IMPROVED MANURE MANAGEMENT TO ENHANCE DAIRY FARM VIABILITY

Final Report

Prepared for

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Abstract and Keywords

Large-scale composting has become an increasingly popular method of organic waste management on livestock farms across New York State (NYS). Composting can be the tool to allow farms to export excess nutrients. To aid farmers in planning, a computer model created in Microsoft Excel, called "Co-Composter," was developed as a planning and management tool for large composting facilities. While designed for farms, the model can be used by others interested in composting non-agricultural materials.

Co-Composter asks an extensive series of quantitative and qualitative questions relating to either an existing facility or a planned facility. Information requested includes manure type and quantity, bulking/bedding material, other compost feedstocks, equipment type and age, and time available. There are also default values built into the model, providing typical values for certain parameters to use when site-specific information is not available. When the user is finished, Co-Composter generates a detailed logistical and economic analysis to help compost managers look at facility planning, equipment, efficiency and feasibility.

The model was developed by faculty and students in the Cornell Department of Biological and Environmental Engineering and the Cornell Waste Management Institute (CWMI). Comparison of results using the model with a standard economic analysis at four farm compost sites provided validation of the model. Training was provided for consultants, educators, and others in NYS.

The Co-Composter model and user's manual are available at the CWMI web site: http://compost.css.cornell.edu/CoCompost.html.

Keywords:

compost; economics; model; manure; farm

Acknowledgements

Cornell Waste Management Institute would like to recognize the many people, agencies, and organizations that made this project possible. Without the involvement of Cornell Cooperative Extension Educators Aaron Gabriel of Washington County, Joan Petzen of Cattaraugus County, Ed Staehr of Onondaga County, and Frans Vokey of Lewis County, meeting project objectives would not have been possible. In addition, CWMI would like to thank the composting managers around New York State who contributed their valuable time. Lastly, the Co-Composter Model could not have become reality without the time and dedication of Cornell Professor Doug Haith, Department of Biological and Environmental Engineering, and Cornell Professor Wayne Knoblauch, Department of Applied Economics and Management.

Cornell Waste Management Institute personnel who worked on this project included Lauri Wellin who kept the pieces together. Particular recognition is deserved for Jean Bonhotal whose practical and detailed knowledge of NYS compost production and producers makes this project part of a program that helps develop the knowledge and actions needed to make composting a viable means of managing organic residuals in NYS. Dan Olmstead at CWMI entered the project midstream and capably took over the training and fine tuning. Lastly, Tom Fiesinger, project manager at NYSERDA, was in integral member of the project team. His administrative management was constructive and he provided thoughtful input to all aspects of the project.

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Summary

Large-scale composting is an increasingly popular method of organic waste management on farms across New York State. As a result of nutrient management issues and regulations for concentrated animal feeding operations (CAFO's), farmers are looking for different ways to manage manure. If managed properly, composting can be an effective way to handle large quantities of animal waste products.

"Co-composting" is a term that refers to the simultaneous composting of several materials. Because many variables are involved in co-composting, a term that refers to the simultaneous composting of several materials, managing a facility that handles multiple organic waste streams is a complex task. Characteristics such as moisture content, carbon to nitrogen (C/N) ratio, organic matter, nutrients, and many others can change significantly depending on the type of materials being used. In farm operations, the number of variables influencing compost production is high, and might encompass herd size, operational costs, availability of equipment, labor hours, availability of bulking agent, and much more.

The overall goal of this project is to upgrade and demonstrate a computer model that farmers, agricultural consultants, planners, and compost managers will use to select and optimize alternative composting strategies for managing animal manures and other farm residues in ways that minimize energy and environmental impacts, and maximize profitability of farm operations.

To achieve the objectives of this project, the Cornell Waste Management Institute (CWMI) worked with the Department of Biological and Environmental Engineering (previously the Department of Agricultural and Biological Engineering) at Cornell University, Cornell Cooperative Extension Educators, Yates County Soil and Water Conservation District staff, and NYS farmers.

The Co-Composter Model is comprised of several distinct sections. These consist of 1) a "user input" page, 2) "user output" page, 3) "background" page, 4) "area and volumes" page, 5) "pad and building costs" page and 6) "turning and handling costs" page. Taken together, the information contained in the model is a tool that provides a detailed analysis for considering the efficiency and feasibility of a composting operation. This project sought input and feedback from stakeholders, partners, and composters across New York State on ways to improve the model. These changes, additions, and deletions are summarized in the full report.

To make the Co-Composter Model more accurate, a team of Cornell researchers studied four dairies to measure compost production factors such as economic impact, equipment optimization and space requirements. Two large dairies in the study employed manure separation. Other dairies generated tipping fees by taking in outside material to mix with manure. One dairy recycles compost as bedding, reducing those costs. Equipment varied among operations. Some bought specialized compost equipment; others

used existing equipment or retrofitted it to perform composting operations. By studying a variety of composting operations, the team was able to assess the costs and returns.

When the Co-Composter projections were compared to a spreadsheet using information collected from the four dairies, economic projections of the model matched actual farm analyses relatively well. The most profitable composting operations used existing equipment to begin composting. Some required minimal site preparation to start, depending on suitable soil and using existing equipment to construct a pad.

To further assess the utility of the model, two dairy composting operations were selected for study. One farm was considering composting; the other is an experienced compost facility. Working with a local agricultural advisor and the farmer, Co-Composter was run and the outputs used to provide advice. The model proved to be an excellent tool in both cases. In the first, the farmer realized that his expectations were not realistic and has deferred starting to compost until he has more time to commit. In the second, refinements were made based on the model outputs.

INTRODUCTION

Large-scale composting is an increasingly popular method of organic waste management on farms across New York State. As a result of nutrient management issues and regulations for concentrated animal feeding operations (CAFO's), farmers are looking for different ways to manage manure. If managed properly, composting can be a safe, effective way to handle large quantities of animal waste products.

In most composting operations, manure is combined with one or more additional materials to optimize the process, and is called "o-composting." Large scale composters may add materials like wood chips, straw, or hay to manure to increase the amount of air flowing through a compost pile. Materials used in this manner are called bulking agents. In other cases, materials like yard waste or food scrap is added. These add different levels of nutrients to the compost and may have associated tipping fees, but do not necessarily add "bulk." These additions are called feedstocks. In general, any combination of the materials discussed here to create a compost product is considered co-composting.

Because many variables are involved in co-composting, managing a facility that handles multiple organic waste streams is a complex task. Characteristics such as moisture content, carbon to nitrogen (C/N) ratio, organic matter, nutrients, and many others can change significantly depending on the type of material being used. In farm operations, the number of variables influencing compost production is high, and might encompass herd size, operational costs, availability of equipment, labor hours, availability of bulking agent, and much more.

Starting a new co-composting operation, or making changes to an existing one, presents a number of challenges. In either case, it is important to make informed decisions looking not just at the overall operation, but the details as well. Built using the capabilities of Microsoft Excel, the Co-Composter Model takes a variety of different management factors into consideration and provides both detailed analyses and an overall summary of the logistic and economic implications a composting facility has under different conditions. The model bases its calculations on a detailed set of data provided by a compost manager or other user and can be used with new or existing composting systems. Default data are provided for many variables if users lack the necessary data for their operation (see Appendix H). Although Co-Composter was developed primarily for dairy farm systems that add other materials to produce compost, it can also be adapted for non-manure systems such as those used by municipalities.

OBJECTIVES

The overall goal of this project is to upgrade and demonstrate a computer model that farmers, agricultural consultants, planners, and compost managers will use to select and optimize alternative composting strategies for managing animal manures and other farm residues in ways that minimize energy and environmental impacts, and maximize profitability of farm operations.

The Co-Composter Model was originally created under a previous project. The current project sought to refine it and to provide training.

Specific task objectives of this project include:

1. Upgrade spreadsheet model from version A to B.
2. Make upgraded model available on the web and track model use, comments.
3. Compile data for the model from literature sources and at least four farm composting operations.
4. Train target model users and seek input on desired model capabilities.
5. Upgrade model based on user input regarding desired model capabilities and develop a model guidebook using data collected.
6. Select four additional farms and apply Version C of model to identify areas of improvement for each case study.
7. Prepare a progress report summarizing results of project that contains a plan for 1) preparing case studies of modeled improvements at two farms, 2) final model evaluation, and 3) technology transfer.
8. Compile data and evaluate composting improvements for 2 case study farms identified in objective 7.
9. Make Version C and guidebook available physically and on the internet and track model use and user comments.
10. Train target audience of model users on Version C and seek input on desired model capabilities
11. Complete final project deliverables including final model version, final guidebook, and final report, using data from participating farms and input from the target audience on desired model capabilities and outputs.

To achieve the objectives described above, the Cornell Waste Management Institute (CWMI) worked with the Department of Biological and Environmental Engineering (previously the Department of Agricultural and Biological Engineering) at Cornell University, Cornell Cooperative Extension Educators, Yates County Soil and Water Conservation District staff, and NYS farmers.

I. UPGRADES AND CHANGES TO THE CO-COMPOSTER MODEL

The Co-Composter Model is comprised of several distinct sections. These consist of 1) a "user input" page, 2) "user output" page, 3) "background" page, 4) "area and volumes" page, 5) "pad and building costs" page and 6) "turning and handling costs" page. Taken together, the information contained in the model is a tool that provides a detailed analysis for considering the efficiency and feasibility of a composting operation. The following paragraphs provide a brief summary of sections contained in the Co-Composter Model.

Co-Composter Summary

User Input Page (see Appendix A). This page contains a detailed list of questions for the user to answer, relating to various aspects of a composting operation. When complete, this worksheet contains information about farm size, number of animals, manure production, quantity and nutrient content, manure separation and digestion practices, farm and compost management practices, equipment costs, economic factors and more. All other pages in the Co-Composter Model rely on data from the user input page to produce results, and this page is the only one a user needs to fill out to view results on other pages. Default values are included for a number of parameters. The purpose of the "user input" page is to collect data from the user about his or her composting operation for use by the model.

User Output Page (see Appendix B). This page takes all data entered into the user input page and summarizes results calculated in the mass balance, areas and volumes, pad and building costs and turning and handling costs pages (Figure 1). The summary includes 1) a system mass-flow diagram of manure that serves as a visual tracking tool of inputs and outputs of the compost system; 2) a detailed "compost recipe" analysis that tabulates all of the feedstocks, bulking agents and other additions; 3) annual compost production based on input volumes and other factors; 4) total land area requirements given annual volumes of raw material storage, composting area, curing pile sizes, and finished compost storage; 5) energy use that takes equipment fuel needs and electricity costs into account; 6) capital equipment costs; and 7) overall operational costs, with the ability to compare different combinations of equipment.

Background Page (see Appendix C)**.** The user input page, and other areas of the Co-Composter Model, contain many technical terms, concepts, abbreviations and variables, some or all of which, the user may be unfamiliar to. The "background" page is a reference document created to help inform the user and allow him or her to gain some familiarity with the technical aspects of the model. Areas included in the background page are cited elsewhere in the model text, either on the user input page or other pages. In the order written, these include variable names; mixture characteristics; explanation of bedding, flush water, waste water, digester, and manure fate; suggestions for improving compost mix; composting system explanations and compost pile dimensions/spacing; other stages of the composting process (not including active composting); storage (raw materials and final) and curing pile dimensions/spacing; land area

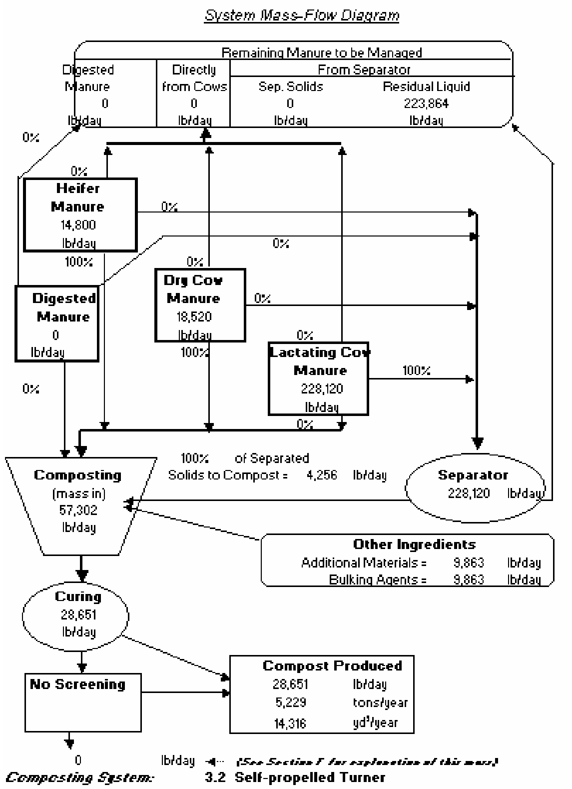

Figure 1. Mass flow diagram generated by Co-Composter as part of summary calculations based on data provided by the user.

calculations; composting time periods and turning interval; leachate detention pond design; building design for extended aerated pile system; time required for handling, turning, and screening; economics (annualization of capital costs, separating costs, materials and compost handling cost, compost turning cost, estimation of operation and maintenance costs, insurance costs, pad and building/aeration costs, screening costs, treatment of rental costs, suggested year 2000 capital costs for composting equipment); estimation of fuel use; conversion tables (area and volume); and references. See Figure 2.

Mass Balance Page (see Appendix D). The mass balance page is a detailed tabulation of all inputs and outputs to the composting system, and is visually represented in the system mass-flow diagram described in the user output page. The mass balance page calculates raw manure production, total manure production (includes raw manure, flush water, and bedding), separated manure production, total manure composted, and manure to be managed by means other than composting.

Areas and Volumes Page (see Appendix E). The areas and volumes page takes into account area requirements for the composting operation by calculating annual volumes of bulking agents, feedstocks, and manures. Volumes and time or holding requirements for raw materials storage, active composting, compost curing, and finished composts are combined to determine area requirements for the compost pad.

(D) Suggestions for Improving Compost Mix *(referred to in 9 of User Input Page and in Mass Balance sheet)*

Characteristic	*Range*	
Moisture content	40 - 65%	(Rynk, 1992)
C:N ratio	20:1 - 40:1	(Rynk, 1992)
Bulk density	less than 40 lb/ft^3	(Rynk, 1992)

The suggestion arrows in Tables 8 and 9 of User Input indicate that adding a given material will affect the particular parameter in the same way relative to the optimal range. The effects of adding a material were determined by comparing the characteristics of that material to the optimal range.

For example,

Material	Density (lb/ft^3)	Moisture Content (%)	C:N
Wood chips	20	30	600

20 falls below the upper limit of 40 lb/ft^3 for bulk density, meaning that an addition of wood chips will help to lower the bulk density of the compost mix if it is too high. Likewise, 30% < (40-65%), and 600 is much greater than (20 - 40), so the moisture % and C/N of the mix will go down and up, respectively.

Material	Density (lb/ft^3)	Moisture Content (%)	C:N
Addition of wood chips	▼	▼	▲

Figure 2. An example of background information regarding the formulation of a good compost mix. Note the reference in upper right corner to main document.

<u>Pad and Building Costs Page</u> (see Appendix F). The pad and building costs page calculates total construction costs using two scenarios; 1) a turned windrow system with, including a pad and pond construction and 2) an extended aeration/biodrying system. Co-Composter incorporates economic factors into both scenarios including annual interest rate, number of years annualized, salvage value, and yearly insurance costs. Overall costs are determined for both systems by calculating total area requirements and factoring in relevant construction costs.

<u>Turning and Handling Costs</u> (see Appendix G). The turning and handling costs page incorporates equipment capacity and horsepower with volume and available labor hours to calculate the feasibility of using certain pieces of machinery. Co-Composter calculates the volume of materials and compost handled (without considering turning and screening); volume of material handled in turning windrows; time required to handle materials, turn windrows, and screen compost; cost of screening equipment rental; and economics of materials handling, turning and screening.

<u>Co-Composter Updates and Changes</u>

Changes and updates to the Co-Composter Model are described in the following sections. Edits are documented by model page (i.e. user input, user output, mass balance etc.). To view the final version of the model, see Appendix A.

User Input Page. Questions posed to the user in this section are the basis for all other tabulations in the Co-Composter Model. Because of this, the majority of changes suggested were related to various portions of the "user input" page. Most questions received at least minor revision, while others were changed significantly and some not at all. Each question in its finalized form is described below, followed by an overview of changes and revisions that were made over the course of this project.

Introduction. The final version asks two questions: 1) will manure be composted; and 2) will it come from a digester. Answers determine what question the user will go to next.

Changes. No changes were made to these questions.

Question 1. User enters # of dairy animals contributing to manure stream. Three animal categories are provided: 1) # heifers (animals 501 to 1000 lbs), 2) dry cows (1001 to 1400 lbs), and 3) lactating cows (1001 – 1400 lbs). User enters an estimate of daily manure production for each category in ft^3/cow per day. Typical values are provided if the user is unsure of manure output per animal, using milk production to roughly estimate manure volume.

Changes. No changes were made to this question.

Question 2. User is asked to provide values in % dry weight for moisture content, nitrogen content and C/N ratio of raw manure. Typical values based on research are provided if the user does not know these values.

Changes. No changes were made to this question.

Question 3. If user digests manure before composting, he or she enters daily volume, density, moisture content (% dry weight), nitrogen content (% dry weight), C/N ratio (% dry weight), percentage of digested manure that is sent to a separator, percentage of digested manure composted. Typical values based on research are provided for density, moisture content, nitrogen content, and C/N ratio if the user does not know these values.

Changes. Composters attending a November 2001 training workshop suggested users be allowed to specify the amount of digested manure being sent to a separator. This was included as an option in the last portion of question 3.

Question 4. A table of typical bedding materials is provided and includes "none," straw, hay, sand, small wood chips or shavings, saw dust, dried paper pulp, dry compost, wet compost, and "other." For each of these bedding types typical values are provided that include density (lbs/ft^3), moisture (%), nitrogen (% dry weight), and C/N ratio. If the user selects "other" they must provide their own values for the parameters listed. Each bedding type is assigned a reference number from 0 to 9.

Part 2 of question 4 asks the user to provide bedding information for each of the three animal categories outlined in question 1 – heifers, dry-cows, and lactating cows by entering the reference number of a bedding type used by each group. In addition, for each animal category, the user also enters the average amount of bedding material used (ft^3/cow per day), average flush water (ft^3/cow per day), % manure going to a separator, and % manure composted. Typical values for all parameters are provided if the user does not have the requested information.

Changes. Composters attending a November 2001 training workshop noted the model reports bedding in cubic feet, but that in general people think in terms of pounds per cow per day. Volume is the critical measurement when calculating area requirements for a composting facility, so this change was not made to the model. A conversions table was added to the "background" page to help users make these calculations.

Question 5. The user is asked if wastewater is added to lactating cow manure either from the milkhouse or parlor. If the user answers "yes," he or she is asked to calculate the amount in ft^3/cow per day. Typical values based on number of cows milked are provided if the user is unsure.

Changes. During a June 2001 meeting of Co-Composter users asked how liquids going into a separator, other than flushwater, are handled in the model. To address this, question 5 was added to Co-Composter so additional sources from milkhouses or parlors can be accounted for.

Question 6. If the user separates cow manure in his or her operation, the model requests information including moisture content of separated solids, density of separated solids (lbs/ft^3), % of total manure solids removed by separation, and percent of separated solids composted. Typical values based on research are provided if the user is unsure.

Part 2 of question 6 asks for capital costs of equipment used for manure separation. Included are costs for the separator unit, costs for plumbing, pipes and pumps, and electricity rates. Typical values are provided for each if the user is unsure.

Changes. In July of 2001, economic factors related to separating manure were added to question 6 that included capital costs of equipment, pumps and pipes, and electricity use. Costs for a building to house a separator unit were not included because equipment at most farms are located in existing structures.

Composters attending a November 2001 training workshop suggested that volume tabulations of manure not being managed through composting be deleted. This change was not made to the model because the amount of manure not handled by a composting system is an important and useful number for composting managers to have.

Question 7. The user is asked how many days manure and/or separated solids will be stored before composting is started. A typical value of 7 days is suggested if the user is unsure.

Changes. During a June 2001 meeting, Co-Composter users asked why the user is unable to enter "0" as a value for the number of days manure and separated solids will be stored before composting, since some operations immediately incorporate the materials. This problem was fixed, and users can now select zero as an option.

Question 8. The user is presented with an interactive table that lists typical feedstocks and compost inputs other than manure. This list includes food waste, shredded paper, cardboard, yard waste, grass clippings, leaves, shrub trimmings, tree trimmings, paper pulp, food processing waste, and "other." If the user adds any of these materials in the composting process, he or she is asked to enter annual volume in ft^3/year, maximum number of days material will be stored before incorporation, tipping fee ($/$ft^3$ if applicable) and acquisition cost ($/$ft^3$ if applicable). Typical values for maximum days of storage, based on research, are provided if the user is unsure.

If the user chooses food processing waste or "other" as a feedstock, he or she must provide values for average density in lb/ft^3, % moisture content, nitrogen content (% dry weight), and C/N ratio. This is necessary because, unlike the other feedstock options in question 8, Co-Composter does not have pre-determined parameter data saved internally for food processing waste and feedstocks that fall under "other."

Changes. In October 2000, March 2001, and June 2001 collaborators noted that the area needed for feedstock storage depends on the time between delivery and incorporation. A change was made to allow users to specify the time that feedstock are stored on site. At the same meeting, questions were raised about whether a distinction should be made between yard waste that includes grass and yard waste that does not, the difference being that grass should be incorporated within 24 hours of arrival. To address this, grass clippings, leaves, shrub trimmings, and tree trimmings were divided into separate categories. Yard waste is the average of these four categories.

Composters attending a November 2001 training workshop asked if feedstock volumes can be calculated on a per day basis as well as an annual basis. This change was not made to the model because a majority of operations do not manage compost piles on a daily basis.

Questions 8 and 9. Questions 8 and 9 have similar parameters and data requirements relating to feedstocks and bulking agents, respectively. Several questions and comments arose pertaining to these questions together.

Changes. In October 2000, a suggestion was made to add a reference table listing tipping fees for various feedstock and bulking materials. This change was not made to the model because tipping fees are highly variable depending on location, availability, and other factors.

During a June 2001 meeting, composters commented on the importance of making clear to the user that feedstocks and bulking agents have positive and negative dollar value. This was accomplished by adding space for the user to enter tipping fees and/or cost of acquiring materials. An area was also added to account for storage period of materials.

Question 9. The user is presented with an interactive table that lists typical bulking agents used in composting operations. This list includes wood chips, straw, corn stalks, dry compost, and "other." If the user adds any of these materials in the composting process, he or she is asked to enter annual volume in ft^3/year, maximum number of days material will be stored before incorporation, tipping fee ($/$ft^3$ if applicable) and acquisition cost ($/$ft^3$ if applicable). Typical values for maximum days of storage, based of research, are provided if the user is unsure.

If the user chooses "other" as a bulking agent, he or she must provide values for average density in lb/ft^3, % moisture content, nitrogen content (% dry weight), and C/N ratio. This is necessary because, unlike the other feedstock options in question 9, Co-Composter does not have pre-determined parameter data saved internally for bulking agents that fall under "other."

Changes. Two suggestions were made at a November 2001 training workshop. The first was to clarify that days of storage for a bulking agent refers to storage on the composting pad. This was completed by re-labeling the "storage period" column to read "max days of storage at the compost pad." The second suggestion made was to clearly indicate that this question is where the user can change material quantities and adjust the compost mix characteristics. This change was made.

Question 10. A table describing compost production methods is provided to the user in question 10. The user decides which one best fits his or her operation and enters the approximate dimensions of a typical compost pile. The user then enters the reference number of the compost production method chosen, which is internally linked to corresponding data in Co-Composter. Options include: 1) compost windrows turned with a bucket loader; 2) compost windrows turned with a small tractor drawn turner; 3) compost windrows turned with a large tractor drawn turner; 4) compost windrows turned with a self-powered turner; 5) compost windrows turned with a self-propelled turner; and 6) extended aerated pile or bio-drying. The last option, extended aerated pile or bio-drying asks for an electricity rate in addition to dimensions.

Changes. No changes were made to this question.

Question 11. The user is asked to provide volume dimensions for the storage of raw materials, curing compost and finished compost. For each, the model asks for width and height of storage pile. Typical values are provided if the user is unsure.

Changes. No changes were made to this question.

Question 12. The user is asked to provide, in days, overall composting time period (start to finish), turning interval, curing period, and final storage period. Typical values are provided if the user is unsure.

Changes. In October 2000, collaborators cited the need to set a minimum time for composting period of 30 days to ensure materials at least complete the thermophilic phase of production. This change was made, so if the user enters a value of less than 30, a warning message flashes telling him or her that a value of at least 30 days must be entered.

Question 13. The user is asked if a leachate detention pond will be used. If the user answers “yes,” then he or she must enter average annual precipitation and desired depth of the pond. Typical values are provided if the user is unsure.

Changes. In October 2000, March 2001, and June 2001 collaborators pointed out that the addition of leachate ponds ought to be optional for the user. This change was made to Co-Composter in the form of a “yes” or “no” statement. If the user indicates “no,” the user simply moves onto the next question. Stakeholders also suggested at the meetings to add 1) background information on pond regulations, because they are different for farms and municipalities; 2) benefits of including a leachate pond; and 3) alternatives, such as buffer strips, to ponds. These changes were added to section J – Leachate Detention Pond Design – on the “background” page of the Co-Composter Model.

Question 14. The user is asked for information that Co-Composter will use in a cost analysis. First, the user enters the current year and annual percent inflation rate between 1991 and the current year. A typical value of 4.4% is provided if the user is unsure. The user is next asked to enter labor data including estimated cost of labor per hour and labor hours per week that are available for operating compost equipment.

Part 2 of question 14 is more complex. The user is presented with an interactive table that tabulates equipment costs associated with composting. Based on compiled data entered prior to question 14, Co-Composter automatically determines the types of equipment that are feasible based on the operations size and available labor-hours. Co-Composter provides a list of feasible loaders typically used in farming and tells the user if composting with a particular horsepower and capacity machine will work. At this point, for each piece of machinery that can be used, the user must enter the actual capital cost of the machine, along with hours that same machine is devoted to non-compost farm work.

If the user does not have, or does not wish to use, the machinery provided, he or she may enter their own machinery under an option called "Optional Fourth Loader." If this option is chosen, the user must enter the capital cost, operation and maintenance costs (fuel, lubrication, maintenance, excluding labor), bucket size, non-compost farm use hours, and approximate horsepower.

Co-Composter will also tell the user if a turner and tractor system is feasible, either by purchasing or renting. If the model tells the user that this is practical, he or she enters the actual capital cost or actual rental costs, depending on feasibility.

> *Changes.* In June 2001, composters using the model asked for more size options for loaders, pointing out that very few operations have 3 yd^3 buckets while more have 2 yd^3 buckets. This problem was addressed by adding more loader options, and a separate section where the user can enter his or her own loader specifications.
>
> In July 2001, stakeholders asked that labor hours be clarified as those used for running compost equipment, but not planning or record keeping. This change was made. Use of a self-propelled turner was also added as an option, and the model was adjusted to allow the user a choice between rental or purchase of turning equipment.
>
> At a November 2001 training workshop, participants suggested that labor hours be placed in a separate section to avoid confusion. This change was made to Co-Composter.

Question 15. The user is asked to enter the cost of constructing a compost pad per square foot. If the user enters a desired pad thickness, Co-Composter will calculate approximate costs per square foot (based on 2001 prices) for 1) dirt only (topsoil and vegetation removed only); 2) recycled asphalt; 3) recycled concrete; 4) sand/gravel/geo-membrane; 5) concrete; and 6) asphalt.

Changes. In July 2001, a table of costs per square foot (in 2001 dollars) for different pad materials was added at the request of model evaluators to help the user select economically feasible options for construction.

Question 16. The user answers question 16 only if he or she is building a bio-drying facility. The user is asked to enter construction costs for building components that include structure ($/ft^2), concrete floor ($/yd^3), curtain ($/linear ft), and retaining walls ($/yd^3). Typical 2001 values are provided if the user is unsure of current costs.

Changes. In July 2001, Co-Composter users suggested several additions to building costs for forced air systems to include end walls and curtains to the front and back of the building. These were added.

Question 17. The user is asked if they will screen finished compost. If he or she answers "yes" then screening equipment capacity must be entered (yd^3/hr). The user must also enter the rental cost of a screener and capital cost of a screener in $ per hour.

Changes. In July 2001, stakeholders asked if Co-Composter could provide an option to users regarding screening equipment because most composters rent rather than purchase. This change was incorporated.

Question 18. The user is asked to answer question 18 if he or she is taking out a loan to pay for composting equipment. Economic factors that the user is asked to provide include interest rate of equipment loan, years of expected use, salvage value as % of original capital cost, and yearly insurance cost as % of capital cost.

Changes. No changes were made to this question.

Question 19. The user is asked to answer question 19 if he or she is taking out a loan to pay for pad and/or building construction costs. Economic factors that the user is asked to provide include interest rate of equipment loan, years of expected use, salvage value as % of original capital cost, and yearly insurance cost as % of capital cost.

Changes. No changes were made to this question.

Question 20. The user is asked what the net value of his or her finished compost product is, in terms of on farm fertilizer value, net revenue etc.

Changes. At a November 2001 training workshop, participants suggested that net value of compost be switched from dollars per cubic yard to dollars per ton. This change was made.

User Output Page. In June 2001, stakeholders suggested that fuel requirements, in the 'energy use' section of the user output page, be broken down for each piece of equipment. This change was made.

Stakeholders also asked in June 2001 that labor costs for each piece of equipment in the 'economics' section be specified as well. This change was made.

Background Page. In October 2000, several changes to the background page in Co-Composter were suggested. Stakeholders observed that searching the page was difficult and suggested splitting information into sections according to topic. This was completed and sections are now organized using a lettered filing system, with an index to further make searches easier.

Suggestions for user guidance were also added to the background page relating to questions 8 and 9 of the user input page, based on October 2000 meetings. These changes included 1) an explanation of how arrows indicate the influence of bulking agents/feedstocks on moisture, C/N ratio, and bulk density; and 2) a word of caution to users that realistic volumes of feedstocks and bulking agents need to be entered. Both suggestions were incorporated into the model.

Composters testing the Co-Composter Model commented in June 2001 that some sort of conversion table was needed for various calculations asked of the user. A table with conversion factors was added to the background page under section (O). This suggestion was added to the model.

Mass Balance Page. In October 2000, stakeholders suggested adding a copy of the "Remaining Manure (Managed by Other Means)" table to the output page as part of Co-Composters operational summary. This change was made.

Areas and Volumes Page. No changes were made to the areas and volumes page.

Pad and Building Costs Page. No changes were made to the pad and building costs page.

Turning and Handling Costs Page. No changes were made to the turning and handling costs page.

II. USE OF THE CO-COMPOSTER MODEL

The Co-Composter Model and user's manual (Appendix I) are available for free on the CWMI website at: http://compost.css.cornell.edu/CoCompost.html

Website Download Statistics

2001 (Month of December):	87
2002	1585
2003	475
Total Downloads December 2001 to March 2003:	2147

III. TRAINING TARGET AUDIENCES

In a survey of individuals who participated in workshops or consultations, one-third of those we were able to reach reported using the model after receiving training on how to use Co-Composter.

November 7, 2001

Co-Composter Training held at Cornell University as part of a combined Certified Crop Advisor/Cornell Cooperative Extension training workshop. 20 people attended; 6 were educators and 17 were farmers, composters, or industry representatives.

November 2001

Presentation and demonstration of model at NYSERDA annual conference.

June 2002

On-site consultation in Penn Yan, NY with Tom Eskildsen, SWCD staff and LaBarrs, small dairy owners in Yates county looking at starting a compost facility to manage on farm agricultural waste.

June 2002 – July 2002

Staff consultation with Frans Vokey, Lewis County Extension Educator, to apply the model for Richard Hoskins, dairy farmer and heifer boarding operation in order to evaluate cost-effectiveness of composting as a manure management option.

November 2002

Training workshop held in Saratoga Springs, NY. Primary audiences were government agency representatives and educators from the capitol region. Approximately 25 in attendance.

January 2003

Presented and demonstrated at NYSERDA 2003 annual conference.

October 2003

Presented and demonstrated at CWMI Advanced Compost Short Course. Approximately 50 in attendance.

Articles

BioCycle Magazine. Article in preparation.

Staehr, E. and J. Bonhotal. *Will Composting Pay on Your Dairy?* Northeast Dairy Business. December 2001. Volume 3 No. 12.

IV. COMPARISON OF CO-COMPOSTER TO FARM DATA

To make Co-Composter Model more accurate, a team of Cornell researchers studied four dairies to measure compost production factors such as economic impact, equipment optimization and space requirements. Two large dairies in the study employed manure separation. Other dairies generated tipping fees by taking in off-farm material to mix with manure. One dairy recycles compost as bedding, reducing those costs. Equipment varied among operations, some bought specialized compost equipment; others used existing equipment or retrofitted it to perform composting operations.

Farm #1 – This 115 head dairy receives food scrap, manure and leaf and yard wastes from municipalities, landscaping companies, restaurants, supermarkets, businesses and schools. Tipping fees are received for most of these materials. They use a skid steer and loader to form and turn windrows. Finished compost is screened and used on site or sold in bags or bulk. The facility sells several grades of compost.

Farm #2 – The dairy has 570 dairy cows and 670 heifers. It produces 31,000 cu yd of separated manure annually. Manure solids are conveyed to a compost building with a concrete/forced air floor. A pump transports liquids to a lagoon. The farm employs an aerated static pile compost system. The dairy uses 90% of the compost produced for bedding and sells the excess.

Farm #3 – The 100 cow dairy imports manure from a 1000 head heifer facility. Manure is transferred to a manure spreader, where it is mixed with straw and/or wood chips. It is then formed into windrows and turned with a loader. Compost is sold in bulk and used on site.

Farm #4 – The 700 cow dairy digests manure in an anaerobic digester. Liquids are separated and transported to a lagoon for spreading or irrigation. Solids are trucked to a pad on-site and formed into windrows using a loader. A compost turner turns the windrows. Finished compost is sold in bulk or bag. Energy from the digester is used on the dairy and also sold to a utility company.

The study compared Co-Composter results with characteristics of the four on-farm composting operations. (See the Evaluation Report [Appendix J] for a additional discussion of this aspect of the project.) The comparisons identified ways to increase the usability of the model and provided feedback on the model's performance. The study also helped to highlight model advantages and limitations. Some changes in the model were made based on this comparison. It is important to remember Co-Composter is not meant for modeling existing systems, but instead it is a planning device to be used by composters and farmers to aid in the decision-making process.

Co-Composter was run for each farm, producing estimated annual costs for the individual composting system. Simultaneously, an economic report and physical parameters were compiled independently for each of the farms. The economic report determined actual costs of the composting operations on each farm, and calculated the total annual cost to the farm. The physical parameters which were reported included the characteristics of the final compost, the number of windrows, the windrow dimensions, and the final compost volume.

Table 1 provides a comparison of the values predicted by Co-Composter with those determined by data collected on the four farms. Given the limited number of farms used to compare with the model as well as the great variety in the composting processes, the agreement between the model and the actual farm data was reasonable. The average value for the percent difference between the model and the values measured on the farms (Table 1), together with the standard deviations of those averages, gives an indication of which parameters the model is better and less effective at predicting. Product volume, pad size and C/N ratio are less well predicted than total costs. Further work would be useful to improve these projections.

The economic predictions of the model matched the actual farm analyses reasonably well. The model overestimated compost production volume for three of the farms. This is likely due to uncertainties in final compost bulk densities. Co-Composter volumes are based on the initial bulk density of the compost mix. The final bulk density, which is influenced in unpredictable ways by weather and management, may be significantly different than the initial density. Co-Composter underestimated the pad size for two of the farms. Co-Composter does not calculate access driveways, machinery storage, or farm lanes, and it is likely the pad size composters are reporting does include such areas. Also, Co-Composter organizes the material storage very efficiently; a compost operation might not organize everything quite so efficiently, and therefore require more land. The C/N ratio predicted by the model was more than twice the actual value for two of the three farms.

	Farm 1			Farm 2			Farm 3			Farm 4		
	Actual Result	Model Result	Percent Difference	Actual Result	Model Result	Percent Difference	Actual Result	Model Result	Percent Difference	Actual Result	Model Result	Percent Difference
Total Annual Product (yd3)	2400	6521	172	3100	3200	3	2000	4046	102	1670	2555	53
Pad size (ac)	7	4	-43	0	0		2	2.5	25	2	0.7	-65
Total Variable Costs ($)	49139	62844	28	31158	21593	-31	21255	24964	17	22333	11142	-50
Total Fixed Costs ($)	10640	5814	-45	23298	29465	26	7873	2038	-74	4800	7867	64
Total Economic Cost to Farm ($)	59779	68656	15	54456	51058	-6	29128	27002	-7	27133	19009	-30
Moisture (%)	52	37	-29	76	76	0	57	81.1	42	72	77	7
C:N (ratio)	12	46	283	30	20	-33	20	26.8	34	12	30	150
Bulk Density (lbs/yd3)	53	20	-62	32	35	9	52	44.2	-15	42	31	-26

	Percent Differences for All Farms	
	Average	Standard Deviation
Total Annual Product (yd3)	83	72
Pad size (ac)	-28	47
Total Variable Costs ($)	-8.9	38
Total Fixed Costs ($)	-7.3	64
Total Economic Cost to Farm ($)	-7.2	18
Moisture (%)	5.1	36
C:N (ratio)	109	139
Bulk Density (lbs/yd3)	-24	30

Table 1. Comparison of predicted and actual values.

V. CASE STUDIES

To further assess the utility of the model, two operations were selected. One farm was considering composting, the other is an experienced compost facility. Working with a local agricultural advisor and the farmer, Co-Composter was run and the outputs used to provide advice. The model proved to be an excellent tool in both cases. In the first, the farmer realized that his expectations were not realistic and has deferred starting to compost until he has more time to commit. In the second, refinements were made based on the model outputs.

Case Study #1

Hoskins Farm

Operated by: Richard Hoskins, 6913 McConnell Rd, Glenfield, NY 13343

Local advisor: Frans Vokey, Cornell Cooperative Extension of Lewis County

Hoskins Farm is a heifer boarding facility. The facility is being renovated to replace a dilapidated barn currently housing a small number of animals, with a new expanded building that has a higher capacity. As part of the growth plan, Hoskins was interested in composting as a simple method of management to handle bedded manure pack removed semi-annually from both the original barn and the new building. The plan is to spread the compost on nearby fields when production is complete.

Analysis of the Hoskins Farm proposed compost plan, in June of 2002, with the Co-Composter Model revealed that given the limited labor available (~3 hours per week), equipment specifications (100HP, 2 cu yd loader), and other facility parameters, that such an operation was not feasible.

In December of 2003, CWMI followed up with CCE staff working with Hoskins to determine how the Hoskins compost plan was proceeding. At that point, Hoskins had not yet started composting, due to time constraints and slower than anticipated progress on the completion of the new heifer barn mentioned above. Non-composting time requirements on the farm did not give the composter adequate resources to establish and maintain the desired compost operation outlined in the beginning. Once the new facility is in operation, Hoskins plans to implement composting.

Case Study #2

Mill Creek Compost Facility

Operated by: Earthworks, Route 26a, Kinderhook, NY 12106

Mill Creek Compost Facility started construction spring 2002. In the planning of the facility they used the latest version of the Co-Composter Model program. The operation was planned as a centralized facility taking manure from several dairy farms in a five mile radius, food processing residuals and food scrap. Compost will be sold in bulk and bag.

Different trials using Co-Composter included:

- Several different labor rates $20, $30 and $40.

The model showed that $20 will work for the facility.

- 2 and 3 yard buckets on the loader vs. operator hours.

The model calculates that it takes 35 hours/week with 2 yd. bucket and 24 hours with 3 yd.

- Entered several sale prices for finished compost

The model found that $15 - $ 20 per yard is feasible.

- Compared the pad size with what the facility had come up with.

The model was within 0.25 acre.

- Ran numbers to see if a screen should be purchased or rented.

As a result of the model calculations, the operation decided it was best to rent a screen as needed and plans to purchase a screen and rent to other facilities in the future.

- Expanded model to figure out trucking cost of incoming material.

Trucking costs can be calculated at cost per mile or cost per cubic yd.

The operator found Co-Composter helpful. It gave him a good idea of what decisions to make.