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

Final Report for
Conservation Innovation Grant

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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.

[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.

[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.

[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.

[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

[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 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

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

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.