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Can Dairy Manure be Profitably Composted in Maine?

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By

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A THESIS

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Manure contains many important nutrients that are vital to the growth of crops. When this material is applied to fields in an inappropriate manner or in quantities too large for the soil to handle, this leads to pollution in the form of leaching and runoff, which causes contamination of ground and surface waters. An average cow produces one hundred pounds of manure per day (18 tons per year). Composted manure could provide farmers with a more environmentally friendly alternative to traditional manure management practices. A review of the composting literature determined that a wide variety of markets do exist for composted dairy manure. The cost of producing the raw compost product was calculated along with the cost of bagging and transporting compost. It was determined that bulk compost could not be profitably transported to market, but that bagged compost can be profitably transported to market.

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INTRODUCTION

It has become increasingly important in the dairy industry to take a closer look at how manure is being disposed of on the farm. Traditionally manure was spread by the cow while she grazed in a pasture. Today many farms are switching to confinement housing, where manure must be collected, stored, and then spread onto fields. Manure contains many important nutrients that are vital to the growth of crops. When this material is applied to fields in quantities too large for the soil to handle, this leads to runoff and leaching, which cause contamination of surface and ground waters (Hubbard & Lowrance). Therefore farmers are being pressured to find more environmentally friendly manure management techniques (Richard).

As the number of cows per acre continues to rise, the problem of manure management becomes more serious. An average dairy cow produces approximately one hundred pounds of manure per day (36,500 pounds or 18 tons a year), and the annual quantity of manure produced by 225 cows could cover one football field one yard deep. Housing a large number of dairy cows in one location can create manure disposal and management problems (Blanchard). Many universities are conducting research to find alternative dairy manure management practices, with the goal of managing manure in a way that does not create additional soil, air, and water pollution problems (Hubbard & Lowrance).

Composting dairy manure may prove to be more than an environmentally friendly alternative to traditional manure management practices. Among the benefits of composting is the ability to suppress some diseases. When composted manure is used in conjunction with chemical fertilizers, vegetable crops have shown an increase in growth and yield (Gouin). Composted manure has also proven to be profitable in the poultry industry. Composted poultry manure is sold to a variety of compost consumers including nurseries, landscapers, and retailers. This has important implications for compost made with dairy manure because it provides information about possible market opportunities.

Objective

The primary objective of this study is to determine if dairy manure can be profitably sold in the state of Maine. As the regulations on the handling of raw dairy manure become increasingly restrictive, dairy farmers must look for alternative ways to manage their manure. If selling composted manure proves to be profitable, then it will be an excellent way for Maine farmers to manage their manure while cultivating an additional source of income. This study will focus primarily on the bagged market which researchers believe has more profit potential.

An Outline of the Study

This study is divided into two sections, Retail Market, represented by one chapter and Supply, represented by the following four chapters. The Retail Market chapter, *An Overview of the Composted Manure Market*, determines if a demand exists and, if so, what specific product characteristics are demanded by consumers. This is an important first step in venturing into a new market. The Retail Market section provides an overview of the compost market by separating the market into two parts, the bagged sector and the bulk sector, and determining the market opportunity of each sector.

The Supply section chapters are entitled, *Producing Composted Manure*, *Bagging Composted Manure*, *Transporting Composted Manure to Market* and *Analysis of Profitability*. The first Supply chapter, *Producing Composted Manure*, quantifies the individual fixed and variable costs involved in constructing and operating a successful dairy manure composting facility. The next chapter, *Bagging Composted Manure*, provides information on the costs involved in bagging compost. The following chapter, *Transporting Composted Manure to Market*, addresses the costs involved in shipping composted manure from its point of origin to its final destination. The final chapter in this section, *Analysis of Profitability*, determines the profitability of producing and transporting both a bulk and bagged product to market.

A summary of the results obtained from Chapters 1-5, the Retail Market and Supply sections, is presented in the final chapter. This final chapter also contains concluding comments, as well as considerations for future research. With every dairy cow creating eighteen tons of manure annually, this research is essential to the well-being of modern dairy farms.

SECTION ONE: RETAIL MARKET

Chapter 1

AN OVERVIEW OF THE COMPOSTED MANURE MARKET

The composted manure market has considerable growth potential and will always exist because of declining soil quality and soil erosion, a belief shared by numerous researchers (Lasoff). Presently, several marketing opportunities exist for composted dairy manure in Maine consisting of five major consumer groups: retailers, landscapers, nurseries, municipalities, and agriculture. Each consumer group uses compost for different applications and, therefore, demands different product characteristics.

The bagged compost market is very competitive; to survive and to be successful, producers need to differentiate their products. The question that needs to be asked is: which product characteristics have the greatest impact on the price and quantity of compost? To assist in answering this question a survey of bagged and bulk compost products in the state of Maine was conducted. This chapter will focus on the various marketing opportunities available to composted manure producers. Additionally, it will discuss the product attributes demanded by the various consumers.

Product Survey

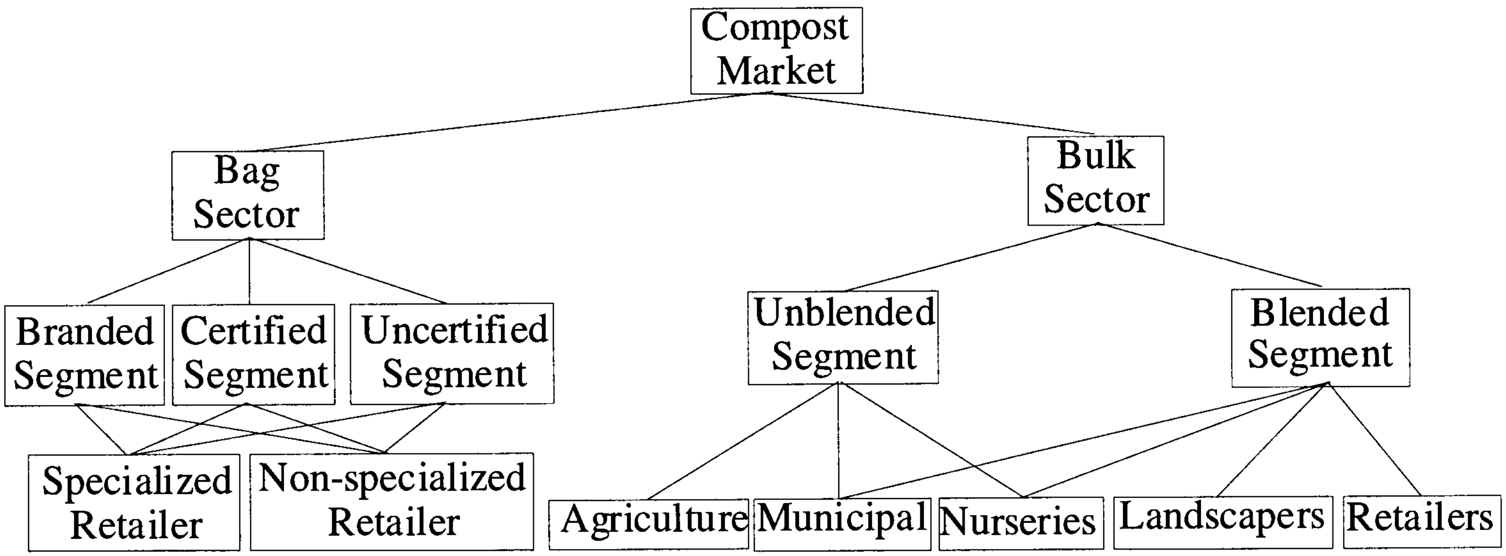
An overview of the compost market was obtained by conducting a review of the compost literature and by implementing a compost product survey. Where retailers in Maine were visited to obtain information about each compost product that they were selling. The survey provides additional information on the products being sold in Maine.

It also provides a glimpse into the organizational structure of the Maine compost market. This survey was conducted in June 2003, where I visited nineteen retailers, nine retailers were non-specialized retailers and ten were specialized retailers in Maine. Three of the retailers involved in the survey do not carry any compost products, while the remaining retailers carry between one to eight different products. Thirty-three bagged compost products and five bulk compost products were included in the survey. Each bagged and bulk compost product involved in this survey was studied to determine the type of information consumers are given about the product and how the product was packaged. Additional information about this product survey will be presented later in this chapter.

Market Sectors

Specializing in a specific segment of the market allows producers to create a more specific product to meet the consumers demands and to be able to price that product appropriately. I observed that the market for composted manure is divided into two sectors, bulk compost and bagged compost, as illustrated in Figure 2.1. The bulk sector is separated into unblended product and blended product segments. The bagged sector is separated into branded product, certified product, and uncertified product segments.

Figure 2.1: An Illustration of the Composted Manure Market



Bulk Sector

Consumers of bulk products consist of retailers, landscapers, nurseries, municipalities, and agriculture, as observed in the market and presented in Figure 2.1. Producers in this sector are faced with a difficult obstacle to overcome, the consumers' unwillingness to switch to composted manure. For example, a man observed in another study, was trying to market composted manure to the Department of Transportation (DOT) in Florida. He encountered one significant problem: the DOT in Florida was not prepared to change the way they handled erosion problems. To overcome this obstacle, he requested that the University of Florida do a study on the effectiveness of composted manure in dealing with erosion. With this study in hand, he again approached the DOT and this time he achieved his goal (Verbanas).

Some companies have successfully marketed and sold bulk compost. A-1 Organics has been successfully producing a bulk composted manure product since 1973, with a production volume of approximately 150,000 cubic yards of composted manure annually. Seventy-five percent of their product is sold in bulk form, and it is marketed by forty different distributors throughout the Rockies. They currently offer twenty-five different products, most of which are mixed blends (Glenn & Farrell).

Bulk composted manure products are considered a commodity. They are more homogenous than bagged products in consistency, large volumes are involved in transactions, and there are limited price fluctuations (Kraenzel). To successfully market a bulk product, producers need to generate a quality consistent product that is priced appropriately, has the capacity to meet quantity demands, and provides consistent results (Compost Management Associates & R. Alexander Associates Inc.).

Using the information obtained from the bulk product survey, the average retail price of bulk compost in Maine is $0.026 per pound. According to Glenn and Farrell, bulk composted manure sold at the retail level is subject to a markup of roughly two times the farm gate price. This indicates that on average the farm gate price of bulk compost is $0.013 per pound. Of the nineteen retailers involved in the product survey only three carried blended bulk products.

Segments of the Bulk Sector

As previously illustrated in Figure 2.1, I observed that the bulk market is divided into two segments: unblended products and blended products. Unblended products have no additives and have only undergone the composting process, while blended products have additional ingredients such as topsoil, organic humus, or chemical nutrients. These market segments meet the demands of the five essential bulk product consumers.

Consumers of Bulk Products

As observed in the market, the five major consumers of bulk composted manure products consist of retailers, landscapers, nurseries, municipalities, and agriculture. Land reclamation projects and landfills also use bulk compost, but they demand a very low quality product and a very low price. In the case of mine rehabilitation, many companies are looking for such a low-grade product that they are not even willing to pay for it (Compost Management Associates & R. Alexander Associates, Inc.). In the case of landfills, compost is used daily to reduce wind erosion, minimize odors, and help prevent the emission of harmful gases into the environment (Composting Council of Canada). Because these markets are best served by municipal waste compost, they will not be viewed as marketing options in this study.

The market indicates that the demands of the bulk product consumers are met by wholesalers or delivered directly by the compost producer. Bulk consumers picking up composted manure at the farm will not be addressed in this paper because of the inconvenience this would cause composted manure producers in the form of time constraints and coordination requirements.

Consumer 1: Retailers

Of the nineteen retailers surveyed only three carried bulk products. The primary consumers of composted manure at the retail level are homeowners. This type of consumer generally demands a blended product. Since retailers represent a large percentage of the overall bagged market, these consumers will be addressed in greater detail in the bagged sector.

Consumer 2: Landscapers

Landscapers use composted manure as a top dressing around new plants and as a soil amendment. Their primary concerns are the presence of weed seeds, herbicides, and pesticides in the composted manure product (USEPA). When deciding to purchase a specific composted manure product the deciding factor should be the product's performance (Compost Management Associates & R. Alexander Associates, Inc.). To increase confidence in product performance, field trials and laboratory tests should be conducted. Results from these tests should then be made available to potential consumers.

This consumer group tends to purchase the blended product because it can be specifically tailored to meet their individual needs.

Consumer 3: Nurseries

In New England, the demand for composted manure by nurseries has been increasing (Lang & Jager). Many factors have contributed to this increase in demand, such as the strong economy and the strong housing industry. When the economy is doing well people are more inclined to purchase more bedding plants and shrubbery for around their homes. To gain the attention of nurseries, composted manure producers must prove that their product is effective and of a high quality, which can be done with the assistance of field trials and laboratory analysis (USEPA). This consumer group purchases both unblended and blended bulk products. It is important to recognize that some nurseries also purchase unblended composted manure so they can blend it themselves, bag it, and sell the resulting product.

Consumer 4: Municipalities

The primary uses that municipalities have for composted manure are as topsoil in parks, and around buildings, properties and roads. While they usually demand only a low quality product, municipalities should also be provided with information on nutrient levels and product performance (Compost Management Associates & R. Alexander Associates, Inc.). Again this information can be obtained by field and laboratory tests. Municipal users demand both the unblended and blended products.

Consumer 5: Agriculture

The agricultural industry represents the area of the compost market that has the highest growth potential, especially in the unblended composted product sector (Lang & Jager). However, a variety of issues make this market difficult to penetrate. The industry's primary concerns about composted manure pertain to quality, consistency, and effectiveness. Farmers need to see field demonstrations and laboratory tests to provide assurance that compost will not cause their costs to increase, crop yields to decrease, or their soil structure and fertility to decline (USEPA). The primary use of unblended composted manure in this industry is field application.

Bagged Sector

The bagged composted manure sector targets specialized and non-specialized retailers who generally serve homeowners. A study conducted for the city of Toronto, stated that a benefit of bagged compost is that it can be transported longer distances more cost effectively than a bulk product (Compost Management Associates & R. Alexander Associates Inc.). However, they did not provide any evidence to support this assertion. If this were true, it would allow producers to access a larger portion of the composted manure market while enjoying increased product prices. This opinion is also shared by Satkofsky, who suggested that bagging allows producers to increase revenue by accessing markets that are further away. Producers usually decide to enter the bagged sector when the demand for composted manure in the local bulk sector is smaller than the producer's supply.

Glacier Gold experienced this phenomenon first hand. According to David Larson, whose family owns Glacier Gold, marketing composted manure was a "nightmare" when only a bulk product was being offered. He found the local market was too small, making it impossible to sell all the composted manure that they were producing. His operation then switched to bagging most of their composted manure, which allowed them to expand their market area. Glacier Gold now sells composted manure throughout the U.S. and Japan (Glenn & Farrell).

Other industries have experienced similar results by bagging their products. The bagged salad industry is an excellent example of how bagging a product can increase sales and establish new marketing opportunities. This industry provides some good insight into how bagging compost might expand the compost market as well. According to Thompson and Wilson the total quantity of un-bagged lettuce being sold per capita decreased from 32.4 pounds in 1989 to 27.6 pounds in 1995. Over this time period, bagged salad sales were growing by a rate of 51.5 percent annually. Like the composted manure industry, the quality of the bagged and bulk product is the same but consumers purchase the bagged product because it is more convenient.

I observed that bagged composted manure per pound does indeed receive a higher price in the market. Using the information obtained from the product survey, the average price received by a retailer in the market is $0.12 per pound. According to Glenn and Farrell, the price charged for composted manure at the retail level is twice what the farmer receives at the farm gate. Using this information the average price received at the farm gate for composted manure was estimated to equal $0.06 per pound. The price for un-certified bagged compost products was determined because the majority of dairy farms in Maine are not organic certified. The average farm gate price for un-certified bagged compost was estimated to equal $0.05 per pound. Producers selling bagged composted manure to non-specialized retailers receive on average $0.065 per pound at the farm gate, while composted manure sold to specialized retailers obtains a farm gate price of approximately $0.05 per pound.

There are some additional costs associated with bagging composted manure that must also be considered the cost of bags, bagging systems, transporting bagged compost to its destination, and storage. These factors will be discussed in greater detail in Chapter 3 and Chapter 4. Quality control factors must also be considered, such as dryness, stability, and consistency (Compost Management Associates & R. Alexander Associates Inc.).

Segments of the Bagged Sector

Through close observation of the bagged sector, the conclusion was made that this sector is divided into three segments: branded products, certified products, and uncertified products. For this study, the consumers of bagged compost products are specialized and non-specialized retailers, although the ultimate end consumer is the retail customer. Traditionally producers of composted manure have not been selling their bagged products directly to the end consumer, therefore, this study will not address this possibility. However the retailer's demand is derived from the end consumer's demands.

Segment 1: Branded Product

It is generally believed that the branded product receives the highest price in the bagged market. Although this phenomenon was difficult to see because all products surveyed were branded, some brands such as the Coast of Maine products appeared to be preferred. If a brand is well known, then the producer can demand a higher price (Kotler). According to the CEO of Sunkist Growers, Russell Hanlin, " An orange is an orange...is an orange. Unless... that orange happens to be Sunkist, a name that 80 percent of consumers know and trust" (Kotler).

Branding requires a large financial investment and access to a large quantity of composted manure, promotion expertise, and distribution channels, among other things. Some producers such as David Larson, of Glacier Gold, found creating two brands of composted manure effective, one for non-specialized retailers and the other for specialized retailers. Even though the product inside the bags is identical, the name and packaging are different. This provides security to specialized retailers because the non-specialized retailers who sometimes use compost as a low cost leaders cannot underprice them, because both retailers are selling different products (Glenn & Farrell). This illustrates that targeting specific markets is a key to successful branding.

Segment 2: Certified Product

For composted manure products to become certified, producers must join a national certification organization. Of which there are several in the United States. The top three are California Compost Quality Council, Organic Materials Review Institute, and Seal of Testing Assurance (Harrison & Brinton). Although none of the compost products surveyed in Maine displayed a seal from a national certification organization, eighteen of the thirty-three products did display an organic seal of approval from a regional certification organization, such as Rodale Organic Gardening or Maine Organic Farmers and Gardeners Association (MOFGA). These organizations require compost to be tested for physical and chemical properties as well as metals and pathogens. A Cornell University study found that consumers are more willing to purchase products if they display a certified seal of approval (Harrison & Brinton).

An article written by Lasoff indicates that producers will receive a premium price for their composted manure if they join an organization and become certified. In an example presented in the article, a company that receives $30 per ton before certification will experience an increase in demand and a potential 50 percent increase in product price once it is certified.

Consumers of Bagged Composted Manure Products

As previously discussed, there are two main consumer groups of bagged composted manure products: specialized and non-specialized retailers. For the purpose of this paper, I define a specialized retailer as one who specializes in landscaping and gardening materials, which is also a retailer that consumers associate with gardening. In contrast, the non-specialized retailer is a business that does not specialize in lawn and garden supplies. These retailers are ones that consumers do not instinctively associate with landscaping. Both of these retailers have one thing in common, they each cater primarily to homeowners who demand a quality consistent product. Homeowners use composted manure for a variety of tasks around the home, such as fortifying flower beds and conditioning vegetable gardens. Their biggest concerns are the presence of weed seeds and chemical contaminants (Harrison & Brinton). They also want information on nutrient and pH levels displayed on the bag, with instructions on how to use the product (Harrison & Brinton).

Price Analysis

The bagged product survey conducted in June revealed that price variation exists between the products in the compost market. Using the small data set obtained from the product survey, a preliminary analysis involving a hedonic price function is used. This function will help determine the implicit price of the various characteristics found in the differentiated bagged compost products. The analysis provides information on why some products are priced higher and the product characteristics that have the greatest impact on the retail price.

Data

As previously stated the data used for this study was collected through a product survey, during the month of June 2003. The various retail outlets involved in the compost product survey were divided into two groups, specialized retailers and non-specialized retailers. The purpose of this division was to separate retailers who specialize in lawn and garden supplies from those retailers who do not. Table 2.1 provides a list of all the retailers involved in the bagged product survey. The survey included both bagged compost products and bulk compost products. Not enough data was collected to conduct an hedonic analyses of the bulk product sector.

The survey gathered information on thirty-three bagged products. Each product's price and weight was recorded and converted into dollars per pound, as presented in Table 2.1. The majority of products weighed forty pounds, with the exception of the Moo Doo products which weighed thirty pounds.

A number of interesting observations were made about the compost products involved in the survey. Products containing aquatic waste appeared to earn a premium price in the market. Only six of the fourteen products surveyed were organic certified, as seen in Table 2.2. Many of the compost products provided an ingredient list but failed to include the nitrogen, phosphorus and potash (N-P-K) ratio and the percentage of organic matter contained in the product, two pieces of information of interest to consumers (Harrison & Brinton). The products that present the N-P-K and/or organic matter can be found in Table 2.2.

Using the data presented in Table 2.1, two outliers are apparent. They consist of the Schoodic Blend product sold at True Value Hardware for $1.99 and the Penobscot Blend product sold at Topsham Home and Garden for $3.99. These two products have a price range that is very large. The lowest product prices for both products is excluded from the study. The summary statistics for the revised data set including, mean, variance, minimum and maximum are presented in Table 2.3.

Table 2.1: The Retailers that Sell Bagged Compost and the Products They Sell.

Retailer	Retail Location	Type of Retailer	Product Name	Quantity (lbs/bag)	Product Price ($/bag)	Price ($/lbs) (PC)
Paris Farmers Union	Auburn	Specialized	Moo Doo	30	$4.15	$0.14
Provenchers Landscaping	Lewiston	Specialized	Schoodic Blend	40	$3.99	$0.10
Home Depot	Bangor	Non-specialized	All-Natural Bovung	40	$4.79	$0.12
Kmart	Bangor	Non-specialized	Organic Manure and Humus	40	$1.99	$0.05
Aubuchon Hardware	Old Town	Non-specialized	Composted Cow Manure	40	$2.79	$0.07
Broadway Hardware	Bangor	Non-specialized	Manure Compost	40	$2.99	$0.07
			Ocean Garden Compost	40	$5.19	$0.13
Windswept Gardens	Bangor	Specialized	Penobscot Blend	40	$6.30	$0.16
			Schoodic Blend	40	$6.00	$0.15
Sprague's Nursery and Garden Center	Bangor	Specialized	Compost Cow Manure	40	$3.29	$0.08
Dawn Till Done Farm	Old Town	Specialized	Seafood Compost	40	$5.95	$0.15
Parks Hardware	Orono	Non-specialized	Kinney Compost	40	$6.95	$0.17
True Value Hardware	Bangor	Non-specialized	Schoodic Blend	40	$1.99	$0.05
Paris Farmers Union	Newport	Specialized	Moo Doo	30	$4.89	$0.16
Everlasting Farm	Bangor	Specialized	Premium Organic Shellfish Compost from Maine	40	$5.95	$0.15

Table 2.1: Continued

Brewer Home, Garden and Farm Center	Brewer	Specialized	Quoddy Blend	40	$5.49	$0.14
			Kinney Compost	40	$6.99	$0.17
			Manure Compost	40	$4.99	$0.12
			Sea Food Compost	40	$5.99	$0.15
			Penobscot Blend	40	$5.49	$0.14
			Cobscook Blend	40	$5.49	$0.14
			Schoodic Blend	40	$4.99	$0.12
			Organic Humus and Manure	40	$3.49	$0.09
Paris Farmers Union	Auburn	Specialized	Cobscook Blend	40	$5.29	$0.13
			Quoddy Blend	40	$5.29	$0.13
			Organic Humus and Manure	40	$2.89	$0.07
Topsham Home and Garden	Topsham	Specialized	Quoddy Blend	40	$5.99	$0.15
			Schoodic Blend	40	$4.49	$0.11
			Penobscot Blend	40	$3.99	$0.10
			Cobscook Blend	40	$4.99	$0.12
			Compost Cow Manure	40	$3.49	$0.09
			Organic Humus and Manure	40	$3.49	$0.09

Table 2.2: The Characteristics of the Bagged Compost Products Involved in the Survey.

Product Name	Company Name	Certified for Organic Use (CO)	Contains Aquatic Waste (F)	N-P-K and/or Organic Matter (N)
Moo Doo	Vermont Natural Ag Products Inc.	Yes	No	Yes
Schoodic Blend	Coast of Maine	Yes	No	No
All-natural Bovung	Scotts Company	No	No	Yes
Organic Manure and Humus	Hyponrx	No	No	Yes
Cobscook Blend	Coast of Maine	Yes	Yes	No
Composted Cow Manure	Jolly Gardener	No	No	Yes
Manure Compost	Greenhouse Gold	No	No	Yes
Ocean Garden Compost	Acadia Gardens: Jolly Gardener	No	Yes	No
Penobscot Blend	Coast of Maine	Yes	Yes	No
Quoddy Blend	Coast of Maine	Yes	Yes	No
Organic Manure and Humus	Earthgro	No	No	No
Seafood Compost	Sunrise Composting	No	Yes	No
Kinney Compost	Kinney Compost	Yes	Yes	No
Premium Organic Shellfish Compost from Maine	Gardeners Gold	No	Yes	No

Yes indicates that the product was organic certified, contains aquatic waste, and when N-P-K and/or organic matter is presented on the bag. No indicates that the product in not organic certified, does not contain aquatic waste, and the N-P-K and/or organic matter was not presented on the bag.

For the hedonic price model, the variables of particular interest include the type of retail outlet that sold the product (R), where '0' represents non-specialized retailers and '1' represents specialized retailers. If the quantity of N-P-K and/or the quantity of organic matter (N) was presented on the package, then '1' indicates that this information is provided and '0' indicates the lack of this information. If the product was organic certified (CO) then it was assigned a value of '1'. If the product was not organic certified then it was assigned a value of '0'. The final variable included in this study was the existence of aquatic waste (F), a value of '1' was assigned to products containing aquatic waste, while a '0' was assigned to products not containing aquatic waste.

Table 2.3: Summary Statistics for all Variables Involved in the Hedonic Pricing Model.

	Price of Compost ($/lb)	Type of Retail Outlet	N-P-K and Organic Matter	Certified Organic	Contains Aquatic Waste
Variable	**PC**	**R**	**N**	**CO**	**F**
Mean	0.123	0.806	0.354	0.548	0.452
Variance	0.001	0.161	0.236	0.256	0.256
Minimum	0.050	0	0	0	0
Maximum	0.175	1	1	1	1

'R' represents the type of retail outlet. Where '1' represents a non-specialized retailer and '0' represents a specialized retailer.
'N' represents if the quantity of N-P-K and/or the quantity of organic matter was presented on the bag. Where '1' indicates that this information is provided and '0' indicates that this information is not provided.
'CO' represents organic certification. Where '1' indicates that a product is organic certified and '0' indicates that a product is not organic certified.
'F' represents aquatic waste. Where '1' indicates that a product contains aquatic waste and '0' indicates that a product does not contain aquatic waste.

Model

For this analysis an hedonic model is used. This model assists in determining how product characteristics affect retail price, when similar products with distinct differences are sold in the same market. As a result of these differences in product characteristics, price variation may exist. This model allows us to indirectly determine the value that consumers place on certain product attributes by observing market transactions (Taylor). The values associated with each attribute are referred to as hedonic prices and are equal to a consumer's willingness to pay, under most circumstances (Taylor).

The first stage hedonic price function is an appropriate method for solving this problem. In this stage the hedonic price function is estimated using the prices of differentiated bagged compost products and the characteristics of these products. This analysis assists in determining the implicit prices (hedonic prices) of certain product attributes (Taylor). This technique will assist in determining the hedonic prices (implicit prices) for each characteristic of the bagged compost products. A linear functional form is selected for this model, because the total price of composted manure is assumed to be the sum of the implicit prices of each attribute (Taylor). The linear equation that will be estimated for this study is Equation 2.1. In this equation 'PC' represents the price of compost in dollars per pound.

Equation 2.1

$$PC = \beta_1 + \beta_2 R + \beta_3 N + \beta_4 CO + \beta_5 F$$

A number of product characteristics were observed in this study including the type of retail outlet that sold the product (R), the quantity of N-P-K and/or the quantity of organic matter presented on the package (N), product organic certification (CO) and the presence of aquatic waste in the product (F). These variables are expressed as dummy variables and ordinary least squares (OLS) will be used to estimate the function.

Results and Discussion of the Hedonic Price Model

The results from the linear regression are presented in Table 2.4. At a 95 percent significance level not all variables are significant. The adjusted R-squared value indicates that 46 percent of the variation in the dependent variable can be explained by the explanatory variables. The variable representing the presence of aquatic waste (F) and the variable indicating if a product is certified organic (CO) are the only significant variables. This indicates that a product containing aquatic waste will receive a price premium of 2.67 cents per pound, while an organic certified product will obtain a price premium of 2.42 cents per pound.

Table 2.4: Parameter Estimates for the First Hedonic Price Function.

Variable	Parameter Estimate	Standard Error	T-statistic
Intercept	*0.09334	0.01631	5.72229
Type of Retail Outlet (R)	0.00709	0.01195	0.59341
N-P-K and Organic Matter (N)	-0.01151	0.01415	-0.35833
Certified Organic (CO)	*0.02423	0.10690	2.26636
Contains Aquatic Waste (F)	*0.02675	0.01183	2.26208
Adjusted R-Squared		0.46063	
Sum of Squared Errors		0.03186	
Degrees of Freedom		26	

** indicates that the variable is significant critical value =2.056.*
'R' represents the type of retail outlet. Where '1' represents a non-specialized retailer and '0' represents a specialized retailer.
'N' represents if the quantity of N-P-K and/or the quantity of organic matter was presented on the bag. Where '1' indicates that this information is provided and '0' indicates that this information is not provided.
'CO' represents organic certification. Where '1' indicates that a product is organic certified and '0' indicates that a product is not organic certified.
'F' represents aquatic waste. Where '1' indicates that a product contains aquatic waste and '0' indicates that a product does not contain aquatic waste.
'PC' represents price of compost per pound.

To determine how the results would change if only products that do not contain aquatic waste were analyzed, the equation was again estimated. The results of this analysis are present in Table 2.5. This time the 'F' variable and all observations containing aquatic waste were excluded. In this analysis, the adjusted R-squared indicates that 52 percent of the variations in the dependent variable can be explained. Here a critical t-value of 2.160 was used resulting in only one significant variable, organic certification. The results indicate that if a product is organic certified then it will receive a price premium of 5.26 cents per pound. This represents a large change in the price premium associated with organic certification. The results present in Table 2.6 indicated that the variables organic certification and aquatic waste might be correlated. When these variables were tested of correlation it was determined that they were not highly correlated.

Table 2.5: Parameter Estimates for the Second Hedonic Price Function.

Variable	Parameter Estimate	Standard Error	T-statistic
Intercept	0.06245	0.01893	3.29763
Type of Retail Outlet (R)	0.01434	0.01491	0.96188
N-P-K and Organic Matter (N)	0.01605	0.01514	1.06018
Certified Organic (CO)	*0.05262	0.01514	3.47488
Adjusted R-Squared	0.52133		
Sum of Squared Errors	0.01732		
Degrees of Freedom	13		

** indicates that the variable is significant critical value = 2.160*
'R' represents the type of retail outlet. Where '1' represents a non-specialized retailer and '0' represents a specialized retailer.
'N' represents if the quantity of N-P-K and/or the quantity of organic matter was presented on the bag. Where '1' indicates that this information is provided and '0' indicates that this information is not provided.
'CO' represents organic certification. Where '1' indicates that a product is organic certified and '0' indicates that a product is not organic certified.
'F' represents aquatic waste. Where '1' indicates that a product contains aquatic waste and '0' indicates that a product does not contain aquatic waste.
'PC' represents price of compost per pound.

Summary

For compost producers to be successful it is important for them to research the composted manure market. Aspiring producers must choose the specific market segment or segments on which they wish to focus, an essential first step to creating a market oriented compost product. Once the market has been selected, the producer must create a product that meets the demands of the target consumer. Providing producers with an awareness of the unique market and customer demands will vastly improve the chances of a new product being successful. The keys to this success consist of the following:

conducting market research, becoming familiar with customer demands, and producing a consistently high quality product.

The results from the hedonic pricing model indicated that an organic certified product and products that contain aquatic waste receive a premium price in the compost market. Since Maine is located on the coast, many producers have access to aquatic waste; this could place Maine producers at an advantage over producers located in states further from the shore.

SECTION TWO: SUPPLY

After the market research has been conducted and the producer has decided upon a marketing strategy, the producer may now develop a product that caters to the specific needs of the target consumer. It is important to remember that even though a market does exist, not all producers can profitably produce a composted manure product to sell in the chosen market. Producers first must calculate all costs involved in the production of the composted manure product before they decide to enter into the market. There are three important costs that must be considered: the cost of producing, the cost of bagging, and the cost of transporting to the intended market, these costs are analyzed in the supply section.

The following three chapters will focus on the supply side of the composted manure industry and each chapter will represent one step toward establishing the cost of producing composted dairy manure in Maine. Chapter 2 determines the cost of producing the raw composted manure product, while Chapter 3 focuses on estimating the cost of bagging composted manure. In Chapter 4 the cost of transporting both bulk and bagged composted manure to market is analyzed. Finally, Chapter 5 evaluates the profitability of the three components involved in compost production. Each of these factors must be scrutinized independently in order to accurately establish the cost of producing, bagging, and transporting compost on Maine dairy farms.

Chapter 2

PRODUCING COMPOSTED MANURE

This chapter establishes the cost of producing composted dairy manure. A model farm is used to simulate the cost of producing composted manure and to illustrate the steps involved in creating a final composted manure product. All production cost are broken down into total costs and cost per pound of dairy manure.

Composting Methods

Composted dairy manure can be produced in a number of different ways, including passive manure piles, passive aerated windrows, aerated static pile, in-vessel methods, and windrows. The composting method used in this study is windrow composting, which is chosen for its simplicity and popularity. However, each method will be summarized for comparison.

Passive Manure Pile

This is the oldest and most common form of composting manure, yet it is also the least effective. The passive manure pile, as the name suggests, is simply a pile of manure, except none of the conditions affecting the composting process are actively controlled. This method works best when bedding, such as straw or sawdust, is used as a bulking ingredient, thus increasing the carbon to nitrogen (C: N) ratio of the manure and decreasing the moisture content. This accelerates the composting process. It is recommended that piles not exceed six feet high and twelve feet wide, which allows air to move through the pile (Rynk et al.). This method of composting is slow, increases the chance of odors, and usually yields an inferior product.

Passive Aerated Windrows

This more recent method eliminates the turning process by supplying air to the compost through perforated pipes that are embedded in each windrow. Rynk recommends that windrows be between three to four feet high and should be constructed on a bed of straw, peat moss or finished compost. This allows moisture to be absorbed and provides insulation, which minimizes flies, odor, and ammonia (Rynk et al.). This method yields a finished product more quickly then the passive piles.

Aerated Static Pile

The aerated static pile method is based on the same concept as the passive aerated windrows. In this method, air is forced through the compost pile by a blower. Use of the blower permits piles to be larger. These piles are five to eight feet high and seventy to ninety feet long. With this technique the pile is not turned and is again formed over a bed of wood chips or chopped straw which contains the perforated aeration pipe. The pipe is connected to a blower that either pushes or pulls air through the pile. The pile is covered with about six inches of fresh composted manure to maintain moisture, reduce heat loss, and to minimize flies and odors, while also filtering out some ammonia (Rynk et al.).

In-Vessel

The most complex and capital intensive systems for composting dairy manure are the various in-vessel methods. These include bin composting, rectangular agitated bins, and silos. In-vessel methods confine the compost mixture to buildings, containers or vessels, and tend to rely on numerous forced aeration and mechanical turning methods, which accelerates the composting process (Rynk et al.). In-vessel composting is both very sophisticated and expensive, and relatively uncommon despite its good results.

Windrow Composting

The composting method on which this paper focuses is windrow composting. This is a relatively simple process that involves placing a mixture of dairy manure and bulking materials into windrows or piles that are turned regularly. The dimensions of the windrows are determined by the capacity of the windrow turner. Unlike the aerated methods air is introduced to the mixture by the turning process, which fluffs the material by creating pore spaces that trap air. This process also releases trapped gases, water vapor, and excessive heat that may exist in the compost mixture (Rynk et al.).

Description of The Model Farm

The model farm was based on a milking herd size of seventy-five cows which is roughly the average milking herd size of a Maine dairy farm. The model farm also includes dry cows and herd replacements. Dry cows represent an additional15 percent of the milking herd size or about twelve dry cows per seventy-five milking cows (Blawat &

Droppoetal). In addition, the model includes sixty-five replacement heifers, based on Wattiaux's estimate of 87 percent of the milking herd size. The total herd size for the model is 152 including milking cows, heifers, and dry cows.

The total daily volume of manure is a direct function of the total milking herd size. I assume that the manure produced on the model farm contains no bedding such as sawdust or straw.

Composting Procedures

The first step in the composting process occurs when the manure is mixed with bulking ingredients to achieve the target C:N ratio of roughly 25:1 and a moisture content of approximately 60 percent (Rynk et al.) This C:N ratio, guarantees that other nutrients such as phosphorus and potassium are available in adequate amounts. These are important for both the composting process and when used to facilitate plant growth. If there is an excess of nitrogen present in the compost mixture, the nitrogen will become unstable, causing it to be lost into the atmosphere. If an excess of carbon exists, this will lead to a longer composting time because the microorganisms will need additional time to use up the surplus carbon (Rynk et al.).

A moisture content of roughly 60 percent is desired throughout the composting process. This supports the metabolic processes of the microbes. Water provides the medium required for chemical reactions to take place, and a method of transportation for the nutrients and microorganisms to move throughout the compost mixture. Runoff and separated liquids should be reapplied to the composting manure to maintain the desired moisture content.

This mixture of manure and bulking ingredients is then placed into windrows, which are turned when the temperature drops below 120 degrees Fahrenheit and when few odors are present. The composting manure stays in the initial composting section for sixty days, then it is moved to the curing area where it is turned less frequently and remains for thirty more days. Finally, it is moved to the storage area where it remains for ninety days. In New England the majority of composted manure is sold from April through October and with the most being sold in June.

Compost Volume

Total Daily Volume of Manure

The total daily volume of manure (T), is a function of the total milking herd size (A), which represents the number of cows on the farm. Dry cows and herd replacements are not considered independently, but are accounted for while computing the total daily volume of manure (T), as illustrated in Equation 3.1.

Equation 3.1

$$T = \frac{A(M_D + P_D M_D + P_H H)}{Y} = 0.0977A$$

Where 'M_D' is the quantity of manure produced by both dry and milking cows (1.836 ft^3). The average sized replacement heifer produces only 0.608 cubic feet (H) of manure daily

(Blanchard). As previously stated dry cows represent an additional 15 percent (P_D) of the milking herd size and heifers represent an additional 87 percent (P_H) of the milking herd size. The variable 'Y' is used to convert the total daily volume of manure (T) from cubic feet to cubic yards (27 ft^3 per 1 yd^3).

Using the model farm's total milking herd size of seventy five cows, the total daily volume of manure produced is calculated to equal 7.3 cubic yards. Appendix B provides a list of all variables and constants used in the following equations, and a brief description of each.

Daily Sawdust Requirement

The total amount of sawdust needed per day (S) is a function of the total daily volume of manure (T). Where one cubic yard of sawdust is equal to 410 pounds (S_C) and one cubic yard of manure is equal to 1,458 pounds (M_C). To achieve the optimum mixture, one pound of sawdust is required for every pound of manure. Equation 3.2 estimates the total amount of sawdust needed per day (S) as a function of the total milking herd size (A).

Equation 3.2

$$S = \frac{TMc}{Sc} = 0.3474A$$

The total daily volume of sawdust required by the model farm is twenty-six yards per day. The total quantity of sawdust could be decreased by putting the manure through a separator. This process would decrease the moisture content of the manure. Additional information about this can be found in Appendix C.

Total Daily Mix of Manure and Sawdust

To control the quality of the end compost product, it is necessary to mix the dairy manure with a bulking ingredient. For this study sawdust (S) is chosen. During the mixing process approximately 20 percent (0.80) (R_M) of the initial manure and sawdust volume is lost (Rynk et al.). Equation 3.3 illustrates the method used to calculate the total volume of manure (T) and sawdust (S) that remains once the two materials are mixed together (T_S). This equation is also a function of total milking herd size (A).

Equation 3.3

$$T_S = (T + S)R_M = 0.35608A$$

The initial volume of manure and sawdust entering the initial stage of the composting process for the model farm is about twenty-seven cubic yards per day.

Quantity of Composted Manure in the Initial Area

There is a continuum of material put into and removed from the initial composting area everyday or every few days. The mixture of manure and sawdust (T_S) remains in the area for approximately sixty days (D_I), therefore on any given day there is roughly sixty days (D_I) worth of material in the initial composting area. The time that the composting manure is in the initial composting area may fluctuate slightly.

Due to shrinkage we consider a volume that is 75 percent (R_I) less then implied by the input of raw manure and sawdust. The method used to calculate the total quantity of composting material located in the initial composting area (N_I) is presented by

Equation 3.4 which measures 'N_I' in cubic yards and express it as a function of the total milking herd size (A).

Equation 3.4

$$N_I = (T_S D_I) R_I = 16.0236A$$

The total amount of composting material located in the initial composting area for the model farm is estimated to be 1,202 cubic yards.

Quantity of Composted Manure in the Curing Area

Composting manure is being moved continuously from the initial composting area to the curing area. This material remains in the curing area for roughly thirty days (D_C). Because of shrinkage we consider a volume 50 percent (R_C) less then implied by the input of raw manure and sawdust (T_S). By the end of the curing phase, the composting process has taken ninety days; sixty days in the initial composting area and thirty days in the curing area.

The quantity of composting manure in the curing area (N_C) can be determined through the use of Equation 3.5, which is a function of the total milking herd size (A).

Equation 3.5

$$N_C = (T_S D_C) R_C = 5.3412A$$

Using the model farm as an example, the quantity of material in the curing area is estimated to be 400 cubic yards at any given time.

Quantity of Composted Manure in the Storage Area

The final section is the storage area. Composting manure is moved into this area every day or every few days. The composted manure remains here for approximately 90 days (D_S). After 180 days the volume of the initial mixture of sawdust and manure (T_S) has reduced by a shrinkage factor of approximately 0.50 (R_S). No significant volume reduction occurs in the storage area. The method used to calculate the volume of composted manure found in the storage area (N_S) is presented in Equation 3.6, which is expressed as a function of the total milking herd size (A).

Equation 3.6

$$Ns = (T_S Ds)Rs = 16.0236A$$

The model dairy farms stored volume is about 1,202 cubic yards of composted manure.

Operations and Their Costs

Mixing Composting Manure and Windrow Formation

Mixing can be done in a variety of different ways, but for this study a PTO driven manure spreader is used. The mixture of manure, sawdust, and urea is transported to the composting site where it is formed into windrows. Fuel and operator wages are the two ownership costs associated with the manure spreader. The manure spreader used in this study is already owned by the dairy farm and will not be purchased at this time.

Table 3.1: The Cost of Producing Composted Dairy Manure on the Model Farm With a Windrow Turner.

Direct Costs	Unit	Price	Quantity (Annual)	Total Annual Cost When a Windrow Turner is used	Total Cost ($/lb)	% of Total Cost
Operating Costs						
Windrow Turner	hr	$13.55	36	$487.80	$0.000169	1.1%
Manure Spreader	hr	$13.55	34	$460.70	$0.000159	1.0%
Sawdust Truck	hr	$21.00	213	$4,473.00	$0.001549	10.1%
Bulking Ingredient Sawdust	yd^3	$6.25	9,519	$28,558.42	$0.009887	64.5%
Urea	lb	$0.12	57,317	$6,872.34	$0.002381	15.5%
Sum of Direct Costs				**$40,852.26**	**$0.014145**	**92.3%**
Indirect Costs (fixed)						
Interest				$17.69	$0.000006	0.0%
New Material				$350.00	$0.000121	0.8%
Insurance				$89.52	$0.000031	0.2%
Windrow Turner		$16,200	1			
Depreciation				$972.00	$0.000337	2.2%
Site Construction		$19,609	1			
Depreciation				$1,960.94	$0.000679	4.4%
Sum of all listed indirect costs				**$3,390.15**	**$0.001174**	**7.6%**
Sum of all listed Costs				**$44,242.41**	**$0.015319**	**100.0%**

Operating costs include the per hour cost of labor, fuel, and repair and maintenance.
The method used to calculate interest can be found in Appendix D.

Table 3.2: The Cost of Producing Composted Dairy Manure on the Model Farm When a Tractor Loader is used to Turn the Compost.

Direct Costs	Unit	Price	Quantity (Annual)	Total Annual Cost When a Tractor Loader is used	Total cost ($/lb.)	% of Total Cost
Operating Costs						
Tractor Loader	hr	$13.07	222	$2,901.54	$0.001001	6.4%
Manure Spreader	hr	$13.55	34	$460.70	$0.000159	1.0%
Sawdust Truck	hr	$21.00	213	$4,473.00	$0.001549	9.8%
Bulking Ingredient Sawdust	yd^3	$6.25	9,519	$28,558.42	$0.009887	63.0%
Urea	lb	$0.12	57,317	$6,872.34	$0.002381	15.0%
Sum of Direct Costs				**$43,266.00**	**$0.014977**	**94.8%**
Indirect Costs (Fixed)						
Interest				$43.86	$0.000015	0.1%
New Material				$350.00	$0.000121	0.8%
Site Construction		$19,609	1			
Depreciation				$1,960.94	$0.000679	4.3%
Sum of all listed indirect costs				**$2,354.80**	**$0.000815**	**5.2%**
Sum of all listed Costs				**$45,620.80**	**$0.015792**	**100.0%**

Operating costs include the per hour cost of labor, fuel, and repair and maintenance.
The method used to calculate interest can be found in Appendix D.

Table 3.1 provides a breakdown of all the costs involved in the production of composted manure on the model farm, when a windrow turner is used in the production process. In addition, Table 3.2 presents the costs of producing composted manure when a tractor loader is used to turn the composting material.

Windrow Turning

The cost of purchasing a windrow turner depends on the type, self-propelled or PTO driven, and the amount of compost turned per hour. Compost turners range in price from $7,400 to $250,000 (Rynk et al.). In this model, the windrow turner cost is $16,200, with an annual cost of $972.00 ($0.000337 /lb of dairy manure) and is responsible for 2 percent of total expenses (Waltner). On small composting operations a tractor loader can be used to turn composted manure thus decreasing total fixed costs.

The initial capital investment of the composting machinery is expensive. If the equipment is not functioning at full capacity, it is suggested that this equipment be used for custom work, thus providing additional income to the equipment owner. This additional work could be done on other composting operations, or the owner could purchase additional manure from other farmers resulting in increased production.

A PTO driven windrow turner is chosen for its low-cost and capacity to handle large quantities of composting manure. The windrow turner requires at least a ninety horse power (hp) tractor. For the purpose of this study, it is assumed that a tractor already exists on the farm and it does not need to be purchased.

In the initial composting area, windrows should be turned at least once per week in the summer and less frequently during the colder months. Turning the windrows accelerates the composting process and reduces fly problems. As composting manure ages, the frequency with which it needs to be turned decreases (Rynk et al.). The costs associated with turning compost consist of purchasing the windrow turner, fuel for the tractor, operator wages, and repairs and maintenance, totaling $13.55 per hour representing 1 percent of total cost. For smaller operations, a tractor loader that already exists on the farm can be substituted for the windrow turner.

Labor

One decision faced by producers of composted manure is whether to hire additional employees or to allocate the responsibilities of the composting operation to existing employees. This study assumes that no additional employees would be hired to work on the composting operation. To accurately estimate the quantity of labor hours required by the composting operation, the following must be considered: hauling sawdust, mixing manure with bulking ingredients, windrow formation, and windrow turning. On average, an agricultural equipment operator earns $8.00 per hour, according to the National Agricultural Statistics Service (USDA, 2000).

Within the composting operation, a major user of labor is the compost turning process. The windrow turner is used to turn the composted manure in the initial composing area (N_I) and the curing area (N_C). It is capable of turning approximately

1,200 cubic yards (W) per hour. To calculate the total amount of labor used by the windrow turner (L_W), Equation 3.7 is used, which is a function of the milking herd size (A).

Equation 3.7

$$L_W = \frac{W_I N_I + W_C N_C}{W} = 4807A$$

This equation takes two important items into consideration: the number of times a year that material is turned in the initial composting area, which is 30 times (W_I), and curing area, which is 18 times (W_C).

The manure spreader uses labor to mix and form the windrows. This study assumes that a box manure spreader is used, which holds sixteen cubic yards of manure and assumes that it can make three trips in one hour from the farm composting site, which indicates that forty-eight cubic yards (M_S) of material can be moved in one hour. Equation 3.8 is a function of the total milking herd size (A) and is used to calculate the labor costs associated with the use of the manure spreader (L_M).

Equation 3.8

$$L_M = \left(\frac{T_S + N_I + N_C}{M_S}\right) = 0.4525A$$

This equation takes into consideration the labor cost of mixing and moving the initial mixture of manure and sawdust (T_S) to the initial composting area (N_I), the curing area (N_C), and the storage area.

The final major user of labor is the process of hauling sawdust (L_H) from the mill to the composting site for use as bulking material. An arbitrary distance of twenty miles between the mill and the composting site was chosen for this study, with the speed limit on the highway assumed to be sixty miles per hour. A round trip from the composting operation to the mill and back, will take approximately 0.67 of an hour (U) (40 minutes). Additionally, it is assumed that the truck can haul thirty cubic yards of sawdust at one time (X), and that it hauls all the sawdust needed per day (S) for all 365 days (D). The method used to calculate the total quantity of labor used to haul the sawdust is presented in Equation 3.9, as a function of the total milking herd size (A).

Equation 3.9

$$L_H = \left(\frac{SD}{X}\right)U = 2.827A$$

To determine the total amount of labor (L_T) used by the composting operation, the labor cost of the manure spreader (L_M), windrow turner (L_W), and sawdust hauling (L_H) are added together, as seen in Equation 3.10. The total amount of labor (L_T) is expressed as a function of the total milking herd size (A).

Equation 3.10

$$L_T = L_W + L_M + L_H = 3.276A$$

For the model dairy farm, 246 labor hours are required per year.

Bulking Ingredients

A number of items must be considered when choosing the appropriate bulking ingredients including, cost, moisture content, C:N, and availability. For this model, sawdust is selected because it is easily obtained by dairy farmers all year round. The estimated cost of sawdust is $3.00 per cubic yard and there is approximately one pound of sawdust used for every pound of manure (Hancock Lumber Company). Sawdust has a relatively low moisture content of roughly 39 percent and a high C:N ratio of 750:1 (Rynk et al.). This combination of a low moisture content and a high C:N ratio will make achieving the desired moisture content and C:N ratio difficult.

Some cheaper alternatives to sawdust do exist, which include potato tops, cull potatoes, corncobs, newspaper, and aquatic waste products. The problems with these alternatives are seasonal and geographical location, but these alternatives may provide the compost producer with an additional source of income in the form of tipping fees. Fees are paid by waste producers to compost producers for taking their waste products. This prompts two interesting questions that future research could answer: how would other bulking ingredients impact the cost of producing composted manure? and, how would different bulking ingredients change the compost production process?

Daily Urea Requirements

Urea is a chemical fertilizer that contains 46 percent nitrogen and costs roughly $0.12 per pound (Saskferco). As noted earlier sawdust and manure must be mixed at a ratio of one pound of manure to one pound of sawdust, insuring adequate moisture content. The urea is added to achieve the desired C:N ratio of 25:1. Without the addition of urea, the mixture will not contain enough nitrogen to create a quality composted manure product. Equation 3.11 calculates the pounds of urea needed to achieve the desired C:N ratio, as a function of the total milking herd size (A).

Equation 3.11

$$F = TBU = 2.179A$$

Where 'F' is the pounds of urea per day required, 'B' is the daily weight of manure per cow (1,458 lbs) and 'U' is the supplement urea requirement (0.015 lbs). The optimal mixture in this model farm is one pound of manure, one pound of sawdust and 0.015 pounds of urea.

Total Fuel

Fuel is primarily used by the tractor, which is responsible for running the manure spreader and windrow turner. A gallon of diesel fuel costs approximately $1.30 including the delivery fee (Hill).

When calculating the total quantity of fuel (T_F), measured in gallons, used by a tractor there are a few preliminary calculations that need to be done. These additional factors include the average fuel consumption for a 90-hp tractor when a windrow turner and a manure spreader are being used, which equals to 4.27 gallons per hour (Z_{TS}) *(ASAE)*. These values were calculated using equations provided by *ASAE Standards*; Appendix D provides a description of these calculations.

The truck used to haul sawdust from the mill to the composting site uses approximately one gallon of diesel fuel for every six miles traveled, or ten gallons per hour (Z_H) when the speed limit is sixty miles per hour. This equates to 6.67 gallons of fuel for a round trip. The total amount of diesel fuel (T_F) consumed on the composting operation is calculated using Equation 3.12, which is expressed as a function of the total milking herd size (A).

Equation 3.12

$$T_F = Z_{TS}(L_W + L_M) + Z_H L_H = 32.245A$$

Where 'L_W' is the number of labor hours used by the windrow turner, 'L_M' is the number of labor hours used by the manure spreader and 'L_H' is the number of labor hours used to haul sawdust. For the model herd, the annual volume of fuel consumed is estimated to be 2,418 gallons.

New Materials

All low-cost equipment is grouped under this heading. The two major items are a thermometer and a microwave. The thermometer is needed to test the temperature of the composted manure, which assists producers with determining when the composted manure is ready to be turned. This piece of equipment costs $270 (Agpro). A microwave oven is also purchased to assist in determining the moisture content of material as it goes through the composting process. The total cost of new materials is $350.00 ($0.000121/lb of dairy manure) as stated in Tables 3.1 and 3.2.

Insurance

Insurance has a value of $90 when the windrow turner is used and only $45 when a tractor loader is used. The per pound cost of the insurance section is $0.000031 with windrow turner and $0.000015 without a windrow turner. According to *ASAE* the cost of insurance is 0.25 percent of the items purchase price.

Site Construction

The Layout of the Composting Site

In the developmental stage of a compost operation one of the most important considerations is the composting site. A site should be constructed on a piece of cleared land, close to the farm in order to minimize manure transportation costs. Appendix A illustrates a sample composting site. Sites require about a 3 percent slope, which allows water to run into a water collection pond, located about four feet from the low end of the site. A two-foot high dike surrounds the site to retain the water and to direct runoff into the pond. The site should be graveled to a depth of about six inches, divided into an initial composting area, a curing area, and a storage area (Rynk et al.).

The suggested dimensions of the windrows are based on recommendations made by the *On-Farm Composting Handbook* and the capacity of the chosen windrow turner. When a small windrow turner is used, the windrows should be three to four feet high and nine to eighteen feet wide; windrows that are turned with a bucket loader can be six to twelve feet high and ten to twenty feet wide. The distance between the windrows should be twenty feet wide, allowing equipment to pass, and the borders surrounding the perimeter of the composting site should be ten feet wide. An equipment storage area, next to a driveway should be provided. The driveway and equipment storage should both be about twenty feet wide and fifty feet long (Rynk et al.).

Construction plans should consider proximity to neighbors and waterways, visibility and the soil type. Properly managed composting manure will emit few odors, except when it has been turned recently. When windrows are being turned, the odors from the composting manure and the noise of the windrow turner can become a nuisance to neighbors. For these reasons, the composting site should be located at least 200-500 feet from any residence or business. It is also important to minimize visibility to the site, when possible, thus maintaining good public relations.

To minimize problems, such as mud on the composting site, the formation of puddles, over-moist composted manure that is difficult to dry, and extreme runoff and leaching, the composting site must be constructed on land with soil that has moderate drainage ability. The distance to wetlands, surface water, and any other type of water source should also be considered, minimizing the chance of water pollution. Therefore, a site should be constructed at least 100-200 feet away from any of these natural water sources (Rynk et al.).

Construction Costs

The composting site should be graveled rather than paved, because of the lower cost of gravel. This also decreases repair and maintenance costs. Additionally, gravel helps reduce the quantity of runoff, the formations of puddles, and the amount of mud on the site.

Gravel is estimated to cost about $12 per cubic yard, while the average per acre price of agricultural land in Maine is approximately $1,190.00 (USDA,1999). Land can be leveled with a bulldozer at a rental cost of $300 a day (Smart).

Construction of a composting site is a one-time-only cost. Table 3.3 illustrates a listing of all the costs involved in the construction of a composting site. Each value was calculated per cubic yard of manure. The construction costs are estimated using some of the equations previously presented in this chapter. Equation 3.3 is used to estimate the volume of sawdust and manure entering the initial composting area. To calculate the total volume of material in the initial composting area at one time Equation 3.4 is used. It is assumed that each windrow is 150 feet long, eight feet high, and fourteen feet wide. The area covered by each windrow is calculated along with the volume of compost contained in each windrow. Using the volume of composting material located in the initial composting area and the volume of material contained in a windrow it is estimated that six windrows are in the initial composting area. This process is then repeated for the curing area, using Equation 3.5, and the storage area, using Equation 3.6. Additionally, two windrows are required in the curing area and six windrows are required in the storage area. On each side of each windrow ten feet is left for equipment to pass between the rows. The estimated size of this composting site is 1.84 acres.

Table 3.3: The Cost of Constructing the Site for the Model Dairy Farm.

Constructio n Costs	Per Unit Cost	Unit	Quantity of each item.	Total Cost	Cost per yd^3	% of Compost Costs
Gravel	$12.00	yd^3	1,1490	$17,441	$6.69	88.6%
Rental	$37.50	1hr	1.84	$67	$0.02	0.3%
Labor	$8.00	hr	1.84	$14	$0.01	10.9%
Fuel	$1.30	gal	11.06	$14	$0.01	0.1%
Land	$1,190.00	acre	1.84	$2,139	$0.82	0.1%
Total Cost				**$19,609**	**$7.55**	**100.0%**

The total initial cost of constructing a composting site per cubic yard of dairy manure is equal to $7.55, as seen in Table 3.3. The most expensive construction cost is gravel, representing 89 percent of the total cost.

Cost Assumptions

This study assumes that all quoted prices for both the fixed and variable costs are competitive and reflect the prices of all competitors. As the operation grows through the addition of more dairy cows, the purchasing of additional manure from other farms or composting materials from other sources, will impact the overall cost of composting. This impact may include the following: the purchase of a larger windrow turner and a tractor, the hiring of additional employees, and the increase in the size of the composting site.

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Any of these changes could lead to additional expenses, but could also increase the output of the composting operation.

Cost and Revenue Estimates

On the model dairy farm, which has 75 milking cows, approximately 1,950 tons of manure are produced annually. To obtain the optimum level of moisture roughly1,950 tons of sawdust are used annually. Achieving the ideal C:N ratio is done by adding approximately 4.75 tons of urea. Once the composting process is complete, the resulting volume of composted manure is roughly equal to 1,296 tons per year. The average farm gate price of bagged composted manure is $0.06 per pound and bulk composted manure is $0.01 per pound. The way these figures were determined was explained in Chapter 1.

Value of Manure

Non-Compost Disposal and/or Utilization Cost

Un-composted manure contains a large number of nutrients that are important to the successful growth and development of field crops. The three most important nutrients found in dairy manure are nitrogen (N), phosphorus (P) and potash (K) (Hubbard & Lowrance). The percentage of 'N' in dairy manure is 0.48 percent, 'P' 0.09 percent and 'K' 0.33 percent.

The cost per pound of 'N', 'P', and 'K' as a chemical fertilizer was obtained from Cavendish Agriculture Services, where they estimated these values to be $0.16 per pound of 'N', $0.31 per pound of 'P', and $0.31 per pound of 'K' (Flapper). The fertilizer value being placed on one cubic yard of manure is $3.02. Typically the market value of manure is half it's fertilizer value. This is the result of uncertainty in the quantity of fertilizer found in manure. Additionally concerns about the presences of weed seeds also contribute to uncertainty. To spread one cubic yard of manure onto a field costs approximately $0.38.

Gain/Loss from Composting

There are a number of benefits associated with spreading composted manure onto fields. The composting process reduces the number of weed seeds originally present in the manure, and kills off many diseases. Composted manure requires fewer trips to the field because it has reduced in volume and provides a more consistent and predictable supply of nutrients. There are a number of environmental benefits associated with composted manure such as a reduction in leaching and runoff, thus minimizing the chance of water pollution. Composted manure can provide farmers with an additional source of income through product sales, and the composting process can become an effective way to dispose of waste products while allowing compost producers to earn tipping fees.

If the environmental benefits of spreading compost on to fields are not taken into consideration, then the savings that producers incur from a decrease in transportation costs will not cover the cost of producing the compost product. Spreading composted dairy manure on to crop land may be beneficial if a cost was placed on the environmental benefits that composted manure provides.

Summary

The cost incurred from producing one pound of composted manure with a windrow turner was determined to be $0.015319. In the case where a tractor loader is used to turn the composted manure the cost incurred for producing one pound of composted manure equals approximately $0.015792. The farm gate price of bulk composted manure is $0.01 per pound and for bagged composted manure is $0.06 per pound; these prices were determined in Chapter 1. Before the profitability of composting dairy manure can be determined, it will be important to determine the cost per mile to transport composted manure. This will be discussed in Chapter 4 and if producers want to bag their product the costs of bagging will be determined in the following chapter.

Chapter 3

BAGGED COMPOSTED MANURE

The goal of this section is to determine the cost of bagging composted dairy manure. Researchers suggest that bagging composted dairy manure allows producers to access a larger portion of the composted manure markets while enjoying increased profits from higher product prices (Satkofsky, and Compost Management Associates & R. Alexander Associates Inc.). This chapter will answer the question: how much does it cost to bag composted dairy manure?

A wide variety of bagging systems are available, consisting of manual, semi-automated, and fully-automated. This section will focus on the manual system, but it will also discuss other options available to compost producers. A manual system was selected for this study because Maine's composted manure industry is small and developing. The manual system provides an excellent starting point for producers venturing into the bagged composted manure sector. As the bagging operation grows, additional pieces can be added on to the existing system making it increasingly automated.

Equipment Types

The wide variety of compost bagging systems allow producers to choose the system and the features that meet their needs. Bagging systems are not appropriate for all compost production operations, especially when a producer is entering the bagged market for the first time. In this case it might be more feasible to have composted materials custom bagged, see Appendix E for further details.

Fully-Automated Systems

In general fully-automated systems have higher capital costs, but their variable costs tend to be lower. For the fully-automated system, fewer employees are required to efficiently operate it. According to a representative from Hamer Packaging Systems, a fully automated system can cost between $400,000 and $500,000 (Brown). On average, fully-automated bagging systems have the ability to bag thirty-five bags per minute and operate twenty-four hours a day. These systems use rolls of preprinted centerfold poly-film bags. According to a representative for Creative Packaging Inc. they cost 10 percent less than pre-formed bags used in some semi-automated and manual systems.

Semi-Automated Systems

In the more common semi-automated systems, bags move along a conveyer through a continuous heat sealer. The bags are then placed onto pallets, where each pallet is wrapped by a machine. These systems usually bag eighteen to twenty bags per minute (Satkofsky). They cost between $50,000 and $400,000. For systems that are not completely automated it is important to remember that physical fatigue will force employees to not be able to work a full eight hour shift. Lifting the bags will cause workers to fatigue after only a few hours (Satkofsky).

Manual

Manual systems are an excellent place to start if a producer is just entering into the bag sector. This system is the cheapest, costing between $15,000 and $50,000, and it provides producers with the opportunity to add on new pieces of equipment as the operation grows to make the bagging process more automated (Satofsky). Under normal production circumstances, a manual bagging operation has the capacity to fill roughly seven pre-formed bags per minute. A manual system usually consists of a supply hopper, a small electronic impulse sealer, and a manually operated stretch wrapper.

The manual bagging system is very popular in the composting industry due to the seasonality of the demand for compost. Many producers only use their bagging operations for roughly three months of the year, and hire either seasonal employees or relocate existing employees to the bagging operation during this period. According to Ceder Grove and Earthgro four employees are needed to assist with bagging their products, one attaches the bag, another removes the bag from the sealer, and two load bags onto pallets (Steuteville).

Fixed Costs

There are a number of fixed costs associated with starting a compost bagging operation such as a bagger, a warehouse, a skid-steer with a bucket, a skid-steer with a forklift attachment, and a screener. Table 4.1 provides information on the fixed costs involved in starting a bagging operation.

Bagger

The bagging system used in this study consists of a bag sealer, a bag carrying conveyor, and a material hopper. Pre-formed bags are required for this system. The bagger has the capacity to handle bags of varying sizes, between eight quarts and three cubic feet. The hopper used by this system can hold four cubic yards of composted manure at any given time. The bagging system requires four employees to efficiently operate the machine. According to a representative from Bouldin and Lawson, this bagging system costs $40,000 (Moffler). This price includes the cost of a soil bagger, a bag carrying conveyer, a bag sealer, shipping, set-up assistance, and operator instruction. The cost of this system represents 26 percent of the total fixed costs as presented in Table 4.1. The deprecation was calculated using the equation found in Appendix D.

The manual bagging system was selected due to its relatively low cost in comparison to automated and semi-automated systems. It can also accommodate bags that weigh forty pounds and more. According to the bag market survey conducted in Chapter 1, the most popular bag size for composted manure is a forty pound bag.

Table 4.1:The Value of Each Fixed Cost Involved in the Bagging Process, for the Model Farm that has a Milking Herd of 75 Cows.

Fixed Cost	Accounting Cost	*Cost per Bag	*Cost per Pound	% of Fixed Costs
Bagger	$40,000			
Depreciation	$2,400	$0.0369	$0.0002	25.7%
Skid-Steer and Bucket	$27,900			
Depreciation	$1,673	$0.0257	$0.0006	17.9%
Skid-Steer and Forks	$27,850			
Depreciation	$1,670	$0.0257	$0.0006	17.9%
Warehouse	$50,000			
Depreciation	$1,250	$0.0192	$0.0005	13.4%
Screener	$35,000			
Depreciation	$2,100	$0.0323	$0.0008	22.5%
Interest	$260	$0.0040	$0.0010	2.8%
Totals		**$0.1438**	**$0.0037**	**100.0%**

**Assumes 65,000 bags are being filled at 40 lbs each.*

Skid-Steers

Two skid-steers are used in the bagging process. The first is used to fill the material hopper with composted manure as needed, while the second is equipped with forks to move empty and full pallets. When purchasing a skid-steer for this operation, another very important restriction has to be considered: the height required to dump the composted manure into the hopper. For this system, the machine must have a reach of 9.5 feet. The cost of each skid-steer is $27,185 (Gibbs). The bucket purchased for this project has the capacity to hold fourteen cubic feet of material. The bucket is larger than what is required, but in order to get a skid-steer with the ability to clear 9.5 feet, a larger machine needed to be purchased. The cost of this bucket is $710 (Gibbs). The price of the skid-steer and bucket together is about $27,900, with an annual depreciation cost of $1,673 representing 18 percent of the total fixed costs.

The second skid-steer has a fork lift attachment, giving it the ability to perform the duties of a fork lift, such as stacking pallets or loading them onto trucks for transport. The forks are forty-eight inches long and a frame is required to attach the forks to the skid-steer. The price of this whole attachment is approximately $660 (Gibbs). The skid-steer and the fork lift attachment combined cost $27,850, with an annual depreciation cost of $1,670 representing 18 percent of total fixed costs.

Warehouse

A warehouse is designed to house the compost bagging system and to store bagged compost, empty plastic bags, and stretch wrap. Appendix F presents a possible floor plan design for the warehouse. Multiple items need to be considered when designing a warehouse. The warehouse must be large enough for a skid-steer to bring composted manure in from outside. The roof needs to be high enough to allow the machine to dump the composted manure into the hopper. Another skid-steer must have enough room to move and stack pallets of composted manure. Finally, three employees will be working around the bagger, and they need the appropriate space to perform their jobs.

The skid-steer used to load the hopper requires 14 feet of height in order to successfully dump the composted manure into the hopper. The bagging system requires a space that is 8.5 feet long, 6.5 feet wide and 9.5 feet high. The bagger also requires a location that can easily be accessed by the skid-steer, which brings composted manure in from the composting site.

It is assumed that the bagging operation would have roughly fifty pallets of composted manure in storage at one time. Since the roof of the building must be sixteen feet high, pallets can be stacked two high, which means that floor space for twenty-five pallets is required. Each pallet is assumed to be three feet long and three feet wide. The amount of space needed to store bagged composted manure is estimated to be 225 square feet.

Space is also needed to store both the stretch warp and the empty bags. This space should be at least eight feet wide to accommodate the skid-steer, used to retrieve pallets of stretch wrap or empty bags. Since the storage area for these two items is located next to the storage area for the bagged composted manure, they have the same depth of twelve feet. The square footage of these two storage areas is forty-five square feet. Separate rooms are not created for these storage areas, but floor space is assigned to accommodate the various items.

At the loading dock and at the entrance from the composting site, enough space must be left to allow the skid-steer to turn around. This machine is eleven feet long, including the bucket or forks, and can turn 360 degrees without moving far forward or backward. Therefore, fourteen feet is left to allow this piece of equipment to turn easily. Around the bagger, at least twelve feet is left to allow the skid-steers to freely move around the warehouse, easily accessing all areas of the building. When the bagging system is operating, three employees will also be working around the machine at all times. A minimum of six feet is left on one side of the bagger to allow these employees the ability to work without being interfered with by moving skid-steers or piles of stored products.

The warehouse is thirty feet long, forty-five feet wide and sixteen feet high, with a total area of 1,485 square feet. The construction cost per square foot for a warehouse is estimated to equal $38.00; this was obtained from the book entitled, *Building Construction Cost Data 2002.* This price is then adjusted for the state of Maine yielding a cost of $33.50 per square foot (Waier et al.). The estimated cost of constructing this warehouse is $50,000, and the annual depreciation cost is $1,250 which represents 13 percent of the total fixed costs.

Screener

A screener is used to insure consistency in compost particle size. The screener chosen for this study is capable of screening twenty-five cubic yards of compost per hour. Twenty-two free swing blades are used to decrease the size of compost particles. The screener is self propelled by a 20-hp diesel engine. Only one employee is need to carry out the screen function. This individual can monitor the screener while driving the skid-steer, that is used to fill the one cubic yard material hopper with compost. The retail cost of the screener is $35,000 (Neuhaus). The annual depreciation cost of the screener is $2,100, which represents 23 percent of total fixed costs.

Interest Cost

A real interest rate is used to calculate the total amount of interest incurred by the bagging operation over a ten-year time period. A detailed description of how the interest rate is calculated for each piece of equipment and for the warehouse can be found in Appendix D. The total amount of interest incurred by this operation is $2,600 over ten years. This translates into an annual cost of $260 and represents only 3 percent of the total fixed costs.

Variable Costs

The variable costs involved in a bagging operation consists of electricity, bags, pallet wrap, diesel, labor, fuel, and repair and maintenance. Table 4.2 provides a list of all variable costs.

Table 4.2: The Value of Each Variable Cost Involved in the Bagging Process for a 75 Milking Cow Herd.

Variable Cost	Quantity	$ per unit	Units	Total Cost	$/ pound	% of Variable Cost
Electricity	3.74	$0.07	kwh	$40	$0.000015	0.1%
Bags	65,000	$0.23	bag	$10,393	$0.004001	36.6%
Pallet Wrap (1/3 per pallet)	360	$28.00	pallet	$10,104	$0.003890	35.6%
Fuel: Diesel	7.27	$1.30	gal	$400	$0.000154	1.4%
Repair and Maintenance:				$1,285	$0.000494	4.5%
Insurance				$452	$0.000174	1.6%
Labor	715	$8.00	hr	$5,719	$0.002202	20.1%
Totals				**$28,393**	**$0.010930**	**100.0%**

Each 1 cubic foot bag weights 40 pounds.
Capacity is 360 bags per hour.

Electricity

The number of kilowatts per hour is calculated using an equation from the *American Society of Agriculture Engineers Standards (ASAE)*. This equation, and an explanation of it, can be found in Appendix G. The bagging system requires roughly 3.74 kilowatts per hour of electricity to operate. One kilowatt of electricity costs $0.07, according to Central Maine Power. Therefore, it costs approximately $0.000015 to bag one pound of composted manure representing 0.1 percent of the total variable costs.

Bags

In order to determine the cost of the bags used in the bagging operation, some assumptions need to be made. The bags are assumed to be plastic and one cubic foot in size, giving them the capacity to hold forty pounds of composted manure. The label on the bag is two sided and consists of three different colors. The estimated cost per bag is $0.23 when 30,000 bags are ordered at once, which is the minimum order size required by Creative Packaging Inc. (Schumpert). The cost of a bag, per pound of composted manure equals $0.004001 representing 37 percent of total variable costs.

Pallet Wrap

To estimate the quantity of stretch wrap used by each bag, some assumptions need to be made. It is assumed that each bag weighs forty pounds and there are sixty bags per pallet. Each pallet will use roughly one third of a role of stretch wrap. Stretch wrap must be purchased in pallets and each pallet contains forty rolls, costing $28.00 a roll

(Williams). An equation is used to estimate the amount of stretch wrap used per bag. This equation, and an explanation of it, can be found in Appendix G. Each bag uses 0.0055 of a roll costing $0.003890 per pound of composted manure, this represents 36 percent of total variable costs.

Fuel

The two skid-steers are the sole consumers of diesel fuel in the bagging enterprise. The quantity of diesel fuel used by each machine is calculated using an equation provided by *ASAE*. This equation, and a description of it, can be found in Appendix D. The total amount of fuel consumed by each machine in an hour is estimated to be 3.20 gallons, which translates into 0.01 gallons per bag. The cost per gallon is $1.30, this estimate includes taxes and delivery to the bagging operation (Hill). The cost per pound for both machines is estimated to be $0.000154 and represents 1 percent of total variable costs.

Repair and Maintenance

The repair and maintenance costs are estimated for the two skid-steers, the screener, the warehouse, and the bagging system. These values are calculated with an equation provided by *ASAE*. The equation used to calculate repair and maintenance costs can be found in Appendix D, along with a description of potential costs. Also included in the costs of repair and maintenance is the cost of lubricating the equipment. It is generally understood that lubrication costs are 15 percent of the fuel costs (Boehlje& Eidman). The repair and maintenance cost for the skid-steers, screener, warehouse, and bagger are equal to $0.000494 per pound, which is 5 percent of the total variable cost.

Labor

Four employees are required to efficiently operate the bagging system. One individual drives the skid-steer, loads the hopper, and if time allows, drives the skid steer that is equipped with forks to move pallets. The second employee is responsible for placing the empty bags onto the bag holder. This individual than steps on the foot petal causing the bag holder to grip the bag and for composted manure to fall from the chute, filling the bag. A third person guides the bags through the bag sealer as they move along the conveyor. The fourth person removes the bags from the conveyor and stacks them onto pallets. Additionally one employee is also required to operate the screener. The hourly wage rate for an agriculture equipment operator in the US is $8.00 (U.S. Department of Labor). The total labor cost per pound is $0.002202, representing 20 percent of total variable costs.

Summary

The variable cost incurred from bagging one pound of composted manure is $0.010930 and the fixed cost associated with bagging composted manure is $0.003700 per pound. Therefore, it is assumed that the total cost of bagging one pound of composted manure is $0.014693. The farm gate price of un-certified, bagged, composted manure is $0.05 per pound as discussed in Chapter 1. The cost of producing one pound of composted manure with a windrow turner is $0.015319, so the total cost of producing and bagging one pound of composted manure is equal to $0.030012 per pound. Before we can determine if bagging composted manure is profitable, it is important to determine the cost per mile of transporting bagged composted manure, which will be discussed in the following chapter.

Chapter 4

TRANSPORTING COMPOSTED MANURE OF MARKET

Transportation costs are often overlooked, but they play an important role in estimating the potential size of Maine's composted manure market. Accurately estimating these costs will help composted manure producers determine the location of their market boundaries, and subsequently establishing the maximum distance that a composted manure producer could profitably transport their products. Failure to accurately estimate these costs could result in the compost manure producer failing to make a profit.

The goal of this chapter is to estimate the cost of transporting both bulk and bagged composted manure products to market. To achieve this, first the theory behind transportation costs will be addressed, followed by a description of the data, and methods used to estimate these costs. The final section of this chapter will present the results and concluding comments. This chapter will answer the question: how much does it cost to transport bulk and bagged composted manure to market?

Theory

Transfer Costs

Transfer costs are defined as all costs involved in transporting composted manure from its point of origin to its final destination. Accurately establishing transfer costs is essential in determining how far composted manure can profitably be transported.

Transfer costs include both fixed and variable costs. Examples of fixed costs are the cost of insurance, loading, and unloading composted manure from a truck (Tomek & Robinson). Alternatively, examples of variable costs include those related to the volume of composted manure being transported and the distance being traveled between the point of origin and the final destination. Another important factor to consider is the mode of transportation; for this study freight trucks will be used (Govindasamy & Cochran).

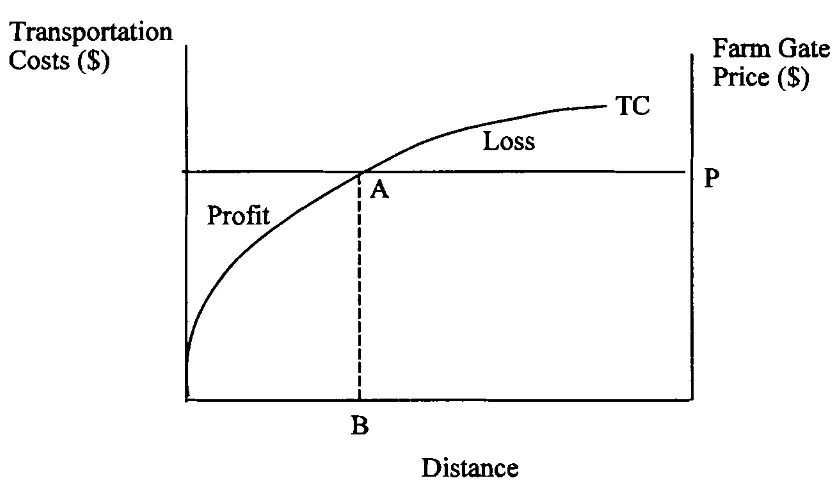
In the case of homogenous products, like composted manure, their origin does not play a significant role in determining the price consumers are willing to pay. It is assumed that the bagged composted manure sector is perfectly competitive. If this is true, it is safe to assume that the farm gate price of bagged composted manure will be the market price minus all transfer costs.

According to Chapman and Walker, transporting finished products is more expensive than transporting raw materials. This assumption is based on the idea that finished products require additional care when they are being handled. This theory implies that bagged composted manure will require additional care when it is being loaded and unloaded to prevent bags from breaking. The bulk product does not demand this additional care. If this theory is correct, it will be more costly to transport bagged composted manure than bulk composted manure. Each of these potential transfer costs will be examined in this chapter.

Market Area

Determining the size of the composted manure market can be a difficult task. The farm gate price, the cost of transporting composted manure to market, and the distance between the point of origin and the final destination must all be considered. As the distance to the market increases, producers' total costs also increase. Researchers generally believe that transportation costs increase at a decreasing rate, indicating that they are not a linear function of distance (Tomek & Robinson, and Judge & Wallace). This can be seen in Figure 5.1, in which the maximum distance that composted manure products can be transported by a producer is represented by point 'D'. At point 'E', the cost of producing, bagging, and transporting the composted manure product is equal to the farm gate price. A producers' break-even point occurs where the farm gate price (P) intersects the distance being traveled (D). If producers ship composted manure beyond this point they will incur losses, but if they ship composted manure below this point then they will enjoy profits.

Figure 5.1:The Theoretical Transportation Function.



Data

Yellow Transport, a company that transports various products all over the United States, provided some of the data used to determine the cost of transporting bagged composted manure to market. Some assumptions needed to be made for rate estimates to be obtained, including the size of the composted manure bag and the number of bags per pallet. This study assumed that composted manure would be sold in forty pound bags with sixty bags per pallet. These assumptions are based on the way the companies such as Erth Products LLC and B and B Bedding are selling their bagged compost products. Size and weight restrictions were placed on a load by Yellow Transport. The Trailers are only 27.5 feet long, 8.75 feet high, and seven feet wide. Additionally, each trailer has a weight limit of twelve tons (Lierz). The study assumed that each shipment of composted manure would represent a full truckload which consists of ten pallets or twelve tons.

The point of origin for all shipments of composted manure was selected with the assistance of the *1997 Census of Agriculture*. Maine's highest milk sales occurred in Kennebec County, and the town of Windsor was chosen as the point of origin, because it is centrally located in Kennebec County.

The final destination points for the composted manure products are represented by thirty different cities located primarily on the East coast of the United States. All the necessary information about each of these cities is presented in Table 5.1.

Table 5.1: Possible Destinations for Maine Composted Manure and There Transportation Costs Provided by Yellow Transport.

State Destination	City Destination	Distance From Windsor to Destination (Miles)	Total Transportation Costs ($). From Windsor to Destination	Cost $/ton
Maine	Augusta	12	$327.00	$27.20
Maine	Lewiston	51	$327.00	$27.20
Maine	Bangor	54	$327.00	$27.20
Maine	Portland	78	$327.00	$27.20
Massachusetts	Boston	188	$327.00	$27.20
Connecticut	Hartford	262	$404.63	$33.80
New York	Albany	318	$327.00	$27.20
Vermont	Concord	324	$327.00	$27.20
Vermont	Montpelier	327	$407.66	$34.00
New York	New York	398	$1,006.88	$84.00
Pennsylvania	Allentown	465	$482.11	$40.20
Pennsylvania	Philadelphia	498	$401.27	$33.40
Pennsylvania	Harrisburg	565	$466.71	$38.80
New York	Buffalo	618	$522.91	$43.60
Pennsylvania	Pittsburgh	768	$632.90	$52.80
Ohio	Akron	782	$1,047.25	$87.20
Ohio	Cleveland	808	$772.26	$60.00
Ohio	Columbus	897	$542.50	$45.20
West Virginia	Charleston	902	$662.42	$56.00
North Carolina	Raleigh	913	$665.51	$55.40
Indiana	Fort Wayne	961	$581.21	$57.40
North Carolina	Charlotte	968	$752.33	$62.60
Tennessee	Knoxville	1068	$784.33	$65.40
Indiana	Indianapolis	1125	$543.36	$45.20
South Carolina	Charleston	1141	$772.26	$64.40

Table 5.1: Continued

Kentucky	Frankfort	1157	$770.13	$64.20
Tennessee	Nashville	1246	$915.06	$73.20
Georgia	Atlanta	1248	$1,580.04	$131.60
Alabama	Huntsville	1282	$969.19	$80.80
Arkansas	Little Rock	1589	$1,613.15	$134.40

The point of origin for all final destinations is Windsor Maine.

The price estimates are based on a twelve tons load of bagged composted manure transported by Yellow Transport.

To alleviate any concerns about Yellow Transport's small hauling capacity of twelve tons, a competing company was also contacted. This company, Bouchard's Transport, operates trailers with a hauling capacity of 23.5 tons. A full truck load would consist of nineteen pallets of composted manure weighing 22.8 tons. Inquiries were made about the total cost of transporting 22.8 tons of composted manure to nine different locations. Bouchard's automatically charged $250.00 for shipments traveling 200 miles or less. Additionally, a representative from Bouchard's said that the total transportation cost does not depend on the volume being transported, but instead upon the distance to be traveled (Smith).

Table 5.2 presents all the necessary information for each city including cost quotes from Bouchard and Yellow Transport. If the cost per ton per mile from Yellow Transport was compared to Bouchard's as seen in Table 5.2, it is evident that it is cheaper to transport products within Maine using the larger trailers. However, once the destination is outside of Maine, both companies charge roughly the same price.

Table 5.2: A Comparison of the Transportation Costs Provided by Yellow Transport and Bouchard's Transport.

State Destination	City Destination	Distance From Windsor to Destination (Miles)	Blanchard Total Transportation Costs ($). From Windsor to Destination	Bouchard Cost $/ton	Yellow Cost $/ton
Maine	Augusta	12	$250.00	$11.00	$27.20
Maine	Lewiston	51	$250.00	$11.00	$27.20
Maine	Bangor	54	$250.00	$11.00	$27.20
Maine	Portland	78	$250.00	$11.00	$27.20
Connecticut	Hartford	262	$691.60	$30.40	$33.80
Pennsylvania	Allentown	465	$888.00	$39.00	$40.20
Ohio	Columbus	897	$1,352.85	$59.40	$45.20
Kentucky	Frankfort	1157	$1,834.00	$80.40	$64.20
Alabama	Huntsville	1282	$1,577.80	$69.20	$80.80

The Price Estimates are Based on a 45,600 pound Load of Bagged Composted Manure Transported by Bouchard's Transport.

The point of origin for all destinations is Windsor, Maine.

Using the data presented in Table 5.1 and 5.2, a number of outliers are apparent. These outliers are caused by a number of different circumstances. In the case of New York City, a $500 congestion surcharge is added to the base shipping price. Atlanta and other destinations located along the route to Florida are charged higher rates because they are located on a popular route, and also, it is difficult to fill trucks for the return trip. For destinations in close proximity to Windsor, Maine, a minimum charge usually applies. If the calculated cost of shipping compost to a specific location is less than the minimum, the minimum charge will apply. This explains why five of Yellow Transportation's destinations have a transportation cost of $327(Lierz).

To help insure the accuracy of the results obtained from this study, a number of locations will not be included in the analysis. Locations charged the minimum rate of $327 in the case of Yellow Transport and $250 in the case of Bouchard's Transport will not be included because these values are not based on distance. The other destinations not included in the study are all outliers; Akron, Atlanta, Charleston, Indianapolis, Little Rock, New York, and Pittsburgh. The descriptive statistics for the total cost of transporting composted manure from its point of origin to its final destination, using the remaining twenty-one locations are presented in Table 5.3.

Table 5.3:The Descriptive Statistics for Total Cost of Transportation and the Distance from Windsor, Maine to all Destinations, Using the Data Provided by Yellow Transport and Bouchard's Transport.

	Total Cost of Transportation ($/ton). From Windsor to Destination	Distance From Windsor to Destination (Miles)
Mean	53.7	820.9
Sample Variance	267.6	119,490.3
Minimum	30.3	262
Maximum	80.8	1,282
Number	21	21

The cost of loading and unloading a truck is often overlooked, but is an important part of accurately calculating transportation costs. According to Yellow Transport (Lierz) and the USEPA, one hour should be allowed to load and unload the contents of the truck; this is not the responsibility of the trucking company it is the responsibility of the customer. To determine the cost of loading and unloading a truck, it is assumed that the hourly wage rate for an employee is $8.00 (U.S. Department of Labor). The job is performed by a skid steer with a fork lift attachment, as was discussed in the previous chapter.

While this chapter mainly focuses on the cost of transporting bagged composted manure, it also takes a glimpse into the cost of transporting bulk composted manure. A study conducted by Bosh and Napit will help determine the cost of transporting bulk composted dairy manure. They estimated the cost of transporting bulk poultry litter. It is assumed that the cost of transporting and handling poultry litter will be the same as composted dairy manure. They each have a similar moisture content, both are dry, and they have the same consistency. In Bosh and Napit's study, they obtained quotes from trucking companies and determined the cost of transporting poultry litter in 1990 to be $0.10 per ton per mile for an average hauling distance of ten miles. The cost of handling the material was estimated to be $11.42 per ton (Govindasamy & Cochran). Another study conducted by Pelletier, Pease and Kenyon determined the cost of transporting poultry litter in the state of Virginia in 1999 to be $0.11 per ton per mile with a truck that has a twenty-five ton hauling capacity. All these prices will be adjusted for inflation in the following section using the Producer Price Index (PPI) for all commodities.

Methods

The cost of transporting composted manure per ton per mile from its point of origin to its final destination is calculated using Equation 5.1. This model was developed by Judge and Wallace.

Equation 5.1

$$TC_{AB} = \beta_1 M_{AB} + \beta_2 M_{AB}^{0.5} + \varepsilon$$

A second equation was also used to estimate the cost of transporting a ton of composted manure from Windsor, Maine to various final destinations. This model is presented by Equation 5.2.

Equation 5.2

$$\ln TC_{AB} = \beta_1 + \beta_2 \ln M_{AB} + \varepsilon$$

where the following is true: 'TC' represents the cost of shipping composted manure to market from point A to point B, 'M' represents the distance in miles from point A (Windsor, Maine) to point B, 'β_1'and 'β_2' are unknown parameters, and 'ϵ' represents unobservable random error. It is generally believed that transportation costs increase with distance, but at a decreasing rate (Judge & Wallace).

The marginal cost function is calculated for both equations. It determines the cost of producing one more unit of output, or traveling an additional mile (Nicholson). It also represents the slope of the total cost function. The marginal cost function for Equation 5.1 is presented by Equation 5.3.

Equation 5.3

$$MC = \beta_1 + 0.5\beta_2 M_{AB}^{-0.5}$$

The marginal cost function for Equation 5.2 is presented by Equation 5.4.

Equation 5.4

$$MC = \beta_2\left(\frac{1}{M_{AB}}\right)$$

These marginal cost equations are used to determine whether the costs of transporting goods from point A to a given point B are increasing or decreasing as the distance between these locations increases. Both equations were calculated by taking the derivative of the total cost functions, Equation 5.1 and Equation 5.2, with respect to 'M_{AB}'.

It is important to determine if the total cost functions are increasing at an increasing or decreasing rate. This is determined by taking the second order derivative of each total cost function. The second order derivative for the first function, Equation 5.1, is represented by Equation 5.5.

Equation 5.5

$$\frac{\partial TC_{AB}}{\partial M_{AB}} = -0.25\beta 2\, M_{AB}^{-1.5}$$

The second order derivative for Equation 5.2 is illustrated in Equation 5.6.

Equation 5.6

$$\frac{\partial TC_{AB}}{\partial M_{AB}} = -\beta_2\left(\frac{1}{M_{AB}^{2}}\right)$$

These two equations are used to estimate if the cost of transporting composted manure increases at a decreasing rate as the distance between the point of origin and the final destination increases.

The next function calculated is average cost. It reflects the marginal cost of the last mile traveled and the greater marginal cost of the previously traveled mile. This function is also used to estimate the change incurred by the average cost function, if the final destination changes. Equation 5.7 represents the average cost function for Equation 5.1.

Equation 5.7

$$AC = \frac{\beta_1 M_{AB} + \beta_2 M_{AB}^{0.5} + \varepsilon}{M_{AB}}$$

The average cost function for Equation 5.2 is presented in Equation 5.8.

Equation 5.8

$$AC = \frac{\beta_1 + \beta_2 \ln M_{AB} + \varepsilon}{M_{AB}}$$

These average cost functions are determined by dividing their total cost by the distance between point A and point B (Nicholson).

Results

With the use of Ordinary Least Squares (OLS), both total cost functions are estimated. The parameter estimates for the first total cost function are displayed in Table 5.4, along with other descriptive statistics.

Table 5.4: Descriptive Statistics for the Total Cost Equation 5.1.

Variable	Parameter Estimate	Standard Error	T-statistic
M_{AB}	0.00102	0.00151	0.67
$M_{AB}^{1/2}$	*0.11177	0.04690	2.38
Adjusted R-Squared	0.94		
Sum of Squared Errors	20.12		
Degrees of Freedom	19		

** Indicates that the variable is significant. Critical t-value is 2.093.*
M_{AB} represents the distance between point A and point B.
The dependent variables is the total cost of transporting compost between point A and point B.

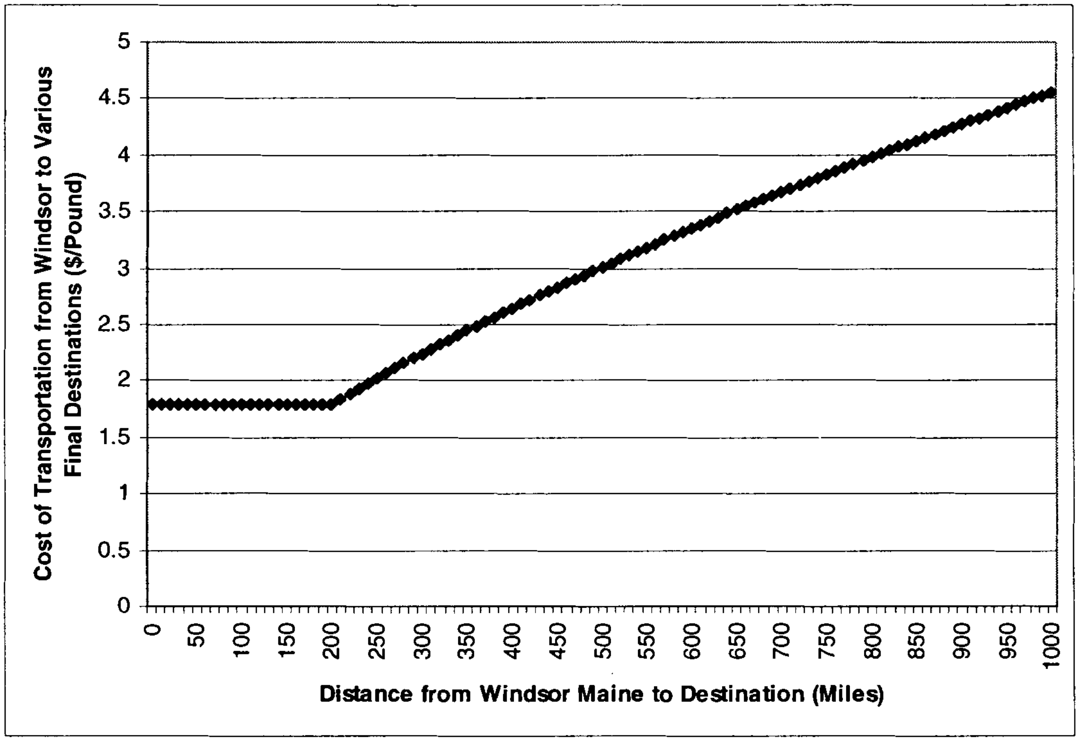
The resulting equation is found in Equation 5.9, which is used to calculate the cost of transporting bagged composted manure products.

Equation 5.9

$$TC_{AB} = 0.11177\, M_{AB}^{0.5}$$

A two tailed t-test is conducted, in which the null hypothesis is H_0: $\beta = 0$, meaning that the independent variable has a positive or negative effect on the dependent variable. The alternative hypothesis is that the independent variable does not have a positive or negative effect on the dependent variable, illustrated as H_1: $\beta \neq 0$. The critical t-value is 2.093, with nineteen degrees of freedom at a 95 percent significance level. For Equation 5.1, '$M_{AB}^{0.5}$' is significant, indicating that a 5 percent probability exists that different data could be obtained (Griffiths et al.). This model also indicates that the cost of transporting bagged composted manure per mile increases, but at a decreasing rate with distance, as seen in Figure 5.2.

Figure 5.2: Total Predicted Cost of Transporting Composted Manure from Windsor, Maine to Various Final Destinations, Equation 5.9.



The natural log of the total cost function (Equation 5.2) is also estimated, with the descriptive statistics for this function presented in Table 5.5.

Table 5.5: Descriptive Statistics for the Natural Log Total Cost Function (Equation 5.2).

Variable	Parameter Estimate	Standard Error	T-statistic
β_1	*0.93768	0.06060	15.47
$\ln M_{AB}$	*1.70870	0.07917	21.58
Adjusted R-Squared	0.95		
Sum of Squared Errors	0.36		
Degrees of Freedom	19		

** Indicates that the variable is significant. Critical t-value is 2.093.*
β_1 *represents the intercept term.*
M_{AB} *represents the distance between point A and point B.*
The dependent variables is the total cost of transporting compost between point A and point B.

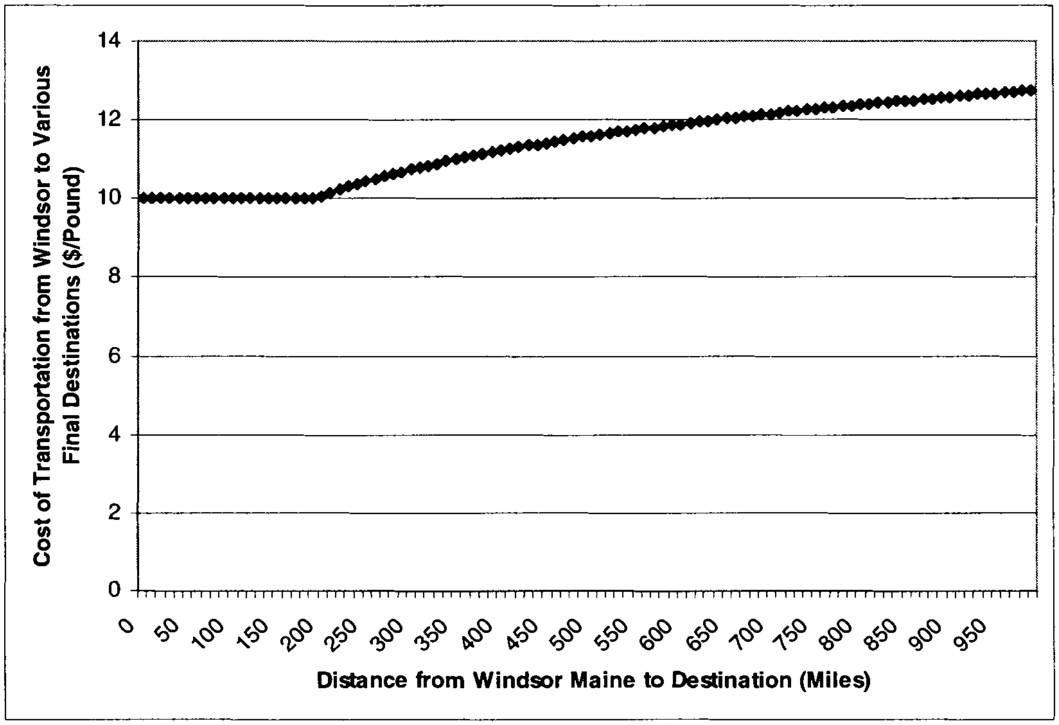
Using the calculated parameter estimates, Equation 5.10 is developed to calculate transportation costs for bagged composted manure products.

Equation 5.10

$$\ln TC_{AB} = 0.93768 + 1.70870 \ln M_{AB}$$

A two tailed t-test is conducted, with the same null and alternative hypotheses as previously stated. Again the critical t-value is 2.093, with nineteen degrees of freedom and a 95 percent significance level. The variable '$\ln M_{AB}$' is significant, indicating the acceptance of the null hypothesis. This model indicated that the cost of transporting bagged composted manure per mile increases but at a decreasing rate with distance, as seen in Figure 5.3. These results are comparable to the previous equation.

Figure 5.3: The Natural Log Total Predicted Cost Function, Equation 5.10. Used to Determine the Cost of Transporting Composted Manure from Windsor, Maine to Various Final Destinations.



Using Equation 5.9 and 5.10, the marginal cost of transporting composted manure to various destinations is calculated. The result is Equation 5.11 and 5.12.

Equation 5.11

$$MC_{AB} = 0.00102 M_{AB} - 0.5(0.11177) M_{AB}^{0.5} + \varepsilon$$

Equation 5.12

$$MC = 1.70870\left(\frac{1}{M_{AB}}\right)$$

The marginal cost functions are graphed and can be seen in Figure 5.4 and 5.5.

Figure 5.4: A Graph of the Marginal Cost of Transporting Composted Manure from Windsor, Maine to Various Final Destinations, Equation 5.11.

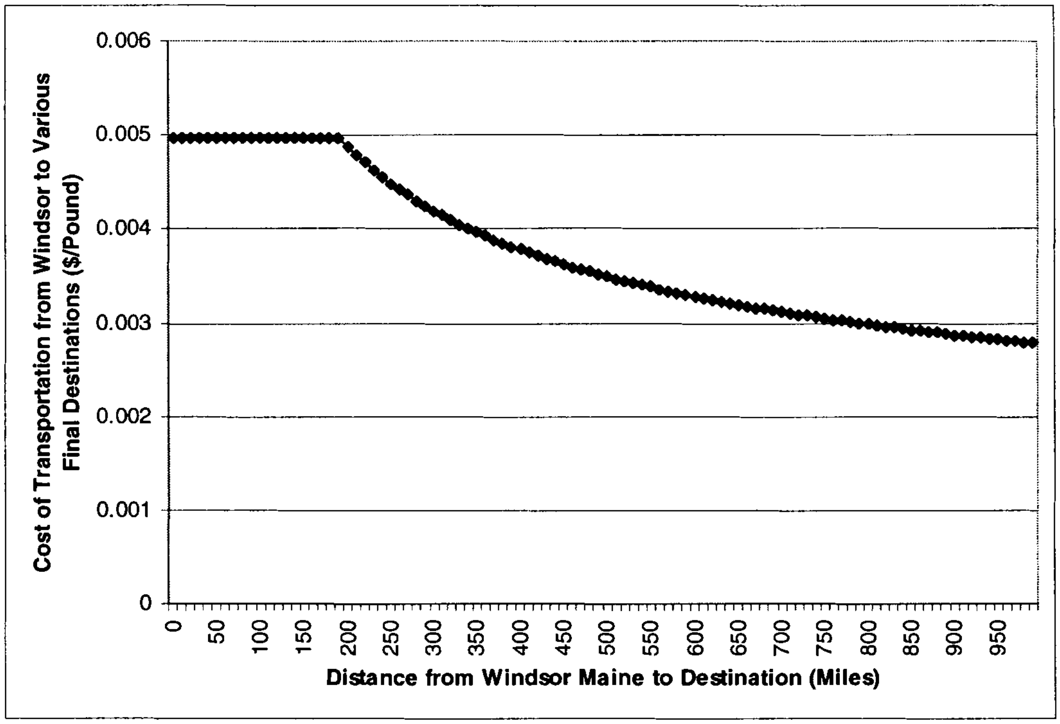
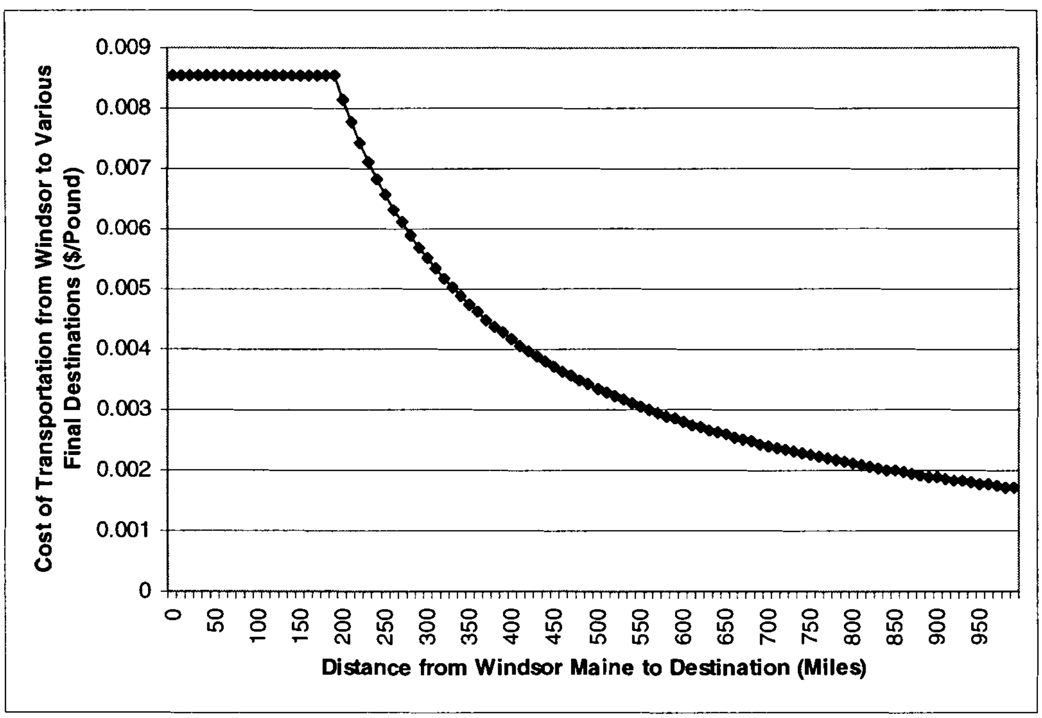


Figure 5.5: A Graph of the Natural Log Marginal Cost of Transporting Composted Manure from Windsor, Maine to Various Final Destinations, Equation 5.12.



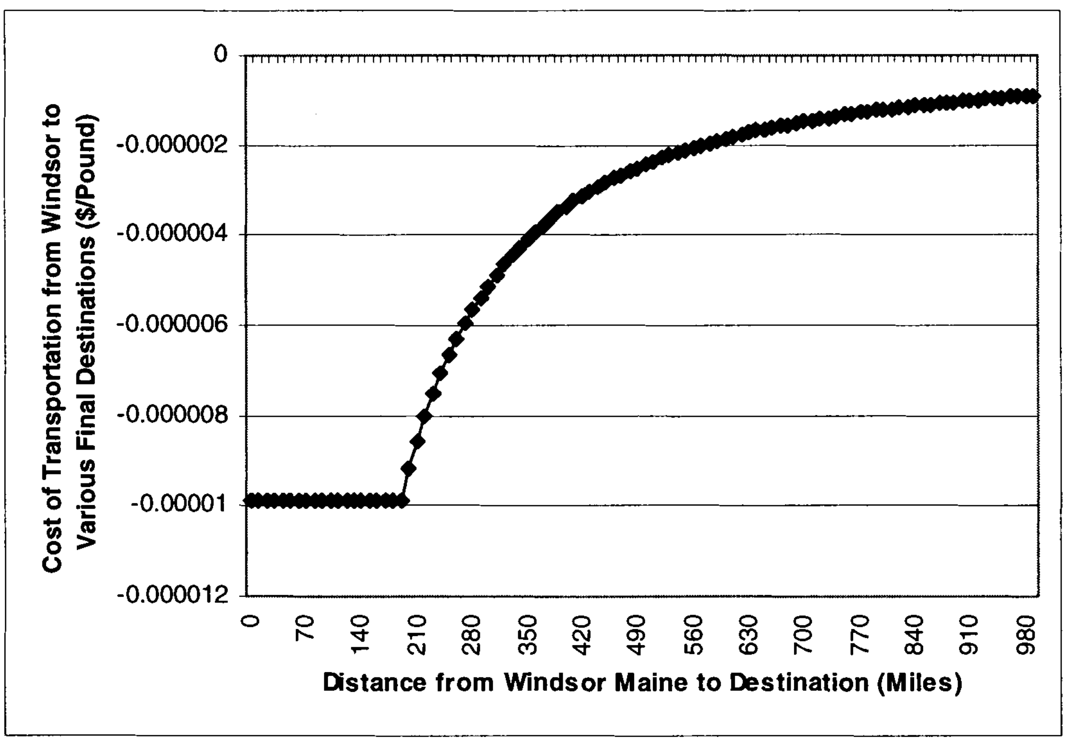
Figures 5.4 and 5.5 illustrate that as the distance to the final destination increases the marginal cost of transporting composted manure is decreasing at a decreasing rate. This is because the marginal cost functions are decreasing, which indicates that the total cost functions are increasing.

The final two equations used in this analysis of the total cost of transporting bagged compost manure are the second order derivatives of both total cost equations. Equation 5.13 and 5.14 represent the second order derivatives of Equation 5.1 and 5.2.

Equation 5.13

$$\frac{\partial TC_{AB}}{\partial M_{AB}} = -0.25(0.11177)M_{AB}^{-1.5}$$

Figure 5.6: The Second Order Derivative of the Total Cost of Transporting Composted Manure from Maine to Various Final Destinations, Equation 5.13.



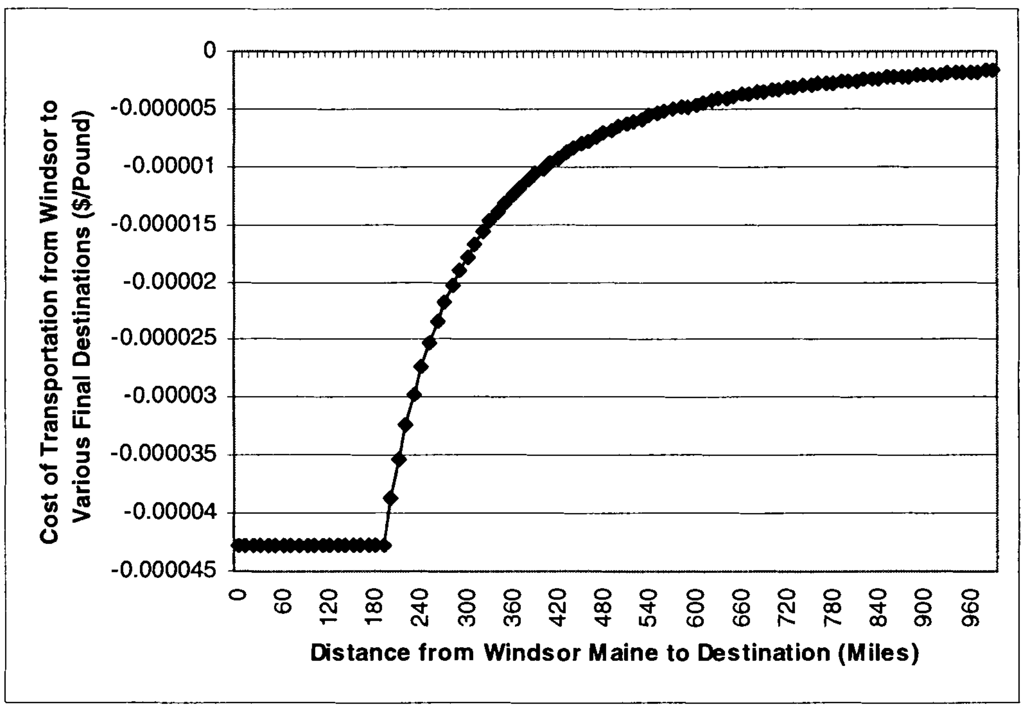
Equation 5.13 is increasing, but at a decreasing rate. According to Figure 5.6 a linear relationship appears to exist after 480 miles have been traveled. In the beginning, as the distance traveled increases, the cost of transporting bagged compost is increasing but at a decreasing rate.

Equation 5.14

$$\frac{\partial TC_{AB}}{\partial M_{AB}} = -0.11177\left(\frac{1}{M_{AB}^{2}}\right)$$

Equation 5.14 is increasing at a decreasing rate. Figure 5.7 illustrates that the total cost of transportation is increasing rapidly between 200 and 300 miles. After approximately 350 miles, have been traveled, a linear relationship between distance and cost beings to develop.

Figure 5.7: The Second Order Derivative of the Natural Log Total Cost of Transporting Composted Manure from Maine to Various Final Destinations, Equation 5.14.



To calculate the average cost functions Equation 5.15 and Equation 5.16 are used.

Equation 5.15

$$AC = 0.00102 + \frac{0.111177 M_{AB}^{0.5}}{M_{AB}}$$

Equation 5.16

$$AC = \frac{0.93768 + 1.708701 \ln M_{AB}}{M_{AB}}$$

The average cost function reflects the marginal cost of the last mile traveled and the somewhat greater marginal cost of the previously traveled mile (Nicholson). In the case of Equation 5.9 and 5.10, the marginal cost curve is less than the average cost curve. Graphs of these functions are displayed in Figure 5.8 and 5.9, which depict functions that are decreasing at a decreasing rate. This indicates that the transportation functions are increasing.

Figure 5.8: A Graph of the Average Cost of Transporting Composted Manure from Windsor, Maine to Various Final Destinations, Equation 5.15.

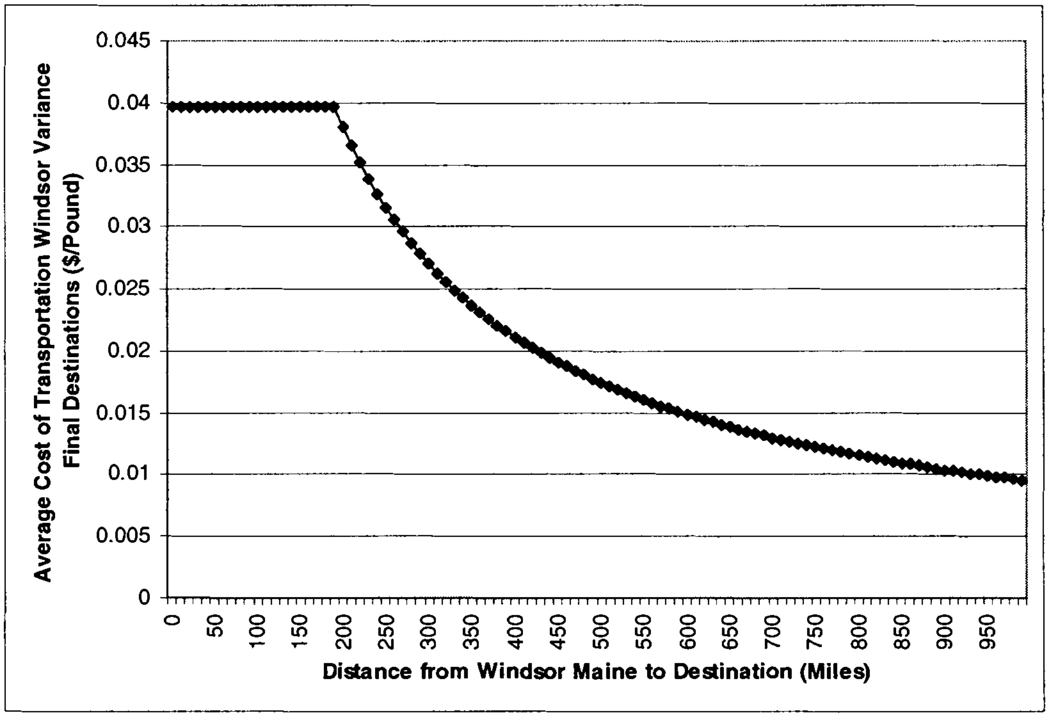
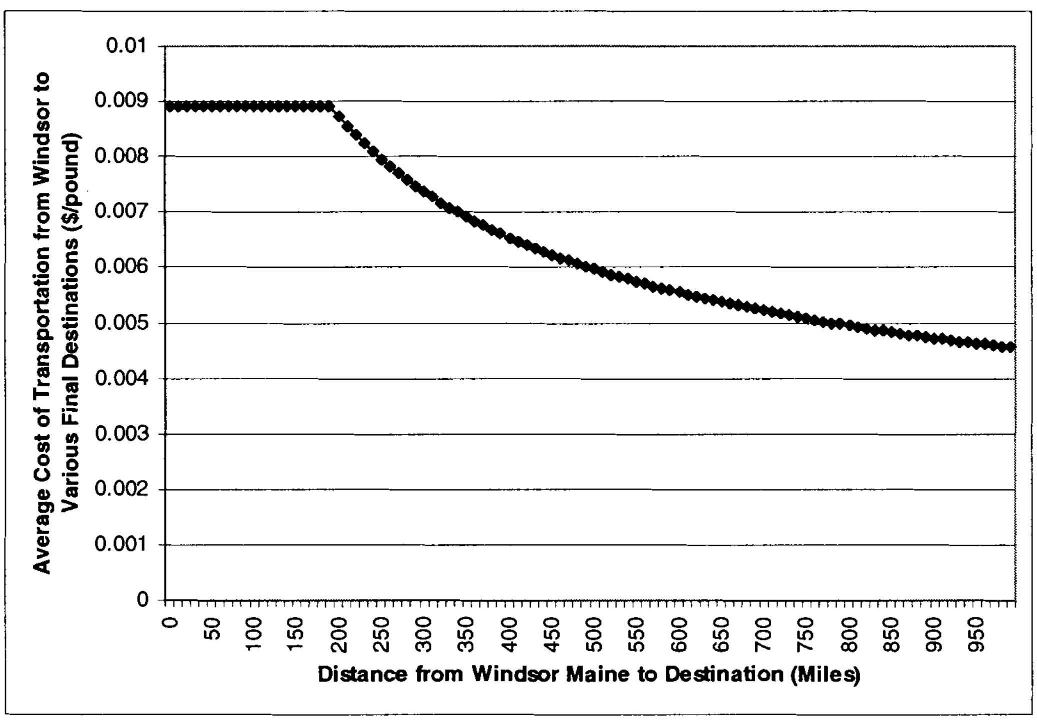


Figure 5.9: The Natural Log Average Cost of Transporting Composted Manure from Windsor, Maine to Various Final Destinations, Equation 5.16.



The Best Model

At a quick glance, Equation 5.9 appears to be the best estimator of the cost of transporting bagged composted manure. This equation has an adjusted R squared value of 94 compared to Equation 5.10, which has an adjusted R squared of 95. To determine if this initial assumption is correct, a likelihood test was conducted with both Equations 5.9 and 5.10. This test produced some interesting results that contradicted the preliminary assumption. It also indicated that Equation 5.9 was not fully ranked, which is a product of multicollinarity meaning that two columns in the covariance matrix are linearly related (Griffiths et al.). As a result of the likelihood test, it was determined that the natural log transportation function is the best equation for estimating the cost of transporting composted dairy manure from Windsor, Maine to its final destination.

Handling Costs

The costs of loading and unloading bagged composted manure products from a truck are important and must be considered. These costs include labor, fuel, and repairs and maintenance. The value of each of these variables appears in Table 5.6.

Table 5.6: The Costs Associated with Loading and Unloading Bagged Composted Manure Products onto Trucks for Transport.

	Quantity	Per Unit Cost	Total Cost	Cost per Ton	Cost per Pound
Labor	2 hr	$8.00	$16.00	$1.33	$0.000666
Fuel (Diesel)	6.4 gal	$1.30	$8.32	$0.69	$0.000346
Repair and Maintenance			$1.00	$0.08	$0.000016
Total			$25.32	$2.10	$0.001028

The equations used to calculate fuel usage and repair and maintenance can be found in Appendix D. The cost of loading and unloading 12 tons of composted manure is estimated to be $25.32, approximately $2.10 per ton.

In 1990 the Producer Price Index (PPI) was 116.3, in 1999 the PPI was 125.5, and for 2002 the PPI was 131.1, with a base year of 1982 (Bureau of Labor Statistics). Using the PPI for all commodities, with a base year of 1982, the cost of trucking bulk composted manure is estimated to be $0.12 per ton per mile, and the cost of handling the compost is estimated to be $13.11 per ton in 2002 dollars (Bureau of Labor Statistics). These estimated costs are based on the previously mentioned study conducted by Bosh and Napit, who determined the cost of transporting poultry litter in 1990. The study conducted by Pelletier, Pease, and Kenyon also determined the cost of transporting bulk poultry litter to be $0.12 per ton per mile.

Summary

This chapter establishes that as the distance between the point of origin and the final destination increases, the cost of transporting bagged composted manure per mile increases at a decreasing rate. This conclusion is illustrated in Figure 5.2 and 5.3. This can also be shown by observing the differences found between transporting composted manure to different locations. The cost of transporting bagged composted manure 500 miles is approximately $0.001853. per pound per mile, but transporting composted manure 1,000 miles would cost roughly $0.002047 per pound per mile. Handling costs are often overlooked, but they play an important role in calculating the cost of transporting bagged, composted manure to market. These costs are estimated to be $0.00102 per pound.

This chapter has estimated that it would cost roughly $0.12 per ton per mile, or $0.00006 per pound per mile, to transport bulk composted manure to market. The handling cost of bulk composted manure is estimated to be roughly $13.70 per ton, or $0.0068 per pound. These estimates were based on the studies conducted for poultry litter. This information will increase the accuracy with which producers estimate the cost of transporting bagged and bulk composted manure products to market.

Chapter 5

ANALYSIS OF PROFITABILITY

Analyzing the potential profitability of a new business prior to making any financial investment is important. This is especially true for the composted dairy manure industry, which has an uncertain future. For this reason the profitability of both the compost production enterprise and the compost bagging enterprise will be analyzed under a wide range of possibilities. This chapter will focus on determining the profitability of producing bulk composted dairy manure, bagging composted dairy manure, and transporting both a bagged product and a bulk product to market.

Sensitivity Analysis

To determine the long-run profitability of the composting operation a sensitivity analysis is conducted. This analysis focuses on the most important variables involved in the production process. The value of each selected variable is fluctuated to observe its effect on the profitability of the enterprises (Leiby). Another important part of the sensitivity analysis is calculating the net present value (NPV) and the net present cost (NPC), which is used to calculate the breakeven price. Both are calculated with the nominal interest rate, because it includes the expected rate of inflation. For this analysis, a nominal interest rate of 5.5 percent for land and equipment loans is used (Barron). An inflation rate of 0.37 percent (CNN) is also used in calculating the NPV and NPC. This inflation rate was obtained from the interest rate of a ten-year treasury bond.

Producing and Bagging Compost Dairy Manure

When producing bulk composted dairy manure, the most important variables to consider are the quantity of manure, the cost of bulking ingredients, the cost of urea, and the farm gate price of a bulk product. The quantity of dairy manure being composted is altered by changing the size of the milking herd. Three different milking herd sizes consisting of 75 milking cows, 125 milking cows, and 150 milking cows are analyzed. In Chapter 1, the farm gate price of bulk composted dairy manure was estimated to equal $12.50 per cubic yard ($0.013 per pound). Two additional prices where also included in this analysis, a low price of $7.50 per cubic yard and a high price of $17.50 per cubic yard. Once again sawdust is used as the bulking ingredient. As presented in Chapter 2, the per cubic yard cost of sawdust is $3.00 ($0.007 per pound). A high cost of $5.00 per cubic yard and a low cost of $1.00 per cubic yard is also included in the analysis of sawdust cost. Additionally, the price of urea as stated in Chapter 2 is $0.12 per pound. A high price of $0.14 per pound and a low price of $0.10 per pound are also included in the analysis of urea. The various fluctuations imposed on each variable are presented in Table 6.1.

In the compost bagging process the most important variables to consider are the farm gate price of bagged compost, the cost of plastic bags, and the number of bags being filled. As presented in Chapter 1, the average farm gate price of un-certified organic bagged compost is $0.05 per pound ($2.00 per 40 pound bag). Values of $0.02 per pound ($0.80 per 40 pound bag) and $0.08 per pound ($3.20 per 40 pound bag) were also used to represent low and high farm gate prices. According to Chapter 3, companies selling plastic bags used to bag compost require a minimum order size of 30,000 bags at a cost of $0.23 per bag. Additionally, a low price of $0.16 per bag and a high price of $0.30 per bag are also included in this analysis. As previously mentioned, three different herd sizes are used to illustrate the effect that the number of bags being filled has on profitability. Table 6.2 presents the analysis of each of the scenarios.

Seventy-eight different scenarios over ten years are considered for the production of compost and twenty-seven different scenarios are considered for the compost bagging enterprise. Table 6.1 presents the best, middle, and worst case scenarios for producing compost and Table 6.2 presents the best, middle, and worst case scenarios for bagging compost.

There are only fourteen profitable scenarios for the compost production enterprise. These scenarios occur when the total milking herd size is 150, 125 and 75, the farm gate price of bulk compost is $17.50 per cubic yard, sawdust costs $1.00 per cubic yard and urea cost $0.10 per pound. The other profitable scenarios occur when the total milking herd size is 150 and 125, the farm gate price of bulk compost is $17.50 per cubic yard, sawdust cost $1.00 per cubic yard and urea cost $0.12 per pound.

Table 6.1: The Best, Middle, and Worst Case Scenarios for Producing Bulk Composted Dairy Manure.

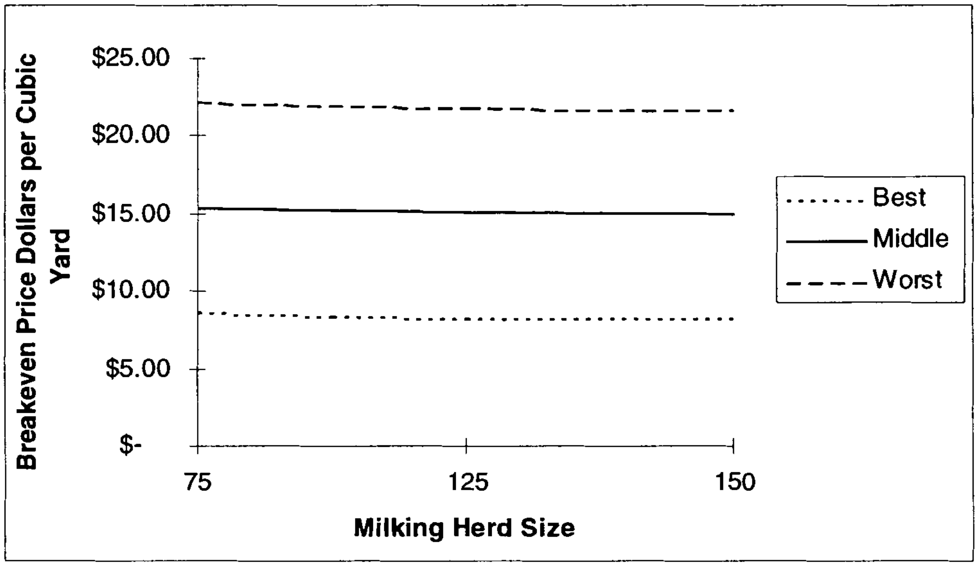
# of Animals	Farm Gate price of Bulk Dairy Compost ($/yd³)	Price of Sawdust ($/yd³)	Price of Urea ($/lb)	NPV	Breakeven Price ($/yd³)
Best					
75	$17.50	$1.00	$0.10	$92,978.00	$8.63
125	$17.50	$1.00	$0.10	$165,868.80	$8.29
150	$17.50	$1.00	$0.10	$202,598.71	$8.20
Middle					
75	$12.50	$3.00	$0.12	($154,740.97)	$15.41
125	$12.50	$3.00	$0.12	($246,995.12)	$15.07
150	$12.50	$3.00	$0.12	($292,837.77)	$14.98
Worst					
75	$7.00	$5.00	$0.14	($402,459.93)	$22.18
125	$7.00	$5.00	$0.14	($659,859.04)	$21.84
150	$7.00	$5.00	$0.14	($788,274.24)	$21.75

The breakeven price for the best, middle, and worst case scenarios are presented in Table 6.1 and Figure 6.1. In the best case scenario, the highest profits are enjoyed by the 150 cow milking herd, which achieves a NPV of $202,598. For this scenario the 150 cow milking herd has a breakeven price of $8.20. While the worst case, also involves the150 cow milking herd size, which experiences the highest deficit with a NPV of ($788,274). The breakeven price of this scenario is the highest of all the different scenarios, with a value of $21.75.

Figure 6.1 provides information on the cost incurred by the three different herd sizes. As the herd size increases the breakeven price per cubic yard of compost decreases.

Figure 6.1 illustrates that there are marginal differences found between each herd size. This figure indicates that the cost per cubic yard decreases with herd size.

Figure 6.1: The Breakeven Price for Producing Composted Manure for the Best, Middle, and Worst Case Scenarios.



For the bagging enterprise eighteen of the twenty-seven scenarios are profitable. Table 6.2 presents the best, middle, and worst case scenarios for the compost bagging enterprise.

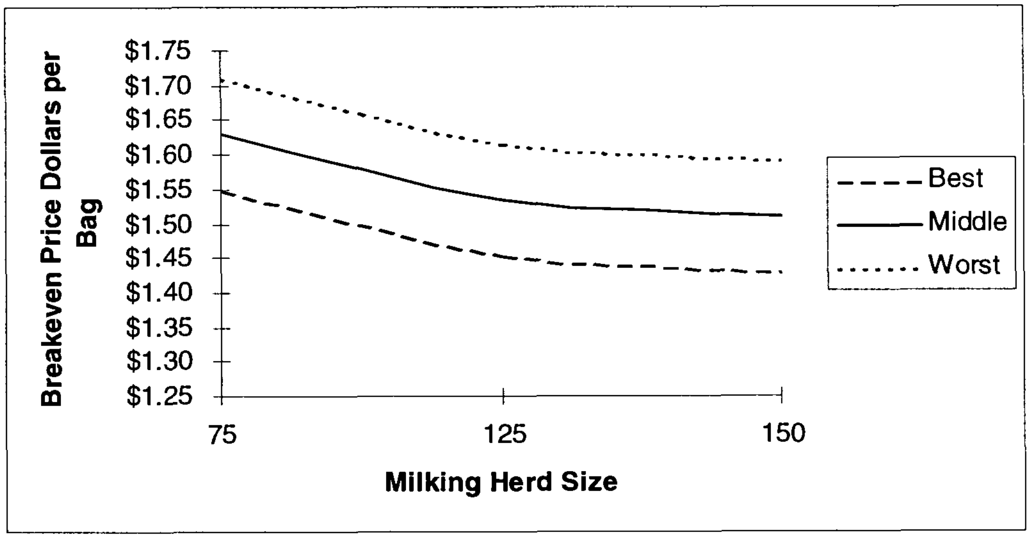
Table 6.2: The Best, Middle, and Worst Case Scenarios for Bagging Composted Dairy Manure.

# of Animals	Farm Gate Price of Bagged Dairy Compost ($/bag)	Price of Bags ($/yd^3)	NPV	Breakeven Price ($/bag)
		Best		
75	$3.20	$0.16	$1,337,638.42	$1.55
125	$3.20	$0.16	$2,298,872.05	$1.45
150	$3.20	$0.16	$2,779,040.92	$1.43
		Middle		
75	$2.00	$0.23	$425,436.31	$1.63
125	$2.00	$0.23	$778,535.37	$1.53
150	$2.00	$0.23	$954,638.42	$1.51
		Worst		
75	$0.80	$0.30	($486,765.81)	$1.71
125	$0.80	$0.30	($741,801.31)	$1.62
150	$0.80	$0.30	($869,764.09)	$1.59

The best case scenario for the compost bagging enterprise occurs when there are 150 milking cows. This happens when the farm gate price of a bagged product is $3.20 and the price per plastic bag is $0.16. In this scenario, the NPV is $2,779,040 and the breakeven price is $1.43. While the worst case scenario again occurs when there are 150 milking cows, but in this case the farm gate price of a bag of composted dairy manure is $0.80 and the cost per plastic bag is $0.30. For this case the NPV of only ($869,764) and a breakeven price of $1.59.

Figure 6.2 presents the breakeven price values for the best, worst, and middle case scenarios for the compost bagging enterprise. This figure again illustrates that the slope of the breakeven price is greatest between the 75 and 125 milking herds. After the 125 milking herd the slope of the breakeven curves decrease, depicting a more linear relationship between breakeven price and the size of the milking herd.

Figure 6.2: The Breakeven Price for Bagging Composted Manure for the Best, Middle, and Worst Case Scenarios.



Transporting Bulk and Bagged Composted Dairy Manure

The cost of transporting bulk composted dairy manure to its final destination is equal to $0.12 per ton per mile with additional handling cost of $13.60 per ton, as presented in Chapter 4. Presented in Table 6.3 are four distances that illustrate that the cost of transporting bulk compost dairy manure increase with distance.

Table 6.3: The Price that Producers Need to Charge for the Delivery of Bulk Composted Manure, in Order to be Profitable.

Distance (miles)	Delivery Cost ($/ton)	Delivery Cost ($/pound)
5	$14.20	$0.01
10	$14.80	$0.01
20	$16.00	$0.01
40	$18.40	$0.01

The product survey presented in Chapter 1 indicated that the bagged compost sector is regional. Therefore, this study assumed that the maximum distance to be traveled would be a 400 mile radius. This allows bagged composted manure to be transported anywhere in New England. The cost of transporting bagged composted dairy manure increases at a decreasing rate, as expressed in Chapter 4 and presented in Table 6.4. Using Equation 5.10 from Chapter 4, the cost of transporting bagged composted manure is estimated for each scenario. Additionally, a handling cost of $2.04 per ton must also be charged as presented in Chapter 4. Table 6.4 presents five different distances and the cost that producers must charge per ton to profitably delivery their bagged compost product.

Table 6.4: The Price that Producers Need to Charge for the Delivery of Bagged Composted Manure.

Distance (miles)	Delivery Cost ($/bag)	Delivery Cost ($/pound)
25	$0.17	$0.004
50	$0.19	$0.005
100	$0.22	$0.006
200	$0.24	$0.006
400	$0.26	$0.007

Summary

This chapter has demonstrated that bulk composted dairy manure can be profitably produced, provided that the farm gate price of bulk compost is greater than or equal to $17.50 per cubic yard, the price of sawdust is less than or equal to $1.00 per cubic yard, urea is $0.10 per pound and the milking herd size is greater than or equal to 75 cows or when the urea cost is $0.12 per pound and the herd size is greater than or equal to 125. This study also determined that for bulk composted dairy manure to be profitable a delivery fee must be charged.

Bagged composted dairy manure provides more profitable opportunities to the compost producer. This chapter determined that bagged composted dairy manure can be profitably produced. To be profitable in the bagged sector the farm gate price of bagged compost must be greater than or equal to $2.00 per 40 pound bag and the price per plastic bag must be less than or equal to $0.23. This study also demonstrates that it is profitable to transport bags of compost 400 miles from the enterprise.

SUMMARY AND CONCLUSIONS

Summary

Can dairy manure be profitably composted in Maine? To successfully answer this question it was addressed from two perspectives, Retail Market and Supply. The first section, Retail Market, determined that a number of marketing opportunities do exist for composted dairy manure in Maine. The market targets the five primary consumer groups: retailers, landscapers, nurseries, municipalities and agriculture.

This study found that the composted dairy manure market consists of two primary sectors, the bagged sector and the bulk sector. Although other options do exist, including consumers bagging their own products at the composting site, they are uncommon.

It was found that the bulk sector is made up of two primary segments, an unblended product and a blended product. When determining which product should be produced the decision should be based on the demands of the targeted consumer. For example, landscapers demand a blended product, while agriculture demands a unblended product.

A preliminary study involving a hedonic pricing model determined that products containing aquatic waste demand a premium price in the compost market of 2.6 cents. Additionally, an organic certified product also demands a premium price in the market of 2.4 cents.

The Retail Market section determined that for a producer to be successful in the composted dairy manure market it is essential for them to be knowledgeable about the targeted consumer's demands. Producers must constantly be aware of their products quality, thus maintaining customer loyalty and product satisfaction.

The Supply section focuses on determining the costs involved in getting a composted product from the composting operation to the consumer. It addresses the cost involved in producing bulk composted manure, bagging composted manure, and transporting both a bagged product and a bulk product to market.

This study determined that one pound of bulk composted dairy manure can be produced for approximately $0.0015319 when a windrow turner is used. It also took into consideration that it is not feasible for all composting operations to purchase a windrow turner. Therefore, the cost of producing one pound of bulk compost with a tractor loader was estimated to be $0.015792. These estimations could represent an over-approximation of the cost of producing composted dairy manure because it was assumed that the manure entering the composting process did not contain any bedding, which is not the case on all dairy farms. The presents of bedding such as sawdust or straw will decrease the quantity of bulking ingredients required for the composting process. Additionally urea was used to achieve the ideal carbon to nitrogen (C:N) ratio. Producers are encouraged to try different ingredient to achieve the ideal C:N ratio.

Sawdust was used as a bulking ingredient for this study, because it is not subject to seasonal changes and is accessible to all producers. This study recommends that producers not restrict themselves to just using sawdust but to explore other options available to them, especially those that pay tipping fees. If another bulking ingredient is used this could affect the urea requirement.

This study has found the cost of bagging composted dairy manure on the model dairy farm to be roughly $0.014630 per pound. If a different bagging system is selected this cost may increase or decrease depending on the value of the alternate system.

Also determined in this study is that as the distance between the point of origin and the final destination increases, the cost of transporting bagged composted manure per mile increases at a decreasing rate.

Conclusions

This study has successfully proven that bagged composted dairy manure can be profitably produced in Maine. Several marketing opportunities are available to compost producers throughout the state, with a direct focus on the bagged product consumers, consisting primarily of specialized and non-specialized retailers. These retailers primarily target homeowners. The average price received by a producer for a bagged composted manure product is estimated to be $0.05 per pound. The cost of producing, bagging, and transporting one pound of compost 400 miles on the model farm is approximately $0.036949. This demonstrates that producers can enjoy a profit of $0.013051 per pound of bagged composted manure.

The bulk compost manure product does not have the same profit potential as the bagged product. A compost producer only receives approximately $0.01 per pound. The total costs involved in producing and transporting a bulk product five mile is estimated to be $0.025319 per pound, indicating that a bulk product would incur a loss of $0.015319 per pound.

Considerations for Future Research

Many dairy farmers in Maine, and around the country, are being pressured to find alternatives to traditional manure management techniques as a result of stricter regulations governing the storage and disposal of dairy manure. Composting dairy manure proves producers with an alternative, but little information is available on the composting process and the costs of production. If more information was made available to dairy producers, then this may increase producer interest in composting. By increasing the number of producers in the composting business this could lead to a decrease in the product price thus decreasing the profitability of a compost enterprise.

This study has introduced a number of interesting items that could be explored further. In Chapter 1 a preliminary hedonic analysis determined that the addition of aquatic waste to a composted manure blend allowed the product to receive a premium price. Organic certified products also receive a premium price. Since Maine is an ocean state it would be interesting to know if aquatic waste can be easily obtained and by how much it would increase the cost of production. The data set used in this analysis consisted of thirty-one observations and was only collected in Maine due to a time constraint. If the survey were to expand beyond Maine's borders to include a larger variety of products, this would increase the accuracy of the hedonic price model. Thus determining which product attributes demand the highest price premium.

The hedonic analysis indicates that certified organic products demand a price premium in the compost market. Organic certification may increase the farm gate price of a compost product and increase the size of the producer's compost market. The question that future research needs to answer is; will the increase in product price and market size cover the additional cost associated with becoming organic certified?

A survey of composted manure consumers would be an excellent addition to the study. This survey should ask consumers what they demand from their composted manure products; it would have provided additional information and allowed for a more complete description of what consumer's demand. If producers knew what qualities consumers demanded, then they could include this information on the bag or in a brochure that accompanies the product. This survey would allow producers to learn more about their consumers, subsequently allowing them to cater more specifically to the consumers needs. This could lead to increased product sales.

Early on in this study it was decided that sawdust and urea would be used to achieve the desired moisture content and C:N ratio. It would be interesting to explore alternatives to sawdust, such as culled potatoes and potato tops, since potatoes are one of Maine's most important agricultural crops. Different bulking ingredients will affect the quantity of urea that needs to be applied. Another option to producers is to allow the manure to dry before mixing it with bulking ingredients. This will decrease the quantity of bulking ingredients needed to achieve the desired moisture content and C:N ratio. This study did not take these alternatives into considerations.

For this study urea was used to achieve the desired C:N ratio. This ingredient is expensive. Research should be conducted to determine ingredients that can be used as an alternative to urea. This could lead to a decrease in the cost of producing bulk composted dairy manure.

This study indicated that a dairy farmer should not compost dairy manure if they intend to spread it on their own fields. The cost savings incurred from making fewer trips to the field will not cover the added costs of the composting process, unless a value is placed on the environmental benefits of spreading composted manure. Composting may provide producers with away of avoiding tipping fees, which are incurred when waste products are disposed of in landfills. Perhaps, the environmental benefits will be so great that composting should be subsided to encourage more producers to compost. This is a very important issue that should be researched carefully.

The composted manure industry is just beginning to develop in Maine and across the nation. This industry has the potential to be successful in Maine. It could increase dairy farm revenues and would provide the dairy industry with an environmentally friendly way to manage manure on the farm. Composted manure provides additional benefits by decreasing the amount of chemical fertilizers and pesticides needed on crops. The composted manure industry has a wide variety of benefits that positively affect the dairy farmers and their communities.

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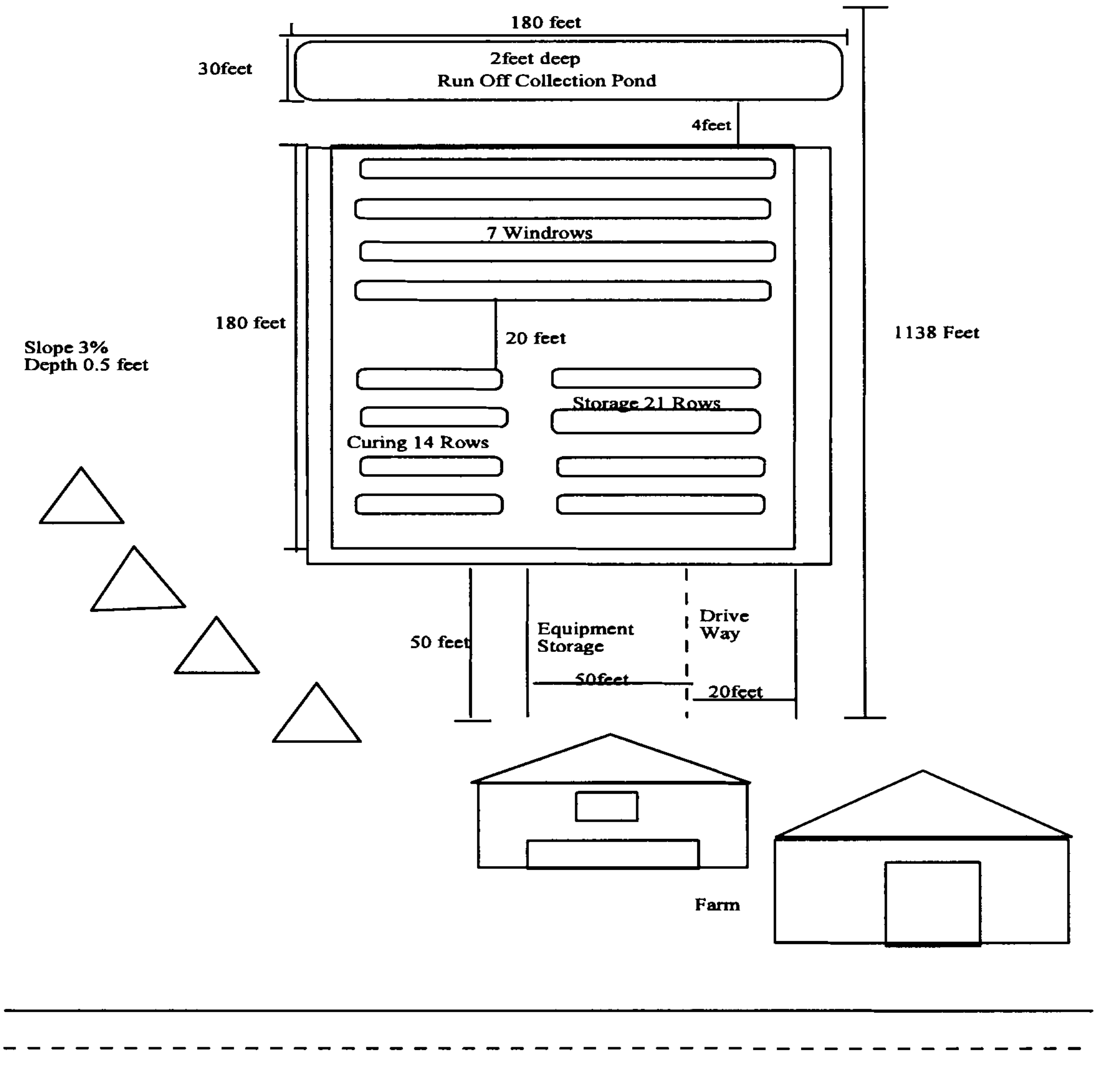
APPENDICES

Appendix A: A Layout of the Composting Site



This site is not drawn to scale, see key for measurements. This site only represents an example of what a composting site might look like.

Key
10 feet borders around the outside
20 feet between all windrows.
Windrows 14 ft wide 4 ft high.
Initial Windrow 150 feet long.
Curing 30 feet long.
Storage100 feet long.
Dike 2feet high, 2feet wide around 3 sides of the site.
200-500 ft from residence or business.
100-200 ft from any wetlands, surface water or any

Appendix B: Variable Names and Descriptions used in Chapter 2 Equations.

Variable	Variable Description
A	The number of cows in the milking herd.
T	The total dairy volume of manure produced.
M_D	Quantity of manure produced by both milking and dry cows (ft^3/day).
H	Quantity of manure produced by a heifer (ft^3/day).
P_D	The percentage that dry cows make up in the total milking herd.
P_H	The percentage that heifers make up in the total milking herd.
Y	Number of cubic feet in a cubic yard.
F	The total quantity of urea need (lbs).
S	The quantity of sawdust needed (yd^3).
S_C	The pounds of sawdust in a cubic yard (410 lb).
M_C	1,458 pounds of manure equals one cubic yard of manure.
R_M	Percentage of volume reduction that occurs as a result of mixing manure and sawdust together (20%).
TS	Total quantity of manure and sawdust combined (yd^3).
R_I	The shrinkage factor that composting material in the initial composting area reduces by (0.75).
D_I	The number of days in the initial composting area. (60 days)
N_I	Total quantity of composting manure in the initial composting area on any give day (yd^3).
N_C	Total quantity of composting manure in the curing area on any give day (yd^3).
N_S	Total quantity of composting manure in the storage area on any give day (yd^3).
R_C	The shrinkage factor that composting material in the curing area has reduced by (0.50).
D_C	Number of days that composting manure spends in the curing area (30 days).

D_S	Number of days that composting manure spends in the storage area (90 days).
R_S	The shrinkage factor that composting material in the storage area has reduced by (0.50).
L_W	The total amount of labor used by the windrow turner (hr).
L_M	The total amount of labor used by the manure spreader (hr).
L_H	The total amount of labor used by the windrow turner (hr).
W	The quantity of cubic yards that the windrow turner can turn in one hour (1,200yd^3).
M_S	The quantity of manure that the manure spreader can move in one hour (48 yd^3).
D	Number of days in a year (365 days).
X	The quantity of sawdust hulled by the truck in one trip (30 yd^3).
U	The time required to go from the composting site to the mill and back, 0.67 hours.
T_F	The total amount of diesel fuel used by the compost production operation (gal).
Z_{TS}	The amount of diesel fuel used in one hour by the manure spreader and windrow turner (4.27 gal).
Z_H	The amount of diesel fuel used in one hour by the sawdust truck (10 gal).
W_I	The number of times in a year that the material in the initial composting area is turned (30).
W_C	The number of times in a year that the material in the curing area in turner (18).
T_S	The volume of manure and sawdust that remains once the two materials are mixed together.

Appendix C: Separating

Dairy manure contains a high level of moisture, approximately 83 percent (Rynk et al.). As a result, a separator is often used to separate out the solids from the liquids. On average, a separator will produce a product with a moisture content of 60 to 70 percent (Barker & Rashash). There are a variety of separators available, such as the stationary incline screen, rotating screen separator, vibrating screen separator and sedimentation. The separator most commonly used on dairy farms is the stationary incline screen (a static screen). This type of separator has the ability to handle large quantities of high moisture manure. This screen has no moving parts and relays on gravity to remove the solids through the separation process. The only problem with the screen is that it can become clogged and needs to be washed frequently (Mukhtar & Auvermann). Farms that would need a separator will already own this piece of equipment, therefore it will not be purchased by the composting operation. For this study a separator has not been used to reduce the moisture content of the manure.

Appendix D: Description of Variable and Fixed Costs

Variable Costs

Fuel Consumption

The skid steers are powered by diesel fuel, and are being used to load the material hopper and to move pallets. The skid steer's fuel consumption is determined using an equation provided by the *ASAE*. This equation is found in Equation D.1.

Equation D.1

$$Q = 0.06P$$

The 'P' variable represents the number of hp required to operate this machine, and 'Q' is the gallons per hour (gal/hr) of gasoline used. According to *ASAE* diesel fuel consumption is approximately 73 percent of gasoline consumption (Q). Using this piece of information it was determined that the skid steer uses approximately 3.20 gal per hour of diesel fuel.

Repair and Maintenance

It is necessary to calculate the repair and maintenance cost for the skid steers, the bagging system, and the screener. To calculate these costs an equation provided by the *ASAE* was used. This equation is represented by Equation D.2.

Equations D.2

$$F = (RF1)(P)\left(\frac{h}{1000}\right)^{RF2}$$

In this equation the 'h' variable represents the number of hours the machine is used. It is assumed that the machine will be used for one hour. The 'RF1' and 'RF2' variables are repair and maintenance factors, their values are provided by the *ASAE*. The 'P' variable represents the machine's listed price in current dollars.

The repair and maintenance cost of the building is calculated using an equation provided by Boehlje and Eidman. This equation is presented in Equation D.3

EquationD.3

$$Crmb = (Pp)(R)$$

In this equation the 'Crmb' represents the cost or repair and maintenance of the building. For this equation it is important to multiply the purchase price (Pp) by the rate per year 'R'. Boehlje and Eidman suggested that 'R' equal 2 percent for normal use. This equation determines the repair and maintenance cost per year. The result is divided by 30,000 to represent the number of bags that this operation will bag in one year.

Fixed Costs

Depreciation

The depreciation is determined for each piece of equipment. It is assumed that each piece of equipment has a ten year life expectancy. The Equation D.4 is used to calculate depreciation.

Equation D.4

$$Sv = \frac{C - Rv}{U}$$

In this equation 'C' represents the list price of the machine in current dollars, 'Rv' is the residual value of the machine, and it is assumed that the residual value is 40 percent of its original price in current dollars. The 'U' variable represents years of useful life, which is assumed to be ten years for all pieces of equipment.

Interest

The real interest rate is used in this study; it is the nominal interest rate minus inflation. A five year interest rate of 5.5 percent was obtained from Farm Credit for equipment, and a ten year interest rate of 6.5 percent for buildings (Barron). The interest rate on money left in a saving account is 0.5 percent (University of Maine Credit Union). Farm Credit will only provide a loan that finances 75 percent of the items' cost and the farmer is responsible for the remaining 25 percent (Barron). The inflation rate was determined using the interest rate of 10 year treasury bonds, which according to CNN money was valued at 3.37 percent. The real interest rate which is generally believed to be 3 percent is subtracted from the interest rate for the treasury bond (3.37) leaving 0.37 percent to represent inflation. To obtain the real interest rate for equipment, subtract the rate of inflation from 5.5 percent, which represents the interest rate charged by Farm Credit on equipment. For the building, the same calculation was preformed except the interest rate is 6.5 percent.

A weighted average is used to calculate the total interest cost for each piece of equipment; 18.75 percent of the loan is covered by Farm Credit's interest rate, leaving 81.75 percent, to be covered by the farmer's savings account's interest rate.

This same process was again used to calculate the interest cost incurred by the building, except in this case 37.50 percent of the building cost had an interest rate of 6.13. In this case the loan is assumed to be for ten years rather than five years. The remaining 62.50 percent of the loan will be subjected to an interest rate of 0.13 percent and a weighted average is again taken to determine the quantity of interest incurred by the building.

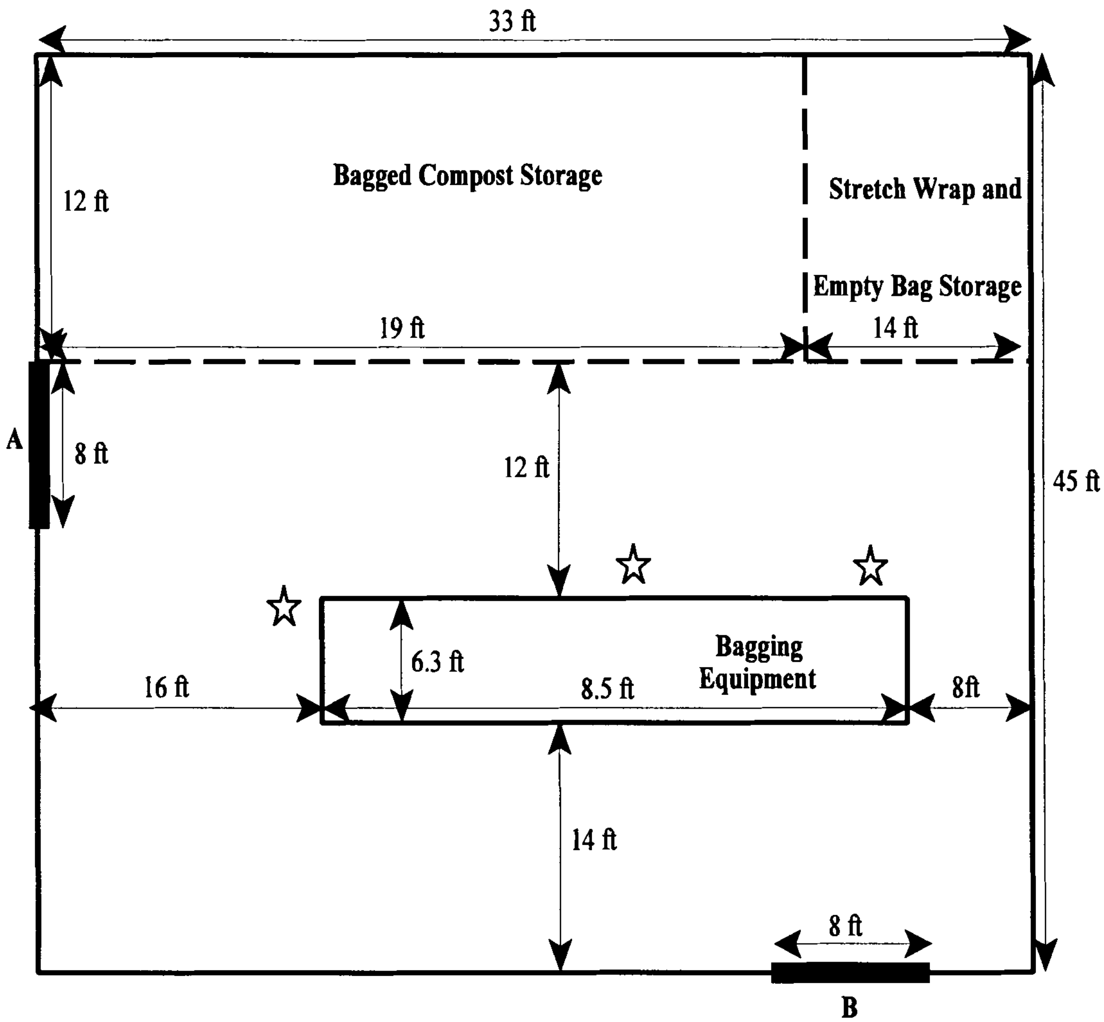
Appendix E: Alternatives to Bagging your own Composted Manure

Many compost producers believe that bagging their own composted manure is too expensive for their level of production. Many producers contract out the bagging of their product to other companies when they are first venturing into the bagged sector. If there is a high demand for their product, and the volume is large enough for a bagging operation to be profitable, then the producer may invest in bagging equipment (Block). For example, Coast of Maine initially subcontracted the bagging of their product out to Jolly Farmer in Poland Springs, Maine (Glenn & Farrell).

Additional benefits can be experienced by producers when they contract out the bagging of their composted manure product. Through contracting, producers could also gain access to additional markets. This is because many retailers don't want to receive a trailer load of just one kind of compost, they want a wide variety of products (Compost Management Associates & R. Alexander Associates Inc.). By accepting bagging contracts this allows the bagger to offer a larger product line to retailers and gives smaller producers access to additional markets.

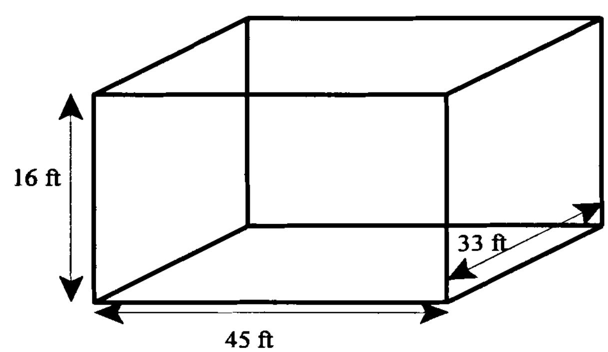
When a compost producer is deciding whether or not to contract out the bagging of their composted manure products there are some items that they must consider, such as the cost of transporting bulk composted manure to the bagging operation. For additional information on the cost of transporting both bagged and bulk composted manure refer to Chapter 5. Transportation costs are often overlooked but can play a large role in determining the profitability of bagging composted manure.

Appendix F: The Floor Plan for the Bagging Warehouse



Key

Star	Working employees.
A	Loading and unloading dock.
B	Entrance from composting site.



Appendix G: Description of Variable and Fixed Costs

Variable Costs

Electricity

The bagging equipment, which consists of the bagger, bag sealer and the bag carrying conveyor, are all powered by electricity, and require 5 horsepower (hp) or 220 volts (V) or 17 amps (A) to operate (Moffler). To determine the number of kilowatts per hour (KWh) this system requires Equation G.1 is used.

Equation G.1

$$Pe = \frac{IF}{1000}$$

This equation was obtained from the *American Society of Agricultural Engineers Standards (ASAE).* In Equation G.1,'I' represents the quantity of amps required by the machine, 'F' is the number of volts needed to operate and 'Pe' is the number of kilowatts per hour required by the bagging system. This equation determined that the bagging system requires 3.74 KWh, which converted into 0.01 KW per day, assuming the machine can fill six bags per minute or 360 bags in one hour.

Pallet Wrap

After each pallet has been stacked with six, forty-pound bags of composted manure, it is then necessary to wrap each pallet in plastic. Each pallet requires approximately one third of a role of wrap. In order to determine the quantity of the roll used by each bag Equation G.2 needs to be used.

Equation G.2

$$W = \frac{Q}{B}$$

In this equation Q represents the quantity of wrap used for a whole pallet, which is 0.333 of a roll. The variable B represents the number of bags on the pallet, and W represents the quantity of wrap used per bag.

Construction Costs

Warehouse Cost

The cost of constructing a warehouse was determined using the estimated cost per square foot, which was obtained from the book, *Building Construction Cost Data 2002.* This estimated cost is then adjusted for location. The location adjustment rates were also obtained from the same book. Equation G.3 provides the equation used to arrive at the estimated cost per square foot.

Equation G.3

$$C_{SF} = \frac{(B_{SC})(A_{M})}{100}$$

In this equation, 'C_{SF}' represents the cost per square foot in Maine, 'B_{SC}' is the base price of constructing one square foot without any location adjustment, and 'A_M' represents the location adjustment for the state of Maine.

BIOGRAPHY OF THE AUTHOR

Anne Grant was born in Truro, Nova Scotia on July 1, 1979. She was raised in Hardwood Lands, Nova Scotia and graduated from Hants East Rural High in 1997. She attended the Nova Scotia Agricultural College and graduated in 2001 with a Bachelor of Science degree in Agricultural Economics. She then went to Maine and entered the Resource Economics and Policy program at the University of Maine in the fall of 2001. Anne is a candidate for the Master of Science degree in Resource Economics and Policy from The University of Maine in December, 2003.