to be made by crop and variety, not just product line.

7 ENERGY

7.1 Significance

Farmers must successfully manage the agro-ecosystem in the most efficient way in order to maximize productivity. With respect to energy, this typically means managing the amount of necessary energy inputs (direct and indirect), while still maintaining a productive and profitable level of output (yield). Direct inputs of energy, not including solar energy, are forms of energy that must be purchased by the farmer, such as diesel fuel, gasoline, natural gas, liquid petroleum, and electricity. Energy can also be applied to the system indirectly via other inputs to the system that require energy in production, which are typically fertilizers and pesticides.

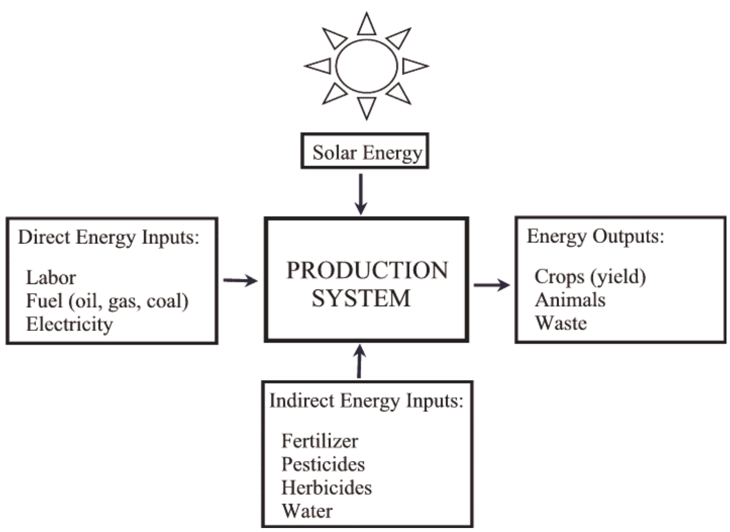


Figure 101 Energy Inputs and Outputs in Agro-Ecosystems[9]

Conventional farming practices over time have shifted to more intensive production methods as a means of increasing productivity. High intensity systems require more energy inputs, more capital and/or more labor; typically, industrialized agriculture has attempted to shift to higher energy and capital (machinery) inputs and less human labor.[10] When considering energy, this is not without consequence, however, as there is an inverse relationship between productivity and energy efficiency.[9] Although productivity increases, a point of diminishing returns is reached with respect to energy. In other words, continuous increases in inputs may increase yield rates but also may cause reductions in productive capacity in future years.[11]

Heavy reliance on fossil fuels in agriculture has contributed to increased air pollution and greenhouse gas emission levels[10] The use of fossil fuels has also led farmers to be more susceptible to market fluctuations in the energy market. Because of price shocks and market fluctuations, the price of energy, including gasoline, diesel and natural gas, has become more volatile than any other Farm input.[12]

Due to the problems associated with traditional petrol based fuels, including inefficiencies, the environmental impacts of production processes, national security issues and reliance on a volatile market, some farmers have attempted to reduce and/or shift direct inputs to more reliant and stable forms of energy. There are several activities and options farmers can utilize, including changing management practices (i.e. adopting conservation tillage), replacing energy inefficient machinery and equipment with more efficient equipment, and reducing the amount of pesticides or fertilizers used (the production of which is highly energy intensive).[11]

7.2 Approach

An input/output approach was used to track energy usage at the Farm. Direct and indirect sources of energy inputs include incoming solar radiation, labor, fossil fuels, electricity, fertilizers and pesticides. Outputs include the caloric content of crops exported from the Farm. Inputs and outputs were measured at an annual, whole-Farm scale and converted to a common unit: the gigajoule (GJ).

To assist Farm management in promoting and maintaining economic profitability and conserving energy resources, an energy output:input ratio was calculated based on quantity sold output and purchased energy inputs. This ratio could assist managers in improving the Farm's energy efficiency by minimizing marginal energy inputs or resolving discrepancies between yield, actual harvest, and quantity sold.

7.3 Direct Energy Inputs at Sunnyside Farms

7.3.1 Solar Energy

The energy accumulated by plants through photosynthesis is called primary production, and net primary production is the energy left after the respiration necessary for plant maintenance. Although plants vary in how efficiently they can capture, convert and store solar energy, typically less than 1% of the incoming solar energy reaching the plant is absorbed and converted to biomass.[13] Through agriculture, stored energy is concentrated in biomass and can be harvested and utilized, either by consuming it directly or by feeding it to animals that are later used for labor or food.

In this context, the total annual incoming solar radiation on the planted portion of the Farm is approximately 69.2 GJ/m^2 (values are from Table 92 in the Weather Appendix), of which approximately 0.4 to 1% will be converted into biomass.

7.3.2 Labor

Agricultural labor is another direct energy input and an important consideration in overall energy analyses. Human labor can be significantly higher in organic farming when compared to conventional practices.[14] Conventional practices are more intensive production systems with respect to external inputs such as pesticides, fertilizers and fossil fuels, but labor is a more substantial component in organic farming. Generally, organic farms tend to shift energy inputs to more human-intensive labor and away from the fossil fuel-intensive chemical products, non-renewable fuels, heavy machinery and other capital inputs.

On the Farm, aggregate labor totals were computed by obtaining man-hours from payroll records. Labor energy was calculated from the hours worked by the field workers and did not include administrative salaries. Total man-hours for 2001 was 47,166 hours and in 2002 was 38,970 hours. Fluck and Baird (1980) estimate the energy equivalent of human labor as 24.75 MJ/hour (594 MJ/day).[15] The value includes the required energy for feeding, clothing, and transporting a worker, but specifically omits energies for leisure time. Therefore, the annual labor energy expended on the Farm was 1,167 GJ for 2001 and 964.5 GJ for 2002.

7.3.3 Fossil Fuel Consumption

Currently, the Farm utilizes liquid petroleum gasoline, on- and off-road diesel fuel and unleaded gasoline in Farm vehicles and buildings. In 2001, Farm operations used a total of 12,034 gallons of petrol-based fuels, costing $18,130.67, including necessary annual infrastructure expenses, such as repairs, service and rent. As of May 2002, the Farm used 11,863 gallons of fuel and spent $13,398.56 on fuel-related expenses (Table 27). Figure 103 and Figure 104 graphically display energy consumption by fuel type and total fuel expenses by year, respectively. Not included in the cost figure are the externalities, or social costs, associated with fossil fuel combustion. The associated externalities are quantified in Section 7.6.

Figure 102 Fuel Depot Tracks Total Usage by Fuel Type

Table 27 Annual Gallons of Fuel Consumed and Expenses

Gallons	2001	2002*
LP Gas	7,614	6,124
Gasoline	2,151	2,759
Diesel	2,270	2,980
Total	**12,034**	**11,863**

Fuel Expenses	2001	2002*
Heating	$11,092.02	$6,122.82
Unleaded	$2,220.81	$2,569.77
Off Road Diesel	$1,576.26	$1,135.35
On Road Diesel	$863.72	$1,367.85
Repairs/Service	$1,452.64	$370.41
Taxes	$925.22	$1,687.10
Rent	$0.00	$145.26
Total	**$18,130.67**	**$13,398.56**

***data for 2002 through May**

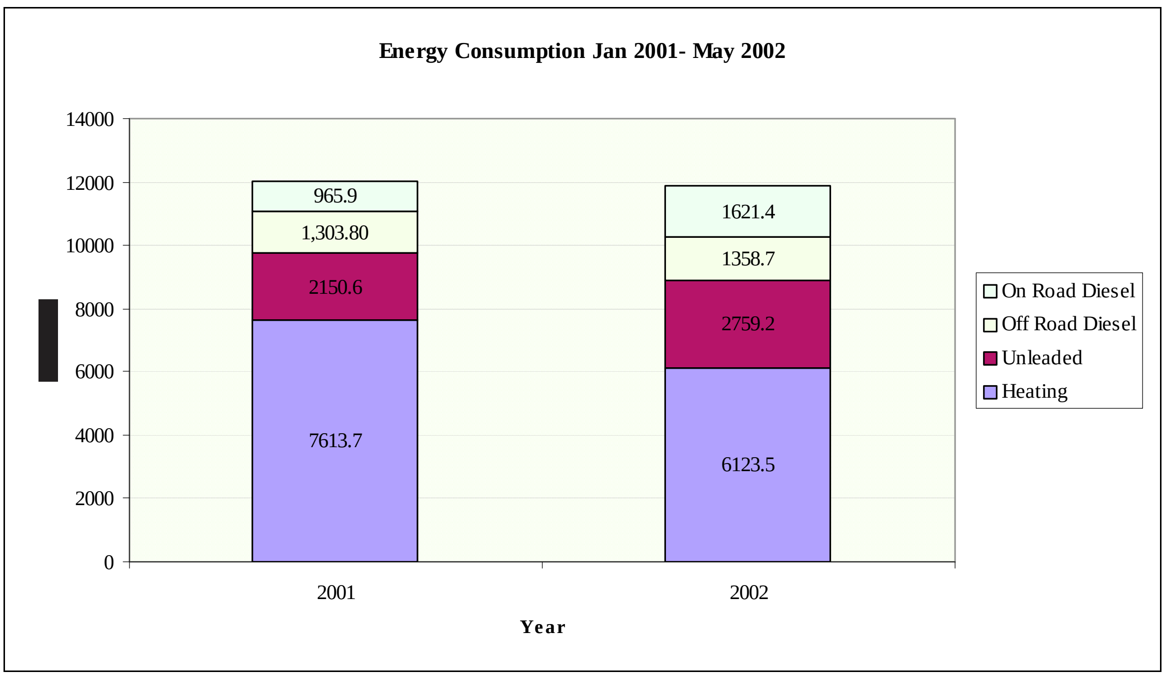


Figure 103 Fuel Consumption by Year

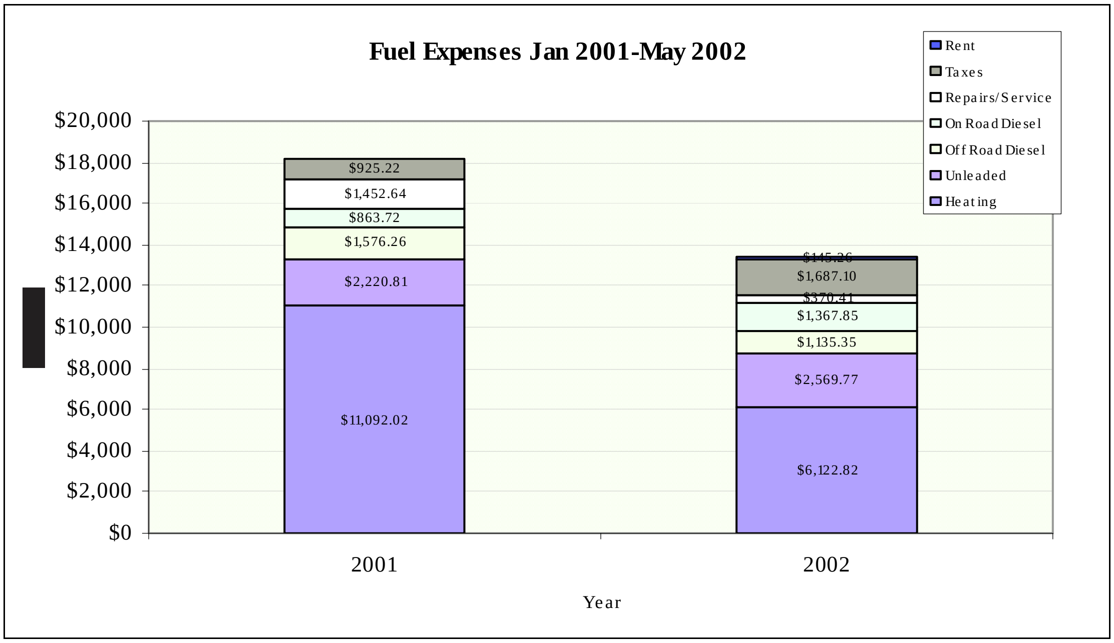


Figure 104 Farm Fuel Expenses by Year

Total energy data (in GJ) by fuel type and year are summarized in Table 28.

Table 28 Total Energy (GJ) Consumed by Fuel Type and Year

Energy (GJ)	2001	2002*
Gasoline	346.47	444.52
Diesel	406.10	533.21
LP Gas	1481.96	1460.88
Total	**2234.54**	**2438.61**

***data for 2002 through May**

7.3.4 Electricity Consumption

Currently, the Farm utilizes electricity pulled off the grid from Allegheny Power, located in Virginia. Data for electricity usage were obtained from utility bills, which detail usage in kilowatt-hours (kWh) and total cost. Due to incomplete data, electricity usage for the billing cycle Jan-Feb 2001 was assumed to be equal to what was used for the same time period in 2002, in order to allow comparisons to be made. In 2001, Farm operations used 118,685 kWh, costing $8,790.67. In 2002, operations decreased slightly to 108,691 kWh, costing $7,608.36. Figure 105 and Figure 106 graphically display electricity consumption at different metered Farm locations and total electricity expenses by year, respectively. Not included in the cost figure are the externalities, or social costs, associated with the environmental implications from electricity generation via fossil fuels.

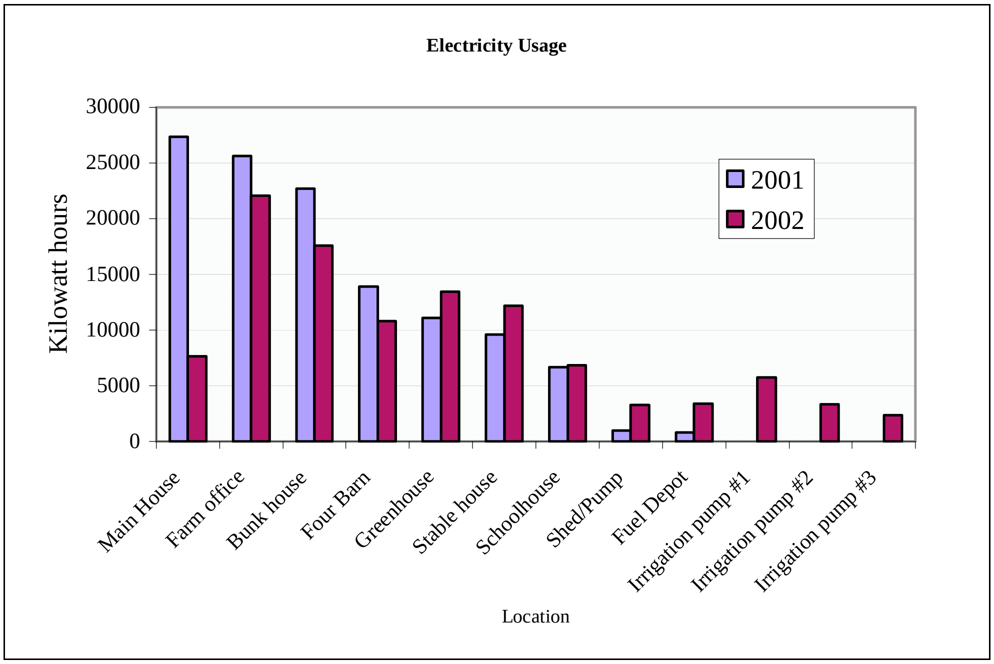


Figure 105 Electricity Usage (kWh) by Location

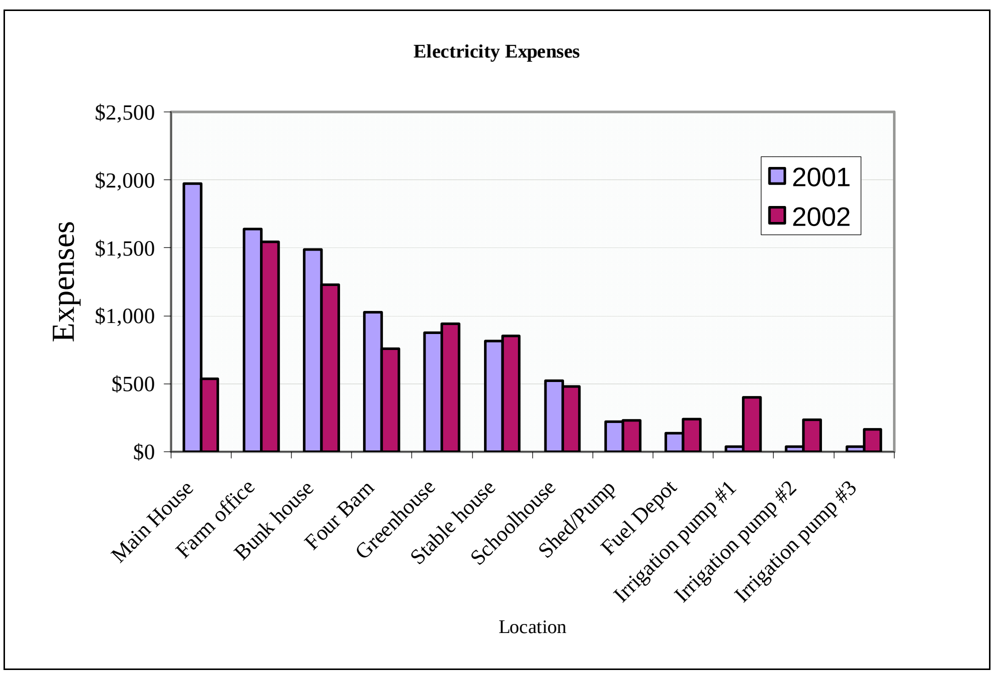


Figure 106 Electricity Expense by Location

Converting from kWh to GJ, total electricity data (in GJ) is summarized in Table 29.

Table 29 Total Energy (GJ) Consumed by Electricity by Year

Energy (GJ)	2001*	2002
	365.47	391.29

*for comparison purposes, assumed electricity use in Jan-Feb in 2001 was the equivalent used 2002 in order to have full-year data for 2001.

7.4 Indirect Energy Inputs

6.3.1 Fertilizers and Pesticides

It is also important to consider the energy value for the fertilizers used on the Farm, given the energy consumed during fertilizer production. This energy therefore is an indirect energy input. Although manufacturing energies vary over time, nutrient, and brand, Pimental (1980) has estimated an average energy requirement for nutrients N, P, and K.[16] In 2002, the Farm purchased and applied approximately 60 lbs N, 1,218 lbs P, and 462 lbs K (as detailed in the Nutrient Tracking Section). Using the energy conversion factors, the nutrient fertilizers the Farm applied required 14.8 GJ for their manufacturing and production.

The energy requirements used in the production of manufactured pesticides was determined using conversion factors and Farm-specific data on pesticide use. Pimental estimates that, on average, 84 MJ/lb are expended in pesticide production.[16] In 2002, the Farm applied approximately 1,532 lbs of pesticides in primarily solid form (small proportion of liquid pesticides were included). Therefore, the pesticides applied by the Farm required approximately 128.52 GJ for their manufacturing and production.

Although the energies for fertilizer and pesticide production were consumed off-site, they are accounted for as an indirect energy input. It should be noted that the Farm purchases fertilizers and pesticides that are in accordance with national organic standards, and therefore actual production energies may be less.

7.5 Energy Outputs

7.5.1 Quantity Sold

Harvest data from the Farm were obtained from the Harvest Logs recorded on a daily basis by the Farm workers as crops were harvested. In order to calculate the energy harvested from the crops, it was first necessary to convert traditional harvest units such as bushels, flats, and cases of various crops to a common unit, the pound, for comparability. Knowing the caloric content of the various fruits, Vegetables, Poultry (Eggs) and Herbs, the energy content (GJ) of the crops harvested was determined (quantified by product line in Table 30 and Table 31). However, there is a significant difference in the pounds harvested and the pounds sold (details in Harvest Log Analysis).

Table 30 Energy for Harvest 2001

Product Line	Energy (GJ) (harvest)	Energy (GJ) (sold)	Energy Difference (harvest - sold)
BER	9.00	7.27	1.73
TFR	70.95	4.37	66.58
VEG	26.72	24.36	2.35
HRB	0.37	0.23	0.14
PLT	45.41	8.99	36.42
Total	**152.44**	**45.22**	**107.22**

Table 31 Energy for Harvest 2002

Product Line	Energy (GJ) (harvest)	Energy (GJ) (sold)	Energy Difference (harvest - sold)
BER	6.10	2.96	3.15
TFR	51.41	26.91	24.5
VEG	23.46	9.07	14.39
HRB	1.02	0.69	0.32
PLT	73.93	5.70	68.22
Total	**155.92**	**45.33**	**110.58**

Table 32 shows total energy inputs, both direct and indirect, and the total energy output for 2001 and 2002. It should be noted that fertilizer and pesticide use for 2001 was assumed to be the same as 2002 in order to calculate an energy output:input ratio, as the 2001 energy data are more complete and accurate. Due to incomplete fuel data in 2002, an efficiency ratio was not calculated.

For 2001, the energy output:input ratio was 0.01 to 1, meaning that for each unit of energy put into the system, 0.01 units of energy were produced. This is a relatively inefficient ratio, but can primarily be explained by the harvest-quantity sold energy difference. In the future, alterations in Farm management practices could decrease the harvest-sold difference and improve the energy efficiency ratio.

Table 32 Overall Farm Energy Use (GJ)

Total Purchased Energy (GJ)	**2001**	**2002**
Direct Inputs		
Labor	1,167.36	964.50
Electricity	365.47	391.29
Fossil Fuels	2,234.54	2,438.61
Indirect Inputs		
Fertilizers	*14.8	14.80
Pesticides	*128.52	128.52
Total Energy Output (GJ)	**2001**	**2002**
Crops Sold	45.22	45.33
Efficiency	**1%**	**

* Fertilizer/Pesticide use was assumed to be the same in 2001 as in 2002.

** Incomplete fuel data in 2002 will not yield an accurate efficiency percentage.

7.6 Environmental Externalities from Energy Usage and Animal Byproducts

The combustion of fossil fuels releases carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), which are greenhouse gases that have been identified as contributors to global warming. Attempts to measure the ecological footprint of the Farm must include quantifying emissions of greenhouse gases from various Farm sources, including fossil fuel combustion, electricity generation, enteric fermentation in Livestock, and emissions from manure management.

Because different gases have different abilities to trap heat in the atmosphere and have different atmospheric lifetimes, the concept of Global Warming Potential (GWP) was developed for ease of comparability. Carbon dioxide is almost always chosen as the reference gas, with a GWP of 1 (Table 33). Atmospheric methane is an integral component in calculating climatic effects from anthropogenic sources, second only to carbon dioxide. Methane is significant because it is estimated to be 21 times more effective at trapping heat in the atmosphere, when compared to carbon dioxide (therefore the GWP of methane is 21).

Table 33 Global Warming Potentials[19] (100 Year Time Horizon)

Gas	GWP
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310

Table 34 summarizes overall annual Farm emissions by source (2001). Figure 107 shows the percent of the Farm's annual emissions in metric tons of carbon equivalents by source. Methods and calculations are broken up by sources in following sections.

Table 34 Annual Farm Emissions by Source (GWP)

Source	Carbon Equivalents (metric tons)
Fossil Fuels	30.83
Electricity Generation	2.38
Enteric Fermentation	25.19
Manure Management	22.08

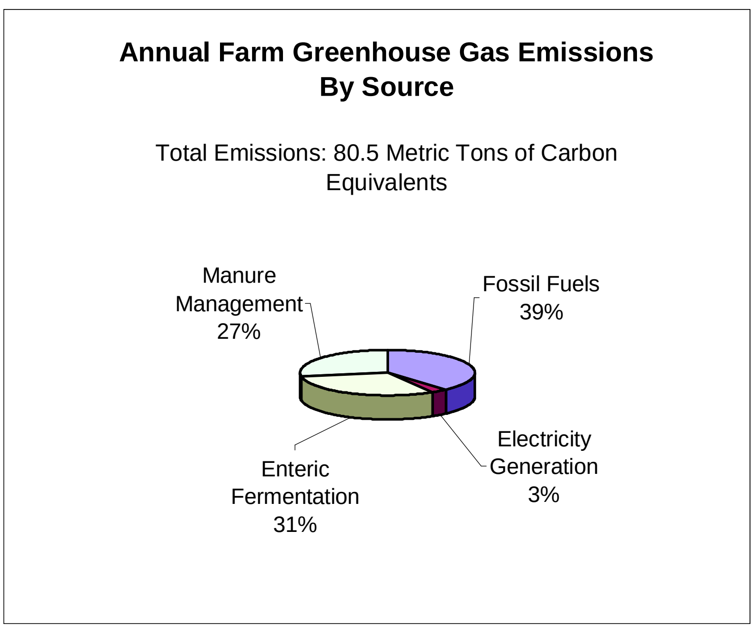


Figure 107 Total Annual Greenhouse Gas Emission (in metric tons of carbon equivalents) By Source

7.6.1 Fossil Fuels

On a nation-wide scale, the combustion of fossil fuels, primarily from mobile sources, releases more greenhouse gases than any other anthropogenic process.[19] If fuel is completely burned, the only carbon containing byproduct is carbon dioxide. But because of inefficiencies, combustion is often incomplete and yields other carbon-based gases, including methane, carbon monoxide, and hydrocarbons. Nitrous oxide and other nitrogen oxides are also formed during incomplete combustion when nitrogen in the fuels combines with oxygen in the air. Of these byproducts, carbon dioxide, methane and nitrous oxide are greenhouse gases that trap heat in the atmosphere and lead to the warming of the climate.[17]

For the purpose of quantifying greenhouse gas emissions, the transaction purchase of fuel is assumed to be the subsequent combustion of the fuel. Therefore, data were obtained from accounting records of the number of gallons and costs of unleaded gasoline, on- and off-road diesel fuel, and liquid petroleum (LP) gas, and the associated aggregate energy values (in GJ). Emission factors for these fuel types were obtained in order to determine the amount of gases (converting all units metric tons) of each gas. The emission factors are provided in Table 35.

Table 35 Greenhouse Gas Emission Factors for Fossil Fuels

	Carbon Dioxide	Methane	Nitrous Oxide
Unleaded Gasoline	18.9 tC/TJ	86.4 g/GJ	0.6 Kg/TJ
Diesel	20.2 tC/TJ	5 Kg/TJ	0.6 Kg/TJ
LP Gas	17.2 tC/TJ	277.8 g/GJ	13.9 g/GJ

Source: Intergovernmental Panel on Climate Change (IPCC) Database on Greenhouse Gas Emission Factors[17]

The amount of emissions of each greenhouse gas was then converted to a common unit (carbon equivalents). Using the GWP factors to measure the emissions of methane and nitrous oxides in carbon equivalents, the total emissions were measured in carbon equivalent units from the combustion of fossil fuels on the Farm, in order to determine the percent of Farm emissions coming from the combustion of fossil fuels (Figure 107). The Farm releases approximately 31 metric tons of carbon equivalents per year that can be attributed to fossil fuel combustion, or 39% of Farm emissions.

7.6.2 Electricity

Because different states vary in the ratio of primary sources of energy for the production of electricity (i.e. coal, fossil fuels, renewable, or nuclear), the Energy Information Administration (EIA) developed state-level coefficients that allow for more accurate predictions of emissions based on the way the electricity is generated. Also, the EIA has adopted a three-year “rolling average” based on data over three years (in this case: 1997, 1998 and 1999) in order to ameliorate any anomalies.[18] The coefficients are listed in Table 36.

Table 36 Greenhouse Gas Emission Factors for Electricity Generation in Virginia

Carbon Dioxide	Methane	Nitrous Oxide
1.088 lbs/kWh	0.0076 lbs/MWh	0.0165 lbs/MWh

Source: U.S. Department of Energy, Energy Information Administration

Based on the state of Virginia's generation methods, on average, the electricity the Farm uses in an average year releases approximately 2.38 metric tons of greenhouse gases (measured in carbon equivalents) and represents 3% of Farm greenhouse gas emissions (Figure 107).

7.6.3 Enteric Fermentation and Manure Management

Methane is produced during the process of digestion in domesticated animals because microbes, present in the guts of the animals, break down the feed consumed by the animals. Ruminants, specifically cattle, goats, and sheep, emit large quantities of methane because they have a large fore-stomach, or rumen, where the fermentation of methane takes place. Swine and horses have a much lower rate of methane emission because their stomachs do not have rumen.

On the Farm, there are approximately 100 cows, 20 pigs, 20 sheep and 5 horses. Utilizing the emission factors for the enteric fermentation of domesticated animals from the Intergovernmental Panel on Climate Change (IPCC), Table 37 displays the methane emissions for each animal type and the carbon equivalent from all Livestock. Enteric fermentation represents approximately 31% of annual Farm greenhouse gas emissions (Figure 107).

Table 37 Methane Emissions from Enteric Fermentation of Domesticated Livestock

Livestock	Methane (Kg/year)
Cattle	4100
Sheep	160
Horses	108
Swine	30
Chicken	Negligible
Total	4398
Metric Tons/Year (methane)	4.39
Metric Tons/Year (carbon equivalents)	25.19

Source: IPCC Database on Greenhouse Gas Emission Factors[17]

Solid waste from domesticated animals is also a significant contributor of methane and nitrous oxide on the Farm. In an anaerobic environment, the decomposition of organic animal wastes produces methane. A significant factor in the amount of methane emissions is how the manure is managed, which includes factors such as temperatures, climatic conditions, and if the environment is oxygen-free.[19] On the Farm, manure management practices have been designed to minimize the emissions from the compost heaps. The composition of the compost includes manure (mostly from cows, although also from horse and chicken manure in small amounts), hay, wood chips, and vegetable and fruit culls. It has been estimated that the amount of solid manure was 130,000 pounds in 2001 and 230,000 pounds in 2002. Once again, utilizing the emission factors for manure management from the IPCC and estimating 10% of horse manure and 5% chicken manure is added, displays the methane emissions for each animal type contributing to manure piles and the carbon equivalent from those Livestock. Manure management represents approximately 27% of annual Farm greenhouse gas emissions (Figure 107).

Table 38 Methane Emissions from Manure Management

Manure	Methane (Kg/year)
Cattle	200
Horses	1.26
Chickens	85.5
Total	286.76
Metric Tons/Year (methane)	.286
Metric Tons/Year (carbon equivalents)	22.08

Source: IPCC Database on Greenhouse Gas Emission Factors[17]

After computing the carbon equivalent units from all sources on the Farm, the primary emission sources were identified (Figure 107). Identifying the sources will allow Farm managers to explore ways to possibly minimize or mitigate impacts, explored further in 7.8.2.

7.7 Comparison to National Averages

7.7.1 Fuel Expenses

The fossil energy use for the Farm is relatively lower than more conventional farms. In 2001, the fossil fuel and electricity cost represented 1.6% of Farm expenses, compared to the national Farm average of 4% (2000). This was expected, as Farm practices utilize more human labor, and less capital (machinery) and petrol-based fuel sources.

7.8 Recommendations for Improved Agricultural Energy Use

7.8.1 Improve Energy Data Collection Recommendations

In order to improve future analyses, data collection and accuracy should be improved. First, Farm management has already begun a key system when Farm vehicles are fueled. This will keep track of the date and number of gallons each vehicle uses. A system that tracks fuel usage by vehicle would provide coarse data, but knowing which vehicles are associated with product lines and activities will allow for a more accurate assessment of energy use by activity/product line. These data were not available for this project as the system was not fully operational at the time of collection and analysis.

Second, Farm mangers should keep more accurate records of the quantities of electricity and fossil fuels used. This will allow the Farm to know its true costs and may identify areas for improved energy efficiency and cost savings.

Third, the Farm can attempt to rectify the harvest-sold discrepancy in order to gain greater energy efficiency, as well as improve profitability.

7.8.2 Improve Energy Efficiency and Transition to Renewable Sources

There are several possible ways for the Farm to increase fuel efficiency and minimize negative environmental externalities associated with fossil fuel combustion. The Farm has already begun precursory investigations into various techniques for on-Farm energy generation, including the harnessing of methane from Livestock and their manure. Also, there are additional options using renewable sources of energy, including solar and hydrogen technologies. Solar power generation is a viable option, and a cost-benefit analysis of purchasing a photovoltaic system for the Farm is included in the Cost-Benefit Analysis Appendix. Emerging gas-electricity hybrid vehicle technologies present a cost-effective option for decreasing the fuel consumption of Farm vehicles, and larger-size cars and sport utility vehicles will soon be available. Using these types of innovations, the Farm could increase efficiency and decrease overall emissions; first, by utilizing existing sources of energy on the farm that are now escaping as waste, and second, by decreasing energies obtained from fossil fuel sources.

8 NUTRIENT TRACKING

8.1 Introduction and Approach

Nutrients are a critical input to agricultural systems because an optimal level of nutrients increases crop health and productivity, improving the size and quality of yield. Often in an effort to improve yield, Farmers apply large quantities of nutrients to their crops, the excess of which can run off into streams causing water quality problems. The most recent state water quality inventories indicate that agriculture, including crop production, animal operations, pastures, and rangeland, impacts 59% of the rivers and streams identified as water quality impaired.[20] Tracking nutrients at Sunnyside helps Farm managers to understand nutrient flows on the Farm and to identify ways that nutrients can be managed more efficiently. Improved nutrient use efficiency has the potential to improve yield, save money and decrease the Farm's environmental footprint.

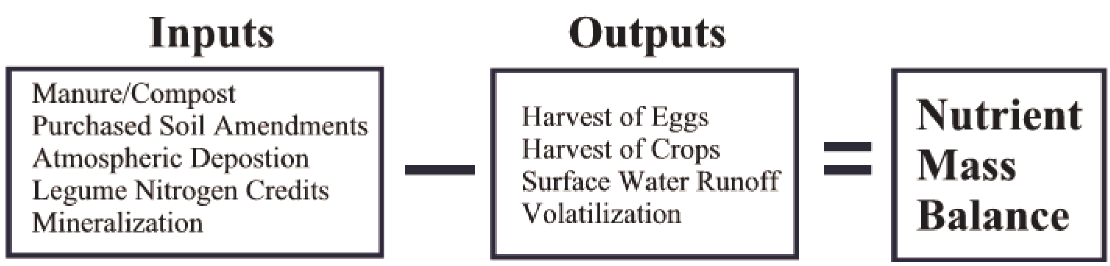


Figure 108 Conceptual Diagram of Approach to Nutrient Budget Section

At Sunnyside, a nutrient budget was used to calculate the mass balance of inputs and outputs of nutrients to the Farm at the whole-Farm scale and at the product line scale. The nutrient balance approach has traditionally been used by Farmers to compare the nutrients supplied to a crop to its nutrient requirements in order to ensure that the maximum potential yield is achieved at the least cost. Because Sunnyside produces such a large variety of crops, crop-scale nutrient budgets were too cumbersome to calculate; however budgets were calculated at the product line scale. The whole-Farm scale analysis provides information about nutrient flows on the Farm as well as insight into larger scale nutrient-related management practices. The inputs and outputs that were considered for these two different scales of analysis are provided in Table 39.

Figure 109 is a conceptual diagram of on-farm nutrient flows, illustrating the major inputs and outputs of nutrients that are typically considered in farm nutrient analyses. The main sources of nutrients to farm systems generally include Livestock manure, purchased soil amendments and credits from legume nitrogen fixation and the mineralization of soil nitrogen from past manure applications. Another nutrient input that is considered in this analysis, but not included in Figure 1, is the deposition of atmospheric nitrogen. Losses that are considered in most nutrient budgets include nutrients removed in crops that are harvested as well as incidental losses like surface water runoff and volatilization. Quantifying the inputs and outputs of nutrients can provide valuable insights in and of themselves.

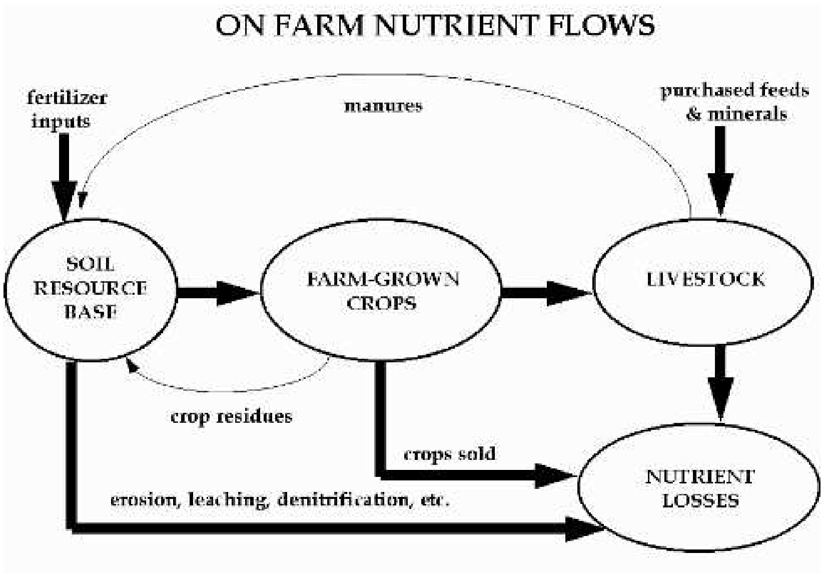


Figure 109 Conceptual Diagram of On Farm Nutrient Flows

8.2 Methods and Calculations

A nutrient budget system developed by the US Department of Agriculture's Natural Resource Conservation Service[21] was used as a model nutrient budget for this project. The only nutrients considered in this study are nitrogen, phosphorus and potassium. These are considered to be the most important nutrients in terms of crop productivity. They are also the most widely available to crop systems and the most applied. Finally, nitrogen and phosphorus are of the most concern in terms of water quality impacts. For this project, nitrogen, phosphorus and potassium were converted to pounds whenever it was necessary so that the units were consistent within the nutrient section as well as with the whole project.

All nutrient calculations were performed after consulting a combination of methodological sources including: agricultural manuals, statistics, extension services and other publications, as well as scientific journals, web pages and databases. When the necessary data could not be found, unconventional sources were used, such as organic gardening journals and agriculture industry newsletters. All calculations involved data collected at Sunnyside during the summer of 2002, thus all calculations are specific to Sunnyside's operations. Nutrient budget analyses were only performed for 2002 because of a lack of consistent nutrient treatment data for 2001.

Unfortunately, due to lack of Farm-specific data, two important components of the nutrient budget were left out of this analysis. Loss of nutrients to surface water runoff and infiltration to groundwater could not be calculated for Sunnyside for two reasons: (1) essential hydrologic information was unavailable and (2) water sample data were insufficient to draw meaningful conclusions from in terms of nutrient loading, even if surface water volume could be calculated. Despite the omission of these analyses, the nutrient budgets that were calculated for this project can provide important insights into the application of nutrients on the Farm by highlighting major nutrient imbalances and inefficient nutrient management practices. The specific inputs that were calculated for the two scales of analysis are listed in Table 39.

Table 39 Nutrient Budget Scales of Analysis

Scale of Budget	Inputs	Outputs
Whole-Farm	Hay Purchased Soil Amendments Livestock Feed Atmospheric Deposition Legume Nitrogen Fixation	Harvest of Crops Egg Harvest
Product Line-Scale	Compost Compost Tea Purchased Soil Amendments Atmospheric Deposition Legume Nitrogen Fixation	Harvest of Crops Egg Harvest

8.3 Nutrient Inputs

Nutrient inputs to Sunnyside Farms were divided into six broad categories including: feed and bedding, manure, on-Farm amendments, purchased soil amendments, nitrogen credits and atmospheric deposition. Several of the categories are subdivided into smaller categories of inputs. For example, manure inputs were calculated for each type of animal. However, atmospheric deposition included only information for wet deposition since dry deposition data were not available. In general, inputs were estimated as precisely as Farm records and outside scientific and agricultural data would allow.

While this project has focused on tracking nitrogen, phosphorus and potassium, there are many more nutrients and minerals that are used on the Farm, particularly as soil amendments. For a complete list of nutrient amendments and their contents that Sunnyside utilized in 2001 and 2002, see Table 98 in the Nutrients Appendix.

8.3.1 Livestock Feed Inputs and Bedding

Sunnyside Farms purchased 228,600 pounds of poultry feed, 462,720 pounds of cattle feed and over 1,000 tons of hay in 2001 and 2002. In terms of the whole-Farm nutrient budget, these were the largest nutrient inputs to the Farm. Hay is used as both feed for cattle and horses as well as bedding. In general, Sunnyside purchases these inputs in bulk and stores them on the Farm. Because there were no records available that indicated the portion of each of these inputs that were used in 2001 versus 2002, these two years of data were combined and averaged. Thus, it was assumed that the same amount of hay and feed inputs were utilized each year.

Figure 109 Feed is Purchased in Bulk and Stored in Silos

A survey of organic poultry and cattle feed showed that they both contain, on average, 88% corn grain and 12% soy grain, with small amounts of trace minerals and vitamins, depending on the brand. Specific brand nutrient content information for Sunnyside was not available. The USDA's Crop Nutrient Tool,[22] which calculates the amount of nitrogen, phosphorus and potassium removed in the harvested section of a crop, was then used to calculate the nutrient content of corn and soy grain and alfalfa hay on a per-pound basis. See Table 40 for the nutrient information provided by the Crop Nutrient Tool. Purchasing records for feed were used for 2001 and 2002 in order to calculate the total number of pounds of grain purchased. The nutrient content of corn and soy grain and hay in pounds was then multiplied times the total number of pounds of each ingredient in feed purchased. The same process was used to calculate the nutrient input for hay.

Table 40 Nutrient Content of Livestock Feed Components

Feed Component	Percent N	Percent P	Percent K
Corn Grain, for Feed	0.014	0.002	0.0003
Soy Grain, for Feed	0.059	0.006	0.013
Hay	1.0	0.1	1.3

The annual input to the Farm from Livestock grain feed is shown in Figure 110. Hay is the major source of nutrients to the Farm in the Livestock feed category. This is due both to its relatively high nutrient content as well as the sheer volume of hay that is used (over 500 tons on average per year).

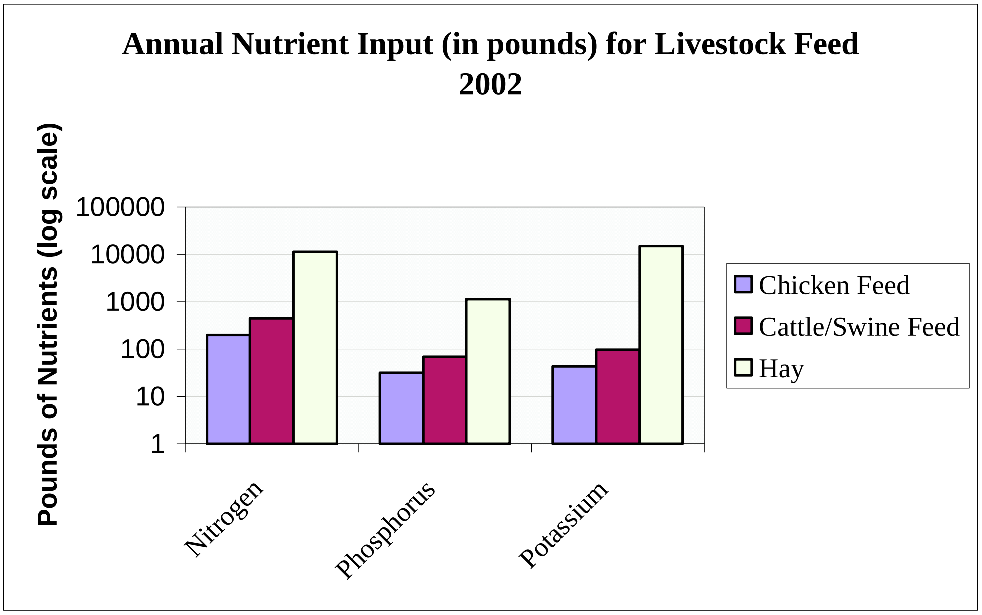


Figure 110 Estimated Annual Nutrient Input for Livestock Feed

8.3.2 Manure Inputs

While population numbers can vary slightly throughout the year, it is estimated that there are about 100 cattle, 20 pigs, 20 sheep, 5 horses and 1,500 chickens at Sunnyside. In terms of calculating nutrient budgets for the Farm, Livestock manure is treated differently depending on the scale of analysis. For example, manure is an important source of plant-available nutrients to the Farm's crops and is applied in compost. Thus, at the product line scale, manure (as well as hay) inputs are calculated as a portion of compost application. At the whole-Farm scale, avoiding double-counting inputs from manure and feed becomes tricky because no information could be located as to the conversion of feed to manure. Therefore, at the whole-Farm scale, feed and bedding were the only Livestock-related inputs, whereas at the product line and block scales, manure is counted in the application of compost, and feed and bedding is excluded.

The first step taken to calculate the annual nutrient input from Livestock on the Farm involved locating information on the average nutrient content of different types of animal manure and the average amount of manure produced for each type of animal. This information was located in animal waste management literature.[23] The averages used for this analysis are listed in Table 41. Based on the assumed populations of these animals on the Farm in 2001 and 2002, estimates for manure nutrient inputs were calculated for each year at the whole-Farm scale. Note that in order to be consistent in budget calculations, nitrogen, phosphorus and potassium were converted to their elemental forms (N, P and K) when necessary, although phosphorus was often applied in the phosphate (P_2O_5) form and potassium was often applied in the potash (K_2O) form.

Table 41 Livestock Fresh Manure Characteristics

Manure Source	Average Animal Live Weight (pounds)	Feces and Urine Production (tons per year)	Nitrogen (pounds per ton)	Phosphate P2O5 (pounds per ton)	Potash K2O (pounds per ton)
Beef	800	22.3	13.4	7.3	8.9
Swine	135	1.9	12.3	9.3	8.8
Sheep	60	0.4	20.8	9.4	19
Chickens	4	0.047	26.6	21.3	11.6

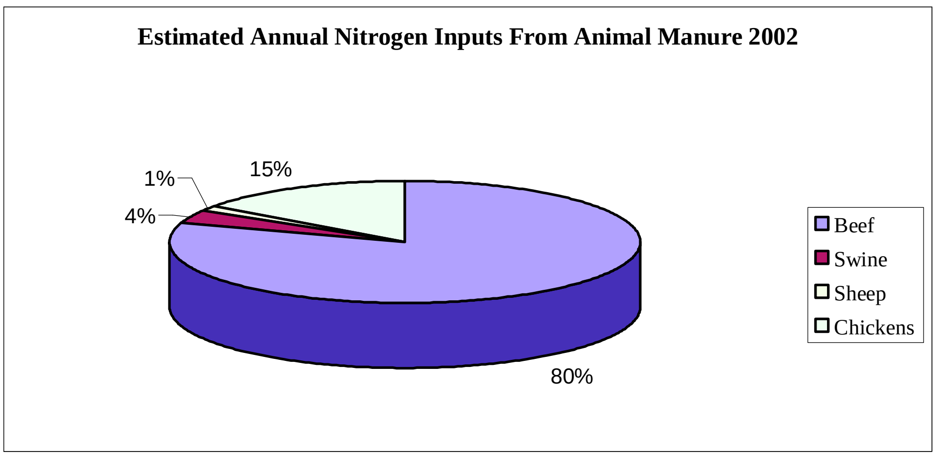


Figure 111 Estimated Annual Nitrogen Inputs from Animals in Pounds per Year

The estimated annual input of nitrogen alone from animal manure is over 12,000 pounds for 2002. Phosphorus and potassium inputs were 3,000 pounds and 6,500 pounds, respectively. The main source of manure nutrients is cattle.

8.3.3 On-Farm Soil Amendments

Compost

Sunnyside Farms applied just over 130,000 pounds, or about 59 tons, of compost to various crops in 2001, and over 230,000 pounds or 104 tons in 2002. Compost is the most applied of all soil amendments used by the Farm. In order to calculate the quantity of nitrogen, phosphorus and potassium (in pounds) that was

Figure 112 Compost Piles are Mostly Hay

applied to the Farm through compost, it was necessary to determine (1) the relative portion of each component of Sunnyside's compost (expressed as a percentage of the whole) and (2) the average nutrient content (in pounds) of each fertilizer component. Although the composition of Sunnyside's compost probably varies substantially throughout the year, the project interns estimated, based on observations during summer 2002, that the compost is generally about 75% hay, 10% horse and cattle manure, 10% sawdust and wood shavings and about 5% vegetable cull material (Table 42). The average nutrient content per pound for each of these components was located through a literature search[24] and is listed in Table 43.

Table 42 Approximate Composition of Sunnyside Compost

Compost Material	Percentage of Total Compost
Timothy Hay	0.75
Horse and Cow Manure	0.1
Sawdust and Wood Shavings	0.1
Vegetable and Fruit Culls	0.05

Table 43 Average Macronutrient Content of Sunnyside Compost Materials

Material (in pounds)	Percent Nitrogen (N)	Percent Phosphorus (P)	Percent Potassium (K)
Timothy Hay	1.0	0.1	1.3
Horse and Cow Manure	1.7	0.3	1.5
Sawdust and Wood Shavings	0.2	0.0	0.2
Vegetable and Fruit Culls	0.01	0.015	0.005

In order to calculate the nutrient content for 1 pound of compost, it was necessary to calculate the percentage of N, P and K in the compost given these percentages for the compost components (see Equation 1).

Equation 1 Sample Compost Nitrogen Calculation

For example, the nitrogen content in one unit of compost (N_c), is calculated by:

$N_c = (\% C_H * \% N_H) + (\% C_M * \% N_M) + (\% C_V * \% N_V) + (\% C_W * \% N_W)$

Where:

C_H = Portion of compost as hay

C_M = Portion of compost as manure

C_V = Portion of compost as vegetable cull

C_W = Portion of compost as wood shavings/saw dust

N_H = Nitrogen content of hay

N_M = Nitrogen content of manure

N_V = Nitrogen content of vegetable cull

N_W = Nitrogen content of wood shavings/saw dust

The same method was used to calculate the phosphorus and potassium contents for one pound of compost. Farm managers keep track of the soil treatments applied at Sunnyside in Treatment Logs. The Treatment Logs include application information for both fertilizer and pest management treatments in terms of date, quantity and location.

Having ascertained the nutrient content for compost on a per-pound basis using the compost application information in the Treatment Logs, the quantity of nutrients applied to each product line, product and block through the application of compost was calculated. The results are presented in Figure 113.

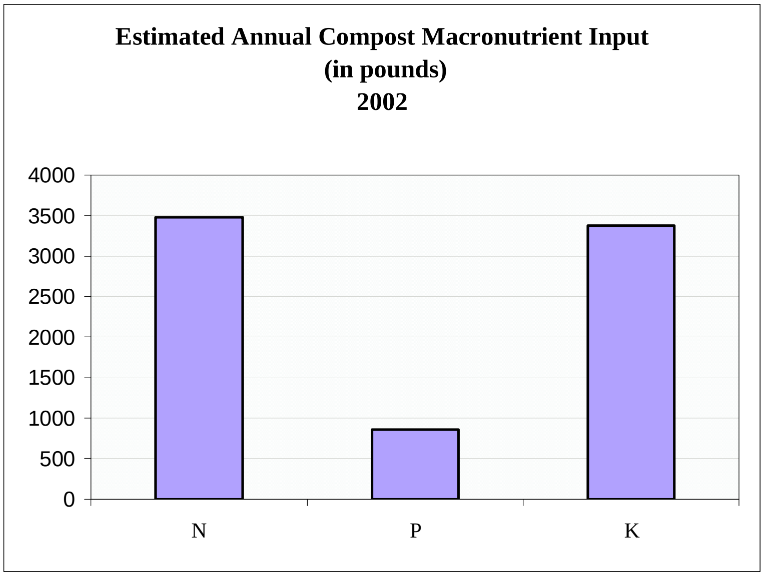


Figure 113 Estimated Annual Compost Macronutrient Input in Pounds for 2002

Compost Tea

Compost tea is produced by adding compost nutrients to water. This process entails placing a porous "tea bag" or basket of compost in water, much like brewing a cup of tea. The addition of compost macronutrients to water turns the nutrients into water-soluble forms, facilitating plant absorption and microbial uptake. Additionally, compost tea is applied to Tree Fruit for its pest management properties. Compost extracts enable biocontrol of plant pathogens through their action on the phyllosphere (i.e., leaf surface and associated microbes). A wide range of mechanisms–such as induced resistance, inhibition of spore germination, antagonism, and competition with pathogens–contribute to the suppressive effect of compost tea.[25] Sunnyside uses a ratio of 1 part compost tea to 4 parts water for its compost tea applications. Assuming that compost tea contains roughly the same amount of N, P and K as compost, the nutrient content of one gallon of compost tea was calculated based on the assumption that one gallon of compost tea weight about the same as one gallon of water, which weighs 8.33 pounds. Therefore, it was estimated that about 1.666 pounds (or one fifth of the total weight) of compost is applied in one gallon of compost tea. The nutrient content information derived for compost was then multiplied by 1.666 to determine the nutrient content, in pounds, of one gallon of compost tea.

Equation 2 Calculating Compost Content in Compost Tea

It was assumed that the weight of compost tea was similar to the weight of water.

(1) Convert volume of compost tea to weight in pounds based on weight of water:

1 gallon of water = 8.33 pounds

(2) Determine portion of one pound of compost tea that is compost, based on brewing ratio of 4 parts water to 1 part tea:

8.33 pounds / 5 parts = 1.666 pounds

(3) Determine nutrient content of 1.666 pounds of compost based on earlier compost nutrient calculations.

Once the nutrient content of one gallon of compost tea was determined, the application records were used to calculate the total quantity of compost tea applied to crops. Compost tea was only applied to the Tree Fruit product line. Application of compost tea is the second largest source of nutrients for crops at Sunnyside. In 2002, 57 pounds of nitrogen, 2 pounds of phosphorus and about 7 pounds of potassium were applied in compost tea.

8.3.4 Purchased Soil Amendments

In addition to on-Farm nutrient amendments, Sunnyside also uses several purchased nutrient supplements. These include: Fish Kelp Meal, Colloidal Phosphate, 0-0-5, Corn Gluten Meal, Sulphate of Potash, Rock Phosphate and 0-0-6. The nutrient contents of these various amendments are listed in Table 44. The quantities applied for these amendments were calculated based on Treatment log information and nutrient content. All quantities applied were converted to pounds of nitrogen, phosphorus and potassium.

Table 44 Macronutrient Content of Off-Farm Nutrient Supplements

Generic Material	Brand	Percent Nitrogen	Percent Phosphorus	Percent Potassium
Fish/Kelp Emulsion	Neptune's Harvest	6	2	1
Colloidal Phosphate	Lanfosco	0	10	0
0-0-5	Not Documented	0	0	5
Corn Gluten Meal	Not Documented	10	0	0
Sulphate of Potash	Royster Clark	0	5	0
Rock Phosphate	Fertrell	0	35	0
0-0-6	Not Documented	0	0	6

Table 44 Annual Macronutrient Input by Amendment Type 2002

Type of Amendment	Nitrogen (in pounds)	Phosphorus (in pounds)	Potassium (in pounds)
Compost	3,470	850	3,370
Compost Tea	57	2	7
Sulphate of Potash	0	0	190
Rock Phosphate	0	1116	0
0-0-6	0	0	186
Fish Emulsion	7	2	1
0-0-5	0	0	85
Colloidal Phosphate	0	100	0
Corn Gluten Meal	55	0	0

The majority of nutrients applied to crops at the Farm come from the application of compost. The Tree Fruit product line receives the most applied nutrients relative to other product lines, with Brambles a close second. Nutrient application for Herbs and Flowering Plants are not included in the input calculations because of a lack of application data specific to these two product lines.

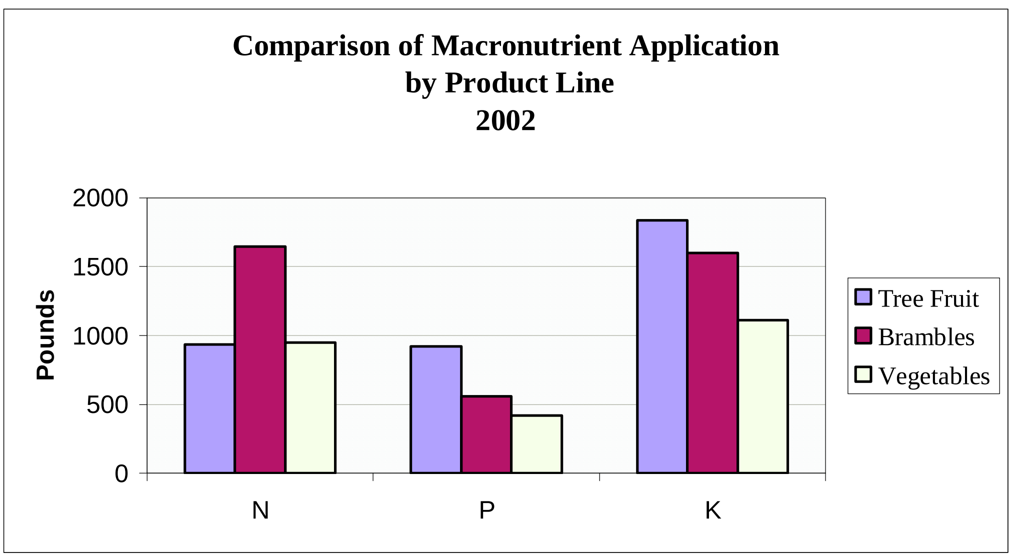


Figure 114 Comparison of Macronutrient Content by Product Line for 2002

This does not include Herb and Flowers/Plants product lines because they were insignificant in comparison to these product lines. This includes all types of soil amendments.

8.3.5 Atmospheric Deposition of Nitrogen

Acid deposition is a broad term used to describe several ways that acids fall out of the atmosphere. It can be deposited in wet or dry forms. Wet deposition refers to acidic rain, fog, and snow. Dry deposition refers to acidic gases and particles that are deposited on land. Wet deposition data for 2001 were obtained from the National

Atmospheric Deposition Program's web page for Virginia;[26] data for 2002 were not available at the time this report was written. The data that were obtained are summarized in Table 45. The data are given as average wet deposition of inorganic nitrogen in kilograms per hectare. Nitrogen in kilograms per hectare was converted to pounds per acre since acres are being used for all area-related calculations.

Table 45 Atmospheric Deposition Rates for Sampling Station VA28 in Shenandoah National Park in Madison County, Virginia for 2001

2001 Total Wet Deposition	Kg/hectare	Pounds of elemental N/acre	Annual Deposition of Nitrogen at Sunnyside
Wet Deposition of Inorganic N	4.36	0.096	48 pounds

8.3.6 Nitrogen Credits

In terms of the nutrient balance, nitrogen credits refer to nitrogen additions from legume nitrogen fixation and the mineralization of nitrogen. Both of these processes occur in the soil. Nitrogen is a very mobile nutrient and occurs in soil and plants in many forms. It can be stored in the soil's organic matter and then released as the organic matter decomposes. Nitrogen that is released by organic matter is referred to as mineralization and nitrogen that is released by soil organisms is referred to as nitrogen legume fixation because the soil organisms responsible for the release are most often associated with legume plants. Phosphorus and potassium are considered 100% plant-available the year of application; therefore no residual amounts were calculated.

8.3.7 Legume Nitrogen Fixation

Legume credits are based on the breakdown of legume residue in the year following harvest and the significance of that residue as a nitrogen fertilizer. Legume credits are generally calculated as the equivalent of one pound of nitrogen per bushel of the harvested legume crop, with a cap of 40 pounds per year per acre.[27] Legume crops at Sunnyside include beans, okra and peas, which are grown on less than one acre. At Sunnyside, for 2002, it is estimated that 19 pounds of nitrogen were fixed by legume crops (based on 40 bushels of legumes harvested).

8.3.8 Mineralization of Nitrogen

Not all of the nitrogen applied in previous manure applications is available to the crop the year of application. A percentage of last year's compost manure application and an even smaller amount of applications in years previous to last will become plant available (via mineralization) during the current crop season. Mineralization rates depend on soil type, pH, and the portion of organic nitrogen applied. Since it was not possible to use mineralization information specific to Sunnyside, local mineralization rates for Virginia were referred to in order to determine the residual release of nitrogen for 2001 and 2002.[27] The data used are summarized in Table 46.

Table 46 Manure Mineralization Rate

Manure Types	% Nitrogen Availability for Organic N Mineralization in Each Year			
	This Year	Last Year	3rd Year	4th Year
Cattle (Dairy & Beef) all types	35	18	9	5
Poultry				
a. Caged layers (Deep pit storage)	60	10	5	3
b. All other	50	15	8	4
Swine (all types)	50	15	8	4
Horse	20	10	5	3
Sheep	30	15	5	3

8.3.9 Chicken Feed for Egg Production

Poultry egg production is a unique (and relatively simple) product line in terms of calculating a nutrient budget. The only nutrient input calculated is purchased feed, while the only nutrient output calculated is eggs. Chicken feed quantities (as discussed in section 8.3.2) is estimated to contribute about 200 pounds of nitrogen, 30 pounds of phosphorus and 45 pounds of potassium to the Farm per year. Nutrient export via sale of eggs will be discussed in the next section on nutrient export.

8.4 Nutrient Export

Nutrient export falls into two categories: harvest and incidental nutrient export. Nutrients are removed when crops are harvested and sold off of the Farm. Incidental nutrient export generally refers to nutrients lost to the environment, including surface water runoff, infiltration to groundwater and volatilization of ammonia nitrogen into the atmosphere. As mentioned previously, due to a lack of hydrological information and water sampling data for Sunnyside, nutrient loss to surface water and groundwater was not calculated for this project.

8.4.1 Nutrient Export From Harvest

The nutrient content of a plant depends on the amount of nutrients available for the plant and the environmental growing conditions and the species. The total uptake of nutrients by crops from agricultural waste (compost) applications increases with increasing soil nutrients, provided toxic levels are not reached or nutrient imbalances do not occur.[28] The total nutrient uptake continues to increase with yield, but the relation does not remain a constant linear relationship. However, for this project a linear relationship was assumed for quantity of nutrients removed per pound of crop harvested because specific crop nutrient content data were not available for the Farm.

The data used to predict the quantity of nutrients removed by harvest are derived from the USDA's Natural Resource Conservation Service's Crop Nutrient Tool.[22] The estimates that this source provides are based on a mix of national averages and a compendium of specialized crop research. The Crop Nutrient Tool is an online calculator, wherein the yield information (for example bushels of apples) is entered and the tool returns the nutrient content in the specified yield. The Crop Nutrient Tool was used to calculate nutrient content per pound of harvested material for each crop and this information was entered into the database. Finally, the database was queried for nutrients removed through harvest at by product line.

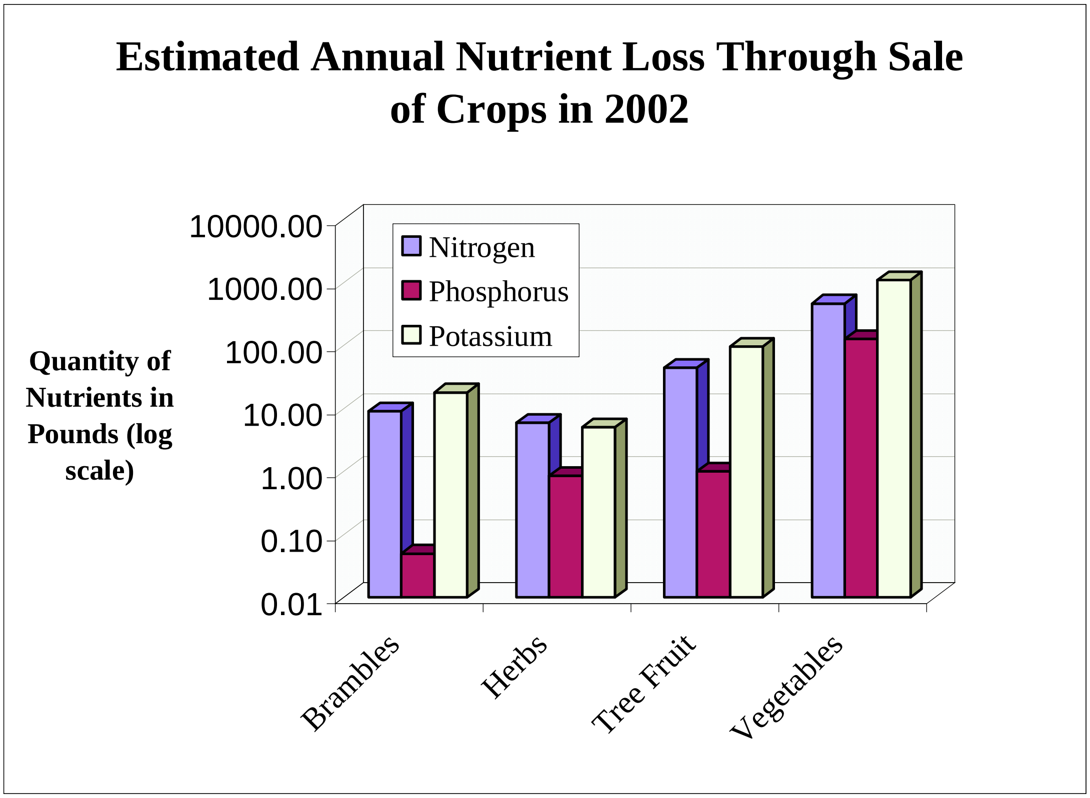


Figure 115 Estimated Annual Nutrient Loss Through Sale of Crops in 2002

In 2002, more nutrients were exported through harvest for Vegetable and Tree Fruit product lines than for Herb and Bramble product lines. This could be due in part to a greater nutrient requirement (in general) for these product lines, or because of the volume harvested of each of these product lines. It is also likely that more nutrients are lost in the harvest of Vegetables than Tree Fruit and Brambles because a greater portion of the plant is actually harvested than for the other product lines. For example, a large portion of nutrients used by Tree Fruit and Brambles are utilized in the production of biomass, like trunk and leaves, or vines, in the case of Brambles. A much smaller proportion is located in the actual fruit, whereas with Vegetables and Tree Fruit, in most cases virtually the entire individual plant is harvested. It is important to note the relative size of each product line in terms of area planted and size of yield. For example, the Herb product line is a much smaller product line than Tree Fruit, Brambles and Vegetables, which are the largest product lines. For more information about the relative size of each product line, see Figure 38.

There is an important caveat associated with drawing conclusions from the Herb information. Parsley nutrient requirements were used for all types of Herb, except for mustard, because there was no information available for other species of Herbs. Tree Fruit, Bramble and Vegetable information, however can be considered very reliable in terms of nutrient requirements. With a few of exceptions, the nutrient requirement for each crop and even several varieties were used in this analysis. However, it is important to remember that these requirements are based on the Crop Nutrient Tool, which uses national averages as well as study-specific data, and does not take into account the change nutrient requirement as a function of changing yield.

Table 47 Nutrients Removed Through the Sale of Crops by Product Line for 2002 (in pounds)

Product Line	Nitrogen	Phosphorus	Potassium
Brambles	9.10	0.05	18.03
Herbs	5.93	0.84	5.09
Tree Fruit	44.07	0	95.98
Vegetables	466.12	128.08	1088.52

8.4.2 Egg Harvest Nutrients

In addition to the crops that are grown at Sunnyside, the harvest and sale of chicken eggs represents a significant loss of nitrogen from the Farm system. Phosphorus and potassium are also lost in this manner, but no data were available on the content of these nutrients in table eggs. The export of nitrogen was calculated by multiplying the pounds of eggs produced times 0.29,[29] or the nitrogen content per pound of eggs produced. It was assumed that the average weight of a table egg is 2 ounces.[29]

Table 48 Pounds of Nitrogen Removed in Sale of Eggs for 2001 and 2002

Year	Eggs Sold Off Farm	Pounds of Eggs	% Nitrogen per Pound of Eggs	Pounds of Nitrogen Removed
2001	1,44,704	18,088	0.017	307
2002	2,235,589	29,448	0.017	500

8.5 Budgets

The results of nutrient tracking are provided as the results of nutrient budgets at different scales. The results of the nutrient budget at the Whole-Farm scale calculates all nutrient inputs minus all outputs for the Whole Farm, whereas the plot-scale budgets calculate these inputs and outputs at the plot scale. Due to data constraints, some nutrient inputs and outputs could only be calculated at the Whole-Farm scale though they could be important at smaller spatial and hierarchical scales. These constraints are noted where appropriate in the following sections. There are other nutrient losses associated with agricultural systems, particularly surface water runoff and infiltration to groundwater that should be considered in any thorough analysis of nutrient losses. However, as previously mentioned, it was not possible to calculate these losses for this project. Therefore, it is possible that a significant amount of nutrients are lost that are not considered in the following budgets. For a summary of the nutrient inputs and outputs calculated for each type of budget refer to Table 39.

8.5.1 Whole-Farm Scale Budget

The Whole-Farm scale nutrient budget is the most detailed budget in terms of the types of inputs and outputs that were calculated. At the Whole-Farm scale, nutrient inputs include hay and animal feed nutrients (and not Livestock manure), atmospheric nitrogen deposition, nitrogen legume fixation, mineralization of nitrogen and purchased fertilizer applications. Outputs were calculated for harvested crops and nitrogen loss through the volatilization of ammonia in chicken manure. Table 49 shows the nutrient budget at the whole Farm scale.

Results of the Whole-Farm nutrient budget indicate a surplus of nutrients at Sunnyside in 2002. These nutrients are probably located in stored feed, hay and amendments, biomass including animals and non-harvested crop material (i.e. trees and vines), soil nitrogen storage and soil organic matter. This budget also shows that the largest sources of nutrients are feed and hay which are converted to manure and compost material. The main losses are from harvest, although surface water losses were not calculated and can be significant in agricultural systems. Of less importance at the Whole-Farm scale are the input of nutrients from atmospheric deposition and the input of nitrogen from purchased amendment sources.

Table 49 Whole Farm Nutrient Budget for 2002

Inputs	Pounds of Elemental N	Pounds of Elemental P	Pounds of Elemental K
Feed and Bedding			
Cattle/Swine Feed	443	70	98
Chicken Feed	2228	31	44
Hay	1114	16	22
Subtotal	**3785**	**117**	**165**
Purchased Soil Amendments			
Fish Kelp Meal	7	2	1
0-0-5	0	0	85
Sulphate of Potash	0	0	190
Rock Phosphate	0	1117	0
0-0-6	0	0	186
Subtotal	**7**	**1119**	**463**
Atmospheric Deposition			
Wet deposition of inorganic N	48	0	0
Subtotal	**48**	**0**	**0**
TOTAL NUTRIENT INPUTS	**3840**	**1236**	**627**
Nutrient Losses			
Harvest of Crops			
Tree Fruit	44	0	95
Vegetables	466	128	1088
Brambles	9	0.05	18
Herbs	6	0.84	5
Harvest of Eggs	500	Unknown	Unknown
Volatilization of chicken manure Nitrogen	346		
TOTAL NUTRIENT LOSSES	**1025**	**128**	**1207**
NUTRIENT BALANCE	**2468**	**1107**	**-580**

8.5.2 Results by Product Line

The inputs for product lines include nutrient treatments applied to the product line, estimated atmospheric deposition rates based on the size of the areas use to grow the product line, legume credits if applicable, and estimated mineralization credits. The only nutrient loss calculated was nutrient loss by harvest. Nutrient balances were calculated only for Vegetables, Tree Fruit and Brambles because of a lack of treatment data specific to Herbs and Flowering Plants.

Table 50 Nutrient Balance for Tree Fruit Product Line 2002

Inputs	Pounds of Elemental N	Pounds of Elemental P	Pounds of Elemental K
On-Farm Amendments			
Compost (Available this year)	306	102	577
Compost Tea (Available this year)	18	2	7
Subtotal	**324**	**104**	**584**
Purchased Soil Amendments			
Fish Kelp Meal	7	2	1
0-0-5	0	0	85
Sulphate of Potash	0	0	0
Rock Phosphate	0	624	0
0-0-6	0	0	186
Subtotal	**7**	**626**	**272**
Nitrogen Credits			
Mineralization Based on Past Year's Manure Application:			
Compost	153	0	0
Compost Tea	10	0	0
Subtotal	**163**	**0**	**0**
Atmospheric Deposition			
Wet deposition of inorganic N	4	0	0
Subtotal	**4**	**0**	**0**
TOTALNUTRIENT INPUTS (without legume nitrogen fixation)	**498**	**730**	**857**
NUTRIENT LOSSES			
Harvest of Tree Fruit	44	0	96
BALANCE	454	730	761

The nutrient balance for the Tree Fruit product line shows that there were more nutrients applied to Tree Fruit than are exported from the Farm during harvest for all three macronutrients. It is likely that a significant portion of the nutrients applied to the Tree Fruit are used by the plant to produce biomass other than fruit, like leaves, trunk, bark etc. which could account for the large, positive difference between nutrients applied and nutrients lost. Results from the soil organic matter analysis for the Tree Fruit product line also indicate that some organic nutrients are accumulating in the soil. However, it is also possible that nutrients are being over-applied to this product line.

Table 51 Nutrient balance for vegetable product line

Inputs	Pounds of Elemental N	Pounds of Elemental P	Pounds of Elemental K
On-Farm Amendments			
Compost	332	417	1110
Subtotal	**332**	**417**	**1110**
Purchased Soil Amendments			
Colloidal Minerals	0	100	0
Sulphate of Potash	0	0	190
Rock Phosphate	0	185	0
Subtotal	**0**	**285**	**190**
Nitrogen Credits			
Nitrogen Legume Fixation	19		
Mineralization Based on Past Year's Manure Application:			
Compost	116	0	0
Subtotal	**135**	**0**	**0**
Atmospheric Deposition			
Wet deposition of inorganic N	1	0	0
Subtotal	**1**	**0**	**0**
TOTALNUTRIENT INPUTS (without legume nitrogen fixation)	**468**	**702**	**1300**
NUTRIENT LOSSES			
Harvest of Vegetables	466	128	1089
BALANCE	1	574	212

The results of the nutrient balance for the vegetable product line are significantly different than for the Tree Fruit product line. Nitrogen input and losses are nearly equal, which indicates that growing Vegetables uses nearly all of the nitrogen available for these crops. It should be noted here that the soil organic matter analysis for this product line indicates an overall increase in soil organic matter. This indicates that nutrients are being applied at appropriate rates are being stored in the soil.

The balance indicates that the production of Vegetables did not utilize all of the phosphorus and potassium available to these crops. This could imply over-application of phosphorus and potassium.

Table 52 Nutrient Budget for Bramble Product Line 2002

Inputs	Pounds of Elemental N	Pounds of Elemental P	Pounds of Elemental K
On-Farm Amendments			
Compost	576	558	1601
Subtotal	**576**	**558**	**1601**
Purchased Soil Amendments			
Rock Phosphate	0	154	0
Subtotal	**0**	**154**	**0**
Nitrogen Credits			
Mineralization Based on Past Year's Manure Application:			
Compost	288	0	0
Subtotal	**288**	**0**	**0**
Atmospheric Deposition			
Wet deposition of inorganic N	1	0	0
Subtotal	**1**	**0**	**0**
TOTALNUTRIENT INPUTS (without legume nitrogen fixation)	**865**	**712**	**1601**
NUTRIENT LOSSES			
Harvest of Brambles	9	0	18
BALANCE	856	712	1583

Similar to the results for Tree Fruit, the nutrient balance for Brambles shows a positive difference in the amount of N, P and K applied versus the amount of these nutrients that were exported in the harvest of Brambles. Since the non-edible biomass of the Bramble product line is a significant portion of the total biomass of Brambles, it is likely that a large portion of the nutrients that are applied are used in the production of leaves and vines. It is also possible that any extra nutrients are being added to the organic matter of the soil. Soil organic matter results indicate the accumulation of organic matter over time for this product line. However, it is also possible that nutrients are applied in excess of the crops' requirements.

8.5.3 Poultry Product Line

The nutrient budget for eggs is presented in Table 53. Eggs are the only component of the Livestock product line analyzed in terms of nutrients and data were available only for nitrogen.

Table 53 Egg Product Line Nutrient Budget

EGGS	Pounds of Elemental N
Inputs	
Chicken Feed	2228
Subtotal	2228
LOSS	
Egg Harvest	500
Subtotal	500
BALANCE	**1728**

The result of the nutrient balance for eggs shows a positive net balance between nutrient input through feed and export through the harvest of eggs. The net balance of approximately 1,728 pounds of nitrogen is nearly the same quantity of nitrogen added to the Farm in chicken manure (1,875 pounds). Thus, the balance of nitrogen is probably mostly found in chicken manure, though some is probably also located in the animals themselves.

The animal waste management literature provides a range of percentage nitrogen loss through the volatilization of ammonia, depending on manure handling practices. For broadcast application methods without cultivation, the nitrogen loss to the air is about 20% of the total nitrogen in manure, which was lost within four days of application.[30] This is because a significant portion of chicken manure nitrogen is in the ammonia form, compared to other types of livestock. At Sunnyside, chickens are transported to various parts of the Farm in mobile chicken units and are also often allowed to roam freely. Because these types of practices prohibit the manure from being "trapped" in bedding, it is likely that a significant portion of chicken manure nitrogen is lost to the atmosphere through volatilization. A 20% loss to the air through ammonia volatilization was assumed for Sunnyside, which resulted in the addition of 1,383 pounds of nitrogen to the Farm in chicken manure. This addition was only considered in the whole-Farm budget since there are no records available in terms of where the chicken units are rotated within the Farm. It might be valuable for management to track this in the future in order to get a better idea of the spatial distribution of this nutrient input.

8.6 Nutrient Expenses

Calculating Sunnyside's annual nutrient expenses is difficult because it is uncertain how much of each of the major expense categories is used each year. For example, hay, feed and soil amendments that were purchased in 2001 were stored and some were used in 2002. Likewise, some of these items that were purchased in 2000, were used in 2001. Thus, in 2001, nutrient-related expenses appear to be substantially more (in relation to total expenses) than in 2002. In reality, the amount of these nutrients actually used each year was probably relatively similar. Nonetheless, as Figures

8 and 9 show, in both 2001 and 2002, feed and hay are the two greatest expenses associated with nutrients.

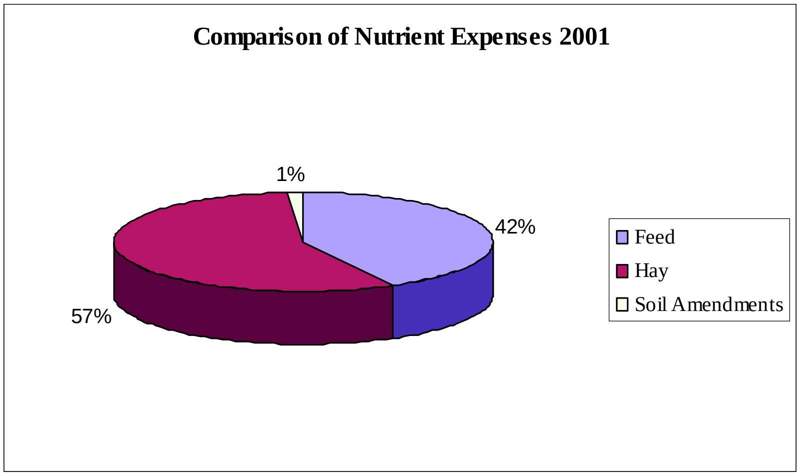


Figure 116 Comparison of Nutrient Expenses in 2001

Soil Amendments include both purchased pest management and purchased fertilizer amendments.

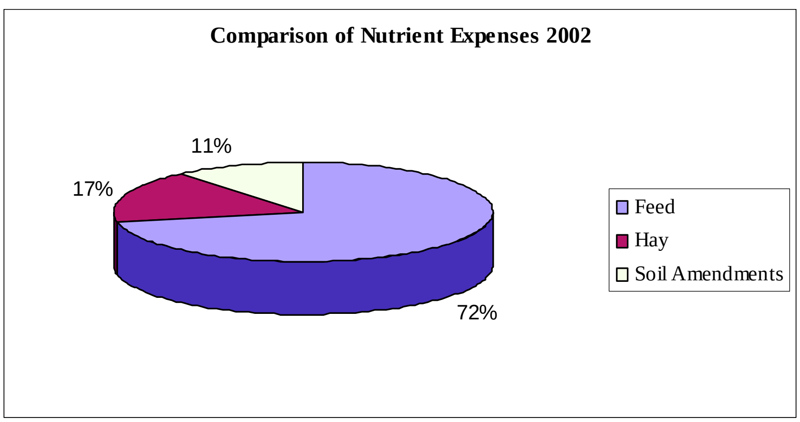


Figure 117 Comparison of Nutrient Expenses in 2002.

Soil Amendments include both purchased pest management and purchased fertilizer amendments.

Table 54 shows that nutrient expenses can make up a significant portion of total Farm expenses. In 2001, nutrient-related expenses were around 5% of total Farm expenses, and about 13% of total expenses in 2002. It is important to note that feed and hay inputs are used not just as a source of nutrients to crops, but are also valuable in terms of other sources of revenue, including organic beef and eggs. In reality, these inputs are probably more valuable in terms of beef and egg production because these two products bring in more revenue for the Farm. Thus, feed and hay can be considered to be an input for beef and egg production and a way to produce essentially "free" nutrients in the form of manure for compost.

Table 54 Nutrient Expenses in 2001 and 2002

Expense Category	2001	2002
Feed	86,140	110,392
Hay	20,600	147,769
Soil Amendments	13,165	3,606
Total	119,905	261,767
As Percent of Total Expenses	5%	11%

8.7 Comparison to National Averages

To compare the macronutrient application at Sunnyside to the national average, USDA's National Agricultural Statistics Service databases were consulted. Annual nutrient application data were available for four crops in 16 states. Unfortunately, only two of the four crops for which information was available are grown at Sunnyside. In order to get a national average for this information, for each crop the total quantity of micronutrients was summed for all states and divided by the total acres of land where the nutrients were applied in these states. The averages are presented in Table 55.

Table 55 National Average Macronutrient Application in Pounds per Acre for 2002 Compared to Macronutrient Application in Pounds per Acre at Sunnyside.

Not all states included in this study.

	Nitrogen	Phosphorus	Potassium
Corn (U.S.)	7	177	120
Cotton (U.S.)	5	36	23
Potatoes (U.S.)	11	6	6
Soybeans (U.S.)	40	20	12
Sunnyside (all crops)	**24**	**13**	**37**

The national averages are compared to the total macronutrient application at Sunnyside divided by the total number of acres planted at Sunnyside. In general, Sunnyside falls in the mid to low range in comparison to the national average nutrient application.

Table 56 Comparison of Sunnyside's Nutrient-Related Expenses to the National Average.

	Percent of Total Farm Expenses	
Expense Category	**Sunnyside 2002**	**National Average for 2002[31]**
Feed	3%	12.8%
Hay	Less than 1%	9.6%
Purchased Soil Amendments	Less than 1%	9.6%

The national average Farm expense for Livestock needs (feed, hay etc.) is 10% of average total Farm costs. The national average for fertilizer and pest management costs is just over 10% of average total Farm costs. Sunnyside spent a total of between 5 and 13% of all of these costs in 2001 and 2002. Sunnyside seems to spend significantly less on purchased nutrients than the national average. This is probably due both to the extensive use of compost at the Farm, but also because total expenses on the Farm are very high, making nutrients a much smaller portion of the total.

8.8 Environmental Impacts/Negative Externalities

There are three main negative environmental externalities associated with the addition of nutrients in agricultural use. These are (1) non-point source pollution caused by excess nitrates and phosphates in agricultural runoff, (2) the damage caused by mining phosphate, potash and other trace minerals, and (3) the energy use associated with the production of industrial chemicals for agriculture. Energy impacts associated with soil amendments are discussed in section 7 (Energy section).

Non-point source pollution is a very important impact associated with the over-application of industrial fertilizers and pesticides in modern agriculture. One of the purported benefits of organic agriculture is that it leads to less nutrient runoff. Proponents of organic agriculture claim that pollution is decreased because organic farming systems help to replenish and maintain soil fertility, eliminate the use of toxic and persistent pesticides and fertilizers, and build biologically diverse agriculture, which requires less synthetic inputs. Since it was not possible to calculate the nutrient loss in surface water at Sunnyside, it is not possible to draw any conclusions about this environmental impact at Sunnyside.

The production of phosphorus and potassium mineral fertilizers relies essentially on the mining of mineral concentrations in the form of ore deposits from the earth's crust. The impacts associated with mining these materials include: changes to the landscape, water contamination, water contamination, localized air pollution and excessive water consumption. The quality of surface and groundwater may be adversely affected by the release of processing water, the erosion of sediments and leaching of toxic minerals from overburden and processing wastes. Water resources may be affected by dewatering operations of beneficiation processes. The quality of air is affected by the release of emissions such as dust and exhaust gases from heavy machinery.[32] Sunnyside purchased about 1,216 pounds of mined phosphorus and about 461 pounds of mined potassium in 2002. However, the Farm used about 1,033 pounds of phosphorus and over 5,000 pounds of potassium from organic sources including compost, compost tea and fish kelp meal.

8.9 Conclusions

Major conclusions that can be drawn from the results of the nutrient budget are listed:

(1) Compost is the most applied of all nutrients on the Farm, then compost tea. This is an advantage for the Farm because compost products are essentially free so long as the Farm produces Livestock.

(2) Chickens are an important source of nitrogen inputs to the Farm. However, chicken manure is probably not being utilized as well as it could be. A significant amount of nitrogen may be lost to the air due to the way chickens are managed.

(3) Atmospheric deposition of nitrogen and nitrogen legume fixation add only about 60 pounds of nitrogen per year to the Farm, and can be considered insignificant nutrient sources, relative to other sources.

(4) Tree Fruit was the only product line to receive compost tea applications. This treatment provides the benefit of added nutrients as well as serving as a pest management tool.

(5) Tree Fruit and Bramble product lines received more nutrients compared to Vegetables. However the Vegetable product line exported more nutrients through harvest than the Tree Fruit and Bramble product lines.

(6) All product lines had surpluses of nutrients after harvest, except for the Vegetable product line, which approximately "broke even" in terms of nitrogen. Vegetables is the only product line to be associated with decreasing soil organic matter. Therefore, it can be concluded that there is a good possibility of nitrogen deficiency for Vegetables.

(7) Without knowing the nutrient requirements for the non-harvested biomass of Tree Fruit and Brambles, it is difficult to draw conclusions about fertilization, though the difference between nutrients applied and nutrients exported in harvest is several orders of magnitude.

8.10 Management Recommendations

Based on the conclusions about nutrient use at Sunnyside Farms, the following recommendations are being made:

(1) Any decisions about the future of Livestock production on the Farm should consider the enormous benefit that the compost provides in terms of nutrients.

(2) Chicken manure nutrients could be better utilized if manure was trapped in absorptive bedding, like hay, and then added to compost.

(3) The Farm should consider growing more legumes to make up for the probable nitrogen deficit associated with the vegetable product line and should continue to use nitrogen-fixing cover crops when leaving fields to fallow.

(4) The Farm should initiate a routine surface water-testing program and should try to get more information about Farm-specific hydrology in order to estimate the amount of nutrients carried away in surface water.

9 PEST MANAGEMENT TREATMENTS

9.1 Purpose

The purpose of the pest management treatment section is to provide Farm managers with information about the quantity of treatments that are applied to each product line. Sunnyside's approach to pest management is referred to as Integrated Pest Management (IPM). IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. Sunnyside's IPM program uses current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods (for example, the application of organic pesticides, soaps, nutrients etc), is used to manage pest damage at Sunnyside. "Pests" is a broad term referring to mice and other animals, unwanted plants (weeds), fungi and microorganisms such as bacteria and viruses.

9.2 Approach

The approach to the pest management treatment analysis was simply to organize and sort the data contained in Treatment Logs, and to convey baseline information about the quantity and timing of pest management treatments at Sunnyside. This baseline information will give Farm managers a good idea about the relative quantities of pest management treatments applied to each product line, which is important when considering future planting scenarios. It also can help Farm managers by providing timing information about past treatments, which can be used to anticipate applications in future years.

Although all pest management treatments were applied in a water base, the treatments were divided into two categories for analysis, solid and liquid. This determination was based on the way that application data were recorded by Farm workers. For example, treatments classified as solids are those that were recorded as a ratio of the solid treatment to water. Treatments classified as a liquid includes treatments that are purchased in liquid form and then diluted in water. In some cases, however, no mixing ratio was recorded for liquid treatments, and thus the diluted quantity was used for calculations, which probably resulted in an overestimation of the actual quantity of the treatment applied. Lime-sulfur, Gnatrol and Botanigard are the three pest treatments where mixing ratio data were not available. The use of lime-sulfur and Botanigard treatments, however, was very limited. About 10 gallons total of Botanigard was applied to the vegetable product line and about 5 gallons of lime-sulfur was applied to the Bramble product line. However, about 50 gallons of Gnatrol was applied to the vegetable product line and it is unclear whether or not this particular treatment was diluted. It is important to keep these discrepancies in data records in mind when drawing conclusions about the quantity of treatments applied to the vegetable product line.

9.3 Results

9.3.1 Types of Treatments Applied

Sunnyside uses a variety of pest management treatments, some of which were not included in this analysis because they were used in very small quantities. The treatments that are included are listed in Table 57.

Table 57 Types of Pest Management Treatments Applied at Sunnyside in 2002.

Treatment Name
Streptomycin
Horticultural Oil
KOP Hydroxide 50
BT
Novodor
Gnatrol
Rotenone
Safer's Soap
T-22 Planter Box
Botanigard
Kaolin
Sulfur
Lime Sulfur

9.3.2 Quantities of Treatments Applied to whole farm

Of the solid pest management treatment applications in 2002, kaolin clay and corn gluten meal were applied in the greatest quantities. Kaolin clay was only applied to Tree Fruit, whereas corn gluten meal was only applied to Vegetables. Sulfur was also applied in a large quantity to Tree Fruit. Corn gluten meal also provides 10% elemental nitrogen in each pound applied and thus is a significant source of this nutrient for Vegetables.

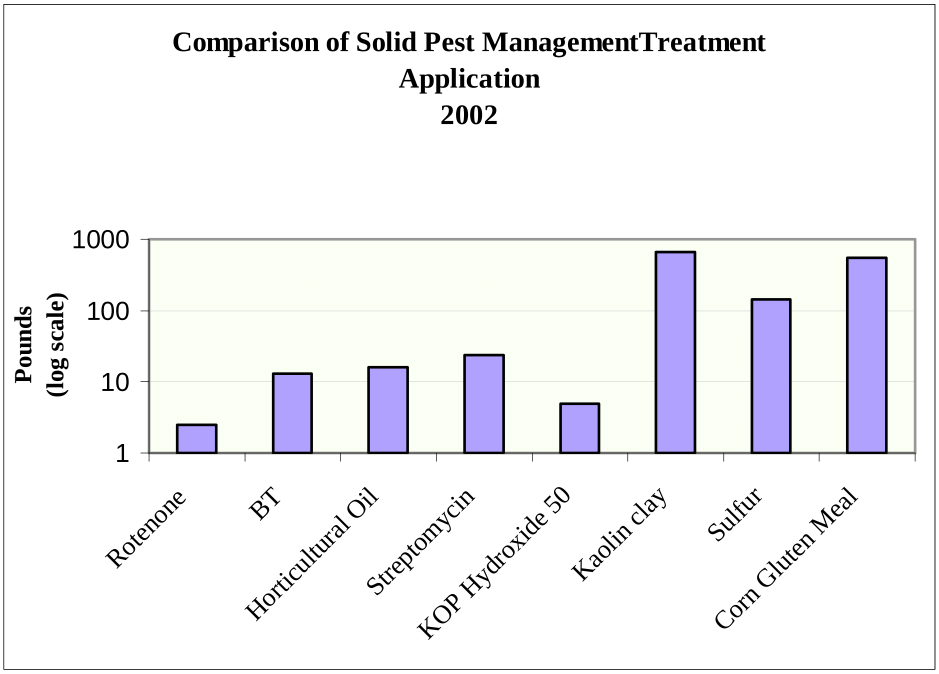


Figure 118 Comparison of Solid Pest Management Treatment Application in 2002.

Compost tea was the most-applied liquid pest treatment, though Gnatrol and Safer's Soap are also applied in significant amounts. This is important because compost tea is a free pest management treatment, created by compost produced on the Farm. It also supplies a significant amount of nutrients. Compost tea is applied to strictly to fruit trees, whereas Gnatrol and Safer's Soap is applied to Vegetables.

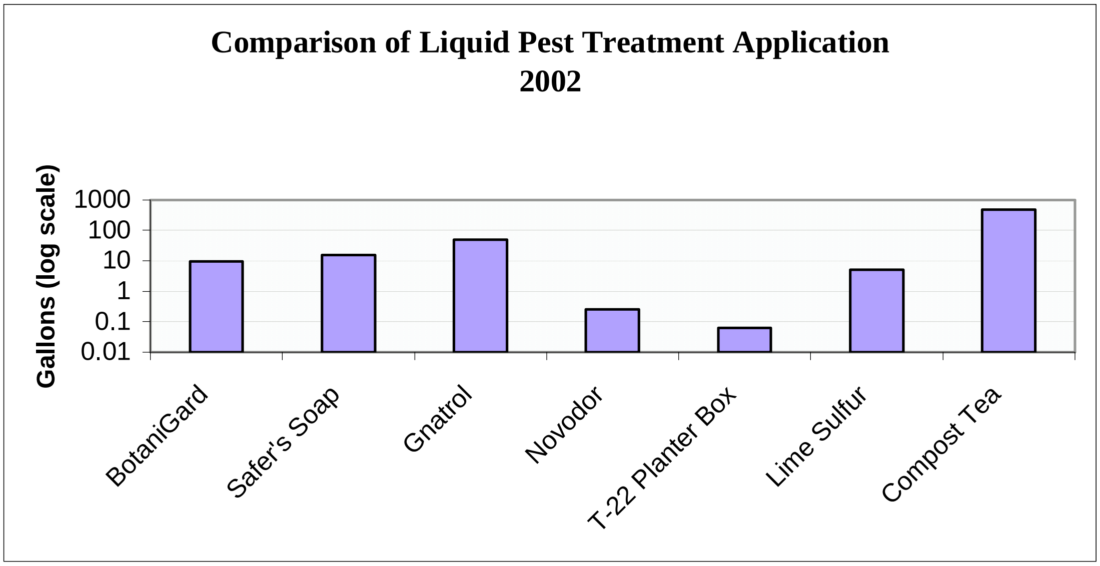


Figure 119 Comparison of Liquid Pest Treatment Application 2002

9.3.3 Quantity of Treatments Applied by Product Line

The Tree Fruit product line receives a much greater quantity of pest management treatments than the Vegetable and Bramble product lines. For example, the Tree Fruit product line receives about 5,000 pounds of solid treatments and about 480 gallons of compost tea. In comparison, the vegetable product line receives about 550 pounds of solid treatments and about 85 gallons of liquid treatments. The Bramble product line received only about 5 gallons of liquid treatments in 2002.

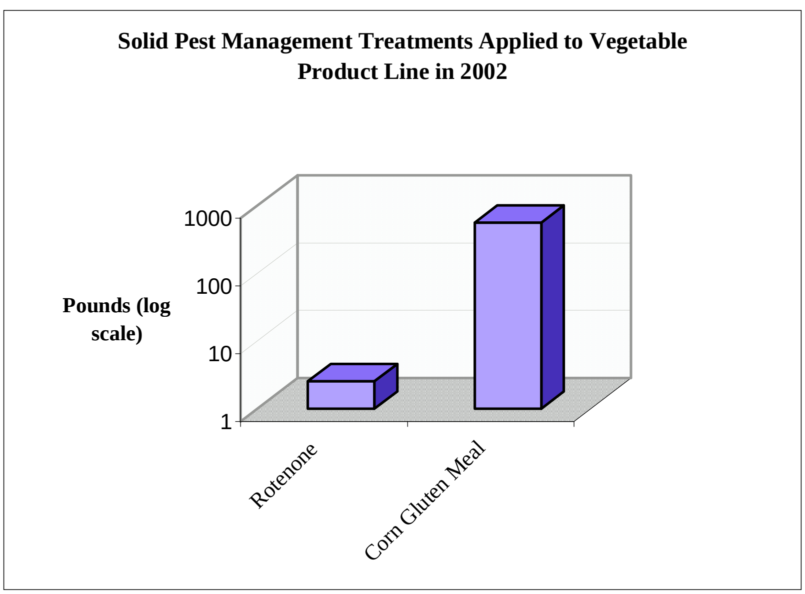


Figure 120 Solid Pest Management Treatments Applied to Vegetable Product Line in 2002

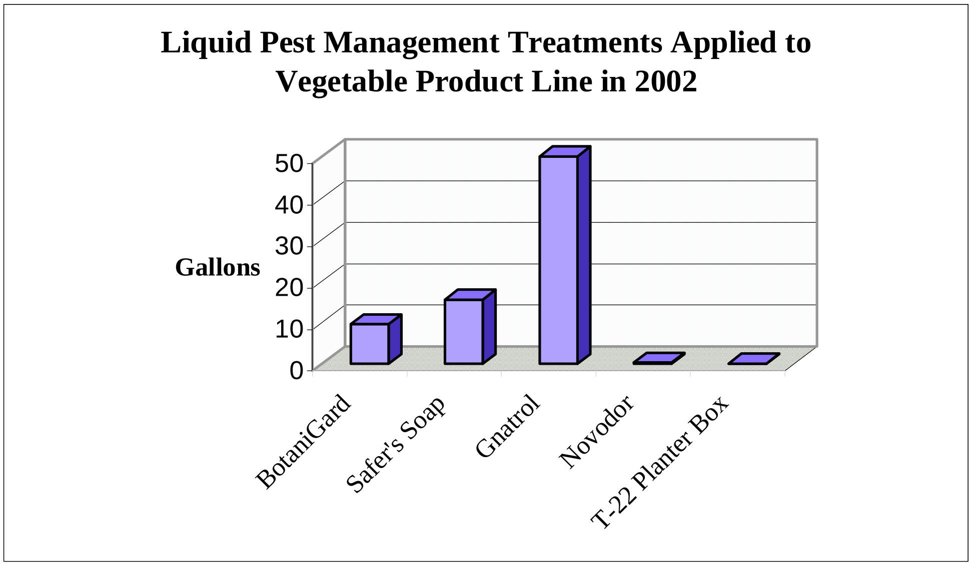


Figure 121 Liquid Pest Management Treatments Applied to Vegetable Product Line in 2002

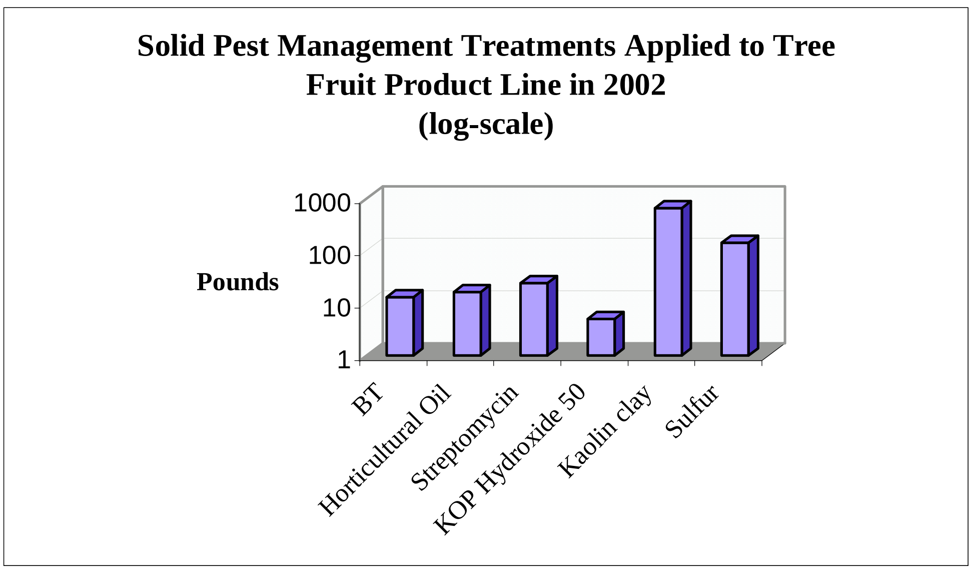


Figure 122 Solid Pest Management Treatments Applied to Tree Fruit Product Line in 2002

About 480 gallons of compost tea were also applied in 2002.

9.3.4 Timing of Pest Management Treatment Applications

Information about the timing of pest management treatment application can help managers make decisions in the future about when to start applying treatments. For example, if a certain pest arrives at the same time every year, an accurate record of pest management applications from past years will help managers to minimize the loss of harvest to these pests. It is also useful for managers to compare the timing of treatments to precipitation records so as to minimize the possibility of losing treatments to runoff.

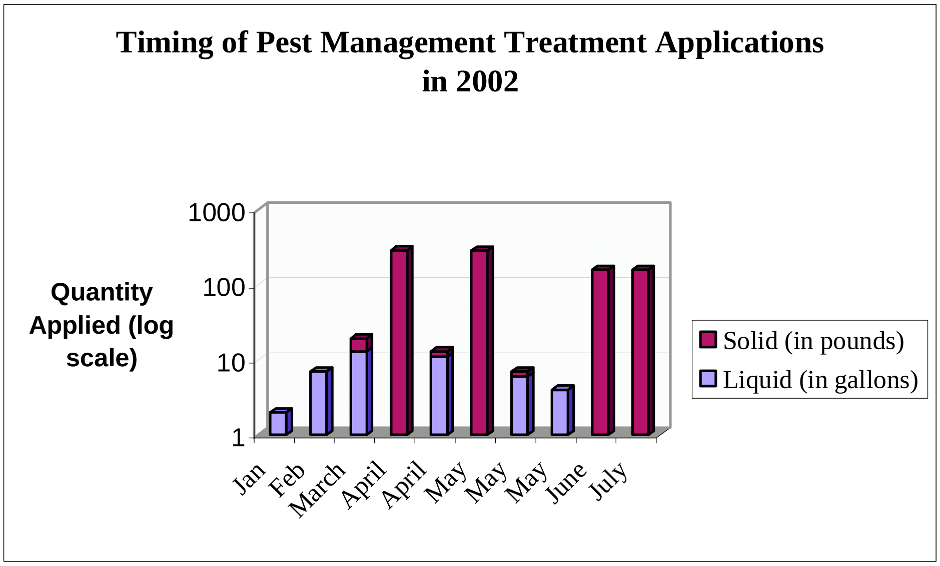


Figure 123 Timing of Pest Management Treatment Applications in 2002

Sunnyside applied the majority of pest management treatments in late spring and mid-summer in 2002.

9.4 Comparison to National Average

The national average application of pesticides is about 1.04 pounds per acre, with Atrazine being the chemical used most often. For herbicides the national average is about 1.5 pounds per acre, and the preferred chemical is Chlorpyrifos. On a per acre basis, Sunnyside applies about 5 pounds of total pest management treatments, which is significantly more than the national average. Biologically-based pesticides, such as pheromones and microbial pesticides which are commonly used at Sunnyside, are considered safer than traditional chemical pesticides. In contrast, Atrazine and Chlorpyrifos are commonly associated with causing ecosystem damage, which is due both to their toxicity as well as their persistence in the environment. Thus, while Sunnyside may use a greater volume of pest management treatments on a per acre basis than the national average, the type of treatment applied is a more environmentally benign alternative, making blanket comparisons impossible.

9.5 Conclusions and Recommendations

The Tree Fruit product line receives a greater quantity of pest management treatments than the Vegetable product line and significantly greater than the Bramble product line. In terms of pest treatments, Brambles receive relatively small inputs. If pest management treatments are of financial concern to the Farm either because of the high cost of treatments or because of the amount of labor used in applying treatments, the Farm should consider planting more Brambles.

10 SOIL

10.1 Significance

The physical, chemical and biological health of soil and its general properties are among the most significant determinants of successful farming. While general soil characteristics are determined by geological and weathering events, land use and management practices influence changes in soil quality over shorter periods of time. As a result, soil is a resource that is frequently mismanaged in conventional agricultural practices. For example, soil erosion in the US and Europe is estimated at 17 tones per hectare per year according to Pimentel (1995), and the soil removed is 1.3 to 5 times richer in organic matter than that left behind. [33]

Assessing soil quality is linked directly to sustainability. Farm managers need to be able to use soil optimally in the present, without compromising the future benefits of high quality soil. Soil quality in general refers to the ability of a soil to fulfill the desired function of a natural or managed system, more specifically to sustain plant life, improve or maintain water and air quality, and cycle nutrients. Several types of tests can be used to assess soil quality. Among the most important to farm managers are chemical tests to assess the availability of nutrients for plant growth and soil organic matter measurements, which provides an indicator for soil fertility, structure, stability, nutrient retention and susceptibility to soil erosion.[34]

10.2 Approach

In this section, five aspects of soil are examined. First, soil types on the Farm are outlined, along with methodologies used for sampling and testing soil. Secondly, erosion, which is a major soil quality resource concern, is estimated based on findings from the RUSLE computer program. This section incorporates soil type information as well as other Farm management practices. Thirdly, a discussion of the value of carbon sequestration in agricultural soils is presented. Next, soil organic matter is discussed in terms of its general importance in agriculture, current organic matter content on the Farm and changes in soil organic matter found on the Farm over the period for which test results are available. Lastly, to assess findings in a broader context, a comparison to national and state values for soil erosion and soil organic matter is presented.

10.3 Sunnyside Farms General Soil Types

The soil on the Farm varies substantially by area. After purchasing the Farm in 1996, the Farm was surveyed to determine general soil characteristics. The six descriptions of soils are based on the fore mentioned survey. In addition, four classes of steepness are also characterized in Table 99 located in the Soil Appendix.

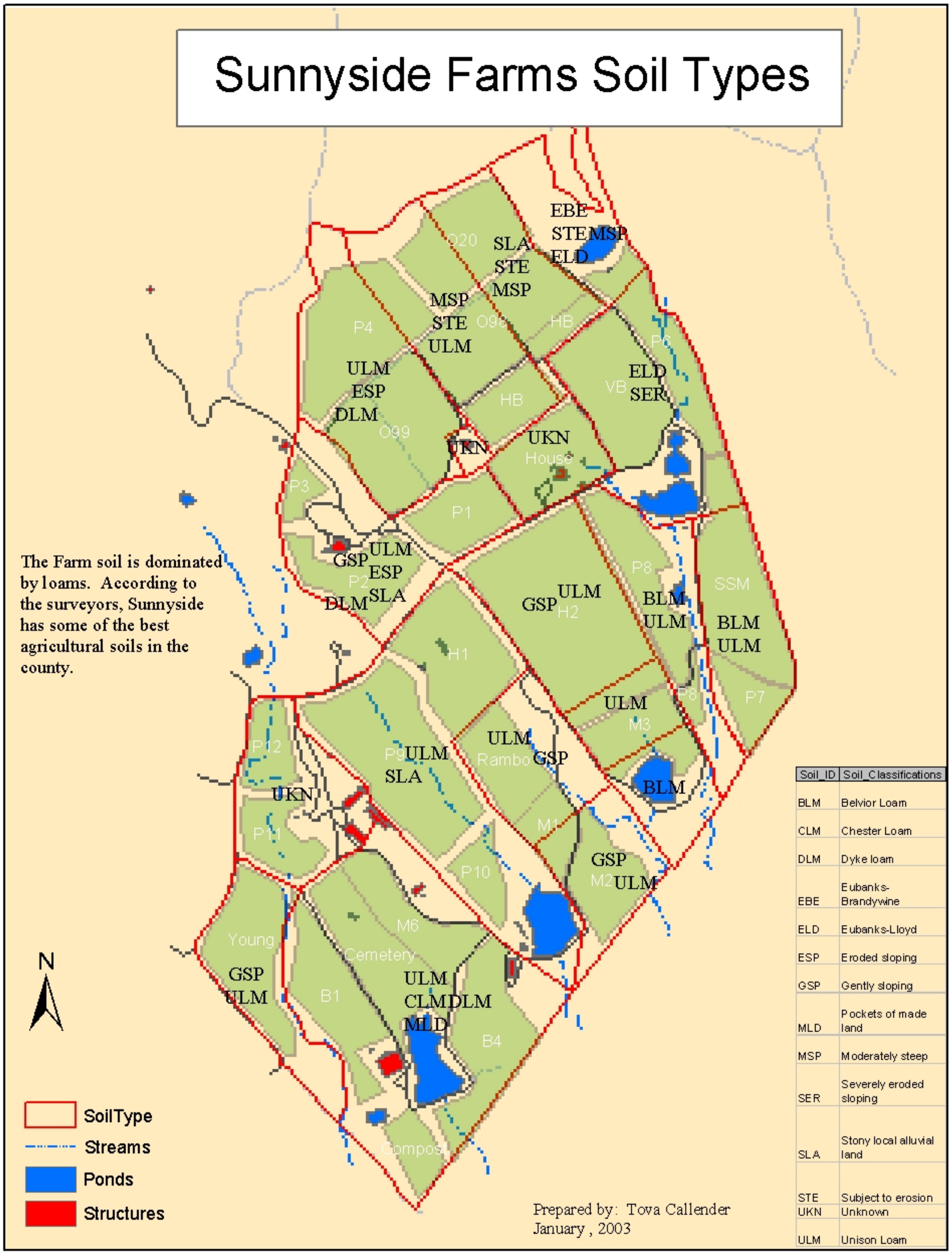


Figure 124 Sunnyside Farms Soil Types Map

10.3.1 Soil Sampling and Testing Methodologies

Summer interns contributed to the existing soil data by performing on site tests. Soil was sampled from various plots using a metal soil-sampling rod. The rod was inserted in the ground to the six-inch mark, and then pulled out. Samples were collected in a zigzag pattern across the plot. A one-acre plot was sampled with 10-15 cores. The cores were then mixed and set to air dry. After drying sufficiently, samples were used to perform a series of tests.

Tests were conducted using a La Motte titration testing kit. This testing system employed color indicators for all results. Tests were conducted for several soil characteristics, including macronutrients such as phosphorous and nitrogen, micronutrients including magnesium and calcium, and general soil characteristics such as humus content, and pH.

Additional testing was carried out at a lab in the fall of 2002. These additional tests were for plots lacking past test results, and were collected with the intent of establishing a baseline for organic matter content of the soil to better assess changes in soil organic matter content from the stacking regime (see page 144).

10.4 Soil Erosion Assessment: The Universal Soil Loss Equation

Excess soil erosion is a serious negative environmental externality associated with agriculture and caused by poor soil management techniques. Erosion decreases the productivity of a soil by removing topsoil, which reduces soil organic matter content and contributes to soil structure degradation. Nutrients removed by erosion are no longer available for plant growth and can cause environmental problems in waterways, as can sediments that accumulate from erosion. The eastern portion of the United States is primarily subject to water erosion (rather than wind erosion which affects the Western states). This results in rills and channels on the surface of the soil, deposits of soils at bases of inclines, and increased sediment in streams, lakes and reservoirs. Water erosion is most conspicuous on steep slopes, but occurs even when not visible. Loss of 1/32 of an inch can represent a 5-ton per acre soil loss.[36]

As soil is a resource of paramount importance to productive farming, an assessment of empirical soil loss was undertaken using the revised universal soil equation (RUSLE). RUSLE is a six variable equation, which allows average soil loss per acre to be assessed based on factors that represent climate, soil, topography and land use. These factors affect rill and interrill erosion caused by surface runoff and raindrop impact. The RUSLE program is a result of years of refinement to the original Universal Soil Loss Equation, which is now a computer program in wide use for conservation planning. This program was provided by the USDA National Sedimentation Laboratory, and was used to make erosion assessments at the Farm. The components of RUSLE affecting soil erosion are represented in the equation below:

Equation 3 Revised Universal Soil Loss Equation

A = R*K*L*S*C*P Where: A = average annual soil loss in tones/acre/year R = climate erosivity K = soil erodability factor L = slope length factor S = slope steepness factor C = cover-management factor P = supporting practices factor

RUSLE is a process-type model based on the analysis of a large quantity of experimental data, or where data are not available, equations that are based on the fundamental erosion processes. It is a lumped model, meaning all factors are not explicitly represented, rather implicit in the soil loss estimate. Only factors R and K are based on plot conditions. The remaining factors are unitless.

10.4.1 RUSLE Factors:

R factor: The R factor represents climate erosivity for a given location. Historical weather data are used to determine this factor, which is the average R based on the sum of storms. Erosivity of a single storm is calculated as a product of the 30-minute maximum duration of the storm and the total energy from the storm. For the Farm, weather data from Washington (1948 to 1980), were used. In the future, data gathered at the Farm's weather station, rather than neighboring stations can be incorporated into the R factor.

K factor: The K factor is the empirical measure of a soil's erodability as determined by inherent properties of the soil. Plot based erosion measurements are used to determine experimental values for K. This factor is influenced by the detachability of soil, run off, infiltration and the transportability of the eroded sediment. The soil properties with the largest effect on the K factor are soil texture, organic matter and permeability of the soil profile.

LS factor: The LS factor measures sediment production. The L and S factors together represent slope steepness, and the effect of length and shape of the segment on sediment production. Rill and interrill erosion are represented in RUSLE, where rill erosion is the impact by surface runoff and increases with a down slope direction, and interrill erosion is primarily from raindrop impact, so is not related to slope.

C factor: The C factor represents the effects of cover-management, such as the differences between plant communities, tillage systems and the addition of mulches. It is one of the most significant factors because it is the one most easily changed by adjusting management practices. The C factor is also affected by canopy cover, ground cover, surface roughness, time since the last mechanical disturbance, organic matter content and the amount of live and dead root mass in the soil. The C factor is an average annual value.

P factor: The P factor represents the supporting practices such as contouring, concave slopes, strip cropping, terraces, grass hedges etc. These practices typically serve to redirect runoff to reduce erosion. In the estimate of P factor, the major considerations are erosivity and transport capacity as a function of slope steepness and hydraulic roughness, and runoff rate as a function of location, soil type and management practices. Sediment size and density are also major considerations. This factor, along with the C factor, can be influenced by management practices.[35]

10.4.2 Data Sources

While RUSLE has many built-in data sets, it is still necessary to draw on outside data for some inputs. Weather data such as temperature, rainfall and freeze free days were based on data from stations in Washington, VA (see Table 84 for more details on weather data). Soil data were compiled from survey results of testing performed on the Farm in 1996. The interns inputted this information as a GIS layer during the summer (Figure 124). The gradients and lengths of segments were also calculated in the GIS. Field observations informed percent rock cover, fall height, percent canopy cover, percent rock fragment and vegetative residue cover.

10.4.3 Limits to the Program

As the databases in RUSLE are generalized data, in some cases, the data do not match exactly with the Farm. For example, as no values for dwarf fruit trees were available, a general fruit orchard value was used. In areas where there is a combination of land uses, the single most dominant land use was selected for the segment.

10.4.4 Division of Segments

In order to use RUSLE, the Farm was divided into seven segments (A through G), which were independently analyzed within the program. The program has a segment length limit of 900 feet, which influenced the block divisions. Segments were divided as to represent different land uses and overall gradients. Land use and blocks included in segments are outlined in Table 58.

Table 58 Blocks Contained in RUSLE Segments with Respective Land Uses

Segment	Blocks Included	Land Use
A	P4, O20, O99, O98, upper HB	Apple, cherry and Asian pear orchards
B	P1, HB, VB , House block	Orchards, brambles, grass
C	SSM	Peach orchard
D	P7, P8	Young fruit trees and raspberries
E	M3 ,H2	Vegetables (treated as tomatoes)
F	H1, M1, M2, P10 , P9	Pasture
G	M6, B4, Cemetery, B1, B12, B11,Young	Old orchards and pasture

10.4.5 Annual Average Soil Loss Results

Through the multiplication of each factor in the universal soil loss equation, RUSLE produces an estimate of average annual soil loss in terms of tons per acre per year. These results can be seen in Table 59.

Table 59 Annual Average Soil Losses

Results are by Segment and Individual Factor Considered in RUSLE.

Factor / Segment	**R** Climate erosivity	**K** Soil erodability factor	**LS** Slope length/ steepness factor	**C** Cover-management factor	**P** Supporting practices factor	**A Average Annual Soil Loss Tons/Acre /Year**
A	250	0.10	2.26	0.05	1	**3**
B	250	0.10	1.61	0.05	1	**2.2**
C	250	0.10	5.69	0.07	1	**11**
D	250	0.10	1.27	0.04	1	**1.5**
E	250	0.10	1.88	0.14	1	**6.6**
F	250	0.10	1.59	0	1	**0**
G	250	0.10	1.69	0.07	1	**3.2**

10.4.6 Discussion of Results

Great differences are apparent within the Farm in average estimated annual soil loss, from zero loss in segment F characterized by a relatively flat pasture area, to 11 tones per acre per year in the steeply sloping peach orchard on Sunnyside Mountain. The second highest value is in segment E, where most of the annual crops are grown. While the final value for soil loss varies, it is contingent on differences in slope steepness and cover management only. All other factors are constant for all segments.

One virtue of RUSLE is that it allows factors to be altered in the program to facilitate identifying the most significant factors in the soil loss estimate. For example, if Sunnyside Mountain had half the gradient (13.05% rather than a very steep 26.1%), the estimated annual soil erosion would be 4.8 tones, rather than 11 tones per acre per year. This suggests that the steep slope in the area is the primary cause for such high erosion rates. As this area is employing all possible soil stabilizing practices (full ground cover, perennial undisturbed crop, and terracing), little more can be done. Care should, however, be taken so that machinery does not unnecessarily bare the soil, or cause unnecessary soil compaction which reduces infiltration rates, further increasing erosion.

When considering the relatively high soil loss estimate for segment E where perennials are grown, it should be noted that RUSLE is not able to accurately reflect all elements of these plots. For example, there was a patchwork of different crops planted mixed in with unplanted areas, but the program included only one crop planted in the entire area, so erosion may be less than suggested under the mono-cropped scenario reflected in RUSLE. Nonetheless, any areas of the farm left tilled and unplanted pose the threat of increased erosion. The management regime for this area should change to include planting of cover crops in the winter and ensure adequate crop residue is left in the fields. The addition of manure should remain a significant part of the regime, as this is helpful in reducing soil erosion.

In conclusion, the overall estimated annual erosion rates were better than average compared to Virginia. Most areas susceptible to higher erosion were higher due to inherent properties of the area, including intense rain events and the steepness of some blocks at the Farm. Management practices that can reduce overall soil erosion should be undertaken in all areas of the Farm whenever possible. These include planting cover crops between plantings and in unplanted areas, rotating annual crops, planting ground covers, adding manure, increasing water infiltration rates, protecting the surface with crop residue and reducing the frequency of soil disturbances.

10.5 Soil Organic Matter

Soil organic matter is an important indicator of soil quality. Organic matter content is the fraction of the soil composed of anything that was once alive. More specifically, it is made up of resistant or stable organic matter (also called humus), active organic traction and microorganisms. Most soils are composed of less than five percent soil organic matter (SOM). It is essential for maintaining the nutrient supply, for improving soil structure, maintaining tilth, minimizing erosion and reducing the effect of environmental pollutants such as heavy metals and pesticides. SOM is also responsible for increasing the rate of water infiltration, reducing runoff and facilitating the penetration of roots.

Soil organic matter can be lost in a variety of ways. Erosion selectively removes particles on the soil surface that typically have the highest SOM values. Microorganisms also consume organic matter, either through incorporation into the organisms or by releasing organic matter as carbon dioxide and water. Tilling soils also reduces SOM, as changing the amount of water and air, and temperature can cause the rate of decomposition to increase.

Organic matter content retention requires a balance between the addition of plant and animal materials and the rate of decomposition. Management activities have a strong impact on both the inputs and rate of loss. Soil organic matter can be maintained through irrigation, fertilization, use of cover crops, applying manure and plant materials, reducing tillage and cooling the soil through the use of vegetative covers.[36]

At the Farm, building this important resource is undertaken through several of the management practices mentioned above. Building organic matter content also forms the basis for using the "stacking" method. This integrated long-term approach to building organic matter in the soil involves rotating various animals through fields needing a crop type change, or in need of rejuvenation. This approach seeks to benefit directly from the behaviors that the animals naturally perform.

The order of rotating the animals through the fields is essential to maximizing the benefits of the system. First, cows are introduced into a field were they graze the tall grass and deposit their waste. Cows are followed by sheep, which graze the grass to a lower level and again deposit their waste. Pigs are introduced next into the field, which root up the soil and mix the dirt. Lastly, chickens are circulated through the area, which scatter the droppings from other animals, eat larvae of pest insects and scratch the dirt further mixing it.[37]

10.5.1 Monitoring Soil Organic Matter

Soil organic matter (SOM) has been monitored through soil testing, which is generally performed priorto planting of crops. As a result of the sparse test data, the recorded set of soil organic matter to date is not very complete. Some blocks were tested after the Farm purchase in 1996, while others were not tested until recent years. At the end of the summer, interns collected samples of most plots that had not been sampled in the past few years. These data, in addition to the existing records, provide a baseline from which to assess changes in soil organic matter over time as a result of management practices or the stacking method. The percent organic matter change over time is illustrated in Figure 126.

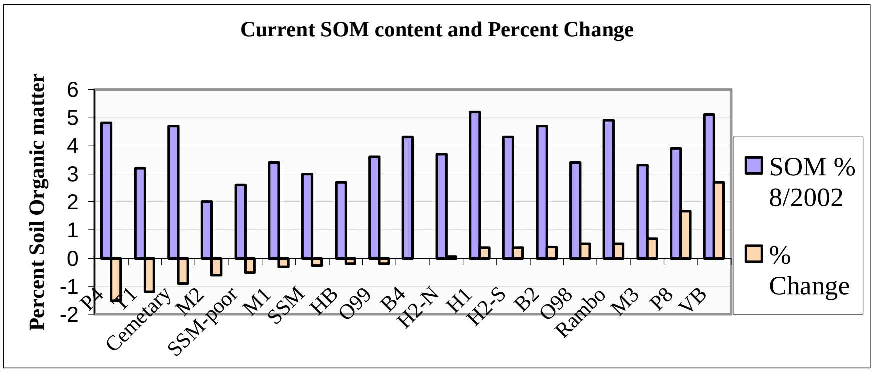


Figure 125 Soil Organic Matter 2002 Levels and Percent Changes Over Time. Only plots with sufficient data are included.

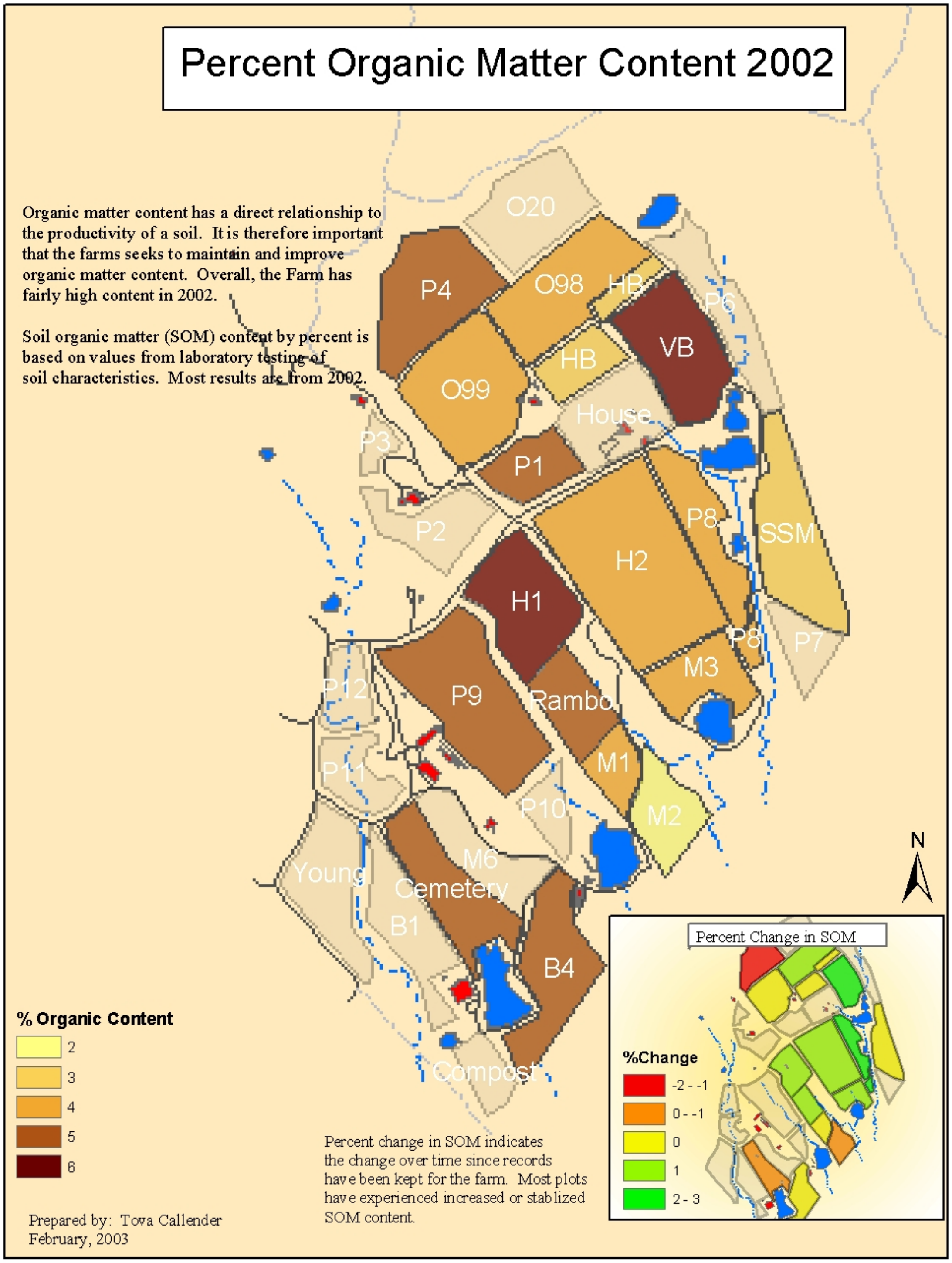


Figure 126 Soil Organic Matter Content and Percent Change on Sunnyside Farms for 2002

10.5.2 Discussion of SOM

Soil organic matter is typically considered very high if greater than 4%, moderate at 2-4% and low if below 2%.[38] All Sunnyside blocks contain 2% organic matter or greater, suggesting that the Farm has a healthy amount of organic matter. It should be noted that accuracy of tests varies slightly with the soil collection method employed.

The highest values are 5.2% in H1 where the mobile chicken units were stationed for several months before the sample was taken and 5.1% in VB where many of the Brambles are grown. P4, where a new orchard was planted and the old orchard area, Rambo, where cows and sheep graze, are the next two highest values for organic matter content. It therefore appears that areas where animals have been and newer blocks that have been treated with compost have high organic matter contents. The exception is the Cemetery block, which although having had animals in it, is decreasing. This is not of concern as it is still has one of the highest SOM values. Blocks with the lowest organic matter contents were M2 at 2%, where flowers were grown in part of the block, and SSM-poor at 2.7%, which is a portion of the block which experiences very poor growth and has rock outcroppings and shallow soil. In the case of M2, it is likely that mismanagement in this area resulted in lost organic matter. During the summer months, only a small portion of the area was planted while the rest was plowed and left tilled and exposed, potentially increasing the rate of decomposition and erosion. As for the poor section of SSM, little can be done about losses since it is likely the shallow underlying bedrock that limits the fertility in this area. HB is another low organic matter block at 2.7%. Brambles are grown in this area, but during the summer, several rows of less productive currant bushes were removed leaving the soil tilled and exposed.

Percent changes of soil organic matter over the time-frames specified in Table 100 varies greatly by plot, where VB and P8, both Brambles plots, experienced the largest gains, and P4 and T1, both pastureland, experienced the greatest losses in percent SOM. Overall, changes are positive since most of the blocks used for crops that are covered most of the year are adding soil organic matter, and those not in use are dropping, except where animals pasture regularly. Exceptions are P4 (which still has a high SOM value), and blocks that had considerable bare soil such as T1, M2, M1 and HB. SSM, which is subject to the greatest amount of erosion from water, is also losing organic matter content. The decrease in SOM in block P4 could be explained by the lack of a permanent irrigation network. This block, which contains new fruit trees, is irrigated with a tank mounted on tractor. Increased irrigation accelerates plant growth, which contributes to organic matter content. Given the dry conditions this summer, it is not surprising that SOM is decreasing in this block.

In conclusion, organic matter content on the Farm is fairly good. Given the lack of information about where stacking has been performed, it is difficult to determine how much this method is contributing to soil organic matter. Now that a baseline is established, records can be kept to assess this in the future. Preliminary data do suggest that the direct addition of organic matter from animals is beneficial. Blocks on the Farm, which are planted but left fallow for large parts of the year, are losing organic matter, and better care should be taken to plant cover crops or leave crop residue to prevent further loss. This applies specifically to blocks M2, M1, HB and T1.

10.6 Carbon Sequestration in Agricultural Soils

Recent domestic agricultural policies and international environmental agreements have indicated that the sequestration of carbon in agricultural soils would present an effective approach for the management of increased atmospheric carbon dioxide (CO_2) concentrations[39]. However, due to associated uncertainties, scientists and policy makers are still debating the scientific efficacy, the potential ecological effects, and the economic and political validity of increasing soil organic carbon (SOC) stored in cropland soils.

Summarizing the results of a number of studies, Schlesinger concluded that conservation and no tillage can result in the sequestration of 1250 grams of carbon per square meter (gC/m^2) and 1740 gC/m^2 respectively for those systems receiving nitrogen fertilizer. However, the benefits from the increased level of sequestered carbon that results may be largely negated by the amount of CO_2 emitted during the manufacturing process of the fertilizers, which was equivalent to 334 gC/m^2, or 19 to 27% of the carbon sequestered in the soil.[40]

Although there are ambiguities regarding the continued effectiveness of carbon sequestration in agricultural soils amongst soil scientists, studies have shown that a steady state of SOC sequestration can be maintained until there are changes in either management practices or weather patterns. Estimates have placed the duration of achieving this steady state at approximately 50 years, though other studies have estimated 20 years, depending on geographic location and soil types. It could be argued that while the range of 20-50 years might be a long-term view for farmers, it may not represent a wide time frame when analyzing such complicated and large-scale systems as carbon cycling. More research needs to be carried out to more accurately determine time frames and effectiveness of management practices.

10.7 Comparison to National Average

In comparing national and state average erosion rates with that at the Farm, Sunnyside is as low as the national average in 1997, and better than Virginia Farms have been between 1982 and 1997.

Table 60 National and State Soil Erosion Averages

All values are in tons per acre per year. Sunnyside Farms average value was calculated by weighting each segment by the percent acreage of the Farm that it occupies. Source: The National Agricultural Statistics Service (NASS)

	Year	Cultivated Cropland (tons/acre/year)	Pastureland (tons/acre/year)
Sunnyside Farms	2002	3.1	n.a.
Virginia	1982	6.6	3.4
	1987	6.4	3.4
	1992	6.4	3.4
	1997	5.9	3.3
National Average	1982	4.4	1.1
	1987	4.0	1.0
	1992	3.5	1.0
	1997	3.1	0.9

As for soil organic content, national averages are not available. The USDA, however, does have values for some counties. The closest county is Appomattox County, VA, which has an average soil organic matter content of 1.5%,[41] as compared to an average Farm organic matter of 4.3%.

10.8 Recommendations

As illustrated in the organic matter and soil erosion results, the Farm is managing soil fairly well. An observation that was overlooked given the level of detail included in formal analysis is the issue of plowed fields being left unplanted. During the summer, interns noted that large sections of plots, such as in M1, M2, M3 and H2 were left plowed and exposed to the elements. Planting a crop cover such as clover in these areas would greatly reduce possible erosion and loss of organic matter. To increase the use of cover crops, priorities must be set by managers. In the summer it seemed that once a crop was removed from a plot, priorities shifted to managing crops in other fields, rather than taking measures to preserve soil productivity in harvested plots.

11 ANALYSIS OF THE FARM'S WATER BALANCE

11.1 Significance

The primary purpose of developing a 'water budget' for Sunnyside Farms is to inform management about irrigation requirements expected under various climate scenarios. Three different climatic conditions are explored: an average year (based on historical precipitation records), a wet year, and a dry year. The maximum number of drought years that are possible without causing the irrigation demand to exceed the available water supply was calculated for different climate scenarios in order to define the Farm's irrigation capacity.

11.2 Approach

The irrigation demand of a crop was determined by calculating the amount of water that the crop needs to grow (potential evapotranspiration), and subtracting off the amount of that demand which is satisfied by precipitation and withdrawal of water from the soil. This water demand can be analyzed for different time increments, such as on a daily or monthly basis. The irrigation demand can also be predicted on various spatial scales, from the estimated water requirement for the whole Farm to the demand for one particular plot. The appropriate level of temporal and spatial resolution is primarily a function of the resolution of available data that are required for the water budget analysis.

For the water budget portion of the analysis, the Farm was broken into the following four 'categories' of crops: Brambles (BRAMB), Vegetables, Flowers, and Grains as 'small crops' (SMCROP), lower orchard Tree Fruit (LORCH), and upper orchard Tree Fruit (UORCH). The crops were grouped into these categories based on slope and aspect, rooting depth, and vegetative factors. A 'water balance' was performed on each category, which is an accounting procedure used to determine the depth of supplementary water that is required by the crop for ideal growth. The volume of irrigation demand was then calculated for each category by multiplying the depth of water requirement (found by the water balance) by the acreage over which the crop category is grown. Finally, the total volume of irrigation demand for all crop categories is summed with the water demand by Livestock to find the whole Farm irrigation demand.

The available water supply was also calculated using a water balance approach. Due to the geography of the Farm, runoff from the drainage basin is either captured by the Farm's ponds or percolates into the water table. The water that percolates into the water table feeds the Farm's wells. This scenario is based on the assumption that the groundwater movement follows the topography of the Farm. Thus, a sum of the monthly runoff from the four categories of Farm crops and the runoff from the drainage basin above the Farm (the forest) was used as an approximation of the available water supply for irrigation.

A conceptual diagram of the approach is presented in Figure 127.

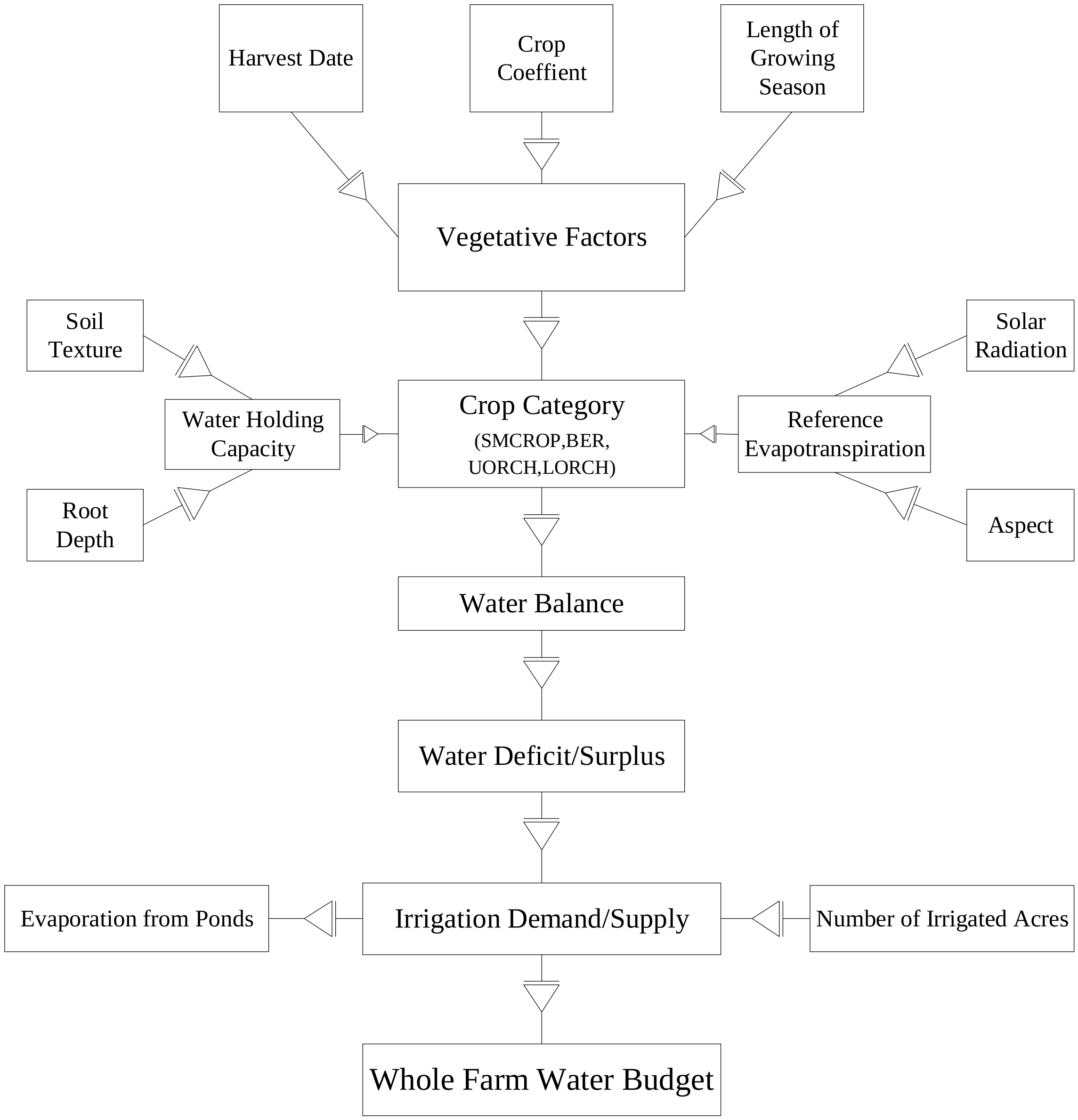


Figure 127 Conceptual Diagram of Water Budget Analysis

11.3 The Water Balance

A 'water balance' is a tool used to quantify the amount of water available to crops by examining the amount of water entering a region (from precipitation and snowmelt) and exiting a region (by evapotranspiration, overland flow, and groundwater recharge) over a desired time step. The water balance is affected by the ability of the soil to retain water, which is a function of the soil texture and the crop rooting depth in the region of interest.

To explain the methodology of the water balance, the following budget for small crops (Vegetables, Flowers, and Grains) on Sunnyside Farms is used as an example.

W_{max}	125

Month	PET	P	P-PET	SM	ΔSM	AET	Deficit	Surplus	Detention	RO_{av}	RO
December				125					21.0		
January	37.3	62.0	24.7	125.0	0.0	37.3	0.0	24.7	22.8	45.7	22.8
February	42.3	53.2	10.9	125.0	0.0	42.3	0.0	10.9	16.9	33.8	16.9
March	71.1	83.8	12.7	125.0	0.0	71.1	0.0	12.7	14.8	29.5	14.8
April	109.7	84.7	-25.0	102.3	-22.7	107.4	2.3	0.0	7.4	14.8	7.4
May	158.0	96.3	-61.7	62.5	-39.9	136.2	21.8	0.0	3.7	7.4	3.7
June	206.4	93.9	-112.5	25.4	-37.1	130.9	75.4	0.0	1.8	3.7	1.8
July	177.5	105.4	-72.1	14.3	-11.1	116.5	61.0	0.0	0.9	1.8	0.9
August	123.9	121.8	-2.1	14.0	-0.2	122.0	1.9	0.0	0.5	0.9	0.5
September	102.6	86.5	-16.0	110.0	-15.0	101.6	1.0	0.0	10.5	21.0	10.5
October	80.5	87.3	6.8	116.7	6.8	80.5	0.0	0.0	5.3	10.5	5.3
November	54.8	80.5	25.7	125.0	8.3	54.8	0.0	17.4	11.3	22.6	11.3
December	38.0	68.5	30.6	125.0	0.0	38.0	0.0	30.6	21.0	41.9	21.0

Figure 128 Water Balance for Small Crops on Sunnyside Farms

11.3.1 Terms and Equations in Water Balance

Water Holding Capacity of Soil (W_{max}):

The water holding capacity of the soil is a function of soil texture and crop rooting depth. The soil texture was assumed to be silt loam for all crops, and an average rooting depth of 0.62 m was assumed for the 'small crop' portion of the Farm, which corresponds to a W_{max} of 125 mm (refer to the Attributes Affecting Crop Category Water Balance section for a list of W_{max} for all crop categories).

Potential Evapotranspiration (PET):

The water balance presented in Figure 128 uses the Food and Agriculture Organization (FAO) Penman-Monteith Method to predict PET (see Estimating P for more detail on this method).

Precipitation (P):

Average monthly depths of precipitation were computed from a 32-year long data record of Washington, VA (see W). Rainfall was taken directly from the data record, while snowfall must be converted to equivalent precipitation. The following formula was used to estimate the equivalent amount of water from the recorded snow depth.

Equation 4 Snow-Water Equivalent

$$SWE = 0.01SD$$

where,

SWE= snow water equivalent

SD= snow depth

Soil Moisture (SM):

Soil moisture is the average amount of water in the soil for a given month. No data were available for soil moisture to use as a 'starting point' for the water balance. However, since the water balance is being used to predict monthly values for an 'average' year, SM can be adjusted so that the December value of the 'average' year being examined is equal to the December value for SM in the previous year. This is why December appears twice in the small crop water balance (Figure 128). Soil moisture is computed as follows:

Equation 5 Soil Moisture

If P-PET>0, SM= the minimum of (P-PET + last month's SM) and W_{max}.
If P-PET≤0, SM= last month's SM*$e^{P-PET/Wmax}$

ΔSM= SM-last month's SM

Actual Evapotranspiration (AET):

Actual evapotranspiration is equal to the potential evapotranspiration when water supply is not limited, that is, when the precipitation exceeds PET. When PET is greater than P, however, the AET is equal to the precipitation less the change in soil moisture.

Equation 6 Actual Evapotranspiration

If P-PET≥0, AET=PET
If P-PET<0, AET= P-ΔSM

Deficit:

The soil moisture deficit is the amount of water that the crop can ideally use (PET) less the amount that is available for use (AET). The deficit is the depth of water that must be added, through irrigation, to the system.

Equation 7 Deficit

$$D=PET-AET$$

Surplus:

The soil moisture surplus is the amount of water that enters the system that cannot be used by the crop, and is beyond the water holding capacity of the soil.

Equation 8 Surplus

$$\text{Surplus} = \text{maximum of } (P\text{-}PET + \text{last month's } SM\text{-}W_{max}) \text{ and } (0)$$

9.3.1.g Detention:

The entire monthly surplus does not run off in a single month; some is detained in the soil. Detention is the amount of water available for runoff less the amount that actually runs off.

Equation 9 Detention

$$\text{Detention} = RO_{av} - RO$$

Available Runoff (RO_{av}): The available runoff is equal to the monthly soil moisture surplus and the amount of detention from the previous month.

Runoff (RO):

'Runoff' refers to water that exits the portion of the soil that is accessible by the crop; it does not differentiate between percolation, overland flow, etc. The runoff is calculated by taking 50% of the total water available for runoff. While this is a common assumption used in water balances, it should ideally be evaluated for the region of interest. This would require knowledge of specific soil characteristics, storm intensity/frequency data and sub-surface morphology, which were not available for this analysis [17].

Equation 10 Runoff

$$RO_{av} = \text{Surplus} + \text{last month's Detention}$$

11.3.2 Estimating Potential Evapotranspiration

Potential evapotranspiration (PET) is the rate at which a plant loses water to the atmosphere when (by the combined effects of evaporation and transpiration) it is not limited by water supply. PET is one of the key terms in the water balance, as it governs the amount of water that should be made available to crops. The rate of PET is controlled primarily by meteorological factors and atmospheric parameters and secondarily by vegetative controls.

There are numerous methods that scientists have developed to measure PET. The methods differ based on how they account for the meteorological and vegetative controls on PET. This analysis uses the FAO Penman-Monteith Method.

The original Penman-Monteith equation was derived by combining the energy balance with the mass transfer method to compute the evaporation from an open water surface using meteorological records (including solar radiation, temperature, humidity and wind speed). The method has been extended to account for vegetative factors by including aerodynamic and surface resistance factors. The FAO uses the following formula (a modified version of the original Penman-Monteith equation) for the evapotranspiration from a uniform grass 'reference surface'[18]:

Equation 11 The FAO Penman-Monteith Model

$$ET_0 = .\frac{408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where,

ET_0= reference evapotranspiration (mm day^{-1})

R_n= net radiation at the crop surface (MJ m^{-2} day^{-1})

G= soil heat flux density (MJ m^{-2} day^{-1})

T= mean daily air temperature at 2 m height (°C)

u_2= wind speed at 2 m height (m s^{-1})

e_s= saturation vapor pressure (kPa)

e_a= actual vapor pressure (kPa)

e_s-e_a= saturation vapor pressure deficit (kPa)

Δ= slope of vapor pressure curve (kPa °C^{-1})

γ= psychrometric constant (kPa °C^{-1})

Secondary terms in the above equation calculated as follows:

$$P_{atm} = 101.3\left(\frac{293 - 0.0065z}{293}\right)^{5.26}$$

$$\gamma = 0.655 \times 10^{-3} P_{atm}$$

$$\Delta = \frac{4098\left(e^{0}(T)\right)}{\left(T + 237.3\right)^{2}}$$

$$u_{2} = 0.748u_{10}$$

$$e^{0}(T) = 0.6108\exp\left(\frac{17.27T}{T + 237.3}\right)$$

$$e_{s} = \frac{\left[e^{0}(T_{\max}) + e^{0}(T_{\min})\right]}{2}$$

$$e_{a} = e^{0}(T_{dew})$$

where,

P_{atm}= atmospheric pressure (kPa)

z= elevation above sea level (m)

u_{10}= wind speed at 10 m height (m s^{-1})

T= mean daily air temperature (°C)

T_{max}= maximum daily air temperature (°C)

T_{min}= minimum daily air temperature (°C)

T_{dew}= dew point temperature (°C)

$e^0(T)$= saturation vapor pressure at T (kPa)

Assumptions:

- The wind speed recorded for Lynchburg WSO Airport is assumed to be taken at a height of 10m, as this is the standard measurement height at airports.
- The soil heat flux density, G, was assumed to be negligible since it is much lower than R_n on a monthly basis.
- The temperature, solar radiation and humidity data taken from nearby weather stations are assumed to be representative of the climactic conditions on Sunnyside Farms.

The FAO Penman-Monteith equation includes both physical and physiological factors that control the evapotranspiration process. Thus, a fine level of spatial and temporal resolution of PET can be explored using this equation. Unfortunately, the equation requires a significant amount of climate data, which were not available for the exact location of the Farm. When on-site data were not available, data from nearby weather stations were used. The sources of the data used for calculation of crop PET can be found in Table 84 in the Weather Appendix. The results of the FAO Penman-Monteith are summarized in Table 61.

Table 61 Estimated Monthly PET using FAO Penman-Monteith Equation.

Month	ET_0 (mm)
January	59.29
February	66.33
March	109.48
April	156.50
May	176.93
June	191.70
July	204.62
August	186.31
September	156.58
October	125.20
November	86.66
December	60.42

11.4 Water Balance by Crop Category

11.4.1 Reference Evapotranspiration

The reference evapotranspiration, ET_0, is useful because it allows different regions to be compared and evapotranspiration of various crops to be computed. Specific crop evapotranspiration is calculated using the following FAO adaptation of the Penman-Monteith equation:

Equation 12 FAO Adaptation of Penman-Monteith Equation

$$ET_c = K_c * ET_{0,c}$$

where,

ET_c = potential evapotranspiration of crop C

$ET_{0,c}$ = reference evapotranspiration in region of crop C

K_c = crop coefficient for crop C

The crop coefficient varies from crop to crop and throughout the growth cycle of a given crop. The reference evapotranspiration varies regionally due to differences in solar radiation input (R_n in Equation 11).

11.4.2 How Categories were Formed

Crop categories were formed by grouping together crops with similar attributes. Table 62 shows the categories that were established, and Figure 129 shows how these categories are distributed spatially.

Table 62 Crop Categories

Category Name	Notes
SMCROP	Includes all varieties of vegtables, grains, and flowers
BRAMB	Includes all varieties of brambles
UORCH	Includes all tree fruit in lower orchards
LORCH	Includes all tree fruit in upper orchards

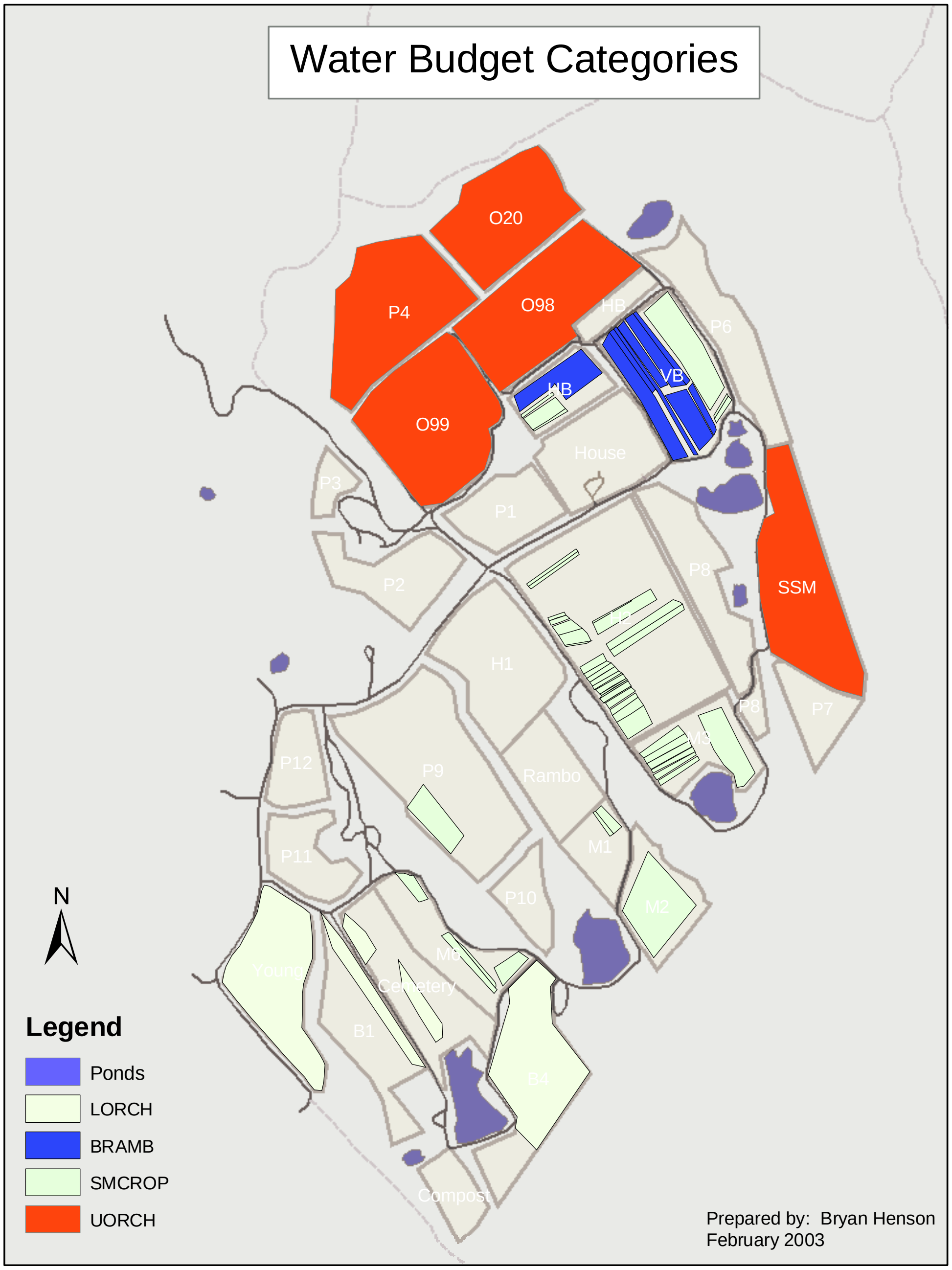


Figure 129 Map of Water Budget Categories

11.4.3 Category Attributes

Attributes affecting $ET_{0,c}$

In this analysis, solar radiation was the only attribute considered to vary in the determination of reference evapotranspiration for each crop category. This variability is due to the fact that some categories differed in slope and aspect. All other terms in Equation 11 were held constant when establishing the reference evapotranspiration. The slope, aspect, and calculated $ET_{0,c}$ (reference evapotranspiration by crop category) are summarized by crop category in the Table 63, below.

%	BRAMB	SMCROP	LORCH	UORCH
Slope	11.5%	8%	8%	17%
Aspect	SE	S	S	SE/SW
Month	Calculated Reference Evapotranspiration			
January	58.20	56.50	56.50	65.96
February	65.44	64.04	64.04	71.79
March	108.81	107.77	107.77	113.56
April	156.59	156.73	156.73	155.94
May	177.94	179.53	179.53	170.72
June	193.58	196.53	196.53	180.13
July	206.27	208.85	208.85	194.50
August	186.88	187.77	187.77	182.80
September	156.11	155.38	155.38	159.44
October	123.95	122.00	122.00	132.86
November	85.26	83.07	83.07	95.24
December	59.29	57.52	57.52	67.34

Table 63 Reference Evapotranspiration by Crop Category

Attributes Affecting Crop Category Water Balance

Variation among crop category water balances is due to differences in reference evapotranspiration, as well as physical crop parameters. The latter includes root depth, soil texture, crop coefficient values (K_c), length of growing season, and dates of growing season.

The soil texture was assumed to be silt loam throughout the Farm. Thus, the available water capacity of the root zone (W_{max}) was calculated by taking an average rooting depth for each crop category. The values of root depth and corresponding W_{max} are presented in Table 64.

Table 64 Rooting depth and Maximum Capacity of the Root Zone (W_{max}) by Crop Category [42]

CROP CATEGORY	SMCROP	BRAMB	UORCH	LORCH
Rooting Depth (m)	0.62	1.25	1.5	1.5
W_{max} (mm)	125	250	300	300

The major difference in the water balance for different crop categories may be attributed to differences in the assigned crop coefficient (K_c). The crop coefficient is a function of the albedo, crop height, aerodynamic properties, and leaf and stomata properties of the specific crop.[42] As these properties change throughout the growth of a crop, the crop coefficient will also vary throughout the growing season. The initial ($K_{c,ini}$), mid-season ($K_{c,mid}$), end of season ($K_{c,end}$), and off-season ($K_{c,off}$) crop coefficients are presented by crop category in Table 65.

Table 65 Seasonal Crop Coefficients by Crop Category [43,44,45]

CROP COEFFICIENTS (by growth stage)	SMCROP	BRAMB	UORCH	LORCH
$K_{c,ini}$	0.7	0.3	0.8	0.8
$K_{c,mid}$	1.05	1.05	1.15	1.15
$K_{c,end}$	0.85	0.5	0.85	0.85
$K_{c,off}$	0.66	0.3	0.76	0.76

Note that the off-season crop coefficient was computed as $K_{c,ini}$-0.05* $K_{c,ini}$ for all categories excluding Brambles.[46] The fact that Vegetables are an annual crop, and that the orchards are pruned after harvest are consistent with a lower potential evapotranspiration in the off-season. The crop coefficients for annual crops and Tree Fruit (LORCH and UORCH) accounted for the fact that a cover crop is used in these areas.

The length of time that crop spends in each growth stage is summarized in Table 66.

Table 66 Lengths of Crop Development Stages by Crop Category (days)[46]

LENGTH OF GROWTH STAGES (days)	SMCROP	BRAMB	UORCH	LORCH
$L_{,ini}$	20	30	15	15
$L_{,dev}$	30	60	45	45
$L_{,mid}$	30	40	60	60
$L_{,late}$	15	80	30	30

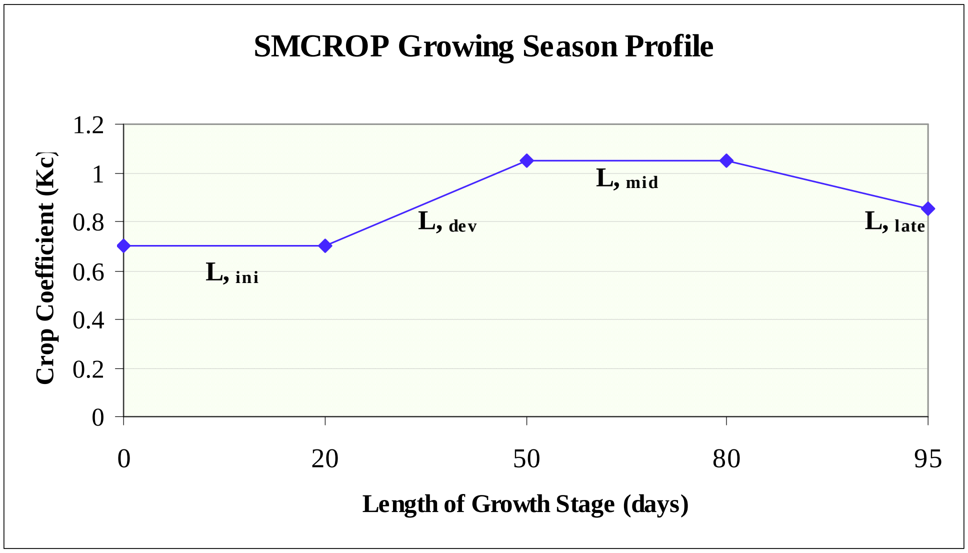


Figure 130 SMCROP growing season profile

This graph (in conjunction with Table 65 and Table 66) shows the relationship between the number of days that the crop spends in each growth stage and the crop coefficient assigned.

In order to correctly assign crop coefficients to each month, the start or end date and length of the growing season must be known. Sunnyside Farms has an extremely diverse range of crops within each product line, and complete information on planting and harvest dates is lacking. Thus, average planting, harvest, and length of growing season were assigned to each crop category as shown in Table 67.

Table 67 Length of Growing Season by Crop Category [45,46]

GROWING SEASON	SMCROP	BRAMB	UORCH	LORCH
Length of Growing Season (	95	210	150	150
Plant Date	April 10th	December 1st	March 15th	March 15th
Harvest Date	July 15th	July 1st	August 15th	August 15th

11.4.4 Drawing Conclusions from Crop Category Water Balance

The most important terms in the water balance, from a planning point of view, are monthly deficit and runoff. The deficit is of primary importance since it corresponds to the depth of irrigation water that will be required by the crop. The runoff is also important, as it can be re-captured by ponds, or be accessed by the wells, and used for irrigation water (see the Runoff section for a definition of runoff specific to this analysis). The deficit and runoff for 'small crops' on Sunnyside Farms are shown pictorially in Figure 131. A large deficit occurs for small crops during the summer months, while there is surplus water during the fall and winter that manifests itself as runoff. The magnitude of the deficit, for all crop categories, is summarized in Figure 132.

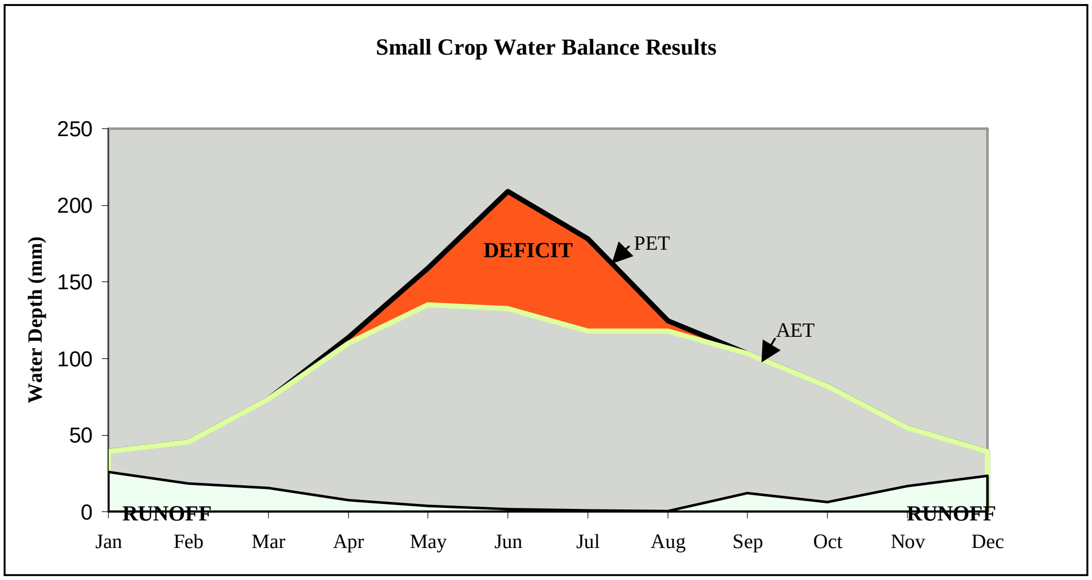


Figure 131 Calculated Average Monthly Runoff and Deficit for the Small Crop Category

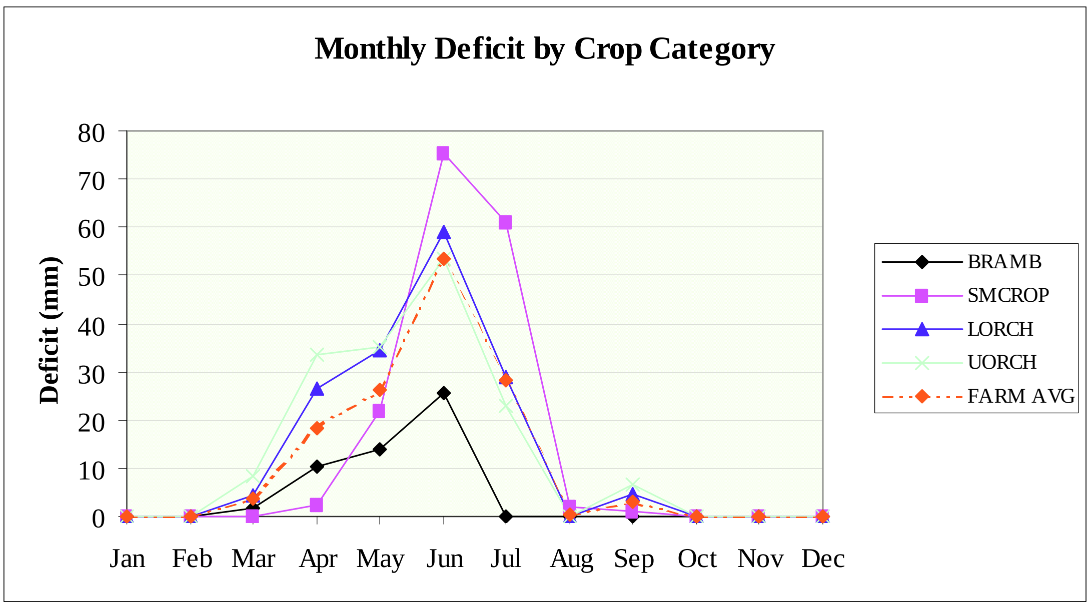


Figure 132 Monthly Water Deficit by Crop Category

The monthly water deficit is expressed as a depth of water. This is useful from a planning point of view, because it shows which crops require the most (or least) water, per unit surface area. Figure 132 shows that Tree Fruit dominate the water demand between March and May, after which the small crops have the largest water deficit until August. During the months of September, October, and November, the orchards again dominate the water deficit.

Similarly, the runoff from the planted portion of the Farm may be expressed as a depth, grouped by crop category (Figure 133). This graph reveals that the Farm's orchards provide no runoff, while the Brambles supply the most runoff for potential use as irrigation water. The values in Figure 133 and Figure 133 may be converted to volumes of water by multiplying by the appropriate surface area of the crop category (See *Irrigation Demand/Supply*).

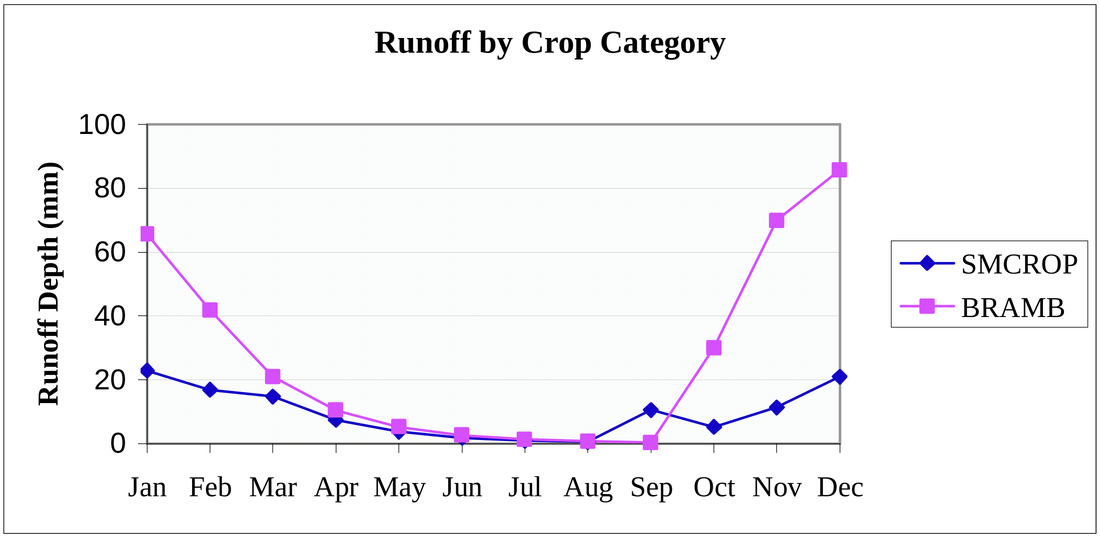


Figure 133 Runoff by crop category

This chart shows that the small crops and Brambles have the most runoff during the winter months. Not pictured are the Tree Fruits, LORCH and UORCH. These crop categories had no runoff.

11.5 Livestock Water Demand

While the water demand by crops was analyzed using a water balance approach, the annual Livestock water consumption can be evaluated using a simple accounting procedure, summarized in Table 68. The results of this calculation appear graphically in Figure 134.

Table 68 Annual Water Consumption by Livestock [47]

Type of Livestock	Water Consumption (gal/day)	Average Yearly Number of Livestock	Yearly Water Consumption (gal)
Beef Cattle	10 (per head)	100	365,000
Horses	10(per head)	5	18,250
Swine	4 (per head)	20	29,200
Sheep	2 (per head)	20	14,600
Chickens	9 (per 100 birds)	1500	49,275
TOTAL			476,325

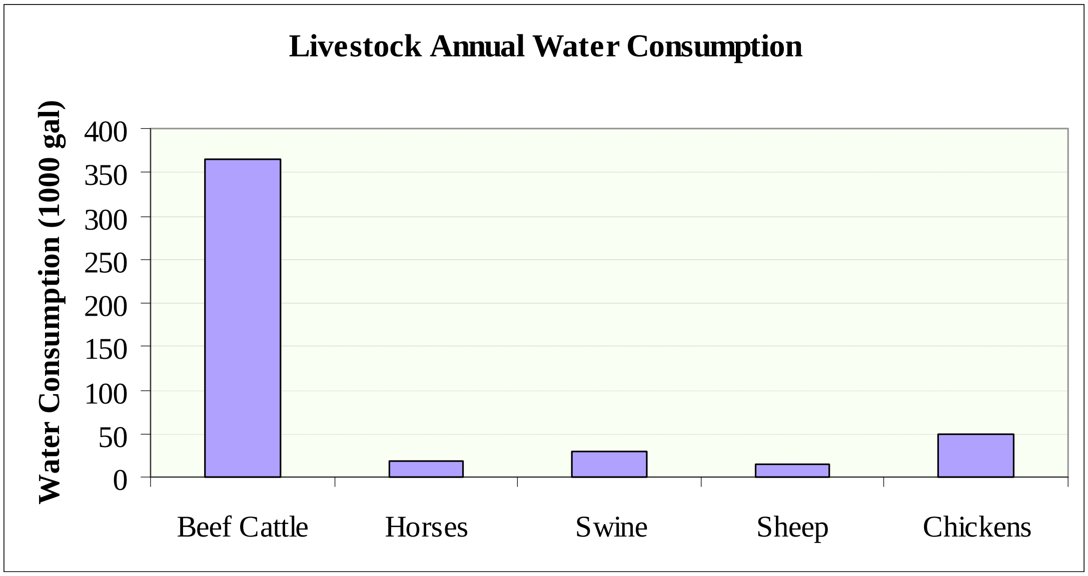


Figure 134 Water Consumption by Livestock

As expected, the largest demand is from the beef cattle.

In order to convert the yearly demand into monthly averages it was assumed that the same number of animals were present during each month. The results (shown in Table 69) can then be incorporated into the monthly water demand of the whole farm.

Table 69 Monthly Water Consumption by Livestock [47]

Month	Livestock Monthly Water Consumption (gal)
January	40,455
February	36,540
March	40,455
April	39,150
May	40,455
June	39,150
July	40,455
August	40,455
September	39,150
October	40,455
November	39,150
December	40,455

11.6 Water Balance of Drainage Basin

In order to make a general approximation of the volume of water available for irrigation, potential areas of runoff were identified, and labeled as 'forest' and 'unplanted' in Figure 135. These areas make up a drainage basin, and it is assumed that an amount of water calculated by the water balance to 'runoff' of these areas is available for irrigation (from the either the well and/or the ponds).

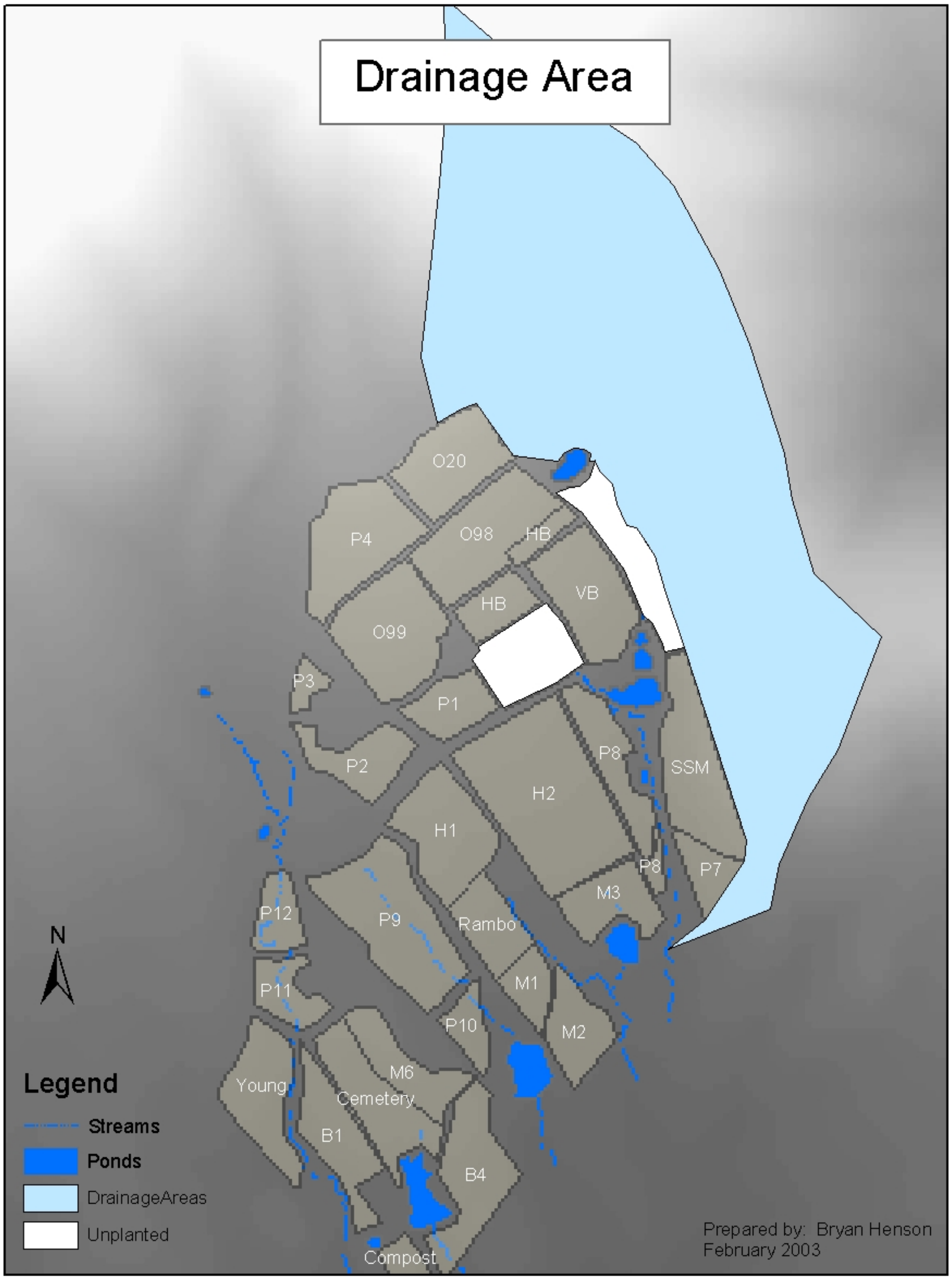


Figure 135 Potential Areas for Runoff

Water balances were performed for the 'forested' and 'unplanted' portions of the Farm. The values used in the calculation of reference evapotranspiration are reported in Table 70. The runoff results of these water balances are displayed in Figure 136. These two sources of runoff are combined with runoff from the planted portions of the Farm to calculate the total volume of water available for irrigation (see Irrigation Demand/Supply).

Table 70 Physical Characteristics of Drainage Areas [42,46]

Drainage Area	Rooting Depth (m)	Wmax (mm)	Kc	Percent Slope/Aspect
Forest	2	400	0.7	20% / SW
Unplanted	0.62	125	see SMCROP	8% / S

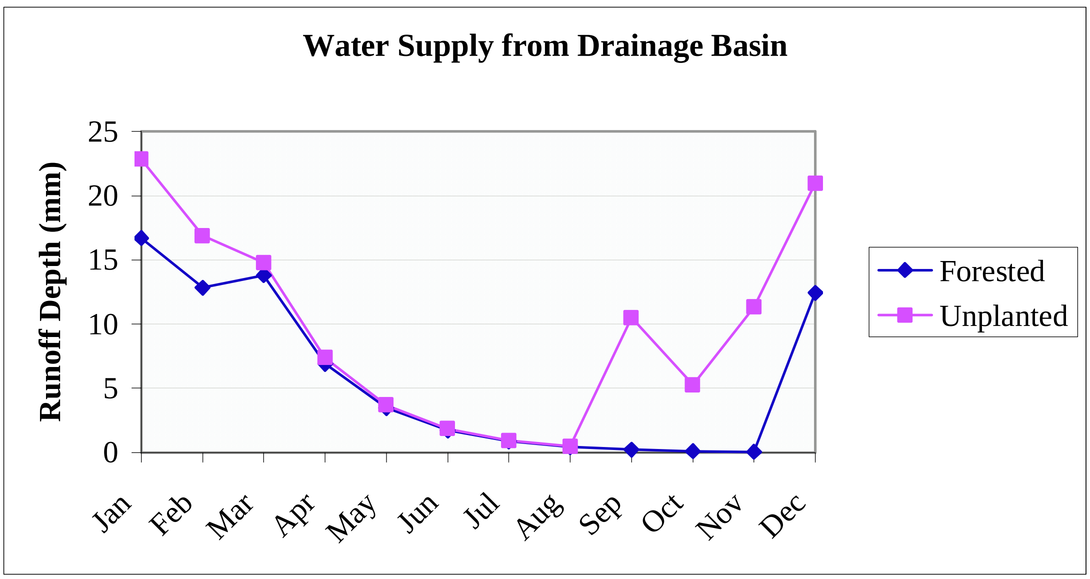


Figure 136 Water Supply from Drainage Basin

11.7 Irrigation Demand/Supply

The values calculated for deficit and runoff can be converted to volumes of irrigation water by multiplying 'depths' by the appropriate surface area. The acreage used to compute the irrigation supply and demand is provided in Table 71. The resulting irrigation demand by crop category is shown in Figure 137. This graph reveals that the overwhelming majority of irrigation water is used to irrigate the Tree Fruit product line.

Table 71 Acreage by Category

Note that the acres corresponding to the crop categories refer to irrigated acres.

Category	Total Acres	Total meters (m^2)
BRAMB	6.35	25,715
SMCROP	8.46	34,225
UORCH	23.61	95,550
LORCH	16.25	65,764
FOREST	122.70	496,567
UNPLANTED	9.54	38,608

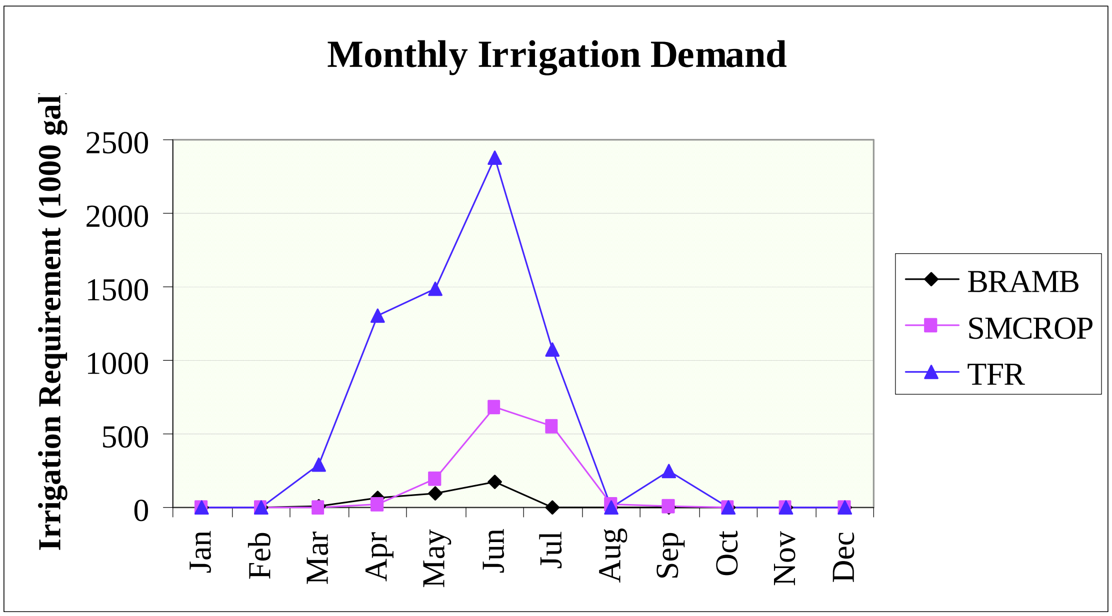


Figure 137 Monthly Irrigation Demand by Crop Category

Note that these values correspond to an average year of rainfall. TFR (Tree Fruit) is the sum of the demand by the crop categories of LORCH and UORCH.

In order to compute the monthly irrigation demand of the whole Farm, the water requirement from each crop category is summed, and the total is combined with the monthly Livestock water demand. The result of the whole Farm irrigation demand is illustrated in Figure 138.

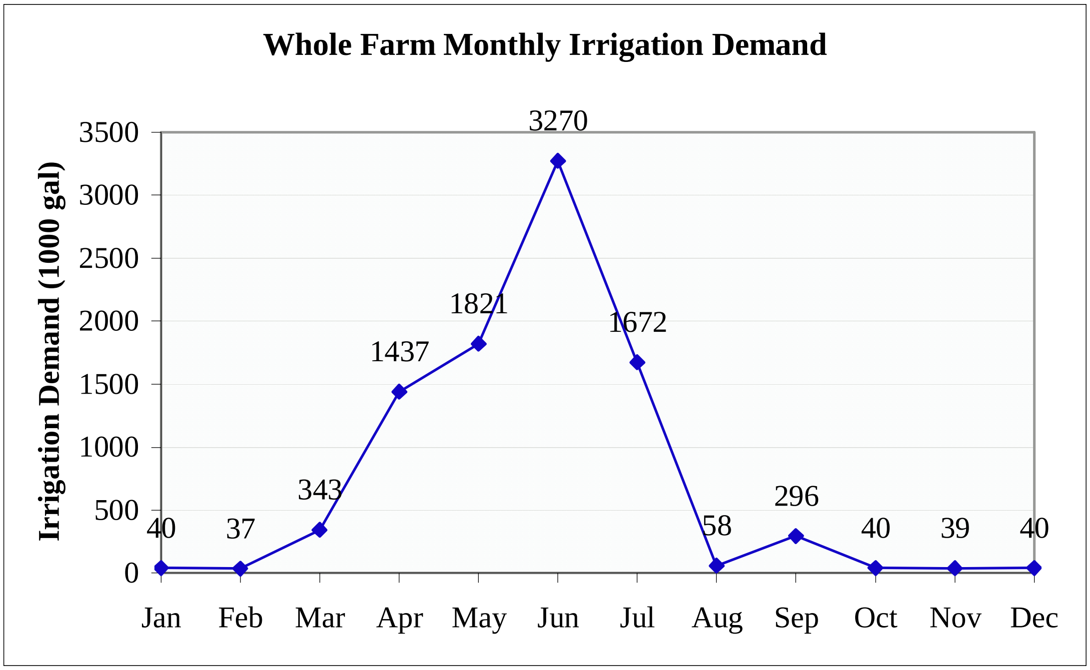


Figure 138 Whole Farm Water Demand in Thousands of Gallons

Peak demand occurs in June, with a water demand of 3.27 million gallons of water. Total annual water demand is 9.09 million gallons of water. Note that these values correspond to an average year of rainfall.

In order to assess the yearly supply of irrigation water, the volumetric water supply from the 'forest', 'unplanted', and 'planted' regions are calculated. The resulting irrigation supply is presented in.

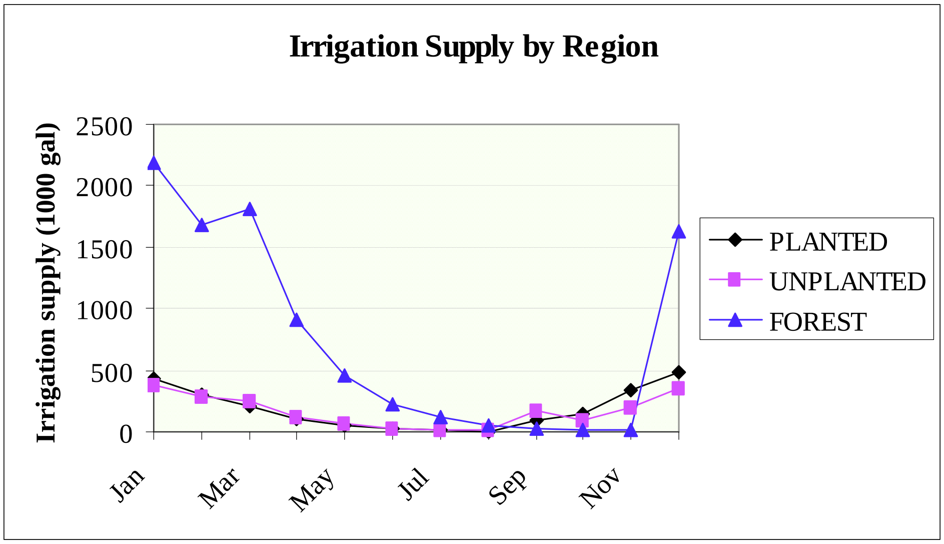


Figure 139 Monthly Supply of Irrigation Water by Drainage Region

Note that these values correspond to an average year of rainfall.

It is important to note that the irrigation water is held in either above ground storage (ponds) or below ground (groundwater); thus, the supply need not exceed the demand on a monthly basis. The crucial value, then, is the total volume of water that is available for irrigation on a yearly basis. By summing the yearly irrigation supply by region, and subtracting the water that evaporates off of the surface of the ponds, the yearly water supply is found to be approximately 9.9 million gallons (see Table 72).

Table 72 Yearly Irrigation Supply for Average Weather Conditions

Yearly Irrigation Supply (gal)	PLANTED	UNPLANTED	FOREST	POND EVAP (-)	TOTAL
	2,192,778	1,953,466	9,123,520	3,368,321	9,901,444

Thus, for an average year of precipitation, the water supply provides 9% more water than is demanded by the Farm.

11.7.1 Weather Attributes (Average Year/Dry Year/Wet Year)

In order to explore the irrigation demand over a range of possible climate scenarios, three classes of precipitation were designated; an 'average year,' a 'dry year' and a 'wet year'. Monthly precipitation for an 'average year' was calculated by simply taking the monthly average of the 32-year Washington, VA precipitation data set. A 'drought year' was based on a monthly precipitation total corresponding to the 25^{th} percentile of the precipitation cumulative frequency distribution. Similarly, a 'wet year' was characterized by a monthly precipitation total corresponding to the 75^{th} percentile of the cumulative frequency distribution. The resulting precipitation profiles are shown graphically in Figure 140.

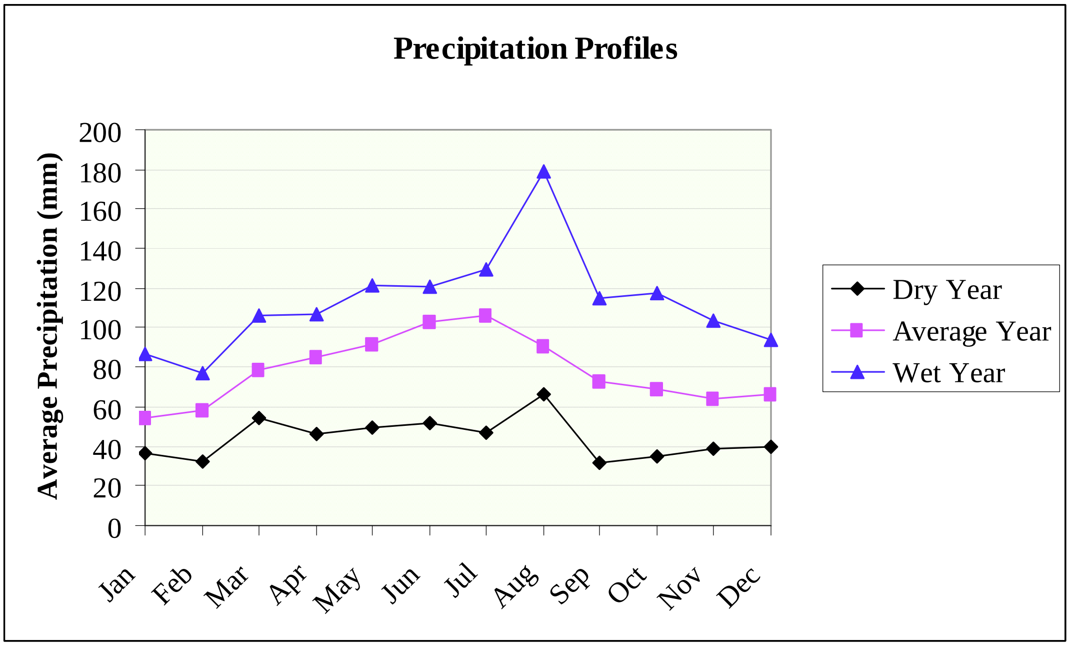


Figure 140 Average Monthly Precipitation for an 'Average' Year of Precipitation, a 'Wet Year' and a 'Dry Year'

11.7.2 Irrigation Demand/Supply (Dry Year)

In order to determine the irrigation demand and supply during a drought year, monthly precipitation totals corresponding to a 'dry year' were used. The amount of incoming solar radiation and monthly minimum, maximum and average temperatures were not altered, as no reliable data were available to make these adjustments. Thus, this analysis may underestimate the actual water demand, and overestimate the actual water supply, during a drought year.

The crop category water balances were run for 'dry year' precipitation. The results of these simulations are presented in Figure 141 and Table 73.

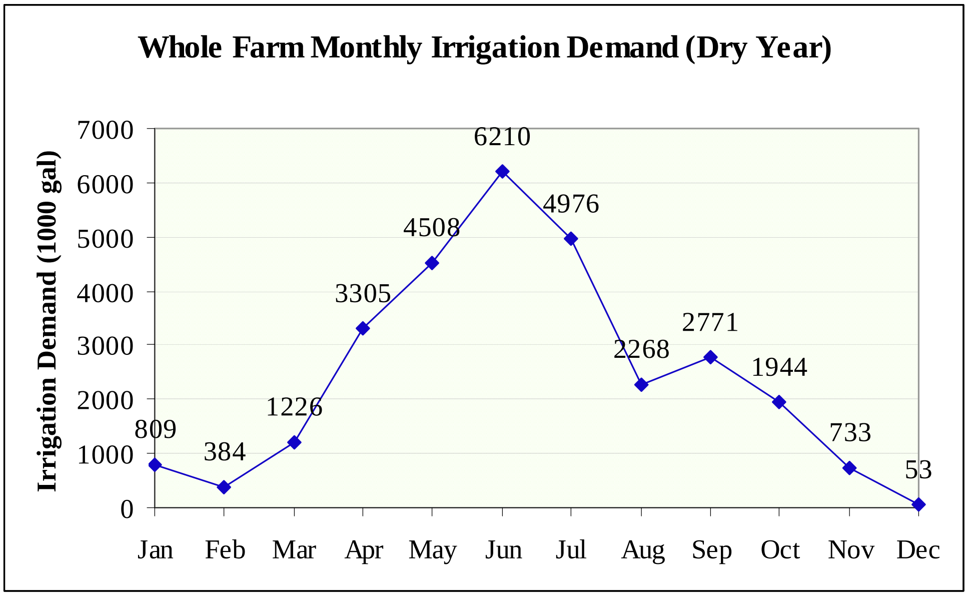


Figure 141 Monthly Irrigation Profile for a Dry Year

Total demand is 29.2 million gallons of water.

Table 73 Yearly Irrigation Supply for a Dry Year

The total irrigation supply is found to be negative in a dry year, which indicates that there will not be any surplus of water for irrigation during a drought year.

Yearly Irrigation Supply-Dry Year (gal)	PLANTED	UNPLANTED	FOREST	POND EVAP (-)	TOTAL
	481,230	351,088	1,626,396	3,368,321	-909,606

These results show that a drought year increases the irrigation demand by 220% (compared to an average year of precipitation), and provides no surplus of water for the irrigation supply.

11.7.3 Irrigation Demand/Supply (Wet Year)

In order to predict the wet year irrigation demand and supply, monthly precipitation totals corresponding to a 'wet year' were used. As in the dry year simulation, the amount of incoming solar radiation and monthly minimum, maximum and average temperatures were not altered, as no reliable data were available to make these adjustments. Thus, this analysis may overestimate the actual water demand, and underestimate the actual water supply, during a wet year.

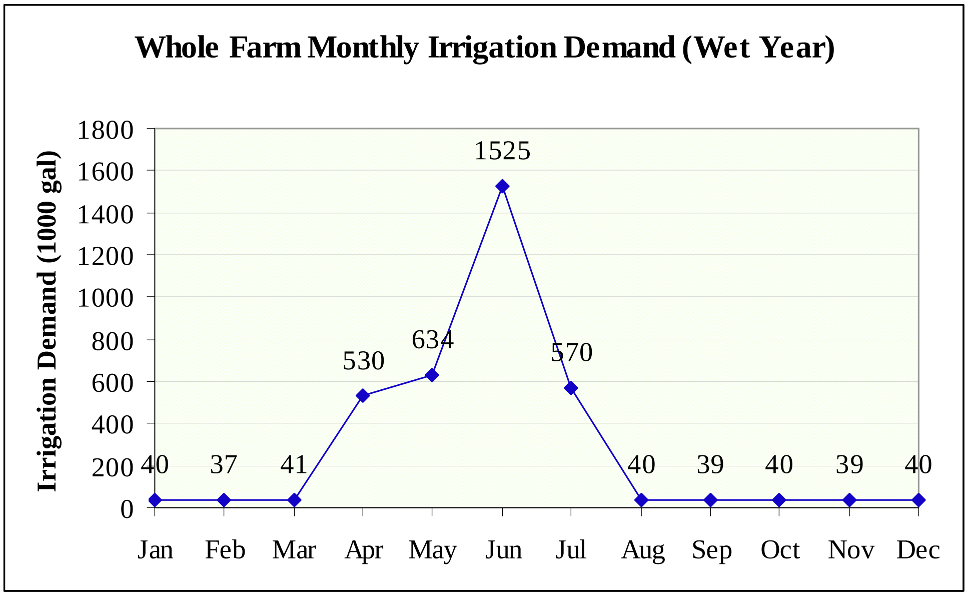


Figure 142 Monthly Irrigation Profile for a Wet Year

Total demand is 3.6 million gallons of water.

Table 74 Yearly irrigation supply for a wet year

Yearly Irrigation Supply-Wet Year (gal)	PLANTED	UNPLANTED	FOREST	POND EVAP (-)	TOTAL
	5,558,838	4,883,264	48,158,316	3,368,321	55,232,098

Thus, for a wet year of precipitation, the water supply provides 500% more water than is demanded by the Farm. The effect of this surplus is explored in section 11.7.5.

11.7.4 Comparison of Irrigation for Various Climactic Conditions

The relative amounts of irrigation supply and demand for different climactic conditions are explored in Table 75. While this table gives a sense of relative differences between precipitation conditions, it does not show which crops will suffer the most during a water shortage.

Table 75 Summary of Irrigation Supply and Demand Volumes for Various Precipitation Conditions

Comparison or Irrigation Supply and Demand (milllions of gallons)					
Average Precipitation		Wet Year		Dry Year	
Supply	Demand	Supply	Demand	Supply	Demand
9.9	9.09	55.23	3.58	0	29.19

In Table 76, the irrigation demand is compared between crop categories. This table shows that there is no significant difference between the water demand of upper and lower orchard crops, and thus the data can be regrouped in Table 77 to view the requirement by product line, the units familiar to Farm management.

Table 76 Yearly Irrigation Requirement per Acre Comparing Crop Categories

Yearly Irrigation Requirement Per Acre (1000 gal)			
Crop Category	Average Year	Wet Year	Dry Year
UORCH	171	57	566
LORCH	170	59	547
BRAMB	55	13	236
SMCROP	175	85	588

Table 77 Yearly Irrigation Requirement per Acre Comparing Product Lines

Product Line Yearly Irrigation Requirement Per Acre (1000 gal)			
Product Line	Average Year	Wet Year	Dry Year
TREE FRUIT	170	58	556
BRAMBLES	55	13	236
VEG,FLP, GRN	175	85	588

Table 77 illustrates a very important conclusion. It shows that while Tree Fruit, Vegetables, Flowers and Grains all have comparable water needs per acre, the Brambles require significantly less water (only 32% of the average of the other product lines). This difference is amplified during drought years. From a planning perspective, this result shows that Brambles minimize the risk of crop failure due to drought.

11.7.5 Number of Drought Years before Irrigation Capacity is Exceeded Under Various Climate Scenarios

Knowing the amount of water deficit that is present during a dry year (see *Water Balance by Crop Category*) and the irrigation capacity during a dry year (see Irrigation Demand/Supply (Dry Year)), the maximum number of drought years before irrigation capacity is exceeded can easily be calculated. This is achieved by running the water balance for several years in a row, or until the demand can no longer be satisfied by the incoming runoff. This simulation can be repeated for various scenarios, such as those presented in Table 78. It is important to note that the large contribution to the water supply by a 'wet year' requires that the simulation be considered relative to the last wet year, or series of wet years.

Table 78 Irrigation Supply Longevity for Various Drought Simulations

Description of Climate Simulation	Time Until Farm's Irrigation Capacity is Exceeded
Wet Year, Average Year, Dry Years	July of second drought year
Wet Year, 5 Average Years, Dry Years	July of second drought year
2 Wet Years, Dry Years	April of fourth drought year

The results of the simulations presented in Table 78 show that the Farm depends entirely on the 'wet years' for its irrigation supply. The average years play no part in determining the length of time until the Farm's irrigation capacity is exceeded. This is shown in Table 78 by comparing the simulation in which there is one average year of precipitation between the wet and dry years with the simulation in which there are five average years between the wet and dry years. Both of these scenarios result in a water shortage in April of the second drought year. These simulations also show that every 'wet year' corresponds to approximately nineteen months of irrigation for 'dry year' conditions. This result is *independent* of how many years ago the 'wet year' occurred, as the average years do not significantly alter the irrigation supply. However, it must be reiterated that the groundwater supply of water was assumed to be an area of constant storage. This implies that the predicted uptake of water by plants (and humans) in the region is not included in the model, and thus these withdrawals are not accounted for. In order to more accurately characterize the groundwater supply, a hydrologic model would need to be developed that would account for aquifer characteristics and soil parameters. These simulations are based on the assumption that the wet and dry years begin on January 1st (though one could run the water balance for any starting point). It was also assumed that pond evaporation continues uniformly for both weather conditions.

11.7.6 Irrigation Costs

Irrigation costs could not be directly calculated from Farm expenditures due to missing data of irrigation pump electricity cost. It is difficult to make a reliable estimate of the anticipated irrigation pumping costs, as the following information would be needed to perform the calculation properly: pump flow rate, total dynamic head, pumping plant efficiency or specific fuel consumption, monthly cost of energy, and hours of operation per season.[48] None of these requirements are known with certainty for the Farm. In order to find an extremely rough approximation of irrigation costs, the following information was used:

Table 79 Irrigation Cost Estimate Data

Item	Value	Source
Power of irrigation pump	10 HP	Observation from summer interns
Cost of electricity	\$0.07/kWhr	Expense table in database
Pump flow rate	3600 gal/hr	Estimated by summer interns
Irrigation requirement	9.09×10^6 gal	Calculated

The cost to irrigate for an average season is estimated by:

$$10HP * \frac{746W}{HP} * \frac{kW}{1000W} * \frac{\$0.07}{kWhr} * \frac{9.9 \times 10^6 gal}{3600 gal/hr} = \$1436$$

The same calculation can be performed for a 'wet year' and 'dry year' using the appropriate irrigation requirements. The results of the irrigation cost estimate are presented in below. These estimates assume that the price of pumping from the ponds and well are equal, and assumes that the cost of electrical pumps is comparable to the cost of diesel-powered pumps.

Table 80 Estimated Cost of Irrigation for Various Climate Conditions

Precipitation Condition	Average Year	Wet Year	Dry Year
Cost of Irrigation ($)	1436	519	4234

Though the cost of irrigation is minute compared to the overall costs of the Farm, the monetary impact of crop failure resulting from a water shortage is enormous. Thus, an area of future research may be to explore ways to increase the water-use efficiency of the crops, and minimize losses (from pond evaporation and groundwater percolation) from the Farm.

11.7.7 Comparison to National and State Averages

Though water use (typically measured in acre*ft/acre) is extremely dependent upon location and precipitation conditions, a general comparison is made with the available data for the state of Virginia and the national average irrigation water use in Table 81, below.

Table 81 Comparison of Water Use on Sunnyside Farms to Virginia State Averages and National Averages

Comparison to State Average Water Use	
Location	Acre-feet of water applied (per irrigated acre)
Sunnyside Farms	0.51
Virginia State Average	0.56
National Average	1.4

It is important to note that the Sunnyside Farms' water use is calculated for the 2001 and 2002 years, while the Virginia average is calculated using data from 1998 and 1994,[49] and the national average uses 1998 values only.[50] If the precipitation and/or solar radiation varied largely between the years from which data were taken, one can expect the water use result comparison to be largely inconclusive. However, if we assume that climactic conditions were comparable between these years, Table 81 shows that the Farm uses 9% less acre-feet of water for every irrigated acre when compared to the state of Virginia, and 64% less than the national average. High water use efficiency is most likely a result of the Farm's extensive use of cover crops.

11.8 Results and Conclusions

The Tree Fruit product line requires the largest volume of irrigation per year. This is due to the fact that more of the Farm's acres are planted with Tree Fruit than any other product line. On a per acre basis, the Vegetable and Tree Fruit product line irrigation requirements are nearly equal. Brambles require a much lower amount of irrigation water, per acre, than all of the other product lines. In fact, Brambles only require one-third the irrigation water that the other product lines call for. From a planning perspective, planting Brambles will minimize the risk of crop failure during drought conditions.

During a year of average rainfall, the water supply to the Farm is nearly balanced by the yearly demand of crops and Livestock; there is no significant surplus. During wet years, the Farm stores surplus water in the ponds and as groundwater. Crops use this surplus water during drought conditions, when the yearly water supply is greatly exceeded by the crops' demand for irrigation water. Thus, the number of wet years preceding a drought will heavily influence the available water supply, which in turn establishes how long the irrigation supply will last, according to the assumptions of the water budget model.

11.9 Recommendations for Water Budget Improvements

In order to increase the accuracy and resolution of the water budget analysis, data must be collected in the following areas:

11.9.1 Model Calibration

To properly calibrate the water balance, the following data must be collected:

- Soil moisture (by soil samples)
- Volume of irrigation water applied to each plot (by metering the pumps)

11.9.2 Water Balance Information

In order to improve the accuracy of the water balance, the following data must be collected:

- Precipitation for locations of different slope, aspect or in known microclimates
- Hydrological conductivity of the soil
- Storm intensity and frequency
- Sub-surface morphology of the Farm (water table depth, aquifer characteristics, etc.)

11.9.3 Evapotranspiration Data

To accurately predict the potential and actual evapotranspiration by product line, the following data must be collected:

- Wind speed at two meters above the ground
- Maximum, minimum, and average daily temperatures
- Maximum, minimum, and average daily relative humidity
- Solar radiation

11.9.4 Crop Parameter Data

To increase the accuracy of crop characterization, the following data must be collected:

- Specific planting and harvest dates
- Calibrated crop coefficients for each plot to be analyzed using the water balance (a detailed methodology of this procedure is outline in the FAO Irrigation and Drainage Paper 56 [46])

The necessary resolution of data collection will depend on the desired spatial and temporal accuracy of the water balance.

11.9.5 Irrigation Costs

To produce a reliable estimation of the cost of irrigation, the following data must be collected:

- Pump flow rate
- Total dynamic head
- Pumping plant efficiency or specific fuel consumption
- Monthly cost of energy
- Hours of pump operation per season

If the recommended data are collected at a fine level of resolution, the water budget will be able to give a reliable, real time calculation of the required irrigation application by plot. This will maximize the efficiency of water use on Sunnyside Farms. Ideally, the weather stations would export their data to the water budget model. The model would then calculate the required irrigation application, and would export this volume to a microprocessor controlling the irrigation pipe valve and irrigation pump. If the system is constructed properly, this process can be completed for each plot on the Farm. An automated system of this type would save money on labor, as well as accurately distributing the required water to each crop.

12 CONCLUSIONS AND RECOMMENDATIONS

As demonstrated in the preceding sections, the tracking system provides useful information for Farm managers. Conclusions made from analyzing this information can help managers evaluate their practices with the goal of increasing ecological and economic efficiency in the context of sustainability. The following section summarizes the main conclusions and recommendations derived from the tracking system, and concludes with an overall comparison of Farm data to national averages.

12.1 Harvest and Yield

- There was a general increase in harvest for all product lines, with the exception of Brambles, from 2001 to 2002.
- The Tree Fruit product line is roughly 10-15% of the national average for per acre yields. Brambles are lower than the national average, but greater than regional averages for per acre yields.
- A large quantity of harvest was left unsold in 2002.
- A significant amount of revenue is lost when products are left unsold and when products are produced but not picked.
- In addition to the lost revenue, the contributing inputs are wasted, namely: labor, seed, irrigation and treatments.

12.2 Labor

Labor costs on the Farm consume roughly 14% of all operating expenses. While not much more than the national average by percent, it represents significantly more in costs because the operating expenses at Sunnyside are much higher than the national average.

Labor requirements vary seasonally. Maintenance activities comprise 40% of labor activities between mid-March and mid-August, and 14% of total labor over the same period was devoted to landscaping the Farm grounds.

As Tree Fruit and Vegetables are very labor intensive, labor expenses exceed revenues for these product lines. Labor by month and product line tracking suggest that labor allocation and planning was insufficient in the summer of 2002. For example, Brambles dominated labor hours in August, while all other product lines were left under-staffed, possibly resulting in lower harvests of Brambles and Vegetables than 2001.

12.3 Expenses and Revenues

12.3.1 Expenses

- P&L expenses increased from $1,590,701 in 2001 to $2,453,566 in 2002.

- In 2002, Whole Farm, Livestock, and Herbs/Flowers/Vegetables were associated with the highest P&L Expenses.
- In 2002, Feed Purchases were associated with the highest P&L expenses.
- Farm operational expenses are higher than the national average.

12.3.2 Revenues

- Farm revenue increased from $296,130 in 2001 to $1,306,186 in 2002.
- The highest revenue-generating product line in 2001 and 2002 was Livestock.
- In 2001, the top sales avenue was Dupont Market while in 2002, the top sales avenue was Green Circle.
- Markets constituted 25% of revenue in 2001 and 7% in 2002.

12.3.3 Net Profitability

- The net loss in 2001 was $1,294,571 and was $1,096,218 in 2002.
- In 2002, Tree Fruit lost the least amount of money by acre relative to other product lines.

12.4 Productivity

Increasing the percentage of harvest that is sold, and decreasing the difference between harvest and yield will have direct, positive effects on the profitability of Tree Fruit, but not Brambles, Poultry and Vegetables and Herbs. At 100% of sales of the current harvest, none of the product lines made a profit. With an increase in harvest of 30% and an 85% sale of harvest, only the Tree Fruit product line is profitable. Under this scenario Tree fruit generated $10,000, Brambles cost $4,000, Vegetables and Herbs cost $4,000, and Poultry cost $18,000. Since the majority of P&L costs for Poultry (egg)s are feed costs, the only way for Poultry (egg)s to become profitable is for the price to increase. Tree Fruit appears to have the greatest revenue generating potential, followed by Brambles and Vegetables and Herbs.

The product line with the lowest cull percentage was the Poultry product line at 16%. The product line with the highest cull percentage was the Tree Fruit product line with a cull percentage of 64%.

12.5 Energy

While conventional systems typically rely on inputs derived from fossil fuels, the Farm is more labor-intensive. Labor costs, therefore, are higher, but petrol-based fuels represent only 1.6% of Farm expenses, compared to the national average of 4%.

The tracking system will (eventually) allow Farm management to identify more energy-intensive areas and make decisions that would improve energy efficiency. Using less fossil fuels and energy derived from fossil fuels help to mitigate harmful environmental externalities, such as air pollutants and greenhouse gas emissions.

12.6 Nutrients

Compost is the most applied of all nutrients on the Farm, then compost tea. This is an advantage for the Farm because compost products are essentially free so long as the Farm produces Livestock.

Chickens are an important source of nitrogen inputs to the Farm. However, chicken manure is probably not being utilized as well as it could be. A significant amount of nitrogen may be lost to the atmosphere due to the way chickens are managed.

All product lines had surpluses of nutrients after harvest, except for the Vegetable product line, which approximately "broke even" in terms of nitrogen. However, this does not necessarily imply a nitrogen deficiency. Soil organic matter is increasing in Vegetable areas of the Farm, which suggests that nutrients are being applied appropriately and being retained.

12.7 Soil

Different types of loams dominant the Farm's soil types.

Based on the Revised Universal Soil Loss Equation, soil erosion on the Farm is 3.1 tones/acre/year. This is equal to the national average in 1997, but lower than the 1997 value for Virginia of 5.9 tones/acre/year.

On the Farm, slope is the largest factor contributing to soil loss from water erosion. Management practices in place are, in most cases, effective at keeping erosion values as low as possible given the slope gradient.

Soil organic matter content (4.3%)is generally higher than the value recorded in neighboring Appomattox county (1.5%). While organic matter contents have decreased in some plots, the areas used intensively for annuals – which have the greatest risk of losing organic matter – are all stable or increasing.

12.8 Water

Brambles use nearly two-thirds less water per acre relative to other product lines.

12.9 Comparison with National Averages

Table 82 Comparison with National Averages

Measure	National	State	Report Card*
Wage of hourly laborer	below	below	D
Fuel Expenses as % of Total Expenses	better	n.a.	B
Operating Expenses	above	n.a.	F
Percent of operating costs spent on labor	above	n.a.	C
Soil erosion estimate	similar	below	B
Soil organic matter content	n.a.	above	B
Nutrient Expenses	below	n.a.	B
Nutrient Inputs	similar	n.a.	C

***Grade ranges from A-F, where C = national average**

Table 82 shows a comparison summary of various data points with the national averages.

12.10 Summary of Recommendations

The following section summarizes the recommendations that were made in light of the preceding conclusions. The section is separated into product line, general management, and specific recommendations.

12.10.1 Product Line Planting Guide

Table 83 Product Line Summary

	Harvest		Expenses and Revenue*			Labor		Ecological
Product Line	Month of Peak Harvest	% of Harvest that is Sold	P&L Expenses Per Acre	Revenue Per Acre	Net Revenue Per Acre	Labor Cost Per Acre	% Labor Intensity (as % of Revenue)	Water Requirement Per Acre (1000 gal)
TFR	September	33.6%	$3,402	$1,482	-$1,920	$2,357	159	170
VEG/HRB/FLW	August	66.1%	$11,040	$9,289	-$1,751	$8,994	101	175
BER	August	77.0%	$10,576	$9,330	-$1,246	$8,571	90	55
Product Line	Month of Peak Harvest	% of Harvest that is Sold	P&L Expenses	Revenue	Net Revenue	Labor Cost	% Labor Intensity (as % of Revenue)	Water Requirement (1000 gal)
PLT	April	83.7%	$49,131	$22,913	-$26,218	$16,526	72	N/A
LVS	–	–	$1,448,946	$1,105,855	-$343,091	$33,504	3	N/A

* Uses 2002 data

Table 83 contains information related to the Farm's Harvest, Expenses and Revenues, Labor, and Ecology. The data illustrate that the Bramble product line is one of the most attractive product lines for the following reasons:

- Brambles have lower water usage compared to the other product lines;
- Brambles have lower labor expenses compared to Tree Fruit and Vegetables;
- Brambles lost the least amount of money per acre relative to other product lines.

12.10.2 General Management and Operational Recommendations

For the Harvest, Activity and Treatment logs, both the quality of the data collection process and the data themselves need to be improved. It is suggested that incentives be provided to management to ensure this. Specific issues regarding the data collection process and the data include:

- Quality of data tracking
- Accuracy level
- Collection frequency
- Lack of crucial information
- Integration of database with software (e.g. accounting software)

There are efficiency issues related to the Farm that need to be addressed in order to attain financial sustainability. These efficiency issues likely stem from:

- Waste: culls, harvest versus yield, percent of harvest sold
- Labor: allocation inefficiencies
- Expenses: very high operating costs

There is a lack of communication within Farm management, in terms of where to sell and how much to sell Farm products. There needs to be better communication with regards to these issues.

The Farm should strive to stay current with regards to sustainable agriculture technologies. Such technologies include:

- Renewable energy
- Information technology

12.10.3 Specific Recommendations

Labor

Labor allocation decisions need to be driven more by what is profitable, and need to be timed such that harvest is not forgone.

Expenses and Revenues

In order to address costs, the Farm should look at Whole Farm expenses, namely Consulting and Insurance expenses, which made up the largest proportion of Whole Farm expenses in 2001 and 2002.

Energy

The Farm can improve its energy efficiency and the impacts of usage by exploring renewable energy alternatives, such as solar and hydrogen technologies, and harnessing methane emissions.

Water

If data are collected onsite at a fine level of resolution (as outlined in 11.9), the water budget will be able to give a reliable, real time calculation of the required irrigation application by plot. This will maximize the efficiency of water use on Sunnyside Farms.

An automated system can be configured to accurately distribute the required water to each plot, enhancing the environmental sustainability of irrigation on the Farm.

Soil

Plots left bare between harvests need to be planted with cover crops or greater quantities of crop residue should be left to reduce soil erosion and loss of organic matter.

Nutrients

Any decisions about the future of Livestock production on the Farm should consider the enormous benefit that the compost provides in terms of nutrients.

Chicken manure nutrients could be better utilized if manure were trapped in absorptive bedding, like hay, and then added to compost.

12.11 Sustainability Conclusions

While long-term sustainability is an overarching goal of the Farm, this project does not explicitly address the role organic farming will play in increasing agricultural sustainability. However, observations can be made about the Farm's operations and practices with respect to sustainability. In this context, sustainability is discussed in terms of three sides of the "sustainability triangle;" economics, ecology and social sustainability.

In terms of ecological sustainability, the Farm has performed well. Generally speaking, the Farm appears to reflect many of the expected environmental benefits of smaller-scale organic farming. Namely, water usage is within the limits of the watershed, soil organic matter levels are relatively high, nutrients are retained and pesticides are environmentally benign. The Farm has a relatively low reliance on fossil fuels, and therefore lower impacts on air quality and greenhouse gas emissions. The ecological benefits of the farm are readily apparent in the abundant habitat that supports diverse flora and fauna. In addition, the variety of the planted crops creates greater biological diversity and naturally decreases pest problems and increases soil quality and nutrient cycling.[51] Given current management practices, Farm activities could continue through time while generally maintaining ecological health and integrity.

Social sustainability is on the whole positive. Laborers are provided with a safe and pleasant environment and salaried workers are compensated fairly. The Farm sets an example of social responsibility by creating a local source of organic food for the District of Columbia area by selling through local markets and businesses; and the Farm is developing and encouraging a link between people, the food they eat and the land on which it is grown. The Farm also serves as a center of education for many people interested in organic farming. Social sustainability is slightly undermined by the wages of hourly workers, which are lower than national and state averages.

In terms of economic sustainability, the Farm falls short. If 2002 operating costs are considered, no product line generated a net revenue. This is despite the fact that energy costs are low and nutrients are nearly a free byproduct of Farm activities. It must be noted that if the Farm owners are considering a longer time frame and broader definition of Farm related activities, the Farm may not be in an adverse economic state. Substantial investment has been made into the product lines, particularly Tree Fruit and Brambles, which will take several years to provide a maximum return.

Nonetheless, the major factor undermining the three areas of sustainability is the harvest loss through culls and the harvest that is not sold. The Farm is adept at converting the various inputs into bountiful produce, but until the level of lost harvest is reduced, output levels will be problematic.

APPENDICES

Weather

Table 84 Data Sources for Primary Weather Data[52,53,54]

Weather Entity	Data Source	Location of Weather Station	Years on Record (Dates)
Precipitation	National Climate Data Center (NCDC)	Washington, VA	32 years (8/1948-12/1980)
Temperature	NCDC	Washington, VA	32 years (8/1948-12/1980)
Humidity	NCDC	Lynchburg, VA	40
Wind Speed	NCDC	Lynchburg, VA	31
Solar Radiation	RReDC	Lynchburg, VA	Not Available

Table 85 Geographic Locations of Weather Stations

Location of Weather Station	Elevation (m)	Longitude	Latitude
Washington, VA	195	78.11 W	38.4 N
Lynchburg, VA	279	79.2 W	37.33 N

Summary of Primary Weather Data Precipitation

Table 86 Average Daily Precipitation by Month

Month	Average Daily Precipitation (mm)	Standard Error
January	2.00	0.20
February	1.90	0.21
March	2.70	0.24
April	2.82	0.24
May	3.11	0.28
June	3.13	0.26
July	3.40	0.37
August	3.93	0.41
September	2.88	0.33
October	2.82	0.41
November	2.68	0.34
December	2.21	0.24

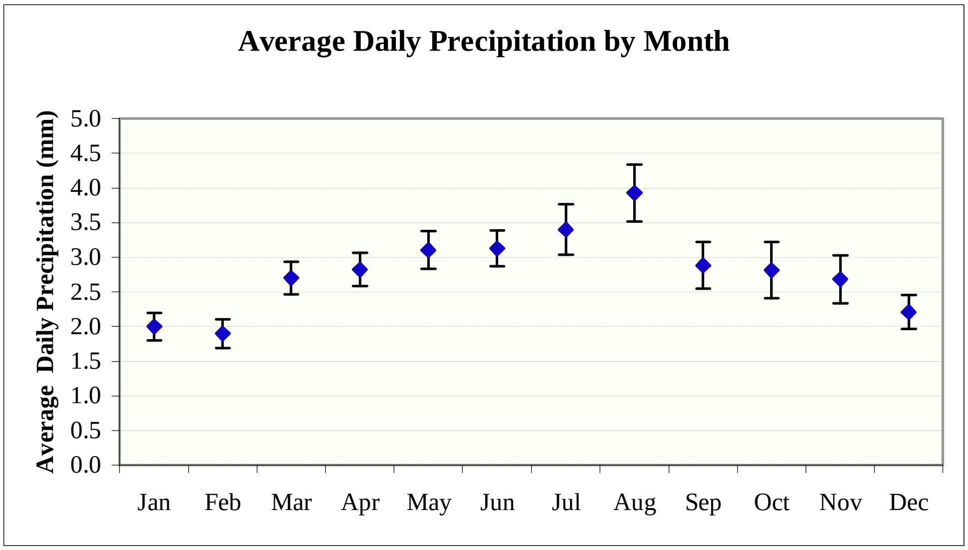


Figure 143 Average Daily Precipitation by Month with Standard Error Bars

Table 87 Average Total Monthly Precipitation

Month	Average Monthly Precipitation (mm)	Standard Error
January	67.47	7.40
February	56.28	6.59
March	86.47	7.01
April	82.62	6.38
May	97.44	7.60
June	97.54	7.19
July	107.27	9.99
August	117.12	11.28
September	104.04	13.58
October	80.62	11.09
November	81.53	9.26
December	69.58	6.71

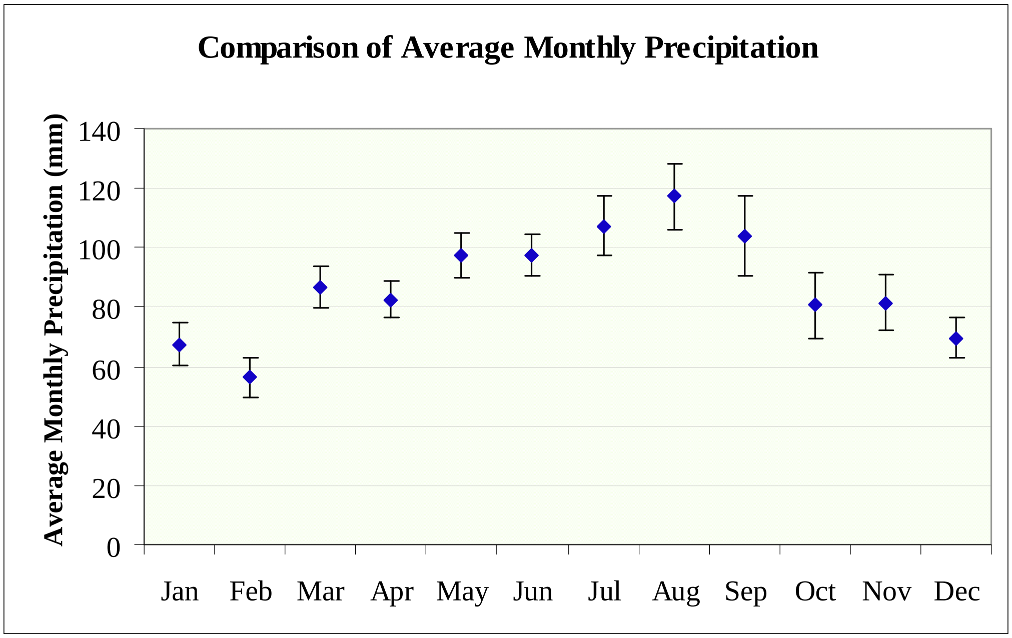


Figure 144 Average Total Monthly Precipitation with Standard Error Bars

Temperature

Table 88 Average Daily Temperature, Minimum Daily Temperature, and Maximum Daily Temperature by Month

Month	Maximum (°C)	Minimum (°C)	Average (°C)
January	5.53	-7.02	-0.75
February	7.10	-5.94	0.58
March	12.47	-1.46	5.51
April	19.00	4.27	11.64
May	23.84	8.80	16.32
June	27.93	13.31	20.62
July	30.16	15.96	23.06
August	29.48	15.36	22.42
September	26.04	11.53	18.78
October	19.99	4.73	12.36
November	14.13	0.06	7.09
December	7.79	-5.25	1.27

Table 89 Average Monthly Temperature

Month	Average Temperature (C)	Standard Error
January	-0.75	0.45
February	0.58	0.39
March	5.51	0.41
April	11.64	0.28
May	16.32	0.29
June	20.62	0.20
July	23.06	0.20
August	22.42	0.18
September	18.78	0.26
October	12.36	0.31
November	7.09	0.41
December	1.27	0.54

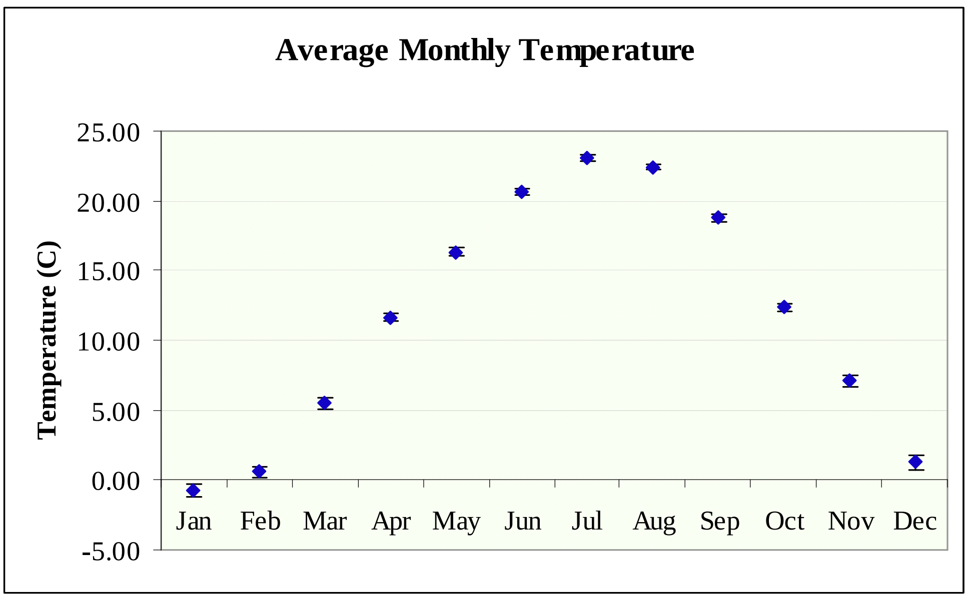


Figure 145 Average Monthly Temperature with Standard Error Bars

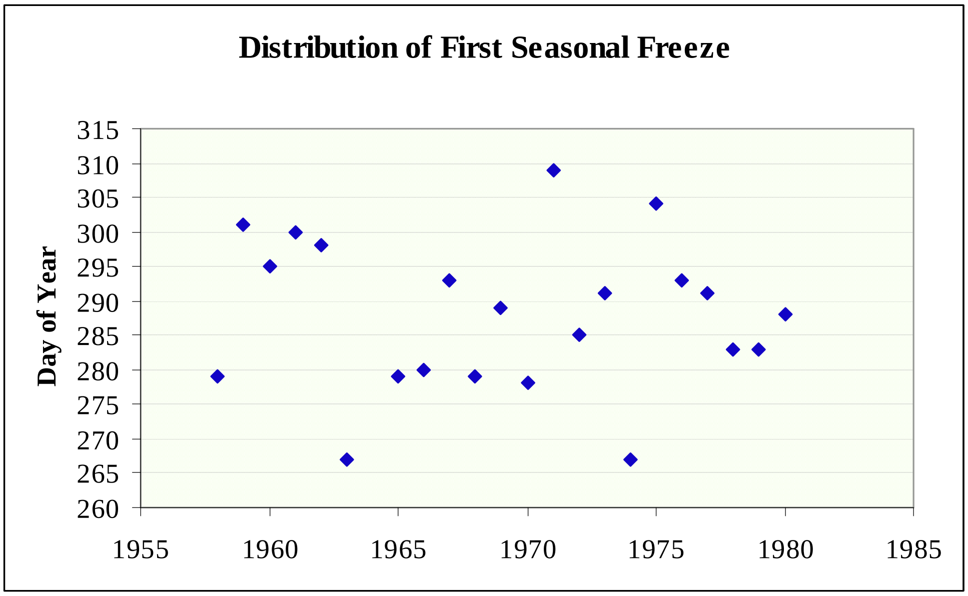


Figure 146 Distribution of the First Freeze of the Growing Season

Humidity

Table 90 Average Daily Dew Point by Month

Month	Dew Point (C)
January	-5.56
February	-4.44
March	-0.56
April	3.89
May	11.11
June	16.11
July	18.33
August	18.33
September	14.44
October	7.78
November	1.67
December	-3.33

Wind Speed

Table 91 Average Daily Wind Speed by Month

Month	Wind Speed (m/s)
January	3.6
February	4
March	4.5
April	4.5
May	4
June	3.6
July	3.6
August	2.7
September	4
October	4.5
November	3.6
December	3.6

Solar Radiation

Table 92 Average Solar Radiation by Month

Solar Radiation (MJ/m^2/day)			
Month	Slope		
	0 degrees	22 degrees	52 degrees
January	8.64	13.65	15.12
February	11.52	15.97	17.28
March	15.48	17.98	18.72
April	19.44	19.16	19.08
May	21.6	19.1	18.36
June	23.4	19.23	18
July	22.32	18.98	18
August	20.16	19.05	18.72
September	16.92	18.03	18.36
October	13.32	16.94	18
November	9.36	14.09	15.48
December	7.56	12.29	13.68

Cost-Benefit Analysis of a Photovoltaic System

In the long run, the Farm anticipates developing fuel cell technologies that will allow the Farm to generate electricity by obtaining hydrogen from methane recovery and the hydrolysis of water with solar energy. At this time, it is in the Farm's interest to analyze the first logical step in this long-term goal: solar energy. This cost-benefit analysis will see if it would be cost-effective (compared to current practices) for the Farm to make this incremental step and purchase a photovoltaic system in order to generate a portion of their electricity on site, and whether this method will reduce the environmental externalities of traditional electricity generation.

Various methods for on site renewable energy generation are currently available for purchase. Several options were researched, but given the geographic characteristics of the Farm and it's long-term goal of electricity generation by obtaining hydrogen from methane recovery and the hydrolysis of water with solar energy, a photovoltaic (PV) system was deemed to be the most feasible and in the Farm's best interest. For example, a micro-hydroelectric turbine system was examined, but given the fact winters are very cold and summers can often be dry on the Farm, the amount of running water necessary to power the turbine may often not be present on the farm and thus complicate generation. A system of this nature was determined to be incompatible with the spatial characteristics of the Farm and therefore not the most feasible option.

The cost of a photovoltaic system is highly dependent on site-specific criteria. Due to the distance between the analyst and the site, possible scenarios were assumed regarding some of the characteristics of the farm. For example, both rooftop and open field PV arrays were priced, although the rooftop modules necessitated certain infrastructure, which was not clear to the analyst if the farm possessed the appropriate infrastructure or if further construction was needed. However, this analysis is comprehensive in that a broad range of array and installation costs were analyzed in a low, middle, high approach in order for the owners of the Farm to determine, given their specific site characteristics, if the cost of the PV system they desire would be cost-effective over different time frames. PowerLight PV systems were priced due to its reputation for quality, service, price competitiveness and reliability[55].

Module and installation costs for a PowerLight PV systems ranged from $5000 per kW for non-tilting ground arrays to $10,000 per kW for rooftop arrays, once again dependent on the site. Maintenance for the modules is very minor (occasional cleaning) and the associated costs are negligible. It was determined, based on current consumption patterns, that the Farm would need seven modules in order to generate 10% of its electricity using the PV system. Therefore, the initial costs calculated to be $35,000, $49,000 and $70,000, respective of the system type. The typical life span of the PowerLight PV system is 25 years, so the costs and benefits of the system were analyzed over three time frames (20 years, 25 years, and 30 years), using several possible discount rates.

In calculating the benefits of the PV system, the cost savings of not purchasing electricity off the grid (reduction in electricity bill) were included as well as the social benefits from reduction in greenhouse gases during electricity production. To calculate the benefit to society of less carbon in the atmosphere, the amount of the reduction in metric tons per year was multiplied by $50 per metric ton[56]. This is a controversial amount as is extremely difficult to quantify all of the benefits to society from the reduction of greenhouse gases, but this amount was used, although it should be noted that it may not capture all of the benefits and will most likely increase in the future as climate change becomes a more pressing issue. In addition, due to the volatility of the electricity market, benefits were calculated based on an electricity cost of $.07 per kW and $.11 per kW to demonstrate the cost savings over different market prices. The results of the analysis are summarized in Table 93 and Table 94.

Table 93 Net Present Value for PV System (at 7.2 ¢/kWh)

Discount Rate	*Initial Cost*	*Term: 20 Years*	*Term: 25 Year*	*Term: 30 Years*
3%	$35,000	$ 4,252.73	$ 10,942.85	$16,713.80
	$49,000	-9,747.27	-3,057.15	2,713.80
	$70,000	-30,747.30	-24,057.20	-18,286.20
5%	$35,000	$ -2,119.70	$ 2,185.46	$ 5,558.67
	$49,000	-16,119.70	-11,814.50	-8,441.33
	$70,000	-27,119.70	-32,814.50	-29,441.30
7%	$35,000	$ -7048.75	$ -4,253.19	$ -2,259.99
	$49,000	-21,048.80	-18,253.20	-16,260.00
	$70,000	-42,048.80	-39,253.20	-37,260.00

Table 94 Net Present Value for PV System (at projected cost of 11 ¢/kWh)

Discount Rate	*Initial Cost*	*Term: 20 Years*	*Term: 25 Year*	*Term: 30 Years*
3%	$35,000	$ 24,944.32	$ 35,161.05	$ 43,974.10
	$49,000	1,212.74	21,161.05	29,974.10
	$70,000	-10,055.70	161.05	8,974.10
5%	$35,000	$ 15,212.74	$ 21,787.32	$26,938.68
	$49,000	1,212.74	7,787.32	12,938.68
	$70,000	-19,787.30	-13,212.70	-8,061.32
7%	$35,000	$ 7,685.40	$ 11,954.62	$ 14,998.51
	$49,000	-6,314.60	-2,045.38	998.51
	$70,000	-27,314.60	-23,045.40	-20,001.50

Table 95 Quantity of Greenhouse Gas Reductions over Time

Reductions of Carbon Equivalents (metric tons)	
20 Years	12.83
25 Years	16.04
30 Years	19.24

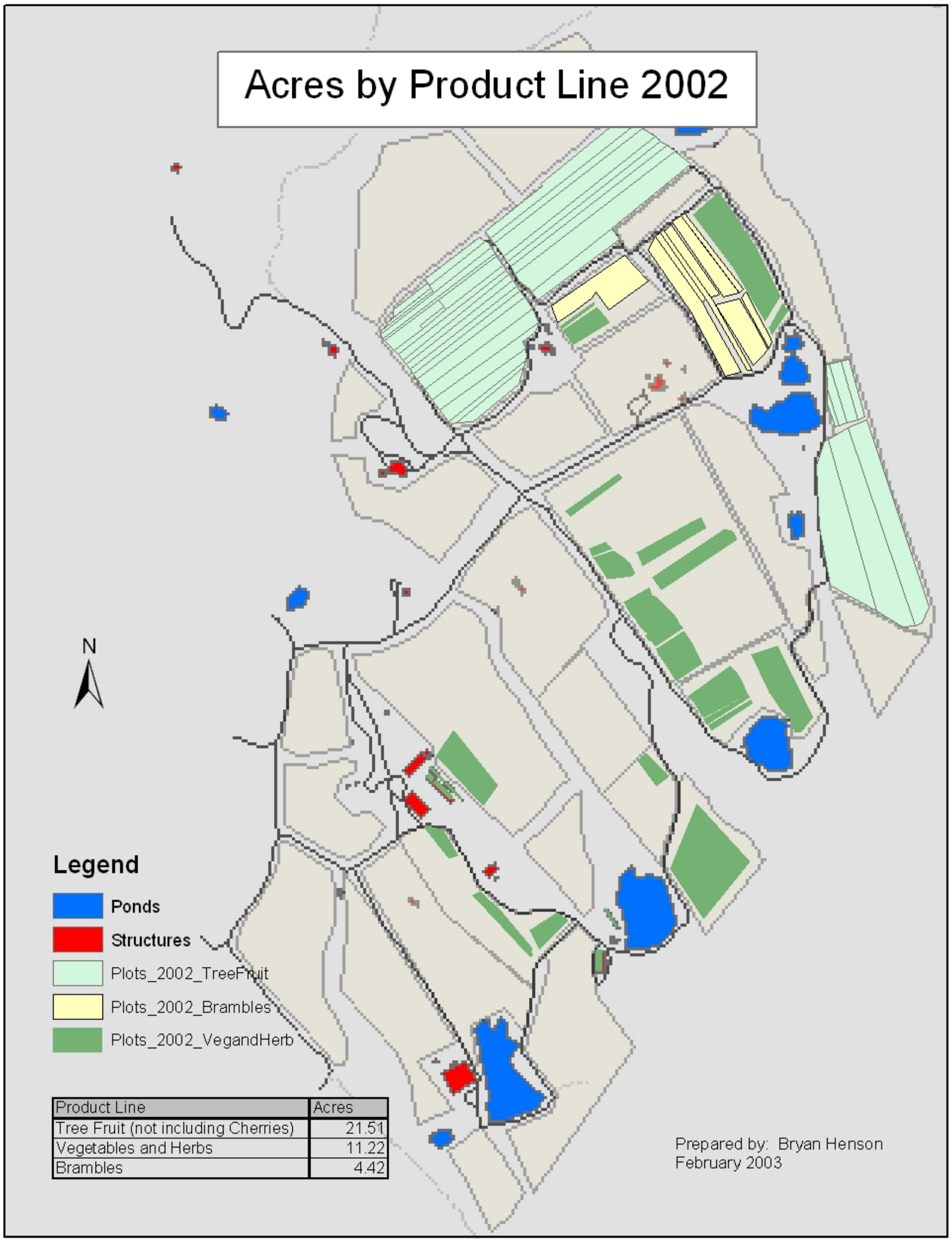
Calculating net present value (NPV), the results show in many cases, (depending on the initial cost, the proposed time frame, the discount rate used, and the cost of electricity when generated conventionally), it would be cost effective for the Farm to generate electricity on site using a PV system. Those results with a positive NPV demonstrate a savings over time for the farm. As expected, the higher the cost of conventionally generated electricity is, the more the Farm would save (Table 94). It is a fair assumption to make that the price of electricity will increase (perhaps dramatically) over the next 20-30 years, and therefore it is highly recommended that the Farm consider PV systems for its generation. Moreover, generating electricity with a PV system is renewable, cleaner, and would result in a dramatic decrease in greenhouse gases over the proposed time frames (Table 95). The reductions of carbon equivalence were dramatic and will have a beneficial impact to society.

In addition, there are other benefits and cost reductions to the Farm that were not included in this analysis that could have significant impact on the cost benefit analysis. First, state and federal programs are available that can subsidize the cost of renewable energy generation and can be explored upon purchase. For instance, Title IX of the 2002 Farm Bill allocates funds for grants and low interest loans for the purchase of renewable energy systems used for agricultural purchases. The Department of Energy has similar programs that can provide tax credits for the installation of renewable systems. Given the Farm's long-term vision, their desire for sustainable systems and the cost-effectiveness presented in this analysis, I would recommend to the Farm that they consider the PV system as a method of clean and renewable on-site electricity generation for the Farm.

GIS/DBMS

Table 96 Primary Database Tables and their Function

	Table Name	Table type	Purpose
Labor	Activity	Hierarchy	Activity log architecture
	Activity Log	Data Entry	Input format based on paper Activity logs
	ActivityLogbyDate	Query Base Table	Track labor allocation by products and activity
Products	CV	Hierarchy	Provide names of varieties, crops and products based on their ProductID's ase table for the CVlist
	Products2002	Hierarchy	Product hierarchy
Employee	Employees	Query Base Table	Source of employee names and ID's
	Harvest-Employee	Query Base Table	Source of employees that participated in a given harvest event
	PayrollHourly	Query Base Table	Source of payroll information for hourly employees
	PayrollSalary	Query Base Table	Source of payroll information for salary employees
Financial	Revenue	Data Entry	Source of revenue data based on the sales accounting information
	Electricity inputs	Data Entry	Input format based on electricity bills
	Expense	Data Entry	Source of expense data from the general ledger
	ExpenseCat	Hierarchy	Expense table architecture
Harvest	EggHaravestLog	Data Entry	Input format based on paper egg Harvest logs
	MasterHarvest	Query Base Table	Source of harvest data
	MasterHarvestDataEntry	Data Entry	Input format based on Harvest logs
Envnmt	Petrolium inputs	Query Base Table	Source of fossil fuel inputs based on fuel bills
	Treatmentlog	Query Base Table	Source of treatment applications
	FuelDepotLog	Query Base Table	Source of fuel use by vehicle
Weather	Precipitation	Query Base Table	Source of precipitation data
	RawWeatherSperryville	Query Base Table	Source of temperature and precipitation data
	RawWeatherWashington	Query Base Table	Source of temperature and precipitation data
	Temperature	Query Base Table	Source of temperature data
Support	Plots_2002	Query Base Table	Source of acreage of the plots and blocks
	UnitConversion	Query Base Table	Source of conversion rates used in converting units to pounds
	Units	Data Entry Constraint	The type of units that can be entered into various data tables



Product Line	Acres
Tree Fruit (not including Cherries)	21.51
Vegetables and Herbs	11.22
Brambles	4.42

Figure 147 Acres by Product Line for 2002

Harvest

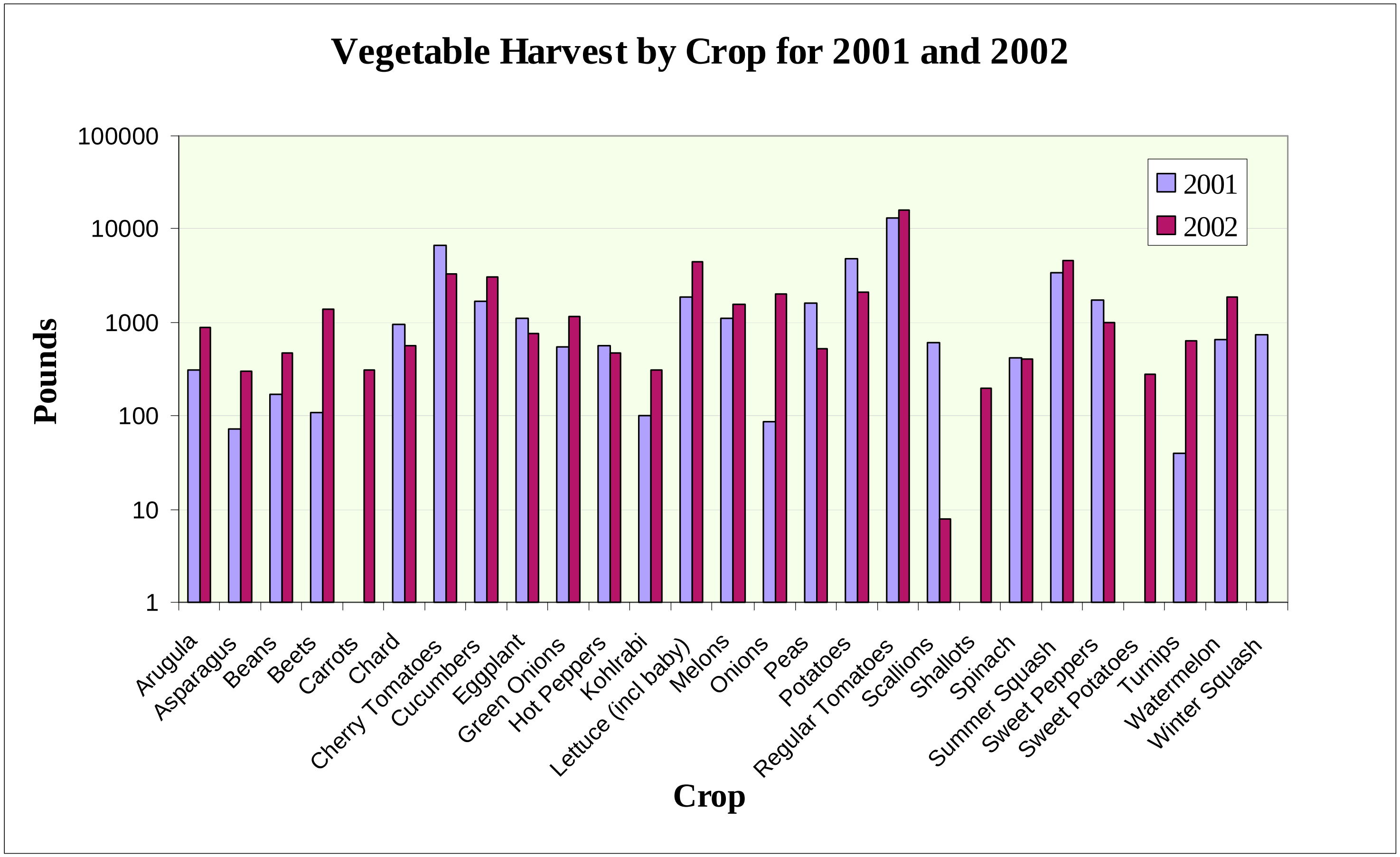


Figure 148 Vegetable Harvest by Crop for 2001 and 2002

Units have been converted to pounds.

Labor

Table 97 Activity Log Activity Category Subsets

Activity Category	Subset	Activity Category	Subset
Administration	Meeting	**Maintenance**	Horses
	Paperwork		Observation
	Touring		Chickens
Capital Expense	Building		Closing
Market	Bunching		Cutting
	Cleaning		Feed Dogs
	Delivery		Repair
	Loading		Installing
	Moving		Landscaping
	Packing		Livestock
	Set Up		Cleaning
	Unloading		Digging
	Washing		Mowing
Planting	Bed Preparation		Preparing
	Preparing		Set Up
	Seeding		Tractor
	Transplanting		Mulching
Treatment	Applying		Washing
	Cultivating		Opening
	Fertilizing		Painting
	Hoeing		Removing
	Irrigation		Sort produce
	Thinning		Stacking
	Preparing		Stump Removal
	Training	**Harvest**	Digging
	Turning		Harvesting
	Watering		Packing
	Weeding		Picking
			Tractor Work

Nutrients

Table 98 Brands and Characteristics of All Soil Amendments Used at Sunnyside in 2001 and 2002

Generic Material	Brand	Treatment Type	Characteristics and Soil Benefits
Fish/Kelp Emulsion	Neptune's Harvest	Soil Amendment	A source of naturally chelated trace elements. Can increase health of both soil and plants
Boronate		Soil Amendment	Boronate can help reduce slowed growth, pale green leaf tips and bronze tint due to boron deficiency.
Colloidal	Lanfosco	Soil Amendment	Like phosphate rock, colloidal rock phosphate gives up its nutrient slowly enough to last for years without leaching or fixing. Unlike other phosphates, it contains colloidal clay that can bind sandy soils and add to their nutrient holding capacity. Most brands are about 10% phosphorus, 24% calcium, 26% silica and a rich load of trace elements[57].
Compost Tea		Soil Amendment	See report section 7.3.3
Dolomite Lime		Soil Amendment	Applied to correct molybdenum deficiencies in acidic soils.
Dolomitic High Magnesium		Soil Amendment	Used to correct magnesium deficiencies in acidic soils , symptoms of which are reddish-brown leaves, yellow striping on leaves.
0-0-5		Soil Amendment	A naturally occurring iron-potassium silicate (also known as glauconite) with the consistency of sand but 10 times the moisture absorption. Used where soil tests show an immediate need for potassium. 5 % potassium.
Gypsum	Fertrell	Soil Amendment	A naturally occurring calcium sulfate, providing calcium to soils without affecting the pH (acidity) level. Provides calcium. Lightens heavily compacted soils
Corn Gluten Meal		Soil Amendment	Corn gluten meal is an all-natural plant product – rich in nitrogen – consisting entirely of a dried protein separated from corn during the manufacture of starch for the food industry. In fact, corn gluten is an ingredient in many feed products.
High Calcium Lime		Soil Amendment	Used to correct calcium deficiencies in acidic soils , symptoms of which are reddish-brown leaves, curling and dying leaves.
High Magnesium Lime		Soil Amendment	Used to correct magnesium deficiencies in acidic soils , symptoms of which are reddish-brown leaves, yellow striping on leaves.
Sulphate of Potash	Royster Clark	Soil Amendment	A natural potash mineral that contains 51% soluble potash. Potassium is second only to nitrogen in terms of the abundance needed by plants. Many crops use as much as 250 lbs of potash per acre per year
Planters II		Soil Amendment	The mineral mixture is a highly metamorphosed fresh water evaporate of the Mississippian-Pennsylvanian geologic transition period containing trace amounts of iron, boron, sulfur, calcium, cobalt, magnesium and molybdenum.
Rock Phosphate	Fertrell	Soil Amendment	An excellent natural source of phosphorus, calcium and many essential trace elements. It contains over 30% total phosphate (3-8% available) and 48% calcium (as CaO). Builds phosphate fertility where levels are low. Increases rooting activity in transplants and sprouting seeds. Also mineralizes the soil and improves quality of crops and soil structure. Its slow release allows plants to use it before it is fixed
0-0-6		Soil Amendment	A naturally-occurring iron-potassium silicate (also known as glauconite) with the consistency of sand but 10 times the moisture absorption. Used where soil tests show an immediate need for potassium. 6% potassium.
Compost		Soil Amendment	See the Compost section for more detail
Zinc Sulfate	Frit Industries	Soil Amendment	Small and yellow leaves are symptoms of zinc deficiency, zinc sulfate is used to address this.

Soil

Table 99 Soil types and slopes found on Sunnyside Farms

Information is sourced from a soil analysis performed in 1996 after the Farm was purchased. This information formed the basis of some general crop placements.

Soil ID	Soil Classifications	Classification Definition
BLM	Belvior Loam	A loam topsoil with silt clay loam subsoil with good tilth. Drainage is moderate to poor; fertility and organic matter content tends from medium to low. This is some of the flattest land on the Farm, which suggests vegetable and herb crops for annual cultivation. However, its characteristics make it more suitable to pasture, hay, corn or small grains, but not alfalfa.
CLM	Chester Loam	Subsoil is a friable silty clay loam, so that even where eroded such as here at Sunnyside, it is still well drained and of good tilth. Tends naturally to be fairly high in fertility, medium in organic matter, and highly acid. Suitable for all crops common to the area, but needs erosion care.
DLM	Dyke loam	This soil is among the best in the county. Deep, well drained soil, with a clay subsoil. High in organic matter and fertility, medium to slightly acid. Good tilth except where there is little surface soil left due to erosion. Best suited to orchards, pasture or, where gently sloping, alfalfa.
EBE	Eubanks-Brandywine	Generally high in fertility and organic matter, and well drained. Those found at Sunnyside are eroded, with little of the original topsoil. Excessively drained, very shallow and stony, though still with good fertility. Recommended for hay or pasture only.
ELD	Eubanks-Lloyd	Generally high in fertility and organic matter, and well drained. Those found at Sunnyside are eroded, with little of the original topsoil. Sandy clay loam with which may be difficult to cultivate and hard to conserve. Recommended for hay or pasture only.
ESP	Eroded sloping	
GSP	Gently sloping	
MLD	Pockets of made land	
MSP	Moderately steep	
SER	Severely eroded sloping	
SLA	Stony local alluvial land	This is a loam with a clay loam subsoil. It is deep, well drained, but stony and poor tilth, with either outcroppings of rock or stones mixed in the soil. Moderately high in organic matter and fertility, medium to strongly acid. Suitable for pasture, apples and forest.
STE	Subject to erosion	
UKN	Unknown	
ULM	Unison Loam	Among the most productive soils in the county, Unison features a loam topsoil with sandy clay loam subsoil. Generally deep, well drained, although the fields on the upper side of the current mail drive have lost topsoil over the years due to erosion. This soil is naturally moderately high in organic matter and fertility, and tends to be of medium acidity. Suitable for crops including corn, alfalfa, hay, grains, and fruit. Steeper slopes must be carefully managed to conserve topsoil when cropping, or put into permanent hay, pasture or fruit.

Table 100 Change in soil organic matter content over time

Only blocks with two or more values of S.O.M. are shown.

Block ID	Percent Change of SOM over t	SOM % 8/2002	Time Frame
P4	-1.51	4.8	6/99-8/02
T1	-1.2	3.2	6/99-8/02
Cemetery	-0.90	4.7	8/02-8/02
M2	-0.6	2	6/96-8/02
SSM-poor	-0.5	2.6	12/01-8/02
M1	-0.3	3.4	6/96-8/02
SSM	-0.25	3	12/01-8/02
HB	-0.2	2.7	3/99-8/02
O99	-0.2	3.6	3/99-8/02
B4	0	4.3	6/96-8/02
H2-N	0.06	3.7	9/99-8/02
H1	0.38	5.2	9/99-8/02
H2-S	0.38	4.3	9/99-8/02
B2	0.4	4.7	8/02-8/02
O98	0.5	3.4	3/99-8/02
Rambo	0.5	4.9	8/02-8/02
M3	0.7	3.3	3/99-8/02
P8	1.67	3.9	12/01-8/02
VB	2.7	5.1	12/01-8/02

Table 101 Input Values for RUSLE

	Segment Number	A	B	C	D	E	F	G
R	slope gradient %	13	11.4	26.1	10	7.36	8.93	9.18
	overall equivalent slope steepness	13.4	11.4	26.1		7.05	8.93	9.18
K	% rock cover	10	5	10	2	2	2	2
	# yrs. to consolidate	7	7	7	7	7	7	7
	Runoff potential	Mod. low	Mod. low	Mod. high	Mod. Low	Mod. low	Mod. low	Mod. low
	soil series	Unison Loam	ELD	Unison loam	Unisom loam	Unisom loam	Unisom loam	Unison loam
	surface texture	Silt loam	Sandy clay loam	Loam	Loam	Loam	Loam	Loam
LS	# of segments	3	2	1	1	3	3	3
	soil texture	Silt loam	Sandy clay loam	Loam	loam	Loam	Loam	Loam
	general land use	No till cropping	No till cropping	No till cropping	No till cropping	Reg. Tilled crop land	Pasture	Pasture
	gradient(%) of segments	16,14,11	11.5,11.4	26.1	10	10,6.3,6.3	7.8,7.8,9.9	8.5,8.6,9.9
	length of segment	300 ft	300 ft	300 ft	300 ft	300 ft	300 ft	300 ft
C	plant comm. Code	Orchard-cover full	Orchard-full cover	Orchard-full cover	Orchard-full cover	Tomato	Brome-grass	Orchard-full cover
	effective root mass (lb/ac) in top 4"	500	500	500	500		3900	500
	% canopy cover	50	50	50	50		100	50
	avg. fall height	5 ft	5	5	2		0.1	5
	roughness (in) for field	1	1	1	1		1	1
	mechanical disturbance	None	None	None	None		None	None
	total % ground cover	14.5	14.5	14.5	14.5		14.5	14.5
	% surface covered by rock fragment	10	5	10	2		2	2
	% vegetative residue surface cover	5	10	5	12.755		12.755	12.755
	surface cover function; B-value choice	1	1	1	1		1	1
P	Contoured			12 ft terraces				

Table 102 RUSLE Input Values for Factor C, Segment E

Date	Field Operation	Residue Added (lb/Acre)
3/1	Add manure	40
4/15	Begin growth	
9/20	Harvest	1287

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