Pilot Project for Value-Added Product Development from Solid Waste Generated on Swine Farms

Final Report for
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Abstract

For more than a decade swine producers in North Carolina have been searching for alternative methods for treating swine waste that not only protect the environment but also produce value-added products whose sale can help to offset waste treatment costs. This Conservation Innovation Grant (CIG) project, "Pilot Project for Value-Added Product Development from Solid Waste Generated on Swine Farms", was initiated to demonstrate the technical and financial viability of products developed from the solid waste byproducts from two alternative waste treatment systems. The overall objective of the project was to determine the cost and market potential for swine waste derived soil amendment products (i.e., compost and vermicompost) to determine the potential for the sale of these materials to help off-set the cost of alternative swine waste treatment systems. While both commercial companies participating in the project reported that they have markets to sell more of their respective products than they currently produce, the independent market analysis for this study indicates that it would take the production volume from less than six percent of the total swine farms in North Carolina to saturate the current market volume for soil amendments in North Carolina and five surrounding states. Based on the market analysis assessment the production of soil amendment products is likely to have a minimal impact on reducing alternative systems costs on a broad scale in the near future. Thus, the CIG Project has helped to identify more specifically the number of farms that should be investing in soil amendment product development and indicates that other sources of revenue from other types of waste byproducts should be aggressively pursued.

Introduction

Animal Feeding Operations (AFOs) and Confined Animal Feeding Operations (CAFOs) have revolutionized the way many farmers raise animals for food. Sectors like the pork industry have quickly adapted their management structure to increase efficiency in food production, thereby allowing more animals to be produced in a smaller area. For several years, a general need has been recognized to improve the waste treatment systems used on AFOs and CAFOs such that the resources within the manure can be better captured, thus reducing the loss of these materials to the environment.

North Carolina's pork industry serves as a prime example of the transition in the livestock industry. Over a five-year period (from 1991 to 1996), the number of hogs in North Carolina grew from 2.6 million to over 10 million, with the population concentrated in approximately 2,400 farms located mostly in the state's central coastal plain. Those hogs produce approximately 20 million tons of feces and urine every year, which is processed and stored in open-air, earthen lagoons until it can be sprayed on farm fields. The lagoon-based waste treatment process -- including the use of recycled lagoon water to flush barns combined with the high density of animals in the barns and the use of high-pressure spray guns for irrigation, add to the loss of ammonia and odor. Losses of ammonia and odor in particular were identified as the major concern with lagoon and sprayfield systems by the National Academy of Sciences (NAS) based upon regional and local risks to public health and quality of life. (NAS 2003.)

Recognizing the need to identify more environmentally benign methods of hog farming, the state of North Carolina embarked on a decade-long process to identify and convert its industry to cleaner technological alternatives. That process began with a blue ribbon commission that identified environmental and health risks associated with large swine operations and recommended improvements to the industry and the laws that regulate it. Soon after, the state passed a moratorium on all new farm construction. In 2000, the major swine producers in the state – Smithfield Foods and Premium Standard Farms – agreed to fund a process to identify environmentally superior technologies (ESTs) that meet technical performance standards. These standards include drastic reductions in ammonia nitrogen emissions, pathogens and odors[1] at a cost that is economically feasible[2] for the industry to implement. Generally, economic feasibility has been defined as a cost that will not result in projected reduction in the hog inventory greater than 12%. [3] It is worth noting that since the receipt of this CIG award, the North Carolina General Assembly through the 2007 Swine Farm Environmental Performance Standards Act instituted a permanent ban on the construction of new lagoons in the state and adopted the EST performance standards established through the Smithfield Agreement for new and expanding farms in the state. Those standards have been promulgated in the North Carolina Administrative Code at 15 NCAC 02T .1307. That law also established a Lagoon Conversion Program to provide cost share dollars for the installation of innovative systems that meet the performance standards.

Currently, five technologies meet NC's technical performance standards. The cost of these systems nevertheless remains high,[4] which bars farmers' access to these alternative technologies. NC State University researchers recognized this issue in assessing economic feasibility under the Smithfield Agreement process (the "Phase 3 Report"), and noted that alternative technologies will become more affordable as cost savings are achieved through on-the-ground refinements and improvements in the marketability of value-added products. (NCSU 2006.) A key element of this project therefore was to assess the production and marketing potential of the solids that are a byproduct of several of these technologies. Viable markets for the byproducts, would enable producers to offset the cost of implementing alternative technologies, and perhaps even generate revenue, thereby making alternative technologies more affordable. Therefore, understanding the potential of value-added products to generate added-income streams, and conversely, recognizing what

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[1] Specific performance standards include (1) the elimination of the discharge of animal waste to surface waters and groundwater through direct discharge, seepage or runoff; (2) the substantial elimination of atmospheric emissions of ammonia; (3) the substantial elimination of emissions of odor that is detectable beyond the boundaries of the parcel or tract of land on which the swine farm is located; (4) the substantial elimination of the release of disease-transmitting vectors and airborne pathogens; and (5) the substantial elimination of nutrient and heavy metal contamination of soil and groundwater. 2000 NC Attorney General's Agreement. These standards are based on guidelines adopted by the North Carolina General Assembly. General Assembly of North Carolina, Session 1997, Session Law 1998-188, House Bill 1480.

[2] The Agreement does not define "economic feasibility."

[3] *See* NCSU March 8, 2006, Phase 3 Technology Report *available at* http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase3report06/phase3report.htm (hereinafter "NCSU 2006").

[4] Employing the Smithfield Agreement metrics, the five technologies have not met the economic feasibility standards for existing farms.

those markets can realistically bear, is key to developing a strategy to implement alternative technologies on swine farms.

Against this backdrop, the overall project objective was to institute pilot projects and conduct analyses to assess the technological and economical viability of two promising value-added products generated from animal waste solids on farms that had installed innovative waste treatment technologies. The specific objectives included:

(1) Evaluating the production and use of soil amendments derived from composted swine waste solids;

(2) Evaluating the production of worm castings that used swine-waste solids as a feed source to determine the price of production and whether the production complies with EST technical performance standards as well as the currently proposed environmental performance standards for new and expanding swine farms; and

(3) Assembling and evaluating market data to analyze the demand for an array of related swine-waste-solids-derived value-added products (i.e., worm castings, soil-less media, fertilizers, etc.), the potential for growth of the market, and the potential profitability of each market.

Project Activities

The project activities were structured into three main areas: (1) the production of the soil amendment products (compost and vermicompost); (2) the cost analysis of the production processes; and (3) the analysis of the market potential for these same value-added products.

The large-scale production of thermophilic compost was conducted by Super Soil Systems USA under the direction of Dr. Ray Campbell. Mr. Bob Binkley headed the efforts to demonstrate the large-scale production of vermicompost for NatureWorks Organics.

Adrian Atkins and Dr. Mitch Renkow, both in the Agricultural and Resource Economics Department at North Carolina State University, performed the cost analysis of the cost of producing the soil amendment products. Their analysis was structured to account for the cost of construction, operation and maintenance costs of the pilot systems, and projections of how cost would change if the technologies were implemented industry wide. The Cost Analysis Report can be found in Appendix A of this report.

Mary Muth, Melanie Ball and Anthony Lentz, at RTI International in conjunction with Brian Murry, at the Nicholas Institute for Environmental Policy Solutions at Duke University, conducted the market analysis. The market analysis was performed to estimate the amount of the various products (from worm castings and the various soil amendments from Super Soil composting) that the soil amendment market could potentially bear, anticipated demand and potential market growth, and potential for market saturation. This report is found in Appendix B.

Thermophilic Composting

The information detailed in this section is based, in part, on the findings provided by Dr. Campbell in a report submitted October 16, 2009, (Appendix C).

Overview

The solids separation/ water treatment technology and the solids composting technologies used by the Super Soils method have met the technical performance standards for ESTs and the state's environmental performance standards for new and existing swine farms. Therefore, further technical performance analysis related to the production of the compost was not required[5]. Grant funds along with Super Soil's contributions resulted in construction of a manufacturing facility to process composted swine solids into value-added products for sale in nursery and consumer markets. Processing capacity should now be adequate to handle solids received from a minimum of 10-15 standard-size finishing farms (5,880 head) in North Carolina. Funding from the CIG project was specifically used to purchase a grinder and develop a mixing/bagging line that can be used to automate production and provide for bulk sales and bagging. Since Super Soil's goal is to develop several value-added products from compost, flexibility was a major objective in development of the mixing/bagging line.

By purchasing a combination of new and refurbished equipment, Super Soil was able to purchase a grinder for particle size reduction and install a computerized mixing/bagging line including two 10-yard hoppers, two 4-yard hoppers, three small chemical hoppers, a mixing head and conveyors to move product from the beginning of the line to a separate conveyor for bulk loading or bagging. The bagging system now consists of a product hopper and bag filling head for both one and two cubic foot bags, a sealer, and conveyor to move the product through bagging, sealing, and stacking/palletizing for shipping. The line will process up to 60-70 cu yd/hr bulk or bags at the rate of 12-14 two cu ft bags or 18-20 one cu ft bags/min. Since processing is very efficient, orders are processed on demand and product inventory is minimized.

Equipment installation was completed on June 24, 2008. Since that time, the mixing/bagging line has been used on demand to process product for distribution in North Carolina, South Carolina, and Virginia.

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[5] *See* NCSU Report, *available at* http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/smithfieldsite.htm.


Mixing and Bagging Equipment Line.

Funding

A total of $215,870 was received from CIG funding. Super Soil spent an additional $1,861.20 on construction materials and subcontracts, $3,787.88 on construction labor, and $25,000 on project management. Super Soil also furnished a 50 x 120 ft building (6,000 sq ft) valued at $217,000 for installation of the processing equipment. After construction, Super Soil manufactured value-added products from composted swine solids for distribution and sales in nursery and consumer markets to assist with the project evaluation. Although a portion of Super Soils value-added products were intended to be used by the NC Department of Transportation (NCDOT) for use in the Roadside Beautification Program to assist in the evaluation of the product on a wide-scale, project delays coupled with reduced state budgets for the Roadside Beautification Program resulting from the economic downturn prevented the evaluation of Super Soils soil amendment products by NCDOT.

Vermiculture

Portions of the information detailed in this section are based on the findings provided by Mr. Bob Binkley in a report submitted October 19, 2009, (Appendix D).

Overview

The collaborator for this portion of the project is NatureWorks Organics, a North Carolina LLC that was originally formed to create a waste remediation solution for North Carolina hog farms through vermiculture of the manure solids captured from the waste stream on individual farms. The resulting vermicompost (worm castings, vermicasts, etc.) would then be sold in order to generate revenue and potentially offset some of the infrastructure costs for innovative waste management systems and the vermicompost operation itself.

The vermiculture component was placed on a farm with an existing EST demonstration site, thus pairing an already operational technology with an emerging technology. The farm chosen for the vermiculture installation (Little Creek Hog Farm) uses a candidate alternative technology (Environmental Technologies Closed Loop Technology) on its 3,500-head swine operation to treat the water and separate the solids, which in turn will be used to produce the vermicompost.[6]

CIG funding was utilized in the design and construction of a vermiculture facility to handle the separated swine waste solids from a swine finishing farm housing approximately 3,500 animals. The vermiculture barn was constructed on the Little Creek Hog Farm on a piece of property adjacent to the farm office and across the road from the swine barns. The facility consists of a roofed structure to house and protect the worm beds from adverse weather conditions. A series of trenches were dug inside the footprint of the barn, into which the worms have been placed, and onto which waste solids from the Closed Loop technology will be applied. The waste solids will be collected in a modified manure spreader that will be used to feed the captured solids to the worms at a controlled rate. The worms eat their way up through the solids to the surface, leaving castings beneath. It is anticipated that worm castings will be harvested every nine to ten months.

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[6] The Closed Loop technology meets all the technical performance standards except for pathogens. It is anticipated that this last criteria will be met by this technology in an upcoming iteration.

Vermicomposting Barn and Trenches.

Due to project delays the vermicomposting barn was not completed in time to conduct the environmental performance of the vermiculture composting process consistent with the NC Attorney General's Agreement process (which is consistent with reviews to determine compliance with the environmental performance standards passed for new and expanding farms in 2007). NatureWorks Organics, as part of its cost share commitment, has provided $52,000 to North Carolina State University to complete the evaluation of the technical characteristics of the vermicompost material. Methods used will be comparable to those described for the emissions and technical analysis of the Super soils compost technology.[7] These include measurement of emissions of odor and ammonia, analysis of reduction in pathogens, and a nitrogen, phosphorus, copper and zinc mass balance analysis. Where possible, analyses completed by other entities will be sought out in lieu of redundant analysis to determine whether the products meet organic standards and Class A bio-solids standards.

The economic analysis of the cost of vermiculture composting was performed and is reported in the Cost Modeling Report found in Appendix A. This analysis accounts for the cost of construction, with estimated operation and maintenance costs, and projections of the amount of worm casting compost that could be produced at the pilot site and if adopted industry-wide.

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[7] *See* http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase2report05/phase2report.htm, *see* Appendices A1, A7, A8, and A9.

While the full-scale vermicomposting facility was being designed and built a small-scale experiment was established at North Carolina State University's Lake Wheeler Road Field Laboratory to collect preliminary data on vermicompost physical and chemical properties and the potential for pathogen reduction in the finished material. During a 12-month period, over 5,200 pounds of separated swine solids were added to a worm bin at a rate of approximately 0.3 pounds per square foot of bed surface area. Approximately 1,560 pounds of castings were collected from the small-scale bed. The recovered castings contained approximately 42% of the nitrogen and 82% of the phosphorus that was present in the waste material originally applied. The vermicomposting of the small-scale bed also provided a 3-log reduction in the number of bacterial indicators for which analysis was conducted, including fecal coliform, E. coli, and enterocci. Because the criteria for the EST determination requires a 4-log reduction[8], an additional treatment will likely be required to meet the EST requirement as well as the new performance standards. NatureWorks Organics already adds a drying step at its centralized process facility that may provide additional treatment. The potential for additional treatment benefits will be verified during the full-scale evaluation that will occur once worm castings become available for analysis by North Carolina State University.

Funding

Of the grant funding, $83,700 was used to design and construct the on-farm vermicomposting system. In addition, NatureWorks Organics contributed $190,000 toward the project, including project management costs, the purchase of worms, and $52,000 in funding provided to North Carolina State University for the environmental performance verification of the system.

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[8] This requirement specifically applies to the terms of the Smithfield Agreement.

Funding Received and Expended

	Received	Expended
Federal Conservation Innovation Grant	$352,988	$352,988
Additional Project Funds and Sources		
North Carolina Department of Natural Resources		
Division of Soil and Water	$96,408	$96,408
Division of Soil and Water, Cost Share Program	$29,000	Obligated, but not yet expended
Nicholas Institute for Environmental Policy Solutions, Duke University (In-Kind Contribution)		$18,411
SuperSoils System USA (Cash and In-Kind Contribution)		$247,649
NatureWorks Organics (Cash and In-Kind Contribution		$190,000
Environmental Defense Fund (In-Kind Contribution)		$8,000
TOTAL	$478,396	$913,456

Results

Both thermophilic composting and vermicomposting offer opportunities to convert separated swine manure solids into a value-added project, provided that these products can be produced and marketed effectively. Both of the commercial companies participating in the project reported that current market demand outstrips their individual production capacities. However, company reports contradict the independent market analysis performed for this CIG project, which indicates that it would take soil amendment production volumes from less than six percent of the total swine farms in North Carolina to saturate the current market demand for soil amendments in North Carolina and surrounding states[9]. Because researchers had only anecdotal evidence of the potential of project participants to increase their respective market shares, we must rely on the market analysis assessment performed for this project that the production of soil amendment products represents a small portion of potential outlets for swine-waste derived byproducts.

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[9] Muth, Mary, Melanie Ball, and Anthony Lentz, Market Analysis for Swine Waste Co-Products: Soil Amendments, Final Report, 2009.

To achieve the economic feasibility of innovative waste management systems on a broad scale basis, other product development and new markets should be aggressively explored and promoted, including use of waste solids for energy generation. With respect to soil amendments and compost byproducts, for these technologies to significantly impact the economic feasibility of alternative swine waste treatment technologies, it will require the development of new market outlets or an increased use in current markets. Producers of soil amendments and compost products should engage in large scale, effective marketing campaigns to realize greater market shares, but overall investments in such production should be conservative to ensure that supply does not outstrip market demand.[10].

Potential for Transferability of Results and Conclusions

Several issues have been identified that should help with future work involving soil amendments from animal waste solids. The most important issues in marketing compost and gaining public acceptance relate in different ways to quality control. So long as compost is perceived as having inconsistent quality, it will not gain wide acceptance for many potential uses. There may also be an unfavorable perception of swine manure as a feedstock for soil amendments, at least for some uses. Feedstock biases have been found to be the greatest marketing challenge facing the compost industry[11]. For soil amendments to gain wide acceptance a system of measuring properties of compost and providing guarantees to the users of the quality characteristics will be essential. Programs such as the U.S. Composting Council's (USCC) Seal of Testing Assurance (STA) can dramatically improve how compost products are defined and provide assurance of characteristics and quality[12]. One of the most important factors to consider in increasing the use of swine waste derived soil amendments is the need to educate residents and businesses on the benefits and proper use of these materials, and to encourage technical assistance providers to help with this education and outreach.

Moreover, the economic analysis provides standardized production costs and will help in evaluating overall construction costs and benefits to implementing soil amendment production alongside or as a compliment to innovative swine waste management systems.

Challenges, Failures, and Improvements for Future Projects

The project faced several challenges that inhibited the swift implementation of the byproduct production processes, including delays related to the construction of the structure to house the vermicompost project, which has delayed production of materials for technical assessment. A performance assessment methodology and plan for use of the Super Soils soil amendments on NCDOT projects also may have helped to guarantee that Super Soil byproducts would be delivered for use and testing in the Roadside Beautification Program. However, delays and budget constraints that prevented

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[10] Humenik et al. Final Report, Development of Marketable By-Products From Alternative Swine Waste Treatment Technologies, Submitted to the Golden Leaf Foundation, July 2005.

[11] Alexander, R. 2000. Compost marketing trends in the U.S. *BioCycle*, Vol.41, No.7, pp. 64-66.

[12] Coker, C.; N. Goldstein. 2004. Characterizing the composting industry. *BioCycle*, Vol.45, No.12, pp. 20-22.

implementation of this aspect of the project owing to the economic downturn could not have been avoided.

For future projects, it is recommended that project participants receive a detailed outline of expected activities, deliverables, and commit to information sharing with Project Coordinators. For this particular project, where cost analysis was a critical component, receipt of input costs from the participating producers would have allowed for a better assessment of production costs and revenue generating potential of the various byproducts. In addition, for projects involving several collaborators from various organizations and economic sectors, regular meetings or status reports are advised.

Appendix A

NC STATE UNIVERSITY

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SOIL AMENDMENT COST AND RETURN REPORT: SUPER SOILS COMPOST MIXING AND BAGGING FACILTY AND NATUREWORKS ORGANICS VERMICOMPOSTING FACILITY

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I. Introduction

In an effort to improve the economic feasibility of their systems, technology providers have placed an emphasis on producing and marketing swine waste by-products. Two such products, each included in the broader category of soil amendments, are Super Soil Systems' thermophilic compost and NatureWorks Organics' vermicompost. Each of these soil amendments uses separated swine solids as the feedstock for its composting process. While the RTI final report ("Market Analysis of Swine Waste Co-Products: Soil Amendments") will focus on the marketability and large-scale market effects associated with the Super Soils and NatureWorks Organics products, the purpose of this report is to analyze the costs and returns associated with the construction and operation of these facilities.

Costs and returns models were constructed using the same assumptions, parameters, and guidelines used by the Task 1 Economics Team in its economic feasibility assessment of alternative swine waste management systems under the Smithfield Foods-Premium Standard Farms Agreements with the North Carolina Attorney General. See Zering and Wohlgenant(d) (http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase2report05/cd,web%20files/B1.pdf) for a detailed description of this modeling process.

Both of the technologies modeled in this report involve the treatment of separated solids. Rather than "complete process" systems which treat the entire waste stream, these are viewed as "add-on" systems that must be used in conjunction with another technology that includes a solids separation unit process. The annualized costs reported in this document are to be viewed as incremental. That is, they represent costs in addition to the costs of the "compete process" system to which they are associated. As discussed in Zering and Wohlgenant(d), the costs of "complete process" systems are themselves incremental (in that they represent only the annualized costs above and beyond the baseline (lagoon and sprayfield) technology.

II. Composting as a Biological Process

Composting can be defined as the aerobic decomposition of organic materials under controlled conditions into a soil-like substance. During this process, microorganisms break down complex organic compounds into simpler substances including carbon dioxide, water, minerals, and stabilized organic matter (compost). Composting is a heat-producing process that enables the destruction of pathogens and weed seeds that may be present in the organic feedstock (Sherman). The most efficient composting occurs when conditions that encourage the growth of microorganisms are established and maintained. Specifically, some of these conditions include: the proper ratio of carbon and nitrogen in the blended organic materials to promote microbial activity and growth, sufficient oxygen levels to support aerobic organisms, moisture levels that uphold biological activity without hindering aeration, and the proper temperature (a warm environment) to promote microorganism growth (Sherman).

The composting process has a thermophilic active stage during which oxygen consumption and heat generation attain their highest levels. Following this active period, there is a mesophilic curing stage during which organic materials compost at a much slower rate. Left unattended, the process will continue until all of the available nutrients are consumed by microorganisms and most of the carbon is converted to carbon dioxide. Generally, however, depending on its desired end use, compost is judged to be "finished" at some earlier point (prior to total decomposition) as determined by factors like C:N ratio, temperature, oxygen demand, and odor (Sherman). Depending on the type of feedstock used, the acceptable range for C:N ratio will vary. Ranges of between 20:1 and 25:1 are often cited as indicative of "mature" compost. The preferred range for moisture content during the composting process is between 50-60 %. At moisture contents below 40 %, composting efficiency is hindered by slowed microbial growth. When moisture levels exceed 65 %, water begins to displace air within the organic material which leads to anaerobic conditions. Oxygen levels in the range of 16-18.5 % are ideal for efficient composting. When oxygen levels fall below 6 %, the composting process slows and odor levels rise. To increase oxygen during the composting process, the compost pile can be turned mechanically or aerated by force via blowers. The most effective composting occurs with pH levels between 6.5 and 8.0. A pH level below 6.0 can slow the process, while a pH level above 8.0 can produce odor and the release of ammonia. The ideal temperature range during the active composting stage is between 130-140° F. As active composting slows, the temperature within the compost pile will fall to 100° F and, ultimately, level out to the ambient air temperature (Sherman).

III. Vermicomposting as a Biological Process (Munroe)

Vermicomposting can be defined as the process by which worms (e.g, *Eisenia fetida*) are used to convert organic materials into a humus-like material. In order to process the material as efficiently as possible, one must maintain a maximum worm population density at all times. This differs from vermiculture, a process in which one optimizes reproductive rates by keeping population densities relatively low. Munroe lists five essential elements necessary for a successful vermicomposting environment: bedding, a food source, adequate moisture, adequate aeration, and protection from temperature extremes. A good bedding source is one that combines high absorbency, good bulking potential, and a high carbon-to-nitrgoen ratio. Shredded paper or cardboard makes an excellent bedding source; on-farm organic resources like straw and hay can be used for bedding also (or, optimally, combined with shredded paper/cardboard). The food source used in this report is separated swine solids—a feedstock that has been found to provide good nutrition to the worms while producing a vermicompost with excellent physical characteristics for a commercial fertilizer. The ideal range of moisture content for optimal vermicomposting is between 70-90%. While the separated swine solids used in this project fall comfortably within this range, the NatureWorks Organics process includes a watering system to precisely control moisture content.

As a general rule-of-thumb in conventional composting, one ton of inputs results in one cubic yard of final product. The weight of this cubic yard of compost, although it varies as a function of moisture content, is around half a ton—that is approximately 50% of the mass is lost during the composting process (mostly as moisture and CO_2). Because the vermicomposting process is more variable than the more prevalent (and established) composting procedure, there is also more variability in regard to projecting vermicompost outputs. Generally, the output from the vermicomposting process will vary from about 10% to close to 50% of the original weight of the inputs. Like in conventional composting, this percentage will vary as a function of the type of inputs used and the type of system used. As the ratio of high-carbon to high-nitrogen inputs increases, one can project a ceteris paribus increase in output weight as a proportion of input weight.

The three basic types of on-farm vermicomposting systems described by Munroe are windrows, beds or bins, and flow-through reactors. Windrows can be either of two types: batch or continuous-flow. A batch system is one in which the bedding and food source are mixed, the worms are added, and nothing more is done until the process is completed. In a continuous-flow system, feed and new bedding are added incrementally to the existing mix on a regular basis.

Like conventional compost, vermicompost has proven benefits to agricultural soil, including increased moisture retention, better nutrient-holding capacity, better soil structure, and higher levels of microbial activity. The existing literature has also identified a few areas in which vermicompost has proven to be superior to conventional compost. These include: level of plant-available nutrients (higher in nitrate, lower in ammonium relative to traditional compost), level of beneficial micro-organisms, ability to stimulate plant growth, ability to suppress disease, and ability to repel pests (Arancon, et al.(a), Arancon, et al.(b)).

See the Muth et al. RTI report ("Market Analysis of Swine Waste Co-Products: Soil Amendments") for a thorough discussion of the marketability and potential value of both conventional compost and vermicompost. Also see the RTI report for a detailed explanation of the types of soil amendment products that Super Soils and NatureWorks Organics are currently producing, and plan to produce in the future.

IV. Site and Technology Overview for the Super Soils Composting Value-Added Process

The Super Soils composting facility and mixing/bagging manufacturing building were constructed at the Hickory Grove site in Sampson County, NC. The facility received separated swine manure solids from the Super Soils on-farm site at Goshen Ridge Farm in Duplin County, NC, approximately 30 miles away from the Hickory Grove site. The separated solids were transported daily via trailers from Goshen Ridge to Hickory Grove. More about the Super Soils process (including data on separation efficiency and costs) can be found at:
http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/supersoils2ndgeneration/pdfs/economic_assessment.pdf

The Super Soils composting facility as constructed at Hickory Grove consisted of an open shed, with dimensions of 250 feet in length by 40 feet in width. Within the shed, five composting bins were housed, as well as designated areas for loading, unloading, and mixing. A concrete pad was used for unloading manure solids and subsequently mixing the manure solids with bulking agents. A front-end loader was used to carry loads of the manure/bulking agent mixture from the mixing pad to the composting bins. Each of the 5 composting bins (or channels) measured 192 feet in length, 6.46 feet in width, and 3.04 feet in depth. A mechanical mixer (automated bin composter) with a 7.5-HP motor moved daily through each of the bins to agitate the compost and advance it through the length of the bin. Retention time in the bins was reported as 30 days (assuming that the composter agitated and advanced the compost in each bin daily), meaning that the mixer advanced the compost by about 6.4 feet (192 feet / 30 days) per day. If the composter was only used 5 days per week, retention time in the bins would increase from 30 days to about 40 days. After advancing the length of the bin (30 days), compost was moved into uncovered windrows for at least 30 days of additional curing. Once 30 days of curing was completed, the composting process was finished and the compost product is considered stable and mature. For a costs and returns analysis of the Super Soils composting facility, see the report available at:
http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase3report06/pdfs/B.11.pdf.

The covered mixing and bagging facility was also constructed at the Hickory Grove site adjacent to the composting facility. An uncovered grinder resting on a constructed concrete pad was also included at this site as part of the Super Soils value-added soil amendment production process. The mixing and bagging facility is comprised of four hoppers, three chemical boxes, a mixer, a mixing belt/conveyor, an incline belt/conveyor, an air compressor, and a bulk loading/bagging/sealing unit process. Hoppers 1 and 2 are each 10 cubic yards in volume, while hoppers 3 and 4 each hold 4 cubic yards of material. The three chemical boxes use a single 0.25 HP agitator/stirrer. The amount of equipment used (and the accompanying total horsepower/electricity cost of the process) depends of the degree of sophistication of the recipe. The most sophisticated soil amendment product made by Super Soils will incorporate all four hoppers and all three chemical boxes, as well as all belts and agitators, the mixer, and the bulk loading/bagging equipment. The simplest recipe would only use a single hopper (with conveyor belt and agitator), the mixer head and belt, incline belt, and bulk loading/bagging equipment. Some of Super Soils product recipes also require that at least one of the components enter the grinding/pulverizing equipment before being loaded into the appropriate hopper.

Bulk soil amendment operations can be overseen by a single line operator. This individual is charged with operating the machinery and keeping the hoppers full of the necessary ingredients for mixing and loading. The system is equipped with a computer that can automate the process to produce the required volume of cubic yards to fill an order. Once the operator enters the required information into the automated system, his primary responsibility becomes hopper maintenance and filling. For bagging operations, the required number of personnel depends on the speed at which an order must be filled. As little as one operator can handle the bagging process, but it becomes more efficient as additional workers are added to the line. To optimize the bagging process, Super Soils would require one worker for line operation and hopper management, two workers on the bagging shoot, and a worker on the sealer. An additional two workers would be needed for stacking of the finished product. The speed and efficiency of the operation could be further optimized by the use of additional equipment like a palleting unit and shrink wrapper. This analysis, however, does not assume the use of this additional equipment. Super Soils is currently operating the equipment with its available personnel—generally two employees, but sometimes as many as three. It fills orders on demand while maintaining very little ready-to-ship inventory. Depending on market demand, the volume of stored inventory could be increased. The model as presented in this report does not include a warehouse/storage facility for soil amendment inventories.

V. Site and Technology Overview for the NatureWorks Organics Vermicomposting Process

The separated swine solids providing the food source for the vermicomposting facility will be collected in conjunction with the Environmental Technologies closed-loop system. The Environmental Technologies closed-loop system is located on Chuck Stokes Farm near Ayden, North Carolina. This technology treats the manure produced from three finishing houses, each with a capacity of 1,224 head. In total, the closed-loop system treated the flushed manure from 3,672-head (495,720 pounds of SSLW) capacity of finishing pigs.

Flushed manure from the houses is diverted to an equalization (buffering) tank as the first step of the closed-loop process. From the equalization tank, manure is pumped to an inclined-screen solids separator. Separated solids are collected in a spreader and eventually will be sent to the on-farm vermicomposting facility. Liquid effluent from the solids separation process is injected with a sanitizer/disinfectant (trichloromelamine, or TCM) and a polymer flocculant (a proprietary polymer formulation developed by Environmental Technologies, LLC) before being pumped into a settling tank. While in the settling tank, flocculated solids fall to the bottom of the tank over a retention time of 3-4 hours. The settled solids at the bottom of the tank will be vermicomposted along with solids collected from the inclined-screen separator. For more on the closed-loop system (including separator efficiency and cost), see: http://www.cals.ncsu.edu/waste_mgt/smithfield_projects/phase3report06/pdfs/B.4.pdf

One of the touted advantages of the vermicomposting process is its relative ease of construction and operation. The facility analyzed in this report consists of simply an enclosed building and concrete trenches to house the worms, bedding material, and food source (separated swine solids). The trenches are also equipped with a watering system and lighting system such that the optimal moisture content and temperature of the process can be constantly maintained. The NatureWorks Organics facility studied in this report was sized to process 11,000 pounds of wet weight manure every 24 hours (plus approximately 20% excess capacity). The separated solids are added to the trenches using a 50-HP tractor. The worms are able to consume 100% of the food source, and no restocking of the worms is anticipated in order to maintain this rate of consumption. Castings are collected every 6-9 months using a tractor-driven harvester. This harvester can remove the worms, harvest the castings, then return the worms back to the trenches without harm. Post-harvest, the castings are warehoused for several days to dry and be tested. Once they are sufficiently dry (depending on the customer and application), the castings are screened and packaged in accordance with the needs of the consumer. For this analysis, no cost invoices were received for bagging or post-harvest processes. Thus, the model assumes that vermicompost will only be sold as bulk castings. NatureWorks Organics does sell bagged products in 2-cubic-yard "Super Sacks," 5-quart bags, and 25-quart bags (Muth et al.). With the necessary cost invoices and operating parameters to describe the bagging process, the model could easily be extended to include the costs and returns of both bulk and bagged vermicompost products.

VI. Modeling Assumptions, Invoiced Cost Summaries, and Projected Costs and Returns for the Super Soils Composting Value-Added Facility (Tables SA.1.-SA.13.)

Tables SA.1. and SA.2. list the modeling assumptions used for Expansion Plan 2 of Super Soils Hickory Grove composting facility. This model is described in detail in the Task 1 team's costs and returns report for this technology (see Zering and Wohlgenant(c)). Most importantly to the Super Soils mixing and bagging facility model that is the focus of this report is the assumption that 6,474 cubic yards of compost are produced annually at the composting facility. Table SA.3. provides some key assumptions and parameters used in the model. Using the solids separation rate and compost volume parameters in Table SA.3., it can be calculated that 6,474 cubic yards of compost can be produced using the annual waste from 1,024,837 pounds of SSLW (7,591 feeder-to-finish head). That is, two standardized 4,320-head feeder-to-finish farms could provide the necessary separated solids for the Expansion 2 compost facility and the mixing/bagging system modeled in this paper. According the manufacturer's estimates on operating capacity, the system can process 65 cubic yards per hour (of bulk product). At top speed (for bulk compost), the system could process the projected 9,711 cubic yards of throughput (at a ratio of 1 part mixing inputs to 2 parts compost) in about 150 hours (or about 30 minutes per day of operation). If used 340 days a year for 8 hours per day, the system could process an estimated 176,800 cubic yards of product per year. At the assumed proportion of compost, it would take 32 standardized 4,320-head farms to produce enough solids to operate this facility at full capacity. The composting facility would need to be expanded by a factor of 18 in order to provide enough feedstock to fully operate the mixing and bagging facility. While it is the purpose of the RTI paper to determine whether enough market demand exists to warrant full capacity operation of this facility, it suffices to say that there is more than enough excess capacity if demand increases would arise. Also note that the costs and returns analyses conducted in this paper assume that only 9,711 cubic yards of product are being processed annually (5.5% of the facility's full capacity).

Table SA.4. lists the motorized components, horsepowers, and electricity costs associated with this system. Annual electric costs are relatively low due to the assumptions regarding throughput discussed in the previous paragraph. As the facility approaches its full capacity, electricity costs will rise in proportion to the increase in throughput. Table SA.5. through SA.7. list the invoiced costs associated with this technology. Four cost invoices were received for this project: on January 29, 2007, September 16, 2007, May 12, 2008, and June 24, 2008. Invoiced costs were received and approved by Mark Rice before being forwarded to the economics team for use in this analysis. Total invoices for the project summed to $213,861.20—primarily for the grinding, mixing, and bagging equipment (85%). The remaining 15% of invoiced costs were related to the construction of the facility housing the equipment.

Tables SA.8. through SA.13. provide predicted cost summaries and itemized cost tables detailing the annualized technology costs under three different scenarios: Tables SA.8. and SA.9. assume a bulk soil amendment is produced, Tables SA.10. and SA.11. assume that 2-cubic-feet bags of soil amendment are produced, and Tables SA.12. and SA.13. assume that 1-cubic-foot bags of soil amendment are produced. Total and annual construction costs are the same for all three scenarios, with the only differences arising in the bagging costs line item of the operating costs section. Any linear combination of bulk and bagged (in either of two sizes) product can be produced at this facility. The model can easily be extended to calculate the costs and break-even prices associated with any combination of bulked and bagged soil amendments. Predicted annualized costs for each scenario are: $119,254.99 for bulk (see Table SA.8.), $208,442.31 for 2-cubic-feet bags (see Table SA.10.), and $258,219.40 for 1-cubic-foot bags (see Table SA.12.). Tables SA.8., SA.10., and SA.12. also provide break-even prices for three different scenarios: 1.) the break-even price to cover only the mixing and bagging facility, 2.) the break-even price to cover the mixing/bagging and composting (Expansion Plan 2) facilities, and 3.) the break-even price to cover the mixing/bagging facility, composting facility, and solids separation technology.

Avoided land application costs of separated solids are accounted for in the Super Soils composting facility model and report. As such, this avoided cost in not included again in the mixing and bagging costs and returns model. As this is modeled to be an on-farm system, transportation costs of separated solids (from a farm to a centralized composting/processing facility) are not included in the model. For a centralized facility analysis, a transportation costs component would need to be added (based on the selection of a site, then a calculation of the amount of potential separated swine solids within a given radius of that proposed site).

VII. Modeling Assumptions, Invoiced Cost Summaries, and Projected Costs and Returns for the NatureWorks Organics Vermicomposting Facility (Tables SA.14.-SA.17)

Table SA.13. lists the modeling assumptions and parameters used in the vermicomposting analysis. Separation efficiencies and moisture content are based on performance data from the Task 1 team's closed-loop costs and returns report. The conversion ratio of 25% (i.e., 25 pounds of harvested castings per every 100 pounds of wet weight separated solids added to the system) is based on Munroe (and literature cited in this reference for existing vermicomposting facilities). Once performance data becomes available for the NatureWorks Organics facility (specifically for conversion efficiency), this system-specific data can replace some of the more general parameters currently in the model. At a processing rate of 11,000 pounds per day (and an assumed 340 production day per year), this system could process 1,870 wet tons of separated solids per year (426.4 dry tons). Using the inclined-screen separator associated with the closed-loop technology, it would take 7,290 feeder-finish head to produce the amount of solids needed for a vermicomposting operation of this size. With a more efficient solids separator (like the one used by Super Soils), enough separated solids could be collected from a single standardized feeder-to-finish farm (4,320 head). In general, solids separation efficiency plays a significant role in analyses involving swine solids. See Table SSCF.38 on page 35 of Zering and Wohlgenant(c) to see the impact that separation efficiency can have. In the RTI report (Muth et al.), there is also a discussion of separation efficiency as it impacts potential regional compost/soil amendment supply. Table SA.15. summarizes the invoiced costs associated with the vermicomposting system. These invoices were collected and verified by Mark Rice. As seen in SA.15., the total invoiced cost of the vermicomposting facility was $136,975. The two largest cost components were for the erection and construction of the facility and for the foundation and concrete work to construct the trenches. Table SA.16. shows the predicted annualized costs and break-even prices of this system. Table SA.17. reports an itemized breakdown of the costs of the technology. Both SA.16. and SA.17. assume the production of a bulk vermicompost product. If bagging costs and operating parameters were made available, the model could easily be extended to include analyses for various sized bagged products (as in the Super Soils mixing and bagging analysis). As reported in Table SA.17., the avoided annualized costs of land applying solids ($14,143.22) almost totally offset the predicted annual operating costs of the vermicomposting facility ($14,291.34). Because of this land application cost avoidance, the annualized costs of the facility are comprised almost entirely of capital expenditures. Total annualized costs of the vermicomposting system were predicted to be $29,359.57. This equates to break-even prices of $62.80 / wet ton (to cover the costs of the vermicomposting facility only) or $78.07 / wet ton (to cover both the facility and the solids separator).

VIII. Conclusions

The purpose of this report is to analyze the costs and returns associated with solids treatment “add-on” technologies. The Super Soils mixing and bagging facility is modeled to be used in conjunction with the Super Soils “2nd Generation” technology and the Super Soils composting facility. The NatureWorks Organics vermicomposting facility is modeled to be used in conjunction with the Environmental Technologies “closed-loop” system. Both technologies are modeled as on-farm systems, meaning that transportation costs are not considered in the analysis. For a centralized facility framework, it would be imperative to include a detailed North Carolina-specific spatial transportation model to the existing costs. As these systems are proposed as alternatives to the baseline method of land applying separated solids, the model explicitly credits each technology for its avoided cost of annual solids application. The Super Soils mixing and bagging facility analysis considers three different scenarios: 1.) production of bulk soil amendment, 2.) production of 1-cubic-foot bags of soil amendment, and 3.) production of 2-cubic-feet bags of soil amendment. The NatureWorks Organics analysis only considers the production of a bulk soil amendment product. This analysis could easily be extended to include a bagged product if the necessary data were made available.

The tables presented in the report summarize the annualized costs of each technology under each production scenario (bulk versus bagged). Break-even prices are also reported for different scenarios (for example, with and without including the annualized cost of the solids separation unit process).

It is important to note that performance data was not collected for either of these technologies to verify processing rates, system efficiencies, etc. The modeling assumptions are largely based on manufacturers' recommendations, existing literature, and the input of the technology providers. The Super Soils composting facility was subject to an extended period of performance data collection as part of an earlier costs and returns analysis. Likewise, the solids separation unit processes for both systems were also subject to a more thorough level of data collection regarding their performance and efficiency. It is important to verify the modeling assumptions used in this report via a prolonged (e.g., 12 months, including a cool and warm season) period of continuous operation, monitoring, and data collection. Until such a demonstration is undertaken, the confidence in these costs and returns projections will remain relatively low as compared to technologies with more robust data collection and performance verification histories.

Tables SA.1. through SA13.: Modeling Assumptions, Estimated Electricity Use for By-Product Technologies, Invoiced Construction Costs, and Predicted Costs and Returns Summaries for Super Soils Composting Value-Added Facility

Table SA.1. Bin Volumes and Loading Rates for Expansion Plan 2* (Vanotti, Campbell)

Length of bin (ft.)	192.0
Width of bin (ft.)	19.6
Depth of bin (ft.)	3.04
Volume of bin (ft.^{3})	11,440
Retention time in bin (days)	30.0
Average daily volume added to bin (ft.^{3})	381.3
Daily volume of swine solids added to bin (ft.^{3})	127.1
Daily volume of cotton gin trash added to bin (ft.^{3})	254.2

* See the Task 1 team's Super Soils composting facility technology report (Zering and Wohlgenant(c))

Table SA.2. Amount (Volume and Weight) of Finished Compost Produced with Expansion Plan 2*

Average feedstock added per bin per day	381.3 ft.^{3}
Total feedstock added per day	1,906.5 ft.^{3}
Volume reduction in bins	74.9 %
Compost volume removed from bins per day	478.6 ft.^{3} (17.73 yd.^{3})
Compost volume removed from bins per year	174,801 ft.^{3} (6,474 yd.^{3})
Density of compost product (before curing)	42.43 lbs. / ft.^{3}
Compost weight** removed from bins per day	20,307 wet lbs. (10.15 wet tons)
Compost weight** removed from bins per year	7,416,986 wet lbs. (3,708 wet tons)

* Assuming that all 5 bins are agitated once per day

** In wet lbs. / tons, with a moisture content of 54.7%.

Table SA.3. Modeling Assumptions for the Composting Value-Added Facility

Solids separation efficiency	88.25 % of dry solids (mass balance basis) (Zering and Wohlgenant)
Moisture content of separated solids	75.1 % (Zering and Wohlgenant)
Solids separation rate	4.3 wet tons / 1,000 lbs. SSLW (@ 75.1 % moisture content) (Zering and Wohlgenant)
Compost volume	5.9 cubic yards of bulk compost / dry ton of separated solids (Zering and Wohlgenant)
Compost weight	3.38 wet tons of bulk compost / dry ton of separated solids (Zering and Wohlgenant)
Bulk compost operating capacity	65 cubic yards / hour (Campbell)
Bagged compost operating capacity (2-cubic-feet bags)	13 bags / minute (Campbell)
Bagged compost operating capacity (1-cubic-foot bags)	19 bags / minute (Campbell)
Mixing capacity	50 cubic yards / hour (Campbell)
Ratio of mixing inputs to compost inputs	1 part mixing inputs : 2 parts compost
Cost of mixing inputs	$15 / cubic yard
Grinding capacity	30 cubic yards / hour (Campbell)
Grinder fuel usage	1.5 gallons of diesel / hour
Diesel cost	$2.75 / gallon
% Grinder throughput	25% of total mixing input volume
Cost of bagging label	$0.13 / bag (Campbell)
Cost of 2-cubic-feet bag	$0.55 / bag (Campbell)
Cost of 1-cubic-foot bag	$0.40 / bag (Campbell)
Compost volume (from bins)*	6,474 cubic yards / year
Mixing volume*	3,237 cubic yards / year
Total soil amendment product produced*	9,711 cubic yards / year

* Assuming compost is produced using Expansion Plan 2 as described in the Task 1 Super Soils composting facility technology report (Zering and Wohlgenant(c))

Table SA.4. Super Soils Composting Value-Added Process Estimated Electric Power Requirements

Unit Process / Component	Motorized Component	HP (hp)	Power (kw)	Run-time (hrs. / day)*	Daily power requirement (kWh / day)
Hopper 1	Belt	3.0	2.6	0.6	1.6
Hopper 1	Agitator	2.0	1.7	0.6	1.0
				Hopper 1 subtotal	**2.6**
Hopper 2	Belt	3.0	2.6	0.4	1.0
Hopper 2	Agitator	2.0	1.7	0.4	0.7
				Hopper 2 subtotal	**1.7**
Hopper 3	Belt	3.0	2.6	0.2	0.5
Hopper 3	Agitator	1.5	1.3	0.2	0.3
				Hopper 3 subtotal	**0.8**
Hopper 4	Belt	1.5	1.3	0.2	0.3
				Hopper 4 subtotal	**0.3**
Chemical box 1	Belt	0.5	0.4	0.4	0.2
Chemical box 1	Stirrer	0.25	0.2	0.4	0.1
				Chemical box 1 subtotal	**0.3**
Chemical boxes 2 and 3	Belts	1.0	0.8	0.4	0.3
				Chemical boxes 2 and 3 subtotal	**0.3**
Mixing head	--	2.0	1.7	0.6	**1.0**
Mixing belt	--	3.0	2.6	0.6	**1.6**
Incline belt	--	1.5	1.3	0.6	**0.8**
Bulk loading/bagging/sealing	Hydraulic power unit	10.0	8.5	0.6	**5.1**
Air compressor	--	5.0	4.3	0.006	**0.03**
				Total kWh / day	**14.53**
				Daily electric costs**	**$1.16**
				Annual electric costs***	**$395.22**

* Daily run-times are based on the assumed compost production rate at Hickory Grove with all 5 bins in operation under Expansion Plan 2 (6,474 cubic yards per year), a soil amendment mix that is 67% compost and 33% other ingredients, and an equal allocation across three recipes which use a varying amount of mixing equipment based on their complexity. It is also assumed that half of the soil amendment product is produced in bulk operations, with the other half being produced in 1-cubic-foot bags.

** Operating costs calculations based on a rate of $0.08 / kWh

*** Based on 340 operating days per year.

Table SA.5. Invoiced Construction Costs of Super Soils Composting Value-Added Process—By-Product Manufacuring Facility (Rice, Campbell)

Component	Cost
Lot clearing for manufacturing facility	$5,300.00
Concrete for manufacturing facility	$4,500.00
Miscellaneous construction for manufacturing facility	$17,441.20
Electric for manufacturing facility	$5,620.00
Total Cost of By-Product Manufacturing Facility	**$32,861.20**

Table SA.6. Invoiced Construction Costs of Super Soils Composting Value-Added Process-- Equipment (Rice, Campbell)

Component	Cost
Grinder and attachments (Sundance Equipment, LLC)	$66,000.00
Mixing and bagging equipment (Horticultural Equipment & Services, LLC)	$115,000,00
Total Cost of Grinding, Mixing, and Bagging Equipment	**$181,000.00**

Table SA.7. Summary of Invoiced Construction Costs for the Super Soils “2nd Generation” Technology

Unit Process	Cost	% of Total Cost
Manufacturing facility	$32,861.20	15.37%
Grinder and attachments	$66,000.00	30.85%
Mixing and bagging equipment	$115,000.00	53.78%
Total Invoiced Cost of Super Soils Composting Value-Added Process	**$213,861.20**	**100.00%**

Table SA.8. Predicted Cost Summary for Composting Value-Added Facility when Producing Bulk Soil Amendment Product

TOTAL CONSTRUCTION COST OF COMPOSTING VALUE-ADDED FACILITY	**$**	**306,035.38**
TOTAL OPERATING COST OF COMPOSTING VALUE-ADDED FACILITY	**$**	**56,529.23**
TOTAL ANNUALIZED COSTS OF COMPOSTING VALUE-ADDED FACILITY	**$**	**119,254.99**
BREAK-EVEN PRICE FOR BULK SOIL AMENDMENT (MIXING/BAGGING FACILITY ONLY)	**$**	**12.28 / cubic yard**
BREAK-EVEN PRICE FOR BULK SOIL AMENDMENT (MIXING/BAGGING PLUS EXPANSION 2 COMPOSTING FACILITY)	**$**	**26.32 / cubic yard**
BREAK-EVEN PRICE FOR BULK SOIL AMENDMENT (MIXING/BAGGING PLUS COMPOSTING FACILITY PLUS SOLIDS SEPARATOR)	**$**	**28.52 / cubic yard**

Table SA.9. Predicted Standardized Costs of Composting Value-Added Facility when Producing Bulk Soil Amendment Product

Component	Total Cost	Annualized Cost
Lot clearing for facility	$ 5,300.00	$ 789.86
Concrete for facility	$ 4,500.00	$ 670.63
Miscellaneous facility costs	$ 17,441.20	$ 2,599.25
Electric for facility	$ 5,620.00	$ 837.55
Grinder	$ 66,000.00	$ 25,610.21
Mixing and bagging equipment	$ 115,000.00	$ 44,683.25
Contractor & Engineering Services & Overhead	$ 92,174.18	$ 13,736.67
Total Construction Cost	$ 306,035.38	$ 62,725.76
Maintenance Cost		$ 6,425.82
Diesel Cost (for grinder)		$ 66.76
Electric Power Cost		$ 395.22
Mixing Materials Cost		$ 48,555.00
Bagging Costs		$ 0.00
Property Taxes		$ 1,086.43
Total Operating Cost		$ 56,529.23
TOTAL ANNUALIZED COST OF MIXING/BAGGING FACILITY		**$ 119,254.99**

Table SA.10. Predicted Cost Summary for Composting Value-Added Facility when Producing Bagged Soil Amendment Product—2-cubic-feet bags

TOTAL CONSTRUCTION COST OF COMPOSTING VALUE-ADDED FACILITY	**$ 306,035.38**
TOTAL OPERATING COST OF COMPOSTING VALUE-ADDED FACILITY	**$ 145,676.55**
TOTAL ANNUALIZED COSTS OF COMPOSTING VALUE-ADDED FACILITY	**$ 208,402.31**
BREAK-EVEN PRICE FOR BAGGED (2 CUBIC FEET) SOIL AMENDMENT (MIXING/BAGGING FACILITY ONLY)	**$ 1.59 / bag**
BREAK-EVEN PRICE FOR BAGGED (2 CUBIC FEET) SOIL AMENDMENT (MIXING/BAGGING PLUS EXPANSION 2 COMPOSTING FACILITY)	**$ 2.63 / bag**
BREAK-EVEN PRICE FOR BAGGED (2 CUBIC FEET) SOIL AMENDMENT (MIXING/BAGGING PLUS COMPOSTING FACILITY PLUS SOLIDS SEPARATOR)	**$ 2.79 / bag**

Table SA.11. Predicted Standardized Costs of Composting Value-Added Facility when Producing Bagged Soil Amendment Product—2-cubic-feet bags

Component	Total Cost	Annualized Cost
Lot clearing for facility	$ 5,300.00	$ 789.86
Concrete for facility	$ 4,500.00	$ 670.63
Miscellaneous facility costs	$ 17,441.20	$ 2,599.25
Electric for facility	$ 5,620.00	$ 837.55
Grinder	$ 66,000.00	$ 25,610.21
Mixing and bagging equipment	$ 115,000.00	$ 44,683.25
Contractor & Engineering Services & Overhead	$ 92,174.18	$ 13,736.67
Total Construction Cost	$ 306,035.38	$ 62,725.76
Maintenance Cost		$ 6,425.82
Diesel Cost (for grinder)		$ 66.76
Electric Power Cost		$ 395.22
Mixing Materials Cost		$ 48,555.00
Bagging Costs		$ 89,147.32
Property Taxes		$ 1,086.43
Total Operating Cost		$ 145,676.55
TOTAL ANNUALIZED COST OF MIXING/BAGGING FACILITY		**$ 208,402.31**

Table SA.12. Predicted Cost Summary for Composting Value-Added Facility when Producing Bagged Soil Amendment Product—1-cubic-foot bags

TOTAL CONSTRUCTION COST OF COMPOSTING VALUE-ADDED FACILITY	**$**	**306,035.38**
TOTAL OPERATING COST OF COMPOSTING VALUE-ADDED FACILITY	**$**	**195,493.64**
TOTAL ANNUALIZED COSTS OF COMPOSTING VALUE-ADDED FACILITY	**$**	**258,219.40**
BREAK-EVEN PRICE FOR BAGGED (1 CUBIC FOOT) SOIL AMENDMENT (MIXING/BAGGING FACILITY ONLY)	**$**	**0.98 / bag**
BREAK-EVEN PRICE FOR BAGGED (1 CUBIC FOOT) SOIL AMENDMENT (MIXING/BAGGING PLUS EXPANSION 2 COMPOSTING FACILITY)	**$**	**1.50 / bag**
BREAK-EVEN PRICE FOR BAGGED (1 CUBIC FOOT) SOIL AMENDMENT (MIXING/BAGGING PLUS COMPOSTING FACILITY PLUS SOLIDS SEPARATOR)	**$**	**1.59 / bag**

Table SA.13. Predicted Standardized Costs of Composting Value-Added Facility when Producing Bagged Soil Amendment Product—1-cubic-foot bags

Component	Total Cost	Annualized Cost
Lot clearing for facility	$ 5,300.00	$ 789.86
Concrete for facility	$ 4,500.00	$ 670.63
Miscellaneous facility costs	$ 17,441.20	$ 2,599.25
Electric for facility	$ 5,620.00	$ 837.55
Grinder	$ 66,000.00	$ 25,610.21
Mixing and bagging equipment	$ 115,000.00	$ 44,683.25
Contractor & Engineering Services & Overhead	$ 92,174.18	$ 13,736.67
Total Construction Cost	$ 306,035.38	$ 62,725.76
Maintenance Cost		$ 6,425.82
Diesel Cost (for grinder)		$ 66.76
Electric Power Cost		$ 395.22
Mixing Materials Cost		$ 48,555.00
Bagging Costs		$ 138,964.41
Property Taxes		$ 1,086.43
Total Operating Cost		$ 195,493.64
TOTAL ANNUALIZED COST OF MIXING/BAGGING FACILITY		**$ 258,219.40**

Tables SA.14. through SA17.: Modeling Assumptions, Invoiced Construction Costs, and Predicted Costs and Returns Summaries for Nature Works Organics Vermicomposting Facility

Table SA.14. Modeling Assumptions for the Vermicomposting Facility

Solids separation efficiency	28.62 % of dry solids (mass balance basis) (Zering and Wohlgenant)
Moisture content of separated solids	77.2 % (Zering and Wohlgenant)
Solids separation rate	1.9 wet tons / 1,000 lbs. SSLW (@ 77.2 % moisture content) (Zering and Wohlgenant)
Harvesting frequency	Twice per year (Binkley)
Processing rate	11,000 pounds (wet weight) of separated solids / 24 hours (Binkley)
Conversion ratio	1 pound of wet weight separated solids : 0.25 pounds of harvested castings
Electricity costs	Based on 1 hour / day usage of a 50-HP tractor, and $5 / day for irrigation and lighting

Table SA.15. Invoiced Costs of the NatureWorks Organics Vermicomposting Technology (Binkley)

Component	Invoiced Cost
Building and erection	$59,400.00
Foundation and concrete work for trenches	$47,400.00
Site preparation	$24,675.00
Watering system	$3,500.00
Lighting system	$2,000.00
Total Invoiced Cost of Vermicomposting System	**$136,975.00**

Table SA.16. Predicted Cost Summary for Vermicomposting Facility when Producing Bulk Vermicompost Product

TOTAL CONSTRUCTION COST OF VERMICOMPOSTING FACILITY	**$**	**196,011.23**
TOTAL OPERATING COST OF VERMICOMPOSTING FACILITY	**$**	**148.12**
TOTAL ANNUALIZED COSTS OF VERMICOMPOSTING FACILITY	**$**	**29,359.57**
BREAK-EVEN PRICE FOR BULK VERMICOMPOST (FACILITY ONLY)	**$**	**62.80 / wet ton**
BREAK-EVEN PRICE FOR BULK VERMICOMPOST (FACILITY PLUS SOLIDS SEPARATOR)	**$**	**78.07 / wet ton**

Table SA.17. Predicted Standardized Costs of Vermicomposting Facility when Producing Bulk Vermicompost Product

Component	**Total Cost**	**Annualized Cost**
Building and erection	$ 59,400.00	$ 8,852.35
Foundation and concrete work for trenches	$ 47,400.00	$ 7,064.00
Site preparation	$ 24,675.00	$ 3,677.30
Watering system	$ 3,500.00	$ 521.60
Lighting system	$ 2,000.00	$ 298.06
Contractor & Engineering Services & Overhead	$ 59,036.23	$ 8,798.14
Total Construction Cost	$ 196,011.23	$ 29,211.45
Maintenance Cost		$ 2,739.50
Harvesting Cost		$ 8,000.00
Electricity Costs		$ 2,856.00
Property Taxes		$ 695.84
Avoided cost of land applying solids[1]		$ (14,143.22)
Total Operating Cost		$ 148.12
TOTAL ANNUALIZED COST OF VERMICOMPOSTING FACILITY		**$ 29,359.57**

1. Assuming nitrogen-based land application to row crops of 3,740,000 wet pounds (1,870 wet tons) of separated solids per year.

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Appendix B

October 2009

Market Analysis of Swine Waste Co-Products: Soil Amendments

Final Report

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Abstract

Developing sustainable alternative waste management technologies is a critical issue for the future of the hog industry in North Carolina. Two companies, Super Soils Systems, Inc. and NatureWorksOrganics, process hog waste into odorless soil amendment products through thermophilic composting and vermicomposting. This study examined the current market volumes for soil amendments in North Carolina and five surrounding states using U.S. Census data and compared it to potential market volumes should hog producers in North Carolina adopt either of these technologies for treating hog waste.

We found that the potential production volume for soil amendments far exceeds current market volumes. Adoption of these technologies by between 11 and 83 average feeder-to-finish farms, out of a population of 1,240 farms, would be sufficient to produce the equivalent of the current market volume in North Carolina and five surrounding states. These estimates suggest that the market for soil amendment products would be saturated by widespread adoption of technologies that produce soil amendments as a byproduct. Thus, production of soil amendments would likely not contribute substantially to the economic feasibility of alternative waste management technologies.

1 Introduction

According to the North Carolina Department of Environment and Natural Resources, North Carolina remains committed to developing alternative hog waste treatment technologies that are both environmentally superior and economically feasible (NCDA&CS, 2009). Recent research on developing environmentally superior waste management practices has focused on producing waste coproducts for use as soil amendments. However, a critical determinant of the economic feasibility of adopting technologies for converting hog waste into soil amendments in North Carolina is whether demand for these products is sufficient to provide a high enough price to cover production costs.

The focus of interest in this report is on the Super Soil Systems and NatureWorksOrganics vermiculture soil amendment products. Duke University's Nicholas Institute for Environmental Policy Solutions contracted with RTI International to conduct a market research study to provide information on the potential size, scope, and value of the markets for these soil amendment products. This study is part of a broader effort for a Natural Resources Conservation Service's Conservation Innovation Grant.

1.1 STUDY BACKGROUND

Rising from almost no presence in the market 20 years ago, the state of North Carolina is now the second largest producer of live hogs (swine) in the United States (NCDA&CS, 2009). Commercial hog production has evolved to a very intensive process wherein large numbers of animals are raised in confined areas and fed diets that maximize growth and turnover rates. This production process requires an equally intensive process for managing the bodily wastes generated by the animals. In North Carolina, the most cost-efficient process for handling swine wastes has been one in which the wastes generated by the building-confined hogs are collected and flushed out of the building and transported to a holding lagoon. Wastes are naturally separated in the lagoon. The liquids are sprayed onto adjacent fields as a fertilizer, and the solids remain to be removed at some point later.

The current system was originally designed with environmental quality objectives in mind but has created a number of environmental problems in the area of the state where the swine operations are concentrated, the eastern Coastal Plain. Primary concerns include emissions of ammonia creating local and regional air quality problems, odor drifting to adjacent properties, and runoff of nitrogen from the sprayfield. The threat of episodic lagoon failures also surfaced in the late 1990s when Hurricane Floyd dumped almost 2 feet of rain on eastern North Carolina, leading to well-publicized lagoon ruptures that ended up releasing wastes into waterbodies and surrounding areas.

The state, spurred in part by a legal settlement between the North Carolina Attorney General's office and the state's largest pork producer, Smithfield Foods, is looking at alternative ways to manage hog waste. Two candidate technologies (Super Soil Systems and NatureWorksOrganics vermiculture) involve separating solid and liquid waste and processing the solid waste into a soil amendment. Of these, Super Soil Systems has been identified as meeting the environmental performance criteria of the agreement, while NatureWorksOrganics is still under evaluation. A critical determinant of the economic feasibility of applying these methods at scale is whether demand is great enough for the soil amendment products that are made from these processes to provide a high enough market price to cover costs. That was the focus of this project.

1.2 OBJECTIVE AND RESEARCH QUESTIONS

The overall objective of this project was to provide a market research study on the potential size, scope, and value of the markets for soil amendment products produced as by-products of alternative hog waste treatment technologies. The focus is on Super Soil Systems and NatureWorksOrganics soil amendment products. Super Soil Systems USA, Inc., based in Clinton, NC, produces thermophilic compost from separated hog waste solids. NatureWorksOrganics, based in Clemmons, NC, produces vermicompost, a compost produced with earthworms using dairy and hog waste, under the brand name Nature'sWay.

The overall objective of this project was to provide a market research study on the potential size, scope, and value of the markets for soil amendment products produced as by-products of alternative hog waste treatment technologies.

Specific research questions addressed included the following:

- What are the characteristics and various end uses of the soil amendment products generated by Super Soil Systems USA, Inc. and NatureWorksOrganics?
- What is the potential size and scope of the soil amendments market for North Carolina producers? Specific data needs include
  - national data on soil amendment volumes and values sold;
  - market prices for Super Soil Systems, NatureWorksOrganics, and substitute products;
  - potential scope of the market for soil amendment products within North Carolina;
  - potential scope of the market for soil amendment products outside of North Carolina, taking into consideration transportation costs; and
  - extent to which Super Soil Systems and NatureWorksOrganics products may be able to serve a national versus regional (Southeast) market.
- Are there impediments to using Super Soil Systems and NatureWorksOrganics products, such as safety or quality concerns, that may inhibit the potential market?
- How much additional volume can the soil amendments market likely bear without saturating the market and affecting the price of products?

Super Soils Systems USA, Inc. and NatureWorksOrganics provided RTI with product and customer information for this report. Much of the information necessary for a thorough review of the compost soil amendment industry is business sensitive. RTI respects the sensitive nature of this information and, to the extent possible, compiled information from other sources, such as published articles and retail Web sites, to support claims made by soil amendment producers.

1.3 ORGANIZATION OF THIS REPORT

The remainder of this report is organized as follows. Section 2 describes the soil amendment products and characteristics. Section 3 presents and discusses market pricing, supply, and demand for soil amendments in the target market areas. A summary of the findings of this study is provided in Section 4. References follow in Section 5.

2 Hog Waste–Derived Soil Amendment Products and Characteristics

In this report, the value-added products derived from hog waste are generically referred to as soil amendments. In this section, we describe the general characteristics and uses of soil amendment products and specific product characteristics of the Super Soil Systems thermophilic compost and NatureWorksOrganics vermicompost produced using earthworms.

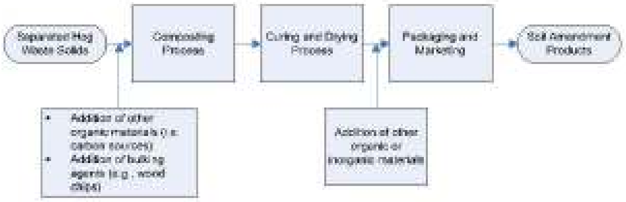
2.1 GENERAL CHARACTERISTICS AND USES OF SOIL AMENDMENTS DERIVED FROM HOG WASTE

Soil amendments are materials that improve soil quality, increase plant performance, and enhance plant appearance. They include any material added to soil to improve its physical properties, such as water retention, permeability, water filtration, drainage, aeration, and structure (Davis and Wilson, 2008). Soil amendments are broadly categorized as organic or inorganic based on the product's source (previously alive versus mined or man-made). Soil amendments such as fertilizer, additives, composts, mulches, manures, and soil conditioners are incorporated into existing soils to create a better environment for plant growth.

The main regulatory compliance issues for any type of compost product include biological concerns (i.e., pathogens) and heavy metal concentrations (Coker, 2007). Quality factors driving market demand include nutrient content, soluble salts, and horticultural characteristics such as water-holding capacity (Coker, 2007). Although nonpathogenic biological content, such as abundance and diversity of microorganisms, may also be important, the relationship between these and compost quality is essentially unknown by the consumer, thus limiting their willingness to pay (Coker, 2007).

The focus of this report is on organic soil amendments derived from hog waste. The products produced by Super Soil Systems USA, Inc. and NatureWorksOrganics are most comparable to compost, although vermicompost is generally considered to be an enhanced type of compost. Figure 2-1 provides a general overview of the production process for compost derived from separated hog waste solids. The vermicomposting process is different from the thermophilic composting process in that the composting process involves using earthworms and the end product is worm castings. In addition to separated solids, other organic materials may be added to either type of compost to provide a carbon source or bulking agent and thus affect the final properties of the product.

Figure 2-1. General Overview of Compost Production from the Waste Feedstock to Soil Amendments



Issues to consider in assessing the markets for compost products include the characteristics of the product, other products that can be derived and marketed from the primary compost product, and challenges that commercially produced compost faces regarding product identity and variability. These issues are discussed below.

2.1.1 Characteristics of Compost Products

Compost is a soil amendment with many end uses such as potting mix in floriculture and horticulture operations, erosion control in landscaping, and maintaining and improving soil organic carbon levels for commercial farming. Compost is a versatile product, possessing the ability to improve the chemical, physical, and biological characteristics of soils or growing media. Conventionally used parameters to assess compost quality include the following (Sherman, 1999):

- pH (5.5 to 7.5)

- soluble salts (<5 mmhos/cm)
- nutrient content
- water-holding capacity
- stability
- organic matter content
- moisture content (35 to 55%)
- particle size (3/8 inch–1 inch)
- bulk density (<1,000 pounds per cubic yard)

Based on these quality parameters, advantages to using compost as a growth media or additive include the following (Sherman, 1999):

- improve water infiltration and drought tolerance
- improve nutrient-holding capacity
- slowly release nutrients to plants
- protect plants from disease
- reduce soil compaction and crusting
- increase ease of cultivation
- improve root growth and yields
- increase microbial and earthworm populations in soil
- reduce fertilizer requirements

As described below, compost is generally either thermophilic compost or vermicompost.

Thermophilic Compost

Thermophilic compost is produced through the aerobic decomposition of organic materials. Marketable thermophilic compost must reach temperatures high enough to sanitize the material and destroy pathogens. State and federal regulations exist to ensure that only safe and environmentally beneficial composts are marketed (U.S. Composting Council, 2008). Compost can be derived from almost any organic material. The following list contains some of the more common feedstocks used in thermophilic composting:

- wood chips (i.e., sawdust and other wood scraps)
- municipal solid waste
- manure
- yard trimmings

- paper products
- food waste

Thermophilic compost requires a certain carbon-to-nitrogen (C:N) ratio, moisture content, and porosity to be marketable. Some separated waste solids are too dense and have a C:N ratio that is too low, requiring a carbon source to balance the nitrogen in the waste. Some compost producers use materials such as cotton gin, paper, and leaves to achieve the appropriate C:N ratio. The added materials can also serve as bulking agents that help aerate compost.

Vermicompost (or Compost from Vermiculture)

Vermicompost is achieved using specific breeds of earthworms to decompose organic or inorganic materials, resulting in worm castings. The process begins with an earthworm bed, lined with a bedding material, such as sawdust, and filled with an appropriate amount of waste (e.g., livestock, food, and yard waste). The earthworms work from the bottom up and are finished composting the waste once they have reached the top of the bed. Vermicompost offers end users the same qualities that thermophilic compost provides. In addition, because of lower temperatures during processing, vermicompost offers end users a compost with higher nitrogen content than thermophilic compost, thus enhancing its fertilizer-like properties (Frederickson, 2007).

2.1.2 Mixed Products

Many soil amendments are commonly mixed with other materials to create an enriched product. For instance, potting mixes typically contain compost, other organic materials, fertilizer, and other additives. Thermophilic compost and vermicompost can also be combined with other soil amendments, such as mulch, to create an enriched product that contains properties of both types of soil amendments. Compost can also be processed to create a fertilizer substitute in the form of pellets, similar to controlled-release fertilizer. Thus, in evaluating the markets for soil amendments derived from hog waste, it is important to consider not only compost products but the mixed products, particularly potting mixes, that use compost as an ingredient.

2.1.3 Labeling Concerns and Product Variability

Compost, by its very nature, has a high degree of nutrient variability. In order for a product to be labeled as a fertilizer, it must meet requirements for guaranteed analysis (i.e., percentages of nitrogen, phosphorus, and potassium). Compost is typically too variable to satisfy these requirements. Neither of the products discussed in this report are currently labeled as a fertilizer although they are marketed to some extent as a fertilizer.

Although efforts are made by some compost producers to minimize nutrient variability, the risk for commercial users (e.g., nurseries and farms) to incorporate the soil amendment into their growing practices still exists. For instance, if a nursery operation uses a compost soil amendment as a growth medium that contains too much or too little of a certain nutrient, the end result could be detrimental and costly. Unless new technologies are developed to reduce variability in compost soil amendments from hog waste, penetration into the commercial market will continue to present challenges.

2.1.4 Organic Certification for Compost

USDA's National Organic Program (NOP) has the authority to develop and administer standards regarding the production and marketing of organic goods. NOP employs certifying agents across the country to inspect organic operations to ensure compliance with USDA organic standards. Although NOP does not certify compost, there are standards for using compost in organic operations, particularly organic food production operations.

Organic Materials Review Institute (OMRI), however, does review organic materials for use in USDA-certified organic operations. OMRI bases standards for certifying organic materials on specific language established by NOP. Approved materials are published in the *OMRI Products List*. As of the writing of this report, no compost derived from hog waste was listed in this database as being reviewed and approved by OMRI. It is currently unknown whether compost derived from hog waste can obtain OMRI certification for use in organic production. It is important to note that although materials used in organic operations must meet NOP standards, any product derived from organic sources can use the term "organic" on the product label without obtaining any certification.

2.2 SUPER SOIL PRODUCT CHARACTERISTICS AND USES

Super Soil Systems USA, Inc. was organized in 1998 by Lewis M. Fetterman, Sr. to provide alternative waste treatment systems. According to Dr. Ray Campbell, Super Soil Systems'

Vice President for Research and Development, the purpose of the company is to ensure long-term sustainability of the livestock and poultry industries and a safe food supply while protecting the environment and preserving our natural resources. The treatment cycle is completed when value-added products are manufactured from the waste solids and packaged for use as fertilizer, horticultural products, or energy production. The first treatment system was built and implemented for testing through funding under the original agreement between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms, and Frontline Farmers. Unless otherwise cited, the information detailed in this section was obtained from Ray Campbell on March 27, 2009, with further updates provided in May 2009.

2.2.1 Current Product Overview

Super Soil Systems USA, Inc. produces thermophilic compost from hog waste solids that are separated and retrieved from nearby hog farms. Once at the processing facility, separated hog waste solids and additional materials are composted to produce a growth medium. The production process takes approximately 2 months for composting (1 month) and curing (1 month) followed by product manufacturing. The final compost product is called Super Soil and is designed not to contain odors associated with using hog waste feedstock. The product is tested frequently for pathogens and heavy metals as part of the standard permit process and adheres to North Carolina Division of Waste Management "Grade A" standards, allowing the product to be distributed directly to the public.

Super Soil products currently marketed include a compost soil amendment and a ready-to-plant container mix. According to Dr. Campbell, these products are currently sold under the "Hickory Grove Farm" brand but will soon be marketed under a new brand and in customer-oriented packaging. The ready-to-plant container mix contains a compost product along with other soil amendments suitable for growing container plants. Each of these products is packaged in 1 cubic-foot (typical size of retail compost product), 2 cubic-feet, and 30 cubic-feet large sacks. Wholesale and retail prices for Super Soil products are generally comparable to other similar products currently on the market.

2.2.2 Future Product Overview

According to Dr. Campbell, Super Soil plans to develop a full line of home garden production products. Future Super Soil products include granulated fertilizer and nutrient-enriched mulch. According to Dr. Campbell, early evaluations indicate that Super Soil fertilizer products contain some fungicidal activity that is important in maintaining bentgrass species in turfgrass management operations, such as golf course fairways and greens. Marketing fertilizer requires more extensive testing than what is required for marketing compost, including testing that ensures consistency in the types and amounts of macro- and micro-nutrients. Although the turf, lawn, and garden markets will be targeted, the fertilizer will also be available for general agricultural use.

2.2.3 Customer Overview

Super Soil products are currently sold primarily in the consumer (household) market, but other potential markets include nurseries, farms for agricultural production, golf courses, and turfgrass operations. Thus, Super Soil Systems USA, Inc. focuses marketing efforts primarily on the retail consumer market, targeting garden centers that attract hobby gardeners and landscapers. Currently, Super Soil products are distributed in North Carolina (six outlets) and South Carolina (one outlet), but plans are underway to expand into nearby markets after new consumer packaging has been developed. In addition, the North Carolina Department of Transportation (NCDOT) has purchased Super Soil compost through the Highway Beautification Program to enhance soil water-holding capacity, nutrient content, and erosion control. Because of budget cuts, NCDOT is not currently able to purchase Super Soil products, although it is interested in doing so if funding is restored (D. Smith, personal communication, May 6, 2009).

Penetrating the commercial markets for soil amendments, including fertilizer and growing media, presents challenges to Super Soil because of the presence of established and nationally advertised products. According to Dr. Campbell, the most important obstacle in the agricultural market will be pricing and product comparability with higher-analysis fertilizers. Super Soil products are relatively more competitive with currently used products in turfgrass management on golf courses and in recreational and urban areas. Also, certification of Super Soil products in organic food production will likely offer a substantial opportunity to market Super Soil products to that industry.

2.3 NATURE'SWAY CHARACTERISTICS AND USES

NatureWorksOrganics began operations in the mid-2000s collecting waste primarily from dairy farms. The company operates four vermicomposting facilities and is building a new processing center in eastern North Carolina to be in a better position to collect waste from hog farms. Unless otherwise cited, the information in this section was collected primarily from Bob Binkley, NatureWorksOrganics' founder on March 25, 2009.

2.3.1 Current Product Overview

NatureWorksOrganics produces vermicompost soil amendment products derived from both dairy and feeder-to-finish hog waste. End products are continuously tested by NatureWorksOrganics to monitor consistency and uniformity. Products currently marketed include raw earthworm castings (vermicompost) used as a soil additive, blended compost products, and tea (liquefied product) used as a foliar spray; however, the primary focus thus far has been on the raw vermicompost product.

The raw product, Nature'sWay, is primarily used in commercial horticulture operations, vineyards, and organic farms. This product is a soil substrate additive, for use in potting, landscaping, and organic row crop production. Research at North Carolina State University documents nutrient values and water use efficiency in using vermicompost in nursery container operations (McGinnis, 2007). Although it cannot be marketed as a fertilizer, Nature'sWay claims to be comparable to soil conditioners boasting fertilizer-like properties and may be used to offset some fertilizer use. Furthermore, because it is not heated like thermophilic composts, it is argued to have more beneficial biological activities to support plant growth.

Commercial Nature'sWay products are sold in 2 cubic-yard "Super Sacks," comparable to a truckload. The retail product is sold in 5-quart bags at prices ranging from $8 to $12, and 25-quart bags for approximately three times more.

2.3.2 Future Product Overview

NatureWorksOrganics plans to market a blended version of its vermicompost soil amendment product. The blended variety, other types of compost, will be used as a long-term soil amendment. The blended product will target the hobby gardener market and will be a ready-made, all-purpose soil amendment. NatureWorksOrganics is pursuing organic certification through the North Carolina Department of Agriculture and Consumer Services.

2.3.3 Customer Overview

Sales of Nature'sWay products to commercial producers account for 90% of total revenue, and sales to retail operations account for the remaining 10%. Commercial customers include vineyards, commercial greenhouse operations and landscapers, and organic farms. They use Nature'sWay for its soil-conditioning properties and to offset fertilizer use in container-grown plants, landscaping, and small-scale organic row cropping.

Retail outlets include some ACE Hardware and Southern States Cooperative stores but primarily include various independent establishments. Retail consumers use Nature'sWay as an alternative fertilizer for household vegetable gardening as well as a soil additive for nonfood gardening. These products are targeted to higher-end outlets in which the clientele are more likely to be familiar with the perceived benefits of using vermicompost compared to traditional compost products. Nature'sWay packaging does not disclose the source of the vermicompost feedstock (i.e., whether compost is derived from dairy or hog waste).

3 Potential Soil Amendment Market Volume and Pricing

In this section, we use the broad term "soil amendments" to refer primarily to compost but also to mixed products (e.g., potting mix) that include compost as an ingredient.

The success of soil amendment products derived from hog waste in the marketplace is contingent on whether revenue generated from sales of soil amendment products can offset the costs of production and, potentially, a portion of the costs of operating hog waste treatment technologies. Hog producers will choose either to produce and market soil amendment products directly or to transfer separated solids to a third party that will produce and market soil amendment products. Decisions to produce soil amendment products will be influenced by expected revenue based on the potential demand for these products relative to the potential supply.

In this section, we discuss the potential demand for soil amendments in the target market, the estimated potential supply of soil amendments from hog waste and the methods used to derive estimated compost volumes, and other considerations regarding market reactions to soil amendments produced from hog waste.

3.1 SOIL AMENDMENTS DEMAND

In this section, we define primary and secondary target markets for soil amendments derived from hog waste, outline the current demand for soil amendment products in the target market areas, and briefly discuss the potential future demand for these products.

3.1.1 Current Soil Amendment Demand

Soil amendment consumers can be generally categorized as follows:

- households (for ornamental and vegetable gardening)
- landscapers
- nurseries
- turf grass operations
- golf courses
- specialty farms
- government agencies (e.g., for parks, schools, and government buildings, and highway beautification)

All of these categories of soil amendment consumers might produce their own soil amendments in addition to purchasing commercial soil amendment products. Larger operations are more likely to self-produce or use substitutes because of the costs of purchasing and shipping the products.

Because of its weight, shipping costs for soil amendment products can often equal or exceed the actual value of the product depending on the distance shipped. Compost production facilities tend to be located near hog farms (i.e., located on the farm or within 5 to 10 miles) to minimize transportation distances because of the hazards and costs associated with transporting raw hog waste. Typically, unbranded products are shipped within a 200-mile radius of the processing facility; as shown in Figure 3-1, a 200-mile radius from a processing facility centered in the main hog-producing region of eastern North Carolina would include most of North Carolina and the majority of Virginia and South Carolina.

For the purposes of this report, we consider a possibly broader market for branded soil amendment products of up to 500 miles from soil amendment processing centers. Thus, we define the *primary market area* to include all states within a 500-mile radius of Clinton, North Carolina, which is approximately the center of the hog-producing regions in North Carolina; this radius includes North Carolina, South Carolina, Virginia, Tennessee, Maryland, and Georgia. However, in some cases, higher-valued compost products may be shipped longer distances. An extreme upper bound on the total potential market (i.e., the secondary market) includes the remainder of the continental United States; thus, we define the *secondary market area* to include all remaining states in the United States. Although bulk compost products are unlikely to be shipped from North Carolina to the secondary market area, some higher-value branded products may be. In particular,

Figure 3-1. States Included within a 200-mile Radius of the Primary Hog-Producing Region in North Carolina

vermicompost products are more likely to be shipped greater distances because of their perceived higher value.

Primary Soil Amendment Market (500 Miles from Primary Production Area)

We used data from the 2002 Economic Census, Industry Series for North American Industrial Classification System (NAICS) code 325314 to calculate estimates of compost and potting soils by state. However, it is uncertain whether the NAICS code used in the analysis fully represents all compost and potting soil sales because Census estimates often miss the smallest establishments (which often total only a small fraction of production volumes). It is also important to note that volumes of product obtained from Census can be considered a measure of the quantity demanded given current market prices. However, changes in the supply of compost that result in changes in market prices will result in changes in the quantity demanded by all end users of compost.

Table 3-1 provides estimates for 2007 of the quantity of commercial compost sold within the six-state region defined as the primary market for hog waste–derived soil amendments. Because state-level sales data are not available, we assumed that the amount of compost marketed is proportional to the household population of the target market relative to the total

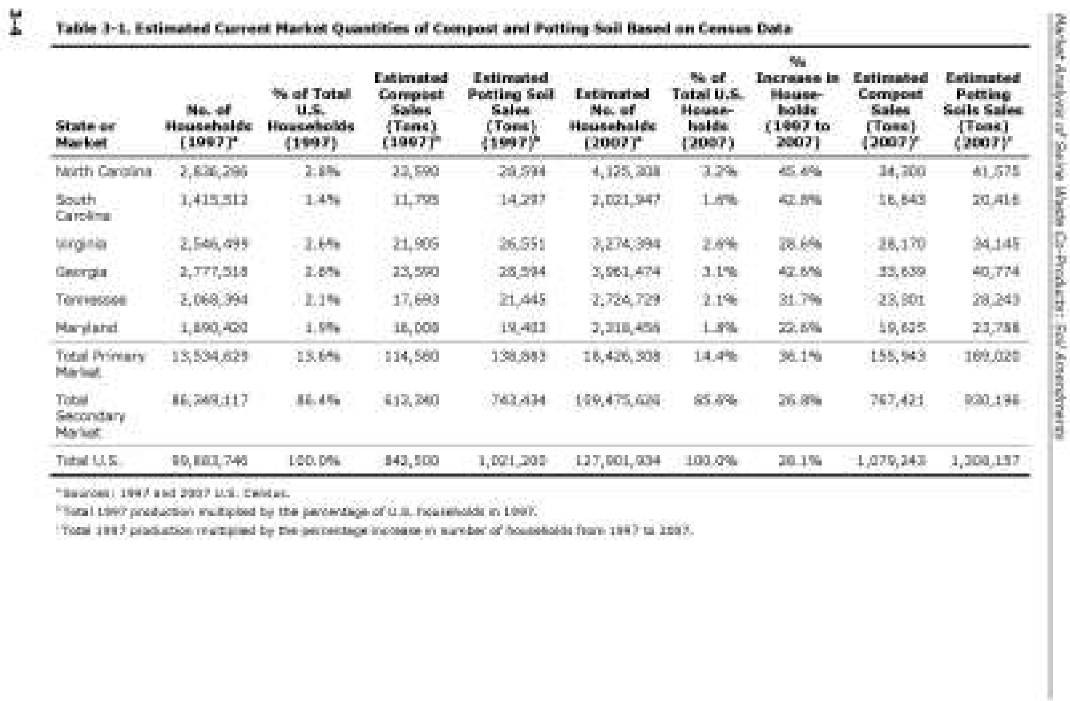


Table 3-1. Estimated Current Market Quantities of Compost and Potting Soil Based on Census Data

State or Market	No. of Households (1997)[a]	% of Total U.S. Households (1997)	Estimated Compost Sales (Tons) (1997)[b]	Estimated Potting Soil Sales (Tons) (1997)[b]	Estimated No. of Households (2007)[a]	% of Total U.S. Households (2007)	% Increase in Households (1997 to 2007)	Estimated Compost Sales (Tons) (2007)[c]	Estimated Potting Soils Sales (Tons) (2007)[c]
North Carolina	2,836,286	2.8%	22,590	28,594	4,125,308	3.2%	45.4%	34,300	41,575
South Carolina	1,415,512	1.4%	11,795	14,297	2,021,947	1.6%	42.8%	16,843	20,416
Virginia	2,546,499	2.6%	21,905	26,551	3,274,394	2.6%	28.6%	28,170	34,145
Georgia	2,777,518	2.8%	23,590	28,594	3,961,474	3.1%	42.6%	33,639	40,774
Tennessee	2,068,394	2.1%	17,693	21,445	2,724,729	2.1%	31.7%	23,301	28,243
Maryland	1,890,420	1.9%	16,008	19,403	2,318,456	1.8%	22.6%	19,625	23,788
Total Primary Market	13,534,629	13.6%	114,560	138,883	18,426,308	14.4%	36.1%	155,943	189,020
Total Secondary Market	86,349,117	86.4%	612,240	742,434	109,475,626	85.6%	26.8%	767,421	930,196
Total U.S.	99,883,746	100.0%	842,500	1,021,200	127,901,934	100.0%	28.1%	1,079,243	1,308,157

[a] Sources: 1997 and 2007 U.S. Census.

[b] Total 1997 production multiplied by the percentage of U.S. households in 1997.

[c] Total 1997 production multiplied by the percentage increase in number of households from 1997 to 2007.

U.S. household population. Therefore, based on 1997 Census data, the primary target market area represented 13.6% of the entire U.S. household population: 114.6 thousand tons of compost (212.2 thousand cubic yards) and 138.9 thousand tons of potting soils (257.2 thousand cubic yards).[1] Assuming compost purchases increased proportionally with the increase in the number of households from 1997 to 2007, approximately 155.9 thousand tons of compost (288.8 thousand cubic yards) and 189.0 thousand tons (350.0 thousand cubic yards) of potting soils were sold in 2007 in the primary target market area. The six-state market represents an estimated 14.4% of the entire U.S. compost market because states in the primary market have had faster population growth compared to the rest of the United States over the past decade.

Secondary Soil Amendment Market

The remainder of the continental United States outside of the six-state market for North Carolina–derived soil amendments accounted for 86.4% of all households in 1997, translating to 613.3 thousand tons of compost (1.1 million cubic yards) and 743.4 thousand tons of potting soils (1.4 million cubic yards). Again, assuming compost purchases increased proportionally with the increase in the number of households, approximately 767.4 thousand tons of compost (1.4 million cubic yards) and 930.2 thousand tons (1.7 million cubic yards) of potting soils were sold in 2007 in the remaining states.

Comparison with Other Market Estimates

In comparison to these estimates, Rudek and Shao (2007) estimated the U.S. market for soilless media and substrate to be 120 to 150 million cubic yards per year in 2001. Their estimate is derived by assuming ballpark estimates of volume use by different segments of the market.[2] However, it does not account for the fact that a large proportion of soil amendment products are self-produced rather than sold through market

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[1] We converted the weight estimates to volume estimates assuming 40 pounds per cubic foot (1,080 pounds per cubic yard) of soil amendment product. This estimate is based on the typical weight indicated on 1 cubic foot bags of retail soil amendment products.

[2] More specifically, the estimate of 120 to 150 million cubic yards is based on extrapolating assumed volumes for containerized nursery production in North Carolina to the U.S. as a whole and then doubling the estimate to represent additional purchases by households. The basis of the calculation is that each of the estimated 12,045 acres of containerized nursery production in North Carolina equates to 60,000 1-gallon containers requiring soilless media (see Appendix E of Rudek and Shao (2007)).

transactions[3]. Although users of soil amendments may decide to purchase rather than self-produce if prices decline, it is unlikely that prices could decline enough to rationalize the difference in the estimates from the two sources. In addition, we note that our estimates are based on extrapolation from Census data collected through a nationally representative industry survey in contrast to extrapolation from assumed use volumes.

3.1.2 Future Potential Soil Amendments Demand

As the population in the Southeast continues to increase at a faster rate than the U.S. average, all potential demand sources for soil amendments in the primary target market will also likely increase. In addition, interest in gardening appears to be on the upswing and thus would translate into increased demand for all types of soil amendment products. For example, in 2008, the National Gardeners Association (NGA) estimated that 31% of all households had a food garden. The number of households expected to participate in food gardening is estimated to increase to 43% of all households in 2009 (NGA, 2009). If this trend continues, even at a slower pace, we can reasonably expect that soil amendment products will reap some benefit from the overall increase in market demand. In addition, if prices of soil amendments decrease in response to a shift out in supply, quantity demanded will increase further.

3.2 SOIL AMENDMENTS SUPPLY

The total supply of soil amendments includes noncommercial and commercial sources. Some households operate their own compost heaps and bins using food and yard waste. Many municipalities and communities also engage in waste reduction efforts by organizing compost activities that provide compost free of charge to users. Furthermore, many landscaping and nursery centers produce their own compost for use in their business operations. The amount of compost reflected in the 2002 Economic Census does not reflect the amount of self-produced or locally produced, no-charge compost. However, in evaluating the markets for soil amendment products derived from hog waste, it is most relevant to focus on the supply of products that will be traded in markets, because these will provide the most direct competition for the products of interest in this study.

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[3] There are currently no data available on the volume of self-produced compost.

The following section outlines the methodology for estimating the supply of soil amendment products that can be generated from the volume of hog waste generated in North Carolina. We also describe the attributes and prices of other substitute products currently on the market.

3.2.1 Potential Supply of Soil Amendments Produced from Hog Waste in North Carolina

We calculated the total potential supply of soil amendments generated from hog waste by applying conversion factors to the inventory of hogs in North Carolina. Table 3-2 presents estimates of soil amendments for the Super Soils process. The specific steps in the calculations are as follows:

- Estimates of total steady-state live weight (SSLW) in 1,000 pounds for hogs on different type of operations were obtained from Table 16 in Zering and Wohlgenant (2005).
- Low, medium, and high estimates of separated solids (dry tons) were calculated using the following conversion factors for separated solids (dry tons) per SSLW (1,000 pounds) obtained from Table 8b in Williams (2006):
  - Low: 0.15 dry tons of separated solids per 1,000 pounds of SSLW
  - Medium: 0.43 dry tons of separated solids per 1,000 pounds of SSLW
  - High: 1.14 dry tons of separated solids per 1,000 pounds of SSLW
- Low, medium, and high estimates of bulk compost volumes were calculated by multiplying the volume of separated solids by the conversion factor of 5.9 cubic yards per dry ton of separated solids obtained from page 4 of Zering and Wohlgenant (2006b).
- Low, medium, and high estimates of bulk compost weights were calculated by multiplying the volume of separated solids by the conversion factor of 3.38 wet tons per dry ton of separated solids obtained from page 4 of Zering and Wohlgenant (2006b).

Table 3-2. Potential Annual Production of Bulk Compost from Hog Waste in North Carolina

Farm Type	No. of Farms[a]	Total SSLW (1,000 lbs)[b]	Separated Solids (dry tons)[c]			Bulk Compost Volume (cubic yards)[d]			Bulk Compost Weight (wet tons)[e]		
			Low	Medium	High	Low	Medium	High	Low	Medium	High
Farrow-wean	212	282,775	42,416	121,593	322,364	250,256	717,400	1,901,948	845,868	2,424,813	6,428,077
Farrow-feeder	114	101,964	15,295	43,846	116,239	90,238	258,683	685,810	305,005	874,347	2,318,037
Farrow-finish	98	92,306	13,846	39,692	105,229	81,691	234,188	620,850	276,115	791,528	2,098,474
Wean-feeder	375	67,755	10,163	29,135	77,241	59,963	171,894	455,720	202,678	581,003	1,540,334
Feeder-finish	1,240	775,655	116,348	333,532	884,247	686,455	1,967,837	5,217,058	2,320,217	6,651,288	17,633,648
Total (all NC)	2,039	1,320,455	198,068	567,796	1,505,319	1,168,603	3,349,994	8,881,380	3,949,877	11,322,981	30,019,088

SSLW=steady state live weight

[a] Source: Zering and Wohlgenant (2005), Table 14.

[b] Source: Zering and Wohlgenant (2005), Table 16.

[c] Separated solids are calculated as dry tons per 1,000 SSLW using the following rates: low=0.15, medium=0.43, and high=1.14. Source: Williams (2006), p. 58, Table 5b.

[d] Compost volume is calculated assuming 5.9 cubic yards of bulk compost per dry ton of separated solids. Source: Zering and Wohlgenant (2006b), p. 4.

[e] Compost weight is calculated assuming 3.38 wet tons of bulk compost per dry ton of separated solids. Source: Zering and Wohlgenant (2006b), p. 4.

Note: Further reduction in weight may occur during curing (estimated to be less than 10%).

The resulting estimates indicate a low estimate of 1.1 million, a medium estimate of 3.3 million, and a high estimate of 8.9 million cubic yards of potential annual compost production from hog waste in North Carolina. This translates to 3.9 million, 11.3 million, and 30.0 million wet tons, respectively, of bulk compost. However, the product weight may be reduced by as much as 10% during the curing process, but a specific estimate of the reduction is not available (see p. 9, Zering and Wohlgenant, 2006b). This adjustment would reduce the weight estimates to 3.5 million, 10.2 million, and 27.0 million pounds per year.

Hog waste from feeder-finish farms will likely be the primary source of feedstock for producing soil amendment products. It may be more difficult to capture separated solids from operations that house sows (farrow-wean, farrow-feeder, and farrow-finish) because access to these operations may be restricted because of biosecurity concerns from traffic (vehicular and pedestrian) coming on and off the farms. Also, the volume of waste generated by wean-feeder operations on a per-pig basis is lower and thus may be logistically more difficult as a source of compost feedstock. Furthermore, operations with young pigs may use more medications (e.g., antibiotics and dewormers) and disinfectants that could potentially compromise the production of soil amendments. Note that feeder-finish operations account for 59% of the estimated SSLW in North Carolina and thus comprise the majority of the waste generated. Focusing on these operations only, the estimated volume production for compost derived from hog waste in North Carolina would be 0.7 million, 2.0 million, or 5.2 million cubic yards per year. This corresponds to 2.3 million, 6.7 million, or 17.6 million tons of bulk compost annually prior to adjusting for additional weight loss during the curing process.

The estimates in Table 3-2 account for the fact that carbon sources and bulking agents (e.g., cotton gin trash and wood chips) are added to separated solids prior to composting. However, these estimates do not include the potential for mixing bulk compost with other materials to produce products such as potting mix. Thus, an additional conversion factor would be required to obtain an estimate of total soil amendments volume potential assuming that a portion of bulk compost is sold to consumers as compost and the remainder is sold to consumers in a mixed product.

The data required for similar calculations for vermicomposting are not currently available. However, based on a ballpark estimate provided by a source in Zering and Wohlgenant (2006a), 1.5 pounds of castings can be produced per finishing head per day in a feeder-finish operation. This results in 5,508 pounds of castings per day on a 3,672-head farm. If all 1,240 feeder-finish farms produced at that rate, the total volume of bulk castings produced per year in North Carolina would be approximately 1.2 million tons before mixing with other materials (approximately half of the lowest estimate for feeder-finish using the Super Soils estimates).[4]

3.2.2 Supply of Other Commercially Available Soil Amendments

The commercial market for soil amendments is diverse both in brands and in product derivation. Compost and other soil amendments can be purchased in bulk and packaged form from warehouse stores, garden centers, and specialized mulch and compost suppliers. Compost derivatives that are commercially available include poultry litter, dairy manure, mushroom, and food and plant waste.

Table 3-3 provides examples of available compost products available to consumers at the retail level and illustrates the large variability in pricing among traditional compost products, between packaged and bulk composts, and between traditional compost and worm castings. Black Kow is a well-recognized, regionally marketed compost producer in the Southeast United States, with products sold in many regional warehouse store garden centers and independent garden centers. The Black Kow Dairy Compost product is labeled as a 0.5-0.5-0.5 fertilizer and is a well-known commercially produced brand-name compost derived from animal waste widely available in the region. Other commercially produced composts available in the Southeast include mushroom compost and food waste compost. The producers of Black Kow also market mushroom compost in their product line. Organic compost composed of food and yard waste is also commercially available in most markets from various brands.

Note that the prices in Table 3-3 do not include additional costs that may be incurred for delivery. In addition, delivery of products may require a minimum purchase volume.

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[4] Production of vermicompost is likely restricted to only hog waste from feeder-finish farms because medications and disinfectants used at other stages of production have an adverse effect on the worms.

Table 3-3. Regional Retail Compost Prices

Compost Type	Price	Source
Black Kow Dairy Waste Compost	$4.97 per 50-lb bag	Lowe's Home Improvement store, Mebane, NC, April 2009
Black Kow Mushroom Compost	$4.78 per cubic foot	Lowe's Home Improvement store, Mebane, NC, April 2009
Whitney Farms Organic Plant & Food Waste Compost	$4.23 per cubic foot	Ideal TrueValue Hardware Stores online http://www.idealtruevalue.com/servlet/the-10837/Detail, retrieved April 2009
Timberline Organic Cow Manure Compost	$1.58 per cubic foot	Lowe's Home Improvement Store, Cary, NC, June 2009
Vermi-Technology Unlimited's Black Castings	$12.99 per 5-lb bag	Garden Supply Company, Cary, NC, June 2009
Mebane Shrubbery compost (derived from leaves)	$15 per scoop (2/3 cubic yard)	Mebane Shrubbery, Mebane, NC, June 2009
American Soil and Mulch compost (derived from chicken manure)	$20 per cubic yard	American Soil and Mulch, Apex, NC, June 2009

3.3 POTENTIAL EFFECT OF INCREASES IN SOIL AMENDMENT SUPPLY ON MARKET PRICES

A substantial increase in the supply of soil amendments due to the adoption of alternative hog waste treatment technologies has the potential to affect market prices. Thus, in evaluating the degree to which sales of soil amendments can be used to offset the costs of implementing the technologies, it is important to estimate the revenue potential based on projected rather than current market prices. Accurate estimates of market prices after widespread adoption of the technologies would require a market model that considers the economic behavior of producers and consumers, which is beyond the scope of this study. However, in the absence of a market model, we can provide a qualitative assessment based on the potential product volume generated from hog waste relative to current market volumes.

We consider two methods of comparison. First, we compare the total compost production potential from hog waste with Census estimates of compost production. Then, we calculate the compost production potential on a per-household basis to determine the plausibility of possible purchases of the product. We focus these comparisons on the bulk compost estimates because of the large variability in the volumes of other soil amendments that could be produced using bulk compost as an ingredient.

Both methods of comparison lead to the qualified conclusion that the total volume of soil amendments that could be produced from hog waste in North Carolina vastly exceeds the current sales of these products in North Carolina and five surrounding states. Market prices are likely to decline substantially in response.

For the first method of comparison, we compare the compost production potential with Census estimates. If we assume that the primary feedstock source for compost is feeder-finish farms, between 2.3 and 17.6 million tons of compost could be produced from hog waste in North Carolina using the Super Soils technology. If we reduce this weight by 10% to account for additional moisture loss during curing, the totals are between 2.1 and 15.8 million tons.[5] In comparison, the estimated compost sales in the six-state area were 0.16 million tons in 2007 using Census estimates. If potting soils are included, the total estimated soil amendment sales were 0.34 million tons. Thus, assuming Census estimates provide a valid comparison, the potential production volume for soil amendments derived from hog waste dwarfs the current market for these products. With these extreme differences, a market model is not necessary to demonstrate that the market would be saturated and market prices would fall drastically (potentially to negative values, implying that producers would pay consumers to haul off the product). In short, the six-state market does not appear to be large enough to absorb the full supply potential of North Carolina swine waste–derived soil amendments. Furthermore, between 11 and 83 average feeder-to-finish farms (depending on separation efficiency) would be sufficient to supply the equivalent of the estimated current market volume of compost in the six-state market.

The second method of comparison is based on calculating per-household estimates of compost purchases that would be required to absorb the potential product volume. Again, assuming that feeder-finish farms are the primary source of feedstock, and that the products will be distributed primarily in the six-state market, each household would need to absorb the equivalent of 0.04 cubic yards (1 cubic foot) to 0.28 cubic yards (8 cubic feet) of compost per year. The volume would be further reduced by the portion of products sold through the commercial market, such as landscapers and golf courses. Baseline data are not available for the average number of cubic feet of compost purchased by households per year or the portion of households that purchase compost. Thus, it is

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[5] Some of this product volume might be sold at cost to the state government for use by the DOT and thus would not be supplied on the commercial market. However, given the current fiscal situation in North Carolina, this is an unlikely method of disposition.

difficult to determine what percentage increase in current purchases are represented by the potential volume from hog waste. However, it is likely that a small portion of the households purchase compost on an annual basis. If we assume that 5% of households purchase compost, then households in the six-state area would need to purchase an additional 0.8 cubic yards (22 cubic feet) to 5.6 cubic yards (151 cubic feet) of compost per year. Increases of this magnitude are likely to have substantial downward effects on market prices for compost and other soil amendment products.

Finally, it is important to note that adoption of the vermicomposting process by all producers instead of the thermophilic composting process would also likely lead to substantial increases in product volumes relative to current market volumes. Although the absolute increase in product volumes is likely substantially less than if all producers adopted the Super Soils technology, the percentage increase relative to current market volumes is much greater. Vermicompost is currently a specialty product with limited awareness among consumers and commercial purchasers and limited availability at retail outlets. Also, the current relative price of vermicompost products is substantially higher as a reflection of the higher costs of production. If vermicomposting is widely adopted as an alternative waste treatment method for hog waste, it is also likely to have substantial downward effects on market prices. In addition, it will be necessary to substantially increase market awareness if vermicomposting is to be considered a viable option.

3.4 OTHER CONSIDERATIONS FOR EVALUATING THE MARKET FOR SOIL AMENDMENTS DERIVED FROM HOG WASTE

In evaluating the demand for soil amendments derived from hog waste, several potential consumer perception issues will need to be investigated more fully. Although it is uncertain whether producers are required to or will elect to state the source of the feedstock on product packaging, purchasers may request this information. On the one hand, producers may believe they will benefit from stating the product source if purchasers view the production of compost as an environmentally friendly method of waste disposal. However, it will be important to understand better what concerns purchasers may have and how these perceptions might affect the potential demand for products.

Some of the potential concerns might include the following:

- **Negative views of the hog industry in North Carolina.** Consumers may be reluctant to purchase products that may be viewed as supporting the hog industry because of publicity regarding environmental problems associated with the hog industry and potential animal welfare issues resulting from the use of confinement operations and sow crates.
- **Potential disease concerns.** Consumers may associate use of hog waste–derived products with "swine" flu or other types of infections. Specifically examples include the following:
  - Recently, the World Health Organization (WHO) declared H1N1 "swine" influenza a Stage-5 pandemic virus. Although no scientific study proves or disproves the possible spread of the virus from animal by-products to humans, little is known about the source of the most recent strain and how the virus spreads. Many consumers stopped purchasing pork-related products altogether, blaming the flu outbreak on industrial hog farming practices (Philpott, 2009).
  - Over the past couple of decades, public concern has grown about the use of nontherapeutic hormones in livestock production. Many studies have drawn links between meat consumption and increased antibiotic resistance in common viruses and bacteria (Mellon, 2001). Although research has not proven links between the use of animal waste by-products on vegetable gardening and antibiotic resistance, there is a possibility of negative consumer perception about using animal waste by-products in household vegetable gardens.
- **Concern about heavy metals and other possible contaminants in hog waste–derived soil amendments.** Some research has shown higher levels of heavy metals in compost derived from hog waste than from other feedstocks (Yang, 2005). Although other research has shown that heavy metal content has been essentially eliminated in compost produced using the treatment options under consideration (Vanotti, 2005), consumers aware of such issues may be skeptical. Consumers may also be concerned that antibiotics fed to pigs or disinfectants used in hog production facilities may remain in composted products. Soil amendments are often marketed with the term "organic" to refer to the use of natural ingredients in their production; thus,

consumers might assume that the feedstock is from operations that do not use chemicals.

Market research that evaluates consumer perceptions of these issues will help facilitate the development of markets for soil amendments derived from hog waste. This research will need to consider the trade-offs between marketing a product as benefiting the environment versus the possible negative perceptions of the hog industry and hog waste in the target market areas.

4 Conclusion

In this report, we evaluated the specific product characteristics for two composting processes that use hog waste as a feedstock, estimated current market volumes in North Carolina and surrounding states, assessed potential supply of soil amendments derived from hog waste in North Carolina, and discussed possible implications of a supply increase of this magnitude on the marketplace. In this section, we summarize the general findings of this study.

4.1 SOIL AMENDMENT PRODUCTS AND SUPPLY

Based on our calculations, the total volume of soil amendments that could be produced from hog waste in North Carolina vastly exceeds the current sales of these products in North Carolina and five surrounding states.

Soil amendments are produced from commercial and noncommercial sources. While compost and similar products are marketed at many garden centers and home improvement warehouses, many municipalities and communities produce compost as a waste reduction effort. Some households have personal compost heaps and bins used to process food and yard waste. Also, some nurseries recycle plant waste for use as soil amendments in their own operations. However, in evaluating the markets for soil amendment products derived from hog waste, it is most relevant to focus on the supply of products that will be traded in the markets.

4.1.1 Soil Amendments Derived From Hog Waste

Super Soils and Nature'sWay are two soil amendment products that are derived from animal waste. Super Soils is thermophilic compost, produced through the decomposition of organic materials. Nature'sWay is vermicompost produced using earthworms to break-down animal waste into worm castings. Both products claim to be odor and pathogen free. Both companies have well-established product lines as well as plans for future products. These products are priced competitively with other similar products in the marketplace.

If all feeder-to-finish farms in North Carolina adopted thermophilic composting as their waste management strategy, North Carolina could produce approximately 6.7 million tons of compost derived from hog waste annually (with an estimated range of 2.3 to 17.6 million tons). If instead, all feeder-to-finish farms in North Carolina adopted vermicomposting as a waste management strategy, approximately 1.2 million tons could be produced annually, not including any additional bulking agents that are typically added and thereby increase total weight.

4.2 MARKET DEMAND AND SUPPLY IMPLICATIONS

Based on extrapolated U.S. Census estimates, the six-state primary market for soil amendments (including North Carolina, South Carolina, Virginia, Georgia, Tennessee, and Maryland) purchased approximately 156,000 and 189,000 tons of compost and potting soil, respectively, in 2007. This geographic area was used because of the cost of shipping, as transporting compost derived from hog waste outside the primary market area is costly as a result of the weight of the product. As the population for the Southeast continues to increase at a faster rate than the U.S. average, all potential demand sources for soil amendments in the primary target market will also likely increase. In addition, interest in gardening appears to be on the upswing and thus will translate into increased demand for all types of soil amendment products.

Although interest in gardening and the population in the primary target market continue to increase, these increases alone are not nearly sufficient to absorb the potentially large increase in supply of soil amendments derived from hog waste. In fact, the volume of compost produced from 11 to 83 average feeder-to-finish farms (depending on separation efficiency), out of a total population of 1,240 feeder-to-finish farms in North Carolina, would be sufficient to supply the equivalent of the estimated current market volume of compost in the six-state market.

The substantial gap between quantity demanded and potential supply demonstrates the very real possibility of market saturation should all feeder-to-finish farms in North Carolina adopt either of these waste treatment technologies. Such market saturation is likely to have substantial downward effects on market prices for compost and other soil amendment products, thus jeopardizing the economic feasibility of implementing technologies that rely on production of hog waste-derived soil amendments as a waste management strategy.

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Appendix C

Pilot Project for Value-added Product Development from Solid Waste Generated on Swine Farms
Super Soil Systems USA, Inc.
Final Report
October 14, 2009

Submitted by
Ray Campbell, Super Soil Systems USA, Inc.

Overview

Complete solutions to farm waste management include mechanisms for nutrient removal and alternative use outside the intensive production region. The Super Soil waste treatment system provides such a solution for swine production by flocculating, dewatering, and removing solids from the liquid waste stream. Approximately 50% of Total Nitrogen, 75% of Total Phosphorus, and 98% of Copper and Zinc in the waste stream are removed with the solids. The remaining water is treated further to remove soluble nitrogen and phosphorus. At the end of the process, the liquid has been sterilized and contains little or no nitrogen, phosphorus, copper, and zinc. Odor and ammonia emissions are also significantly reduced.

Solids removed from the waste stream are transported to a Central Processing Facility where they are composted to kill pathogens and further reduce ammonia emissions and odor. By the end of the process, nutrients are stable and the compost meets "Class A" standards set by State and Federal regulations.

To enhance value of the composted waste, and provide market alternatives, Super Soil manufactures value-added products from two different compost products made from swine solids. Funding from the CIG project was used to purchase a grinder and develop a mixing/bagging line that could be used to automate production and provide for bulk sales and bagging. Since Super Soil's goal is to develop several value-added products from compost, flexibility was a major concern in development of the mixing/bagging line.

By purchasing a combination of new and refurbished equipment, Super Soil was able to purchase a grinder for particle size reduction and install a computerized mixing/bagging line including two 10 yd hoppers, two 4 yd hoppers, three small chemical hoppers, a mixing head and conveyors to move product from beginning of the line to a separate conveyor for bulk loading or bagging. A bagging system consist of a product hopper and bag filling head for both one and two cu ft bags, a sealer, and conveyor to move the product through bagging, sealing, and stacking/palletizing for shipping. The line will process up to 60-70 cu yd/hr bulk or bags at the rate of 12-14 two cu ft bags or 18-20 one cu ft bags/min. Since processing is very efficient, orders are processed on demand and product inventory is minimized.

Equipment installation was completed on June 24, 2008. Since that time, the mixing/bagging line has been used on demand to process product for distribution in North Carolina, South Carolina, and Virginia.

Funding

A total of $215,870 was received from CIG funding. Super Soil spent an additional $1,861.20 on construction materials and subcontracts, $3,787.88 on construction labor, and $25,000 on project management. Super Soil also furnished a 50 x 120 ft building (6,000 sq ft) building valued at $217,000 for installation of the processing equipment. After construction, Super Soil manufactured value-added products from composted swine solids for distribution and sales in nursery and consumer markets and to DOT for use in the Roadside Beautification Program.

Results/Accomplishments

Grant funds along with Super Soil's contributions resulted in construction of a manufacturing facility to process composted swine solids into value-added products for sale in nursery and consumer markets. Processing capacity should be adequate to handle solids received from a minimum of 10-15 standard sized finishing farms (5,880 head) in North Carolina. Efficiency and processing speeds can be further enhanced as needed to handle even larger capacity. The mixing/bagging line is constructed flexible enough to allow processing of a wide variety of products as they are developed. Computer controls make it easy to change recipes and to develop new products. The large hoppers accommodate up to 4 ingredients while small chemical hoppers accommodate up to three ingredients. The mixing head decreases particle size so that the compost does not have to be ground to meet particle size and consistency standards. A conveyor system allows either bulk or bag processing. An automated bagging and sealing system facilitates filling both 1 and 2 cu ft bags.

Lessons Learned

The decision to construct a mixing bagging line that is flexible proved to be very valuable as we continue to develop new products. The working loads for belts and motors in the equipment also proved to be critical for processing compost. Standard equipment designed specifically for processing very light weight materials commonly used in the horticultural industry may not perform well under heavy loads demanded for processing compost and other wetter materials.

Moisture control in compost, bark and other ingredients prior to processing is critical for trouble-free operation of grinders and mixing equipment. Super Soil is now making arrangements to store all composted products and other ingredients under shelter or cover for protection from rainfall.

As we began bagging, it became evident that a well trained staff working as a unit is critical to maximizing efficiency with the processing equipment. The equipment can be operated with as little as one individual but a minimum of 3-4 individuals is required for optimal efficiency. The addition of palletizing and loading equipment will further enhance efficiency.

Transferability

The core processing equipment developed for this facility is transferable to similar processing applications in the composting and landscaping industries.

Conclusions

The construction of a mixing/bagging line in an enclosed facility makes it possible to produce value-added products from composted swine solids and other waste materials year-round provided all of the ingredients are stored out of rain. The processing facility makes it possible to manufacture a wide variety of products from composted swine solids and other waste products. Moreover, it is a critical link in the removal of nutrients from farms and utilization outside the intensive animal production region. In the end, such facilities will be critical to reducing environmental impact of animal production while providing a mechanism for expansion and alternative income sources.

Appendix D

NatureWorks Organics
CIG Report

Submitted October 19, 2009
By
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Background

NatureWorks Organics (NWO) is a North Carolina LLC that was originally formed to create a waste remediation solution for North Carolina hog farms through vermiculture of the manure solids captured from the waste stream on individual farms. The resulting vermicompost (worm castings, vermicasts, etc.) would then be sold in order to generate
revenue for the company and potentially offset some of the infrastructure costs.

While the scope of this report does not allow for an extensive, detailed status account, it is adequate to state that the company's original impetus and mission are succeeding in regard to the revenue generation and this CIG project is well on the way toward documenting the value of the remediation component.

In addition, NWO has made significant progress toward commercializing its products and sells primarily into commercial fertilizer channels in bulk quantities. The product is then used as-is or is blended with other organic inputs to create products from potting substrates for nurseries to proprietary organic blends for consumer, landscaper and farmer alike. The company is also developing a rapidly growing retail channel which has more than doubled in 2009. Market data clearly indicate that sales are related to products' performance rather than their organic nature.

Failure and Success

NWO was able to acquire a test in 75 "big box" stores of a particular retailer. While the sales volume was not adequate to generate expansion, the learning from the experience caused a change in marketing strategy/emphasis to commercial/wholesale, as well as a better understanding of the retail marketplace (including specific acceptance data) which have served well ever since. The understanding of the customer acceptance cycle combined with the extensive, university-based research behind NWO products have become the foundations of commercial and retail channel success alike.

The company's vermicomposting techniques have been a success throughout and have continued to improve. Large-scale vermicomposting is a proven capability across a wide array of waste materials. The company is in negotiations with two large food processing companies that will pay "tipping fees" that will generate a modest profit and the vermicasts are purposed for a new product that will launch in 2010.

Project Cost

To date, NatureWorks' expenditures are on the order of \$185,000 including capex, labor, travel and grant funds. Two projected harvests in 2010 from the CIG project should generate a gross revenue number of ~ \$460,000 with additional incremental cost of \$76,000.

Results

Validation of product pricing, along with the promise of margin improvement during the next 24 months, is most likely the best result to date. The project has also created the opportunity to further validate/improve vermicomposting techniques, as well as to collaborate with two other small companies that will further enhance remediation capabilities and product line. It is the consensus of NWO's board that the results to date of this project have exceeded the original justification for projected and unanticipated costs to date.