Fall 1998

Energy requirements for certified organic farms in New Jersey : a survey and analysis of tomato production

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ABSTRACT

ENERGY REQUIREMENTS FOR CERTIFIED ORGANIC FARMS IN NEW JERSEY: A SURVEY AND ANALYSIS OF TOMATO PRODUCTION

by
Cecilia Kelnhofer-Feeley

The focus of this thesis is to document the fossil fuel and electrical energy consumption required to grow certified organic tomatoes in the State of New Jersey. First, in order to evaluate the energy requirement for agriculture, a literature review of energy changes during the twentieth century is discussed. Secondly, an in-depth look at energy requirements for all farming types is evaluated. Third, previous studies of the energy requirements in agriculture are examined; this includes both analyzing organic and conventional farming practices. A survey was generated from the information gathered. The survey was conducted via face-to-face interviews. When all the necessary data was gathered through the surveys, the results were codified and analyzed. The method used to analyze the data is statistical analysis concluding with a discussion of the results. After gathering, documenting, and codifying the information, conclusions were drawn from the analysis, including the lack of correlation between energy use and tomato yields for organic farmers. The conclusion leads to policy recommendations for farmers regarding both agricultural and environmental policies.

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FOR CERTIFIED ORGANIC FARMS IN NEW JERSEY:
A SURVEY AND ANALYSIS OF TOMATO PRODUCTION

by
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A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Masters of Science

Department of Environmental Policy Studies, College of Science and Liberal Arts

January 1998

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APPROVAL PAGE

ENERGY REQUIREMENTS FOR CERTIFIED ORGANIC FARMS IN NEW JERSEY: A SURVEY AND ANALYSIS OF TOMATO PRODUCTION

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To my family

ACKNOWLEDGEMENT

I would like to express my appreciation to Dr. John Opie, Dr. Michael W. Hamm, Dr. Patrick Beaton, and Dr. Norbert Elliot who not only served as my research committee, providing valuable guidance and insight, but also gave me advice and motivation.

Also deserving recognition for their financial support are Dr. Lazar Spasovic and the Institute for Transportation. In addition, I wish to thank Michael Feeley for his encouragement and support over the years.

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CHAPTER 1

INTRODUCTION

The focus of this thesis is to document the fossil fuel and electrical energy consumption required to grow certified organic tomatoes in the State of New Jersey. The problem involved the wide range that exists for the energy requirements by New Jersey's organic farmers. This data for this range was collected, documented, and codified in order to analyze the actual fossil fuel and electrical energy requirements of the farmers.

In order to provide documentation for this problem, several things were done. First, previous studies of the energy requirements in agriculture are examined. Second, an in-depth look at energy requirements for all farming types is evaluated. Third, in order to evaluate the energy requirement for agriculture, an overview of energy changes during the twentieth century is discussed. These three steps all include both analyzing organic and conventional farming practices. After the literature review of the fossil fuel and electric energy requirements in agriculture has been fully understood, then lastly a method for analyzing the thesis can be developed.

The chosen method utilized to explore the *problem statement* is a face-to-face interview survey. Before completing the interview, the instrument used to gather data, i.e. the survey, must be understood. After understanding how to use the survey, the actual survey was constructed. A synopsis of the survey is presented. (Note: The actual survey instrument is located in Appendix A.) After the synopsis of the instrument, an analysis of the survey group is discussed, in this case New Jersey's certified organic tomato farmers. The survey and the farmers leads us to the actual interviews where the data was gathered.

When all the necessary data was gathered, the results were codified and analyzed. The method used to analyze the data is statistical analysis concluding with a discussion of the results.

After gathering, documenting, and codifying the information, conclusion were drawn from the analysis. The conclusion led to policy recommendations for farmers regarding both agricultural and environmental policies.

CHAPTER 2

LITERATURE SURVEY AND PROBLEM STATEMENT

The literature survey and problem statement chapter involves establishing energy requirements for agricultural production. The chapter is broken up into three sections. The first section analyzes the twentieth century reliance on fossil fuels and electricity for commercial farm production in the US. The second section involves examining published studies which illustrate the present-day requirements of energy usage in agriculture. In the first two sections both conventional and organic farm studies are presented. The third section states and explains the objective of this thesis.

2.1 Issues Involving Agriculture and Energy in the Twentieth Century

Numerous studies have been implemented to understand the energy requirements for United States' food production. Studies concentrate on themes as general and comprehensive as evaluating all energy used in the twentieth century in US agriculture to as specific as the growth of pesticides used in corn farming in the US. The common thread for all the studies is to illustrate a growth curve in the amount of energy consumed for agricultural processes in the US during the twentieth century.

One of the most comprehensive energy consumption reports, by Cutler Cleveland, evaluated the entire quantity of fossil fuels and electricity used in agriculture in the United States from 1910-1990 (1995). The study illustrates how "direct and indirect use of fossil fuels and electricity increased more than sixfold from 1910-1978, reaching a peak of about 5% of national energy use in 1978."(Cleveland, 1995) Energy use did decline from 1978 through 1990. Cleveland's study reveals the growing dependence on non-renewable energy sources in the agricultural sector. Furthermore, Cleveland illustrates that as the energy-intensity of agriculture rose, so did the agriculture quantities produced. However, during the 1980's there was a slight downturn in the amount of energy consumed in farming practices. This downturn is attributed to an increase in farm size and an increase in fuel prices. (Cleveland, 119)

Another major study was conduction by the National Research Council (NRC). The NRC documented the scientific and technological changes that occurred in agriculture after World War I. First animal and human labor was replaced by tractors and machinery. Secondly, in the late 1950's fertilizers and pesticides were applied due to their high-yield effectiveness and their ability to allow for continuous cropping. These changes in the twentieth century have revolutionized the demographics of agriculture. In 1940 direct farming employed 17% of the labor force, by 1986 only 2%. (NRC 1988) New fields such as chemical production, food processing, machinery manufacturing, and transportation replaced small, localized farmers.

A study titled "Energy and Agriculture" (L.W. Faidley 1992) depicts the dramatic growing consumption levels of energy by geographical region. Faidley charts North America's steady rise in commercial energy use in agriculture between 1972 to 1982. In 1972, North Americans consumed 67,693 million kilogram oil equivalent (hereafter kg OE) or 3.9% of the total commercial energy used. Although the total dropped to 66,161 million kg OE, the percentage of the total commercial energy rose to 4.0%. The level of energy consumed per agricultural worker rose substantially, from 18,929 in 1972 to 25,744 in 1982. Faidley divided the energy consumption levels into four categories: farm machinery, pump irrigation, mineral fertilizer, and chemical pesticides. Figure 1 illustrates the 10 year changes in these four categories. In North America, the only category which had a decrease over the time span was farm machinery. Farm machinery decreased from 48,853 million kg OE or 71.9% of the total in 1972 to 44,212 million kg OE or 66.8.

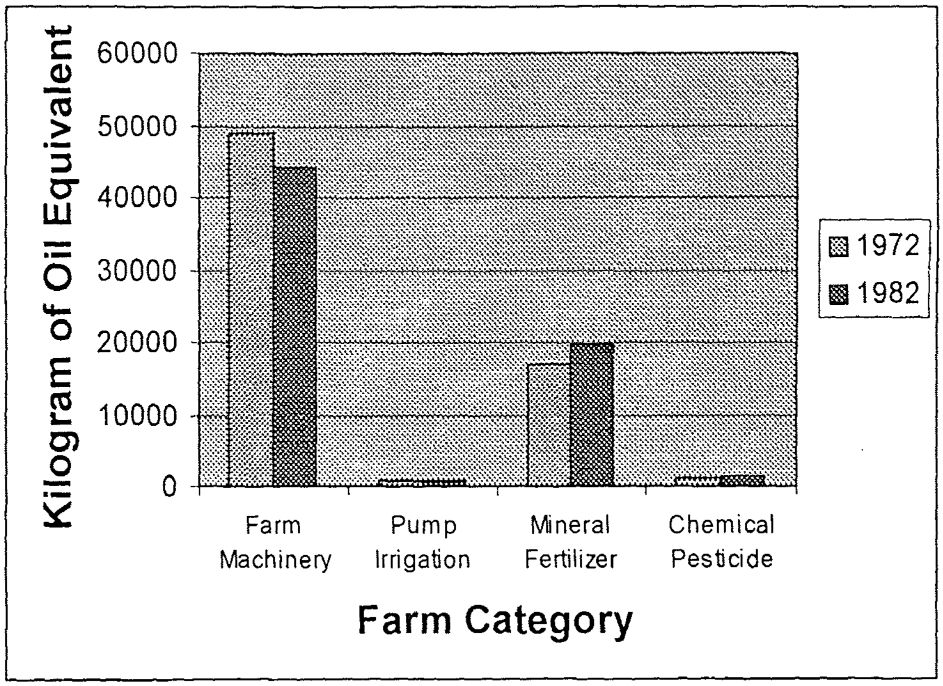


Figure 1 – 10 Year Change of Energy Consumption Levels in North America
Source: Faidley, 1992

While Faidley's goal was to depict North America's decrease in commercial energy use in agriculture, the tables illustrate the decline was only limited to farm machinery. (Note, Faidley's information is energy used only on the farm, the 4.0% does not include transportation, processing, or preparation.)

A study titled "Limitations of the Energy Approach in Defining Priorities in Agriculture," (S.B. Hill and J.A. Ramsey, 1976) lists six of the most important issues that have been revealed from previous agricultural energy studies. First is that "energy requirements within the food system are small relative to other sectors of the economy."

This is described by the small percentage of the total commercial energy requirements (as described above, in 1982 only 4.0% of commercial energy went directly into farming practices). Secondly is that "in terms of energy conversions our food system is inefficient." This is illustrated by the ratio of calories of energy needed to return one calorie of food. Third, "there is a large variation in energy conversion efficiency between different crop and livestock systems." Fourth, "most of the energy consumed within the food chain is used for processing, packaging and preparation." While energy used on the farm may be conservative, it constitutes only 20% of the total energy requirements in the food system. Fifth, "our dependence on fossil fuels is relatively recent." Cutler Cleveland's study on the increasing demand for fossil fuels and electricity is one of the many studies that support this fact. Lastly, "progress in agriculture has been largely energy addictive." This can be illustrated by the new farming technologies that generally rely on fossil fuels to be productive (i.e. irrigation, fertilizers, pesticides, etc.) (Endahl 1989)

2.2 Previous Studies on Agricultural Energy Requirements

Investigations have been done to explore the areas where energy requirements increased significantly for agricultural practices. Energy requirements have increased most in the areas of irrigation, synthetic fertilizers, synthetic pesticides, electricity and machinery (Schroll, 1994; Pimental, 1992; Smil, 1992).

The concept of analyzing energy is used for a product was originated in the 1920s. The original concept was developed to understand the amount of wealth that was utilized for a specific gain. While F. Soddy further developed the concept to track more than the mere raw materials that went into production, the original concept evolved into an ecological understanding for all environmental consequences of producing an output. In the 1960's H.T. Odum applied the concept of energy analysis to agriculture. Odum's study concentrated on the analyzing six agricultural systems including a hunter-gatherer society from a rain forest, a rice and cattle cultivators from a Monsoon region, to industrialized corn production in the North America. (1971)

Other studies have been done to define the actual areas where energy usage is the most efficient (Bowers, 1992; Sloggett, 1992). These studies evaluated the energy usage variations among several different farming techniques. For instance, one study examined how field spraying fertilizers is more energy efficient (approximately eight times more efficient) than the practice of spread fertilizing (Bowers, 1992). However, that data showed that depending on the application of the farming technique, the most efficient may not necessarily be the most practical for all applications.

Studies involving European agricultural energy requirements have documented the averages for various crops. Figure 2 illustrates the on-farm energy requirements. One finding that came out of the data was the identification of energy intensive agriculture. When knowing the energy intensive areas by crop, these energy required can be reduced to more efficient farming levels. For instance, reducing energy requirements for tillage and harvesting could lower the total direct energy requirements.

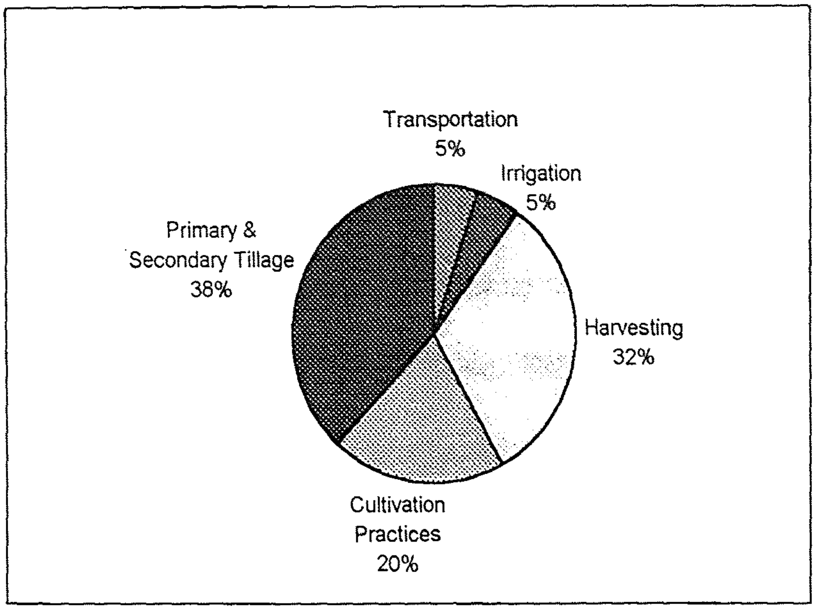


Figure 2 - Agricultural Direct Energy Requirements
Note: The percentages indicate the relationship each agriculture practice has to the total amount of direct energy requirements.
Source: Pellizzi et al, 1988

Several reports indicate the reduced energy requirements of organic farming methods (Goering, 1993; National Research Council, 1989; USDA, 1980). The Pimental, Berardi and Fast study (1983) illustrated the energy efficiency of organic farming technologies as compared to conventional methods. The study focused on four crops: corn, wheat, potatoes, and apples. The study concluded that for corn and wheat, organic farming was more efficient, but for potatoes and corn conventional farming techniques were more efficient.

These are examples of agricultural energy studies that occurred throughout the United States. The focus of this thesis is the State of New Jersey. New Jersey is in a unique position with its North-east US location. Although New Jersey is not primarily an agricultural state, in 1996 New Jersey was listed as the eighth largest tomato producing state by the US Dept. of Agriculture. (James, 1997) Historically, New Jersey has been among the top tomato producing states in the US. (Gould, 1983) Additionally, the "Jersey Tomato" is considered one of the finest.

In a study titled "Production Costs and Relative Profitability of Organically Grown Vegetables," Dhillon and Palladino study the economic aspects of organic tomatoes, as well as five other vegetable crops. This study illustrates the economic benefits of growing organic food in the "Garden State" (Dhillon, 1981), focusing on the economic conditions of organic versus conventional farming in New Jersey. While Dhillon and Palladino studied the economics of organic tomatoes, the energy requirements (which have the possibility to affect the costs of tomatoes) were not studied in detail. This thesis will study and illustrate the energy required and distribution for organic tomato farmers in New Jersey. This thesis in combination with the fore-mentioned study will allow for a greater understanding of agricultural energy requirements.

2.3 The Objective of the Thesis

Many organic farming studies concentrate on the environmental issues. For the most part, organic farming is considered environmentally friendly (Goering, 1993; USDA, 1980). In order to qualify something as environmental friendly, the energy impact of that good must be evaluated. In this case, the full documentation of a crop's life-cycle analysis for organic farming must be evaluated for the accurate energy requirements and the range of energy used by organic farmers. This has not been analyzed for organic tomatoes grown in New Jersey.

Several reports indicate the reduced energy requirements of organic farming methods (Goering, 1993; National Research Council, 1989; USDA, 1980). In 1980 the United States Department of Agriculture published its *Report and Recommendations on Organic Farming*. In the report, Secretary Bergland states "energy shortages, food safety and environmental concerns have contributed to the demand for more comprehensive information on organic farming technologies" (p. iii). Thus, organic farming became linked to a low energy, environmentally friendly farming practice.

A small portion of the tomatoes grown in New Jersey are organic. The actual energy requirements for organic farming must be evaluated to understand the full potential of the energy savings of organic farming. For some crops, the energy required for organic production may be very energy intensive. However, this study suggests the amount of energy used in growing organic tomatoes may vary greatly from farmer to farmer.

As illustrated earlier in this chapter, there are many comprehensive studies depicting the fossil fuels and energy requirements for farming. There are also several comprehensive studies on the low-energy advantages for organic farming as compared to conventional farming (Temple et al, 1994, Goering, et al, 1993, Stanhill, 1989; Lockeretz, et al, 1976). Though, to make policy changes, one must understand numerically the benefits of organic farming. In order to ensure an energy efficient agricultural system, the entire energy requirement of the crop must be evaluated. The US Dept. of Agriculture suggests organic farming potentially has lower energy requirements than conventional farming. (USDA iii) However, the USDA did not analyze the energy consumption on a crop by crop basis. This information is needed to develop future agricultural policies involving organic farming.

This leads to the objective of this thesis. The objective is to illustrate the different fossil fuel and electrical energy requirements of certified organic tomato farmers in New Jersey. The problem statement is: Given that energy requirements are derived from both direct and indirect agricultural operations, the range of actual energy requirements for certified organic New Jersey farmers must be examined, documented, and codified in order for proper analysis to occur. Direct energy requirements as addressed in the problem statement are machinery, irrigation, and transportation required for the agricultural process. The indirect energy requirements as addressed in the problem statement are farm equipment, fertilizers, pest management, and packaging.

In order to examine, document, and codify the energy usage of farmers, a survey instrument was constructed to gather the information. Chapter 3 focuses on the survey instrument. Chapter 4 analyzes the data gathered, and chapter 5 draws conclusions from the data analysis and provides policy recommendations.

CHAPTER 3

THE SURVEY

The survey was the key instrument used in proving the objective of the thesis. In order to understand fully how the problem statement was addressed, it is essential to understand the interview-survey instrument used. This chapter is broken down into five sections. The first section details why the interview-survey technique was utilized, and an interview's strengths and weakness. The next section explains the construction of the survey. The third section explains the questions asked in the survey. A fourth section will address the study group, farmers who grow tomatoes according to the North-east Organic Farming Association of New Jersey Organic Certification as well as the organization's qualifications as to what practices are acceptable for being considered organic. The final part of Chapter 3 addresses the actual field interviewing techniques used in interviewing the farmers.

3.1 An Overview of the Interview Survey

There are three different types of surveys used to gather data from individuals. These are mail questionnaires, telephones interviews, and face-to-face interviews. Each of these survey techniques requires several steps to implemented correctly. Each approach also has its own benefits and drawbacks. The types of survey instruments must be understood in order to understand why the face-to-face interview was chosen.

Each approach has benefits and drawbacks. For instance, mail questionnaires must be meticulously written, so the questions can be understood by the participant in order to derive the answers needed. One must first examine the critical points of their study before choosing an option. In general, the benefits of the face-to-face interview are:

- When the complete population is known.
- When the control over selection of respondents within a sampling unit is needed.
- Likelihood that selected respondents will be located.
- High response for homogenous specialized samples (ministers, students, farmers).
- High per question response rate.
- For lengthy questionnaires.
- Highly complex or open-ended questions.
- Sequence of control of the questions is needed.
- The questions are tedious or boring.
  (Benefits adapted from Dillman, p. 39-78)

The general benefits that applied to the farmer's questionnaire included knowledge of the entire population, the high likelihood that respondents could be located, a high response from those being questioned, and high per question response rate. These general benefits resulted in the entire population to be included and all of the questions were addressed at the survey.

The drawbacks of the face-to-face interview are:

- Low likelihood that social desirability bias can be avoided.
- Low likelihood that interviewer distortion and subversion can be avoided.
- Low likelihood that personnel requirements can be met.
- High interview costs.
- Low insensitivity of costs to increasing geographical dispersion.
  (Drawbacks adapted from Dillman, p. 39-78)

Some of the drawing of face-to-face interviews were avoided or not as extreme as they potentially could have been. For instance, the length of the survey would have produced comparable interviewing cost for either a telephone interview or a face-to-face interview. Also, personnel requirements were able to be addressed easily due to the small population size. All of the interviews were conducted by one interviewer, thereby reducing levels of interview variance.

3.2 Steps in Constructing the Survey

In order to construct an appropriate survey instrument, a three step survey design method was utilized. The first step involved interviewing a focus group in order to understand the population and develop the questionnaire. The second step involved implementing a pilot test to sample the construction and validity of the survey. The final step in constructing the survey involved addressing issues found during the pilot test. When these issues were addressed the final survey tool was able to be distributed.

A focus group was interviewed to help develop the survey (Babbie 1995). The focus groups consisted of four organic farmers from New York and Pennsylvania. The farmers were chosen from outside the study population so as not to diminish the final survey's potential sample population. The farmer's were also chosen due to the geographical proximity to New Jersey. New York and Pennsylvania were also used due to the similar conditions of the states including terrain, growing seasons and weather patterns. The focus groups were interviewed in May and June 1996. Through their responses a survey was drafted.

After a rough survey was been completed, it was pilot tested on farmers that were in the focus group population but were not utilized. Four farmers participated in the pilot test. The farmers interviewed divulged that certain areas of the interview were not worded correctly, and other areas resulted in misinformation.

Upon completion of the pilot test, a three-tier survey took place. The first tier consisted of a mailing to the entire study population. A telephone interview was the second tier. After contact was made, a short telephone interview was conducted to the participants. Some of the mailing population were found not to qualify under the conditions, so they were removed from the survey list. The final tier of the survey process consisted of face-to-face interviews with the farmers to record the responses. The interviews occurred approximately one to two weeks after the telephone interview. The responses from the participants were then analyzed and converted into Megajoules of fossil fuels and energy required in the farmers' tomato production. However, first a critical understanding on the survey instrument is needed.

3.3 The Survey Used

The final survey questionnaire consisted of 45 questions, although some questions had several parts. The beginning of the survey involved gaining background information about including the organizational structure of the farm, farm size, tomato acreage, number of tomato varieties, yield, etc. The next section discussed seedlings and greenhouse practices. The third section of the survey discussed farm equipment. The main focus for this section involved tractors and attachments of the farm machinery used in the tomato section of the farm. The fourth section questioned fertilizers used on the farm. The fifth section involved pest management practices. The sixth section discussed irrigation practices and soil makeup of the region. The seventh section concentrated on sales and transport of the tomatoes, how were they shipped if at all. The eighth section discussed the packing and washing of the tomatoes. The final section of the questionnaire asked for miscellaneous information about the farm and farming procedures.

For a sample of the questionnaire see Appendix A. The levels of measurement to be used in the survey included nominal measurements and ratio measurements. Variables with nominal measurements include type of farm land (owned or rented) and type of farm type. The variables with ratio measurements include yield of tomatoes, and various farm operations times.

3.4 The Group Interviewed: Certified Organic Farmers in New Jersey

New Jersey is a large agricultural center and the second largest tomato producing state in the nation. Tomato growing is popular and profitable for both convention and organic farmers in New Jersey. A small portion of the tomatoes grown in New Jersey are organic.

In 1979, Rutgers University published a study on the economic benefits of growing organic vegetables in the "Garden State" (Dhillon, 1981). The demand for organic produce has been rising steadily through the 1980's. The number of New Jersey's certified organic farmers has also been rising to meet the consumers' demands (NOFA-NJ, 1995).

The basic definition of what is considered organic was enacted into federal law in 1990 to be effective in late 1996 (7 USCA 6501 et. Seq.). To be generally considered organic, synthetic pesticides and fertilizers can not have been applied on the soil within the previous three years. The foods must not contain any preservatives, synthetic hormones or colorings. Also, the food can not be irradiated.

The North-east Organic Farming Association of New Jersey (hereafter NOFA-NJ) follows the federal guidelines, but certifies farmers at a much stricter adherence level as to what can be qualified as "organic". NOFA-NJ's 1996 Certification Standards and Procedures is a 46 page document describing the requirements for certification. NOFA-NJ describes in detail their classification of substances and practices and the reporting of regulated substances and practices. The classifications include detailed lists of the following: seeds, bulbs, tubers, potting mixes, manure, compost, mulches, mineral amendments and fertilizers, plant growth regulators and hormones, weed control, insect control, nematode control, animal control, fungi control, bacteria control, virus control, disease control, and spray adjuvants. Practices that must be adhered to include soil testing and tissue analysis at least every three years, crop rotation practices, utilization of cover crops, limited usage of treated lumber, harvesting, storage, transportation, preservation, and processing methods.

3.5 The Interviewing Process

The survey was done orally, with the farmer's answering the questions face-to-face. All of the interviews took place between Aug. 31, 1996 and Oct. 9, 1996. Although 21 interviews were conducted, only 20 qualified for the analysis process. The study group consisted of all certified organic tomato farmers located in New Jersey. The 20 interviews conducted accounts for 100% of the 1996 study group. The one farmer who was omitted from the study group was unable to grow tomatoes in the season.

Of the 20 interviews, 85% were interviewed on the farms, the other 15% were interviewed at convenient locations for the farmers. Trial interviews were tested to run between 30 to 45 minutes. However, the actual interviewing process took between 55 minutes and 4 hours.

All of the farmers were met at their convenience. None of the farmers were required to travel to the interview. The interviewing process was very accommodating to the farmers. The interviews took place both on weekends and weekdays, with the hours ranging from as early as 9:00 am to as late as 8:00 pm.

Setting appointments for the interviews was also very diverse. Some farmers were able to arrange convenient appointment with one phone call, others needed more than 12 to set up convenient times and places. The range of availability of the farmers varied. Some required several weeks for planning and scheduling, others were met within hours of the call for an appointment.

CHAPTER 4

DATA ANALYSIS AND THE RESULTS

After the survey was completed, the results were coded and analyzed. This chapter is composed of two sections. The first section illustrates the numeric coding of the data as well as formulas utilized to analyze the data. The second section depicts a series of tables and charts that allow for interpretation and analysis of the survey results.

4.1 Statistical Analysis of Data

Upon completion of the surveys, the information gathered was entered in a database. Prior to entering the data, codes were given for non-numeric data. Energy usage rates for agricultural practices were utilized to allow for an understanding of the average fuel expended. For control purposes in the study, fuel type and machinery types were taken from a "composite of average fuel consumption and energy expended" per process from an existing study. (Bowers, 1992) Wendell Bowers' "Agricultural Field Equipment" was the major source for the data used to estimate average fuel expended per operation. While the data was gathered from a comprehensive source, it does not account for variations due to soil types, type and age of field equipment, field conditions, fuel type used, etc. (Bowers, 1992)

One condition of the thesis was to allow for an assumption to make the variable – soil type, type and age of equipment, field condition, and fuel type used - as constant. Using the information provided by various sources, the information for energy was held at a constant for the previously mentioned variations. The exact amounts and data sources for the energy consumption is illustrated in Table 1.

For the coding of the energy usage rates for each agricultural practice, the farm operations were divided into six classifications. The six classifications of agricultural practices are: primary tillage, secondary tillage, pest management, fertilizer application, planting and cultivation. Primary tillage is the first tillage involving plowing for crop planting. Secondary tillage involves field preparation for crop planting. Pest management involves energy related methods to reduce crop damage to various unwanted pests (including fungi, insects, and large animals). Fertilizer application involve methods which require fossil fuels or electricity in any fertilizer application. Planting encompasses the period in which the tomato crop is initially planted in the field. Cultivation involves fossil fuel and electrical based methods required eradicating weeds as well as loosening compacted soil in the tomato area. There are additional farming processes that require fossil fuel or electrical energy but were omitted from the data analysis. These additional processes include, but are not limited to, irrigation, drying and cooling (if necessary for tomatoes), transportation and storage. (Shahbazi, 1991) These processes may require additional energy, but are not included in the Table 1 or the data generated from Table 1.

Table 1 - Farm Operation Fuel Consumption Levels

Farm Operation	**Fuel Consumption(Liter/Hectare)**
Primary Tillage	
Moldboard Plow[1]	17.49
Chisel Plow -Deep[1]	10.2
Chisel Plow -Deep[1]	5.8
Powered Rotary Tiller[1]	14.97
Three Bottom Plow[4] / Double	**12.115**
Secondary Tillage	
Disc Plow[1]	6.08
Disc Till[1]	5.14
Drag Bar/Harrow[4] / Wheel Hoe[4]	**5.61**
Fertilizer Application	
Fertilizer Spreader[1]	9.82
Broadcast Spreader[1]	1.4
Drop spreader[4] / Spin Spreader[4]	**5.61**
Load Manure[4]	**5.61**
Pest Management	
Pump Spray[3]	2.0
Airblast Sprayer[2]	6.0
120 Gallon Sprayer[3]	6.0
Electric Fence[4] / York Rake[4]	**4.66**
Planting	
Water Wheel*[1]	2.81
Rotary Hoe[1]	1.96
Cultivation	
Cultivator[1]	3.93
Lawnmower[4]	**3.93**

1 Source: Bowers, Wendell. "Agricultural Field Equipment." *Energy in Farm Production*. Ed. R.C. Fluck. Elseviers: New York, 1992. p 117-129.

2 Source: Helsel, Zane R. "Energy and Alternatives for Fertilizer and Pesticide Use." *Energy in Farm Production*. Ed. R.C. Fluck. Elseviers: New York, 1992. p 177-201.

3 Source: Butler, B.J. and L.E. Bode. "Effects of Applications Methods on Energy Use." Energy in Plant Nutrition and Pest Control." Ed. Zane R. Helsel. Elseviers: New York: 1987. p 257-266.

4 Source: Data sources were not available, therefore the amount of energy represents the average of the other farm operations in the category type.

The information from Table 1 allowed for an understanding of energy expenditures by farming activity. The table allowed for an equation to be established that allowed for comparisons between farmer. The first equation utilized was:

(1) $$TE = E_i + E_s + E_f + E_m + E_p + E_c$$

Where TE = Total Energy Expended for Farming Machinery
E_i = Total Energy for Primary Tillage or Initial Tillage
E_s = Total Energy for Secondary Tillage
E_f = Total Energy for Fertilizers
E_m = Total Energy for Pest Management Practices
E_p = Total Energy for Planting
E_c = Total Energy for Cultivating

After obtaining the Total Energy Expended for Farming Machinery (TE) the data required conversion from liters per hectare to gallons per acre. The conversion of gallons per acre was generated from the following formula:

(2) $$TE_g = TE * .1067$$

Where TE_g = Total Energy Expended for Farming Machinery in Gallons per Acre. The number 0.1067 is the number to convert from liters per hectare to gallons per acre. At this point, TE_g was found for every farmer.

The next step required converting the Energy Used in Gallons per Acre to the amount of energy used in the tomato acreage of the field. This was done with the following formula:

(3) $$TE_a = TE_g * A_t$$

Where A_t is the Acreage of tomatoes grown and TE_a is the Total Energy Expended for Farming Machinery in Gallons for the entire Tomato Area.

The final calculation was to convert all energy used to a uniform measurement. The unit of measurement utilized was one pound of tomatoes. This was done with the following formula:

(4) $$TE_t = TE_a / Y_t$$

Where TE_t is the Total Energy Expended for Farming Machinery by pounds of tomatoes in gallons per acre, and Y_t is the farmers total yield by pounds of tomatoes.

After all the energy utilized was converted into a standardized format, various forms of statistical analysis were able to be completed.

4.2 Date Analysis and the Results

Many observations can be made from the data gathered via the survey. A series of tables and charts were generated using Excel and SPSS software packages to analyze the data. These charts and tables will then be interpreted to understand the energy used for organic farming in New Jersey.

One use for the data is to illustrate the areas where farmers rely on energy usage in their tomato production. As illustrated in Figure 3, the tillage process is the most energy intensive farming practices used in organic tomato farming. The data allows us to infer that if certified organic tomato farmers in New Jersey are interested in reducing their energy usage, low-tillage practices could be one option. An assuming of a moderate level of variations across all types of uses (tractor type and age, soil conditions, etc), then changes in tillage practices can probably save more energy than other farming practices, such as cultivation or planting. Approximately 46% of all the energy used is for tillage practices. Figure 2 is a composite of energy use on all organic farms in New Jersey.

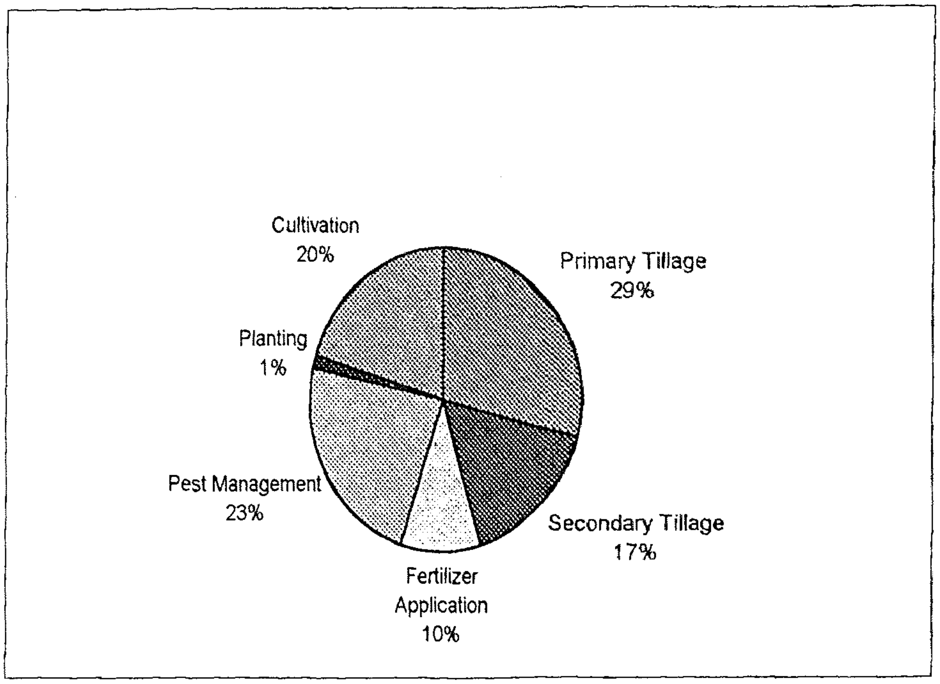


Figure 3 – Total Energy Use Analysis for Organic Tomato Farmers in New Jersey
Note: The percentages indicate the relationship each agriculture practice has to the total amount of direct energy requirements.

Figure 3 illustrates the dispersal of energy used for growing tomatoes on all the farms in the study. Figure 4 illustrates the energy requirements used on each of the farms in New Jersey. Figure 4 depicts the various energy levels used in the 1996 growing for all farmers. The data ranged from a low of 0.0 gallons per pound of tomatoes (Farmer 19) produced to a high of 0.002898 gallons per pound of tomatoes (Farmer 20).

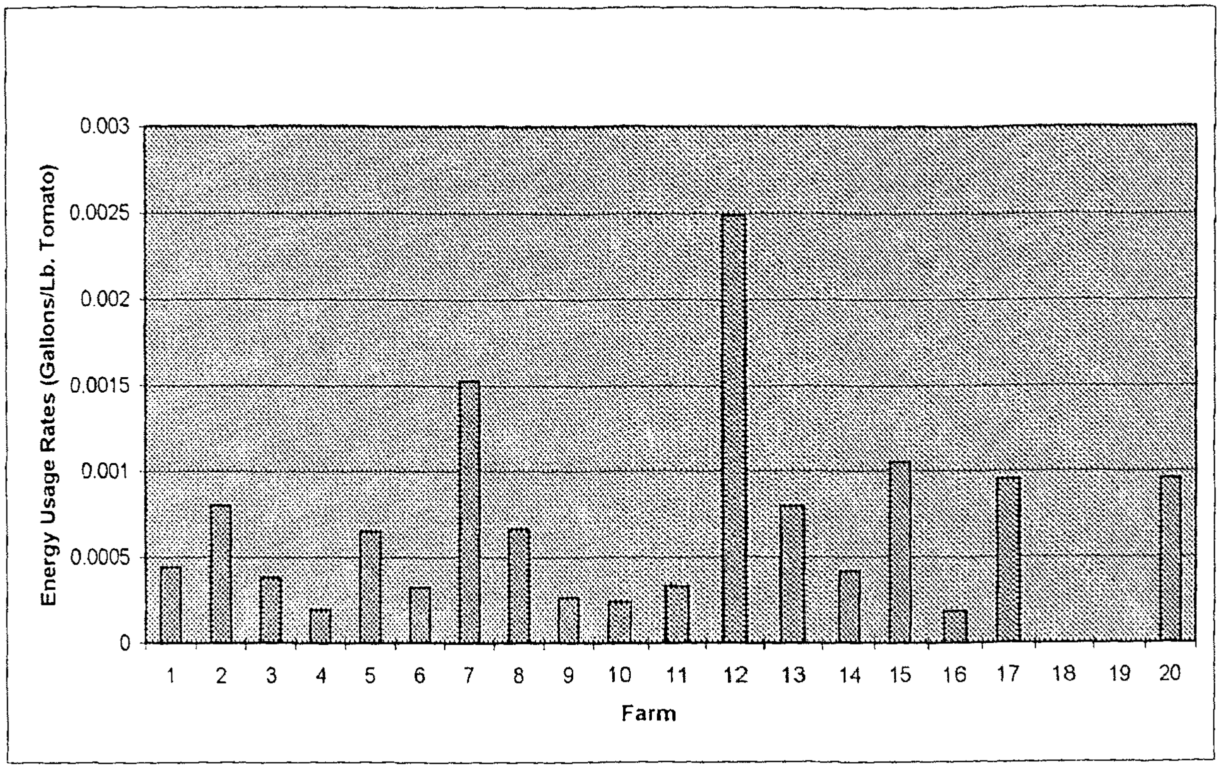


Figure 4 – Energy Rates for Certified Organic Tomato Farmers in New Jersey
Note: For Farmer 18 the data was omitted from this analysis due to abnormally low tomato yields which resulted in abnormally high energy usage rates.
For Farmer 19 there was no energy used to generate the tomato yield.

After examining the energy rates fir the tomato farmers, analyzing tractor energy used (for all practices listed in Table 1) and its relationship to other variable such as tomato yield, acres with tomatoes, numbers of fertilizers used, number of pest management practices used, and transportation distance can be done. Table 2 illustrates the negative correlation between tractor energy use and tomato yield. The correlation table is an analysis tool which illustrates the relationship between two or more data sets. The correlation table can reflect an association between various data sets, such as a positive correlation, a negative correlation or unrelated correlation (correlation near zero). The negative, yet low correlation would indicate that energy input does not have a linear influence or impact tomato yields. The surprising information revealed by Table 2 is a low, negative relationship between fossil fuel energy and yield (-0.15446). The area with the highest relationship, which still is significantly low (0.656685), is between the number of pest management practices used and the tomato yield. The correlation table indicates that no linear correlations can be found from the six variables tested. Meanwhile, there is a negative relationship between energy used and number of fertilizers and tomato yield.

Table 2 - Correlation Table for Relationships Between Energy Used and Other Variables for All Farms

	Tractor Energy	*Tomato Yield*	*Acres with Tomatoes*	*Number of Fertilizers*	*Number of Pest Management*	*Transportation Distance*
Tractor Energy	1					
Tomato Yield	-0.15446	1				
Acres with Tomatoes	0.023036	0.585259	1			
No. of Fertilizers	-0.09597	0.076545	-0.01605	1		
No. of Pest Management	0.159759	0.656685	0.448908	0.021028	1	
Transportation Distance	-0.12099	0.494918	0.485626	-0.18487	0.31025	1

As well as the energy utilization rates can reveal information about the farms, other variables can be utilized to further understand how the energy is utilized. One area where energy is used is for plastic mulch (e.g. plastic cover) on the tomato fields. As indicated in Table 3, the rates for plastic mulch were split evenly among the farmers. Fifty percent of the farmers utilized black plastic for pest management, weed management, or mulch, while the other 50% did not use it.

Table 3 – Plastic Mulch Used

	Frequency	Percent
Valid No	10	50.0
Yes	10	50.0
Total	20	100.0

The number of pest management types used were also divided evenly between the farmers. (Plastic mulch was separated from other pest management practices is due to encouraged usage by the co-op association.) The number of pest management practices is the number of methods utilized, not the number of operations for the season. The range of what farmers considered as pest management included dogs and fences for animal and rodent protection, companion planting to reduce the insects and weeds, and bleaches and sulfur sprays to reduce fungi. For a complete list of pest management practices utilized see Appendix 4. As Table 4 illustrates, pest management practices ranged fairly evenly. Twenty percent of the farmers used no pest management practices on their tomatoes, 20% use one method, 20% used two methods, 20% used 3 methods, and 20% used 4-5 methods.

Table 4 - Number of Pest Management Types Used

	Frequency	Percent
Valid 0	4	20.0
1	4	20.0
2	4	20.0
3	4	20.0
4	2	10.0
5	2	10.0
Total	20	100.0

As illustrated in Table 5, the range in number of fertilizers used varies. Almost two-thirds of the farmers use 2 or less types of fertilizers. The range of what farmers considered as fertilizers includes various types of manures and composts, blood and bone meal, and fish and seaweed emulsions. The number of fertilizers is composed of the number of methods utilized, not the number of applications per season. For a complete list of fertilizers used by Certified Organic Tomato farmers in New Jersey see Appendix 5.

Table 5 - Number of Fertilizers Types Used

	Frequency	Percent
Valid 0		10.0
1	4	20.0
2	7	35.0
3	1	5.0
4	3	15.0
5	2	10.0
6	1	5.0
Total	20	100.0

It is important to evaluate the number of pest management practices and fertilizers used in the organic farming procedures. These practices can utilize a large amount of fossil fuels or electrical energy, however as depicted in the correlation Table 2, the use does not influence the tomato yield.

CHAPTER 5

CONCLUSION AND DISCUSSION

Upon completion of interviewing, coding and graphing all NOFA-NJ Certified tomato farmers in New Jersey there are several observations that can be made. The data reached all ends of the spectrum. While one farmer's energy via farm equipment use per pound of tomatoes was uncharacteristically high, another farmer did not use any fossil fuel or electricity for tractor or farm equipment. There was also a broad range of utilization rates for fertilizers and pest management practices. Pest management practices ranged from none used to five types. Fertilizers ranged from non-use to six different methods. Although, many of the pest management practices and fertilizers utilized were not applied by a electric or fossil-fueled apparatus, some farmers chose the most low impact method possible.

There are several policy implications that can be made from the data and analysis. Policies that can be developed from the information provided in this thesis can range from the farmers own on-farm policies to NOFA-NJ policies about what the will be considered organic. The information can also be use to help in the writing of the National Organic Standards.

The policy implication of the negative correlation as developed in Chapter 4 would indicate that low-energy farming practices would not necessarily result in a lower yield of tomatoes. This finding can have a profound impact on the energy requirements for organic farmers. The data as provided by the charts implies that while a wide range of fossil fuel and electrical energy is used in producing organic tomatoes, there is no direct linear relationship, hence no impact on yields.

The information gathered demonstrates the issues concerning energy requirements in agriculture. In Chapter 2, it was noted that "there is a large variation in energy conversion efficiency between different crop and livestock systems." (Hill and Ramsay, 1976) This key point is illustrated by the data displayed in Chapter 4. As illustrated in Figure 4 and Table 2, there is a large variation of energy required for organic tomato farming, and yet there appears to be no correlation between energy consumed and yields.

While many conclusions are drawn from the data, some qualifications must be made. First, there are geographic, precipitation, soil, and temperature differences which can have a significant impact on the tomato yields. (Hunt, 1992) These variables were not quantified, so thier influences may alter some of the conclusions constructed from the data. It is important to stress that for certain situations (pest management, tillage, etc.) the most effective farming techniques may be used. These conditions may increase the demand for energy usage while resulting in only negligible tomato yields results.

Farmers can utilize the information to analyze their environmental expenditures. They can compare their energy requirements with those of their competitors. This data collection of tomato production using different energy levels, as well as detailing the areas where energy is most intensive, will allow farmers to concentrate on the most energy-inefficient processes of their farming practices. For instance, if one farmer uses low impact farming techniques for tillage but uses a variety of fossil-fuel dependent pest management practices, the farmer can look to reduce some areas of pest management. The analysis in this thesis will allow farmers to understand what others are doing thereby making them capable of changing some of their more energy intensive practices. However, these changes will be best implemented by farmers whose policies already include good levels of documentation for external inputs and product yields. Additionally, the correlation table can be used to justify the reduction in fossil fuels and electrical energy.

NOFA-NJ can utilize the information to help newly certified organic farmers reduce levels of fossil fuel dependence. They can use the data found to illustrate issues involving high yields with low fossil-fuel and electrical inputs. NOFA-NJ can lead their certified farmers into adopting lower impact practices that have been proven to work in this region of the country. NOFA-NJ can also start a practice requiring the documentation of external inputs in the fossil-fuel and electrical category. The certification group already requires a great deal of data regarding what pest management and fertilizer practices used on certified farms, they can start requiring energy usage levels on farms. This data does not have to be gathered in the extensive format as done in this thesis, a simple document requiring total gallons of gas (diesel) consumed per year on the total farm could provide some useful data on energy requirements.

The data gathered for this thesis can be used in the writing of the National Standards. The data gathered is real-world information showing energy requirements and actual on-farm techniques and practices in New Jersey. Much of the data gathered in the survey can be extrapolated to focus on the energy requirements of the North-east.

Further research can be done with the data gathered. A study could be done utilizing the data and comparing the results with conventional farmers in New Jersey. Analysis can be done to understand the most energy-efficient farming techniques regardless if they fall under the classification of certified organic, organic, or conventional, etc. A comparison of the data will allow for the New Jersey Department of Agriculture to monitor the energy levels for agriculture in the state and encourage the least impactful methods. A comparison will also allow for an understanding if organic farmers rely more or less heavily on farm machinery than conventional. For example, do organic farmers substitute conventional pesticides and fertilizers with tractors and other farm equipment.

APPENDIX A

THE SURVEY

Survey for the Fossil Fuel and Electrical Energy Usage on Farms

Date: ____________

Questionnaire for Farmers

Section 1 - Background Information

1. **Farmers name:** ____

2. **Farm name:** ____

3. **Location:** ____

____

4. **County:** ____

5. **Phone number:** ____

6. **E-mail address:** ____

7. **Is farm organic?** (circle one) **Yes** or **No**

   If Yes, is farm certified **Yes** or **No**

8. **List all certifications:** ____

____

9. **How long has your farm been organic:** ____

10. **How long have you been farming:** ______________________________

11. **How long have you been farming tomatoes:** ______________________________

12. **What is the length of the growing season:** ______________________________

13. **How many people work on the farm?** ______________________________

14. **Size of farm:** (in acres) ______________________________

15. **Acres with tomatoes:** ______________________________

16. **The tomato operation is on** (circle one)

A. **Rented land**
B. **Owned land**
C. **Both**
D. **Other (please explain)** ______________________________

17. **Farm type:** (circle one)

A. **Individual**
B. **Partnership**
C. **Corporation**

18. **Number of tomato varieties?** ______________________

19. **What are the names of each variety?** ______________________

____

____

____

20. **Average yield of tomatoes:** ______________________

Section 2 - Planting

21. Plants originate from: (Circle One)

    A. Starter plants
    B. Seeds

22. If starter plants: (Circle One)

    A. Purchased
    B. Self grown

22A. If purchased, from where and how are they shipped? ____________________________

____

23. Are the starter plants grown in heated and cooled greenhouses? Yes or No

24. If yes, Is the heating and cooling electric? Yes or No

25. Approximately how many BTU's of electricity is used to control greenhouse

    temperature? ____

26. If not electric, how is the greenhouse temperature controlled? _________________________

    ____

Section 3 - Equipment Information

27. **When buying farm equipment do you usually buy:** (Circle One)

   A. Used
   B. New
   C. Both

28. **List year and type of each tractor used with tomatoes**

   ____

   ____

   ____

   ____

29. **Machinery used with tomatoes**

   Plow

   How many hours used per season ______________________

   Disc

   How many hours used per season ______________________

   Rotary Hoe

   How many hours used per season ______________________

30. **Machinery for specific functions:**

A. *Primary Tillage*

Moldboard Plow

How many hours used per season ______________________________

Chisel Plow - Shallow

How many hours used per season ______________________________

Offset Disc

How many hours used per season ______________________________

Powered Rotary Tiller

How many hours used per season ______________________________

Other, please explain ____________________________________

How many hours used per season ______________________________

B. *Secondary Tillage*

Disc Stalks

How many hours used per season ______________________________

Disc Plowed Soil

How many hours used per season ______________________________

Disc Tilled Soil

How many hours used per season ______________________________

Field Cultivation - Plowed

How many hours used per season ______________________________

Field Cultivation - Tilled

How many hours used per season ______________________________

Other, please explain ______________________________

How many hours used per season ______________________________

C. *Fertilizer Applications*

Field Sprayer

How many hours used per season ______________________________

Fertilizer Spreader

How many hours used per season ______________________________

Other, please explain ______________________________

How many hours used per season ______________________________

D. *Planting*

Row Crop Tractor

How many hours used per season ______________________________

No-Till Planter

How many hours used per season ______________________________

Other, please explain ____________________________________

How many hours used per season ______________________________

E. *Cultivation*

Cultivator

How many hours used per season ______________________________

Rotary Hoe *(Aerate Soil, Reduces Weeds)*

How many hours used per season ______________________________

Section 4 - Fertilizing

31. **Fertilizers Used**:

A. Type ______________________

How many hours used per season ______________________

Quantity used per season ______________________

How is it applied ______________________

Reason used ______________________

B. Type ______________________

How many hours used per season ______________________

Quantity used per season ______________________

How is it applied ______________________

Reason used ______________________

C. Type ______________________

How many hours used per season ______________________

Quantity used per season ______________________

How is it applied ______________________

Reason used ______________________

D. Type ______________________

How many hours used per season ______________________

Quantity used per season ______________________

How is it applied ______________________

Reason used ______________________

Section 5 - Pest Management

32. **Pest Management Used**:

A. Type ______________________________

How many hours used per season ______________________________

Quantity used per season ______________________________

How is it applied ______________________________

Reason used ______________________________

B. Type ______________________________

How many hours used per season ______________________________

Quantity used per season ______________________________

How is it applied ______________________________

Reason used ______________________________

C. Type ______________________________

How many hours used per season ______________________________

Quantity used per season ______________________________

How is it applied ______________________________

Reason used ______________________________

D. Type ______________________________

How many hours used per season ______________________________

Quantity used per season ______________________________

How is it applied ______________________________

Reason used ______________________________

Section 6 - Irrigation

33. **Irrigation System**:

Type ______________________________

How many hours used per season ______________________________

Estimated gallons of water used per season ______________________________

Energy source for irrigation ______________________________

34. **Water supply / source**: ______________________________

35. **Soil type:** ______________________________

36. **Terrain type:** ______________________________

Section 7 - Tomato Sales

37. Are the tomatoes sold at a farm stand? Yes or No

How many miles between the farm and the farm stand ____________________

____

38. Are tomatoes sold at a farmers market Yes or No

How many miles between the farm and the farmers market _______________

____

39. Are tomatoes sold to a wholesalers? Yes or No

How many miles between the farm and the wholesalers __________________

____

40. Are Tomatoes sold at another site other than the ones listed above?

(Farmstand, farmers market, or wholesalers) Yes or No

If yes, please explain ____

____

How many miles between the farm and the other option ________ __________

____

Section 8 - Packaging

41. **What type(s) of units are tomatoes shipped in?**

A) Crates
B) Lug boxes
C) 2-layer flats
D) Crates and lug boxes
E) Crates and 2-layer flats
F) Lug boxes and 2-layer flats
G) Crates, lug boxes, and 2-layer flats
H) Other (please explain) ________________________________

____

42. **By what process are the tomatoes boxed?**

A) Manually
B) By machine (what type) ______________________________

C) Other (please explain) ________________________________

____

43. **Are tomatoes washed before sale?** Yes or No

If yes, how are they washed? (explain) ____________________________

____

Section 9 - Miscellaneous Information

44. Other important information about tomato growing you would like to mention:

____

____

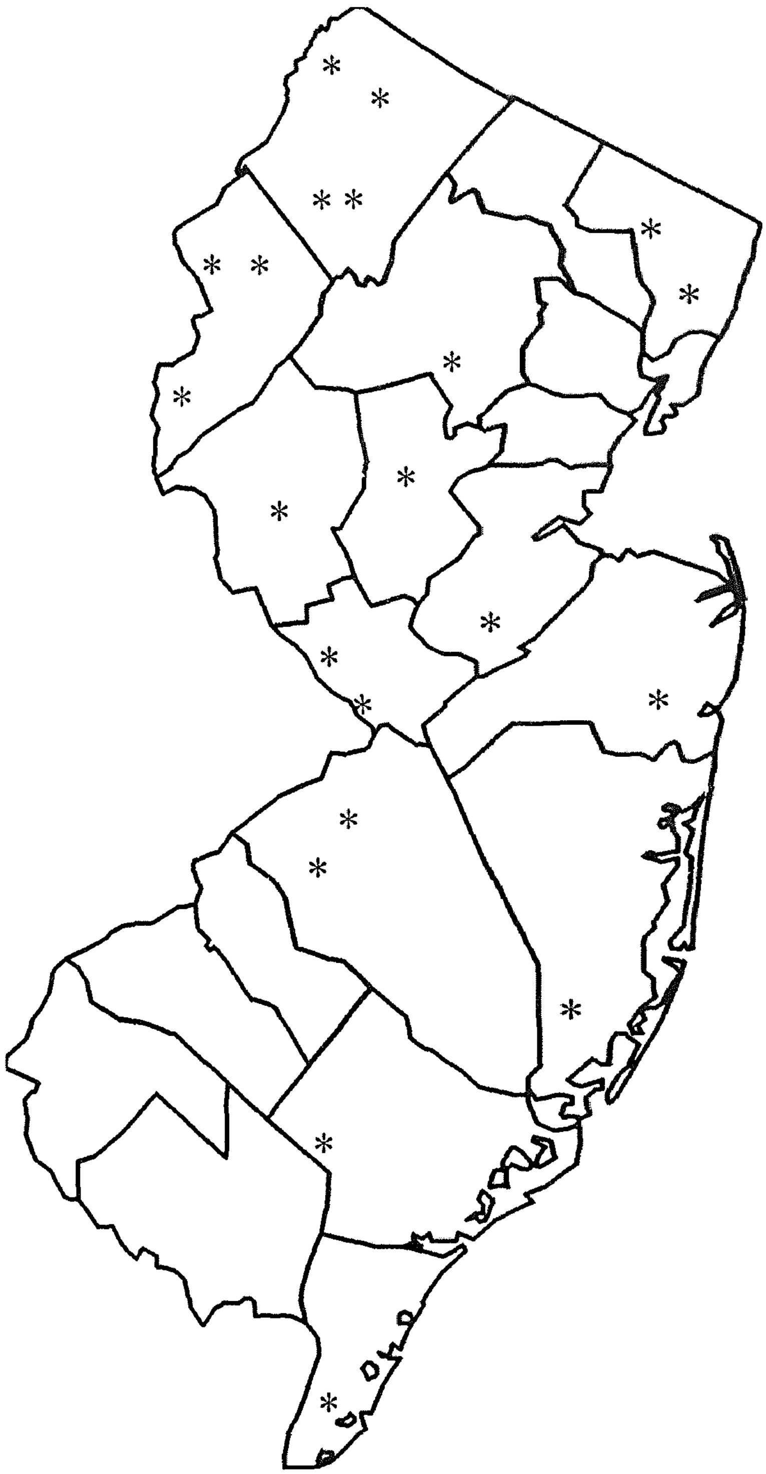
____

____

____

APPENDIX B

MAP OF NEW JERSEY WITH FARM HIGHLIGHTED (*)



APPENDIX C

LIST OF FARMS INTERVIEWED

Asbury's Natural Village Farm
PO Box 165
Asbury, NJ 08802
908-213-0377

Country Heritage Herb Farm
One Spring Hill Road
Annandale, NJ 08801
908-735-5454

Dubois Farms
329 Harding Highway
Buena, NJ 08310
609-697-9356

E.R. and Son Farm
572 Buckelew Ave.
Jamesburg, NJ 08831
908-521-2591

Farmer John's Organic Produce
31 King George Road
Warren, NJ 07059
908-356-9498

Fields of Dreams
117 Fredon-Springdale Road
Newton, NJ 07860
201-300-0563

Indian Hill Farm
2734 Monmouth Road
Jobstown, NJ 08041
609-723-6603

J.C. Hazlett Farm & Market
570 Route 47 North
Cape May Courthouse, NJ 08210
609-861-5551

Kokoro Gardens
329 Pennington Titusville Road
Pennington, NJ 08534
609-683-4208

Mill Creek Organic Farm
95 Eayrestown Road
Medford, NJ 08055
609-953-0372

Old Hook Farm
650 Old Hook Road
Emerson, NJ 07630
201-265-4835

Pippin Hill Heirloom Farm
32 Pippin Hill Road
Blairstown, NJ 07825
908-362-9046

River Bend Farm
200 Casino Drive
Farmingdale, NJ 07727
908-938-5137

Starbrite Farms
4 Old Orchard Road
Blairstown, NJ 07825
908-362-7595

Stephens Farm
467 Route 284
Sussex, NJ 07461
201-875-2849

Stone Hollow Farm
136 Route 72
Barnegat, NJ 08005
609-698-2405

Tony DiPippo's Farm
148 Crescent Ave.
Waldwick, NJ
201-445-4984

Vallevue of Morristown
33 Picatinny Road
Morristown, NJ 07960
201-292-0677

Walnut Grove Farm
189 Route 519
Newton, NJ 07860
201-383-5029

Watershed Organic Farm
260 Wargo Road
Pennington, NJ 08534
609-737-8899

APPENDIX 4

LIST OF PEST MANAGEMENT PRACTICES

Bold = Produced or Purchased Off Farm

Bleach
BT
Copper
Dietonaious Earth
Fish Oil
Folair Feed
Hinder Repellent
Hydrogen Peroxide
Pyreline E
Rhotenone,
Roto tiller
Soaps
Sulfur

Cover Crops
Companion Planting
Lady Bugs
Dogs
Electric Fence
Hay/Straw
Hoes
Hot Pepper Tea
Pick Bugs
Plain Fence
Trapping

APPENDIX 5

LIST OF FERTILIZERS USED

Bold = Produced or Purchased Off Farm

Bone Meal
Boran
Dried Blood
Espoma Plant
Fish Emulsion
Fish/kelp
Foliar Feed
Gypsum
Kelp Meal
Lime
Potash
Potassium
Rock
Phosphate
Sulfur

Alfalfa
Compost
Green Manure
Manure
Manure Tea
Rye Cover

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