NRES 285 Performance Metrics and Assessment Techniques for Sustainability Projects Sustainable Student Farm Vermicomposting Project (I-Compost) Evaluation

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Introduction

 The Vermicomposting project (also known as I-Compost) in Sustainable Student Farm (SSF) began as part of the Transplant and Vermi-Composting Multiuse Greenhouse project. It is a pilot project to close the loop between the student farm and the university dining hall. The Transplant and Vermi-Composting Multiuse Greenhouse project received $65,222 grant from Student Sustainability Committee (SSC) on April 24, 2013. It also received $8,565 grant from the Office of Public Engagement on November 28, 2012 and $1,000 grant from Ernst & Young on March 21, 2012. The constructions of greenhouse and vermicomposting unit are completed on Fall 2013.

 The I-Compost proposal listed several goals:

 1. Reduce campus carbon footprints by reducing food wastes going to the landfill.

 2. Increasing students' awareness on environmental sustainability.

 3. Prevent soil depletion by using vermicompost to promote healthy soil system and reduce nutrients runoff.

 This project fits the campus sustainability goals stated in the Climate Action Plan to achieve Zero Waste campus policy and preserve university land. In addition, this project can also be used for educational purpose and other outreach programs.

 This project is led by SSF manager Zachary Grant and a team formed by business students. Other groups involved are University dining services, College of ACES, University of Illinois Facilities and Services, Urbana Landscape Recycling Center, SSF, College of Business, and Department of Crop Sciences Urban and Peri-Urban food production assistant professor Sam Wortman.

 In terms of education, students can get first-hand experience and knowledge about vermicomposting through volunteering. Faculty members can conduct related research and organize field trips or classes to the farm. Moreover, the community can learn about vermicomposting through SSF open house and publication.

 In the evaluation, I focus on the cost analysis for the first year and the greenhouse gas associated with it. Since the vermicomposting project is still in its initial stage, not much educational and outreach program can be carried out. Currently, the vermicomposting project is introduced to students through the SSC and iCAP website, The Green Observer, SSF open house and student volunteering.

Methods

 Vermicomposting is a process which uses certain species of earthworms to increase the rate of decomposition of a mixture of organic waste and bedding materials. The end-product, known as vermicompost, can improve soil quality. I-Compost uses Red Wiggler Worms from Uncle Jim's Worm Farm, pre-consumer fruits and vegetables wastes from the dining hall of Busey-Evans Residence Hall, and leaves from Urbana Landscape Recycling Center as bedding materials.

 Red Wiggler Worm is the common name of *Eisenia fetida*. According to Sinha, R.K. et al. (2009), the net reproduction rate of *Eisenia fetida* is 10.4 per week and the hatching successful rate is 83.2%. *Eisenia fetida* can feed food wastes the same as its body weight every day. Earthworms are sensitive to light, temperature, and moisture content. They can tolerate high level of contamination in soils. They break down organic waste rapidly and produce "vermicasts" that contain microbes and nutrients good for soils. Besides, they kill pathogens and perform detoxification and desalinization to their surroundings (p.8-9).

 Zackary Bell Grant is the SSF farm manager who is in-charge of this vermicomposting project. He purchased 80 Ib Red Wiggler Worms (80,000 worms) and a self-contained vermicomposting 5x16 unit. There is an electric winch attached to one side of the vermicomposting unit to ease the harvesting of vermicompost. The vermicomposting unit is located inside the greenhouse used for transplants. It is kept from the seasonal changes in outdoor environment to ensure the survival of worms and avoid the negative environmental impacts of outdoor composting. He said that the red worms reside within two inches of the forest floor so they will migrate up as new layer of waste and bedding mixture is added to the system. The red worms are sensitive to light so they tend to stay in the mixture. Therefore, there will not be any issue with migration of worms outside the vermicomposting unit. However, it is possible that the worms may fall out with the vermicompost during harvesting. In addition, the worms will reproduce among themselves so it is expected that no additional cost is required for buying more worms. Zack monitors the worm population every day and controls the temperature of the greenhouse within appropriate range. The temperature of the greenhouse is kept at 45-50 F during winter. The worms cannot survive at the temperature below 40 F. The optimum temperature for transplants is 60-80 F. The food waste used in vermicomposting is restricted to pre-consumer fruits and vegetables. No bones, meat, dairy products, and oils. This helps to prevent strong smells and keep pests away. The leaves also cover the smell and fruit flies.

 Zack collects food waste from the dining hall three times per week and gets leaves from Urbana Landscape Recycling Center every six months. The leaves and waste are mixed in 2:1 ratio which gives the best C:N ratio. The system is fed three times per week with 200-300 lbs of leaves and 100-150 lbs of vegetable waste each time. It takes about 5 to 6 months to get the first pile of vermicompost, followed by constant supply each month. The first harvest is expected on July 2014 and Zack expects to harvest every two weeks after that. The vermicompost will be used for transplant and in high tunnel greenhouse. The storage of vermicompost depends on the amounts collected in the future. It is estimated that this vermicomposting project can prevent about 25,000 Ibs of wastes from going to the landfill per year and produce around 12,500 Ibs of vermicompost each year.

(Grant, Z.B. Personal interview. 16 April, 2014)

Cost-Benefit Analysis

 Based on the budget sheet provided by Zackary Grant, the total funding is $74,787 and the estimated expense is $74,011.18. All the data below are also provided by Zackary Grant.

|  |  |  |
| --- | --- | --- |
| Greenhouse construction cost |  | $ 64083.93 |
| GH Supplies cost |  | $ 1,499.25 |
| Operational cost for greenhouse | Propane (1200-1600 gallon/yr) | $ 2700-$3840 |
| Electricity (12000 kWh/yr) | $ 895.20 |
| Water (960 gal/yr) | $ 3369.60 |
| Total | $ 72547.98 - $ 73687.98 |

FY 2013 rate for electric ($/kWh) = 0.0746 [Source: UIUC Energy Management]

FY 2013 rate for water ($/kgal) = 3.51[Source: UIUC Energy Management]

Price of propane ($/gal) = 2.25-2.40 [Source: Zackary Bell Grant]

 I do not include the greenhouse construction cost into the cost-benefit analysis of the vermicomposting project. However, I assume that the vermicomposting project accounts for 10% of the greenhouse operational cost on propane and electricity. Also note that the propane usage is greatly affected by the weather especially the temperature during winter. The table below is an estimate of the vermicomposting cost.

|  |  |  |
| --- | --- | --- |
| Set-up cost | Self-contained vermicomposting 5x16 unit | $ 8428 |
| Red Wiggler Worm (80 Ibs or 80,000 worms) | $1280 |
| Operational cost | Fuel (transport) | $ 1193.39 (303.2753 gal) |
| Labor cost | Farm general labor and Volunteer |
| Electricity  | $89.52 |
| Propane  | $270-$384 |
| Total  |  | $ 11260.91 - $ 11374.91 |

U.S. On-Highway Diesel Fuel Prices = 3.935 dollars per gal [Source: US Energy Information Administration]

 The estimated vermicompost produced is 12500 Ibs per year. This is equivalent to about four yards of potting mix used for transplants which cost around $700 per year. The landfill cost paid by UIUC is approximately $520.83 per ton [Source: UIUC Recycling Facility]. Therefore, the total landfill cost saved is $ 6432.25 per year. Adding the costs saved from buying the potting mix and the landfill costs, the total cost saved by implementing vermicomposting project is $ 7132.25 per year. Assuming no maintenance cost or change in operational cost in the next few years, the cost spent on vermicomposting project can be covered in the second year.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Cost spent  | Cost saved  | Balance  |
| First year  | $ 11260.91 - $ 11374.91 | $ 7132.25  | ~ -$4185.66 |
| Second year  | $1552.91 - $1666.91  | $ 7132.25  | ~ $ 5522.34 |
|  |  | Total  | $ 1336.68 |

Greenhouse Gas (GHG) Emissions

|  |  |  |
| --- | --- | --- |
| Electricity | 12000 kWh (1000 kWh/month) | 20064 Ibs CO2  |
| Propane | 1200-1600 gallons per year | 14916 - 19888 Ibs CO2  |
| Total |  | 34980 - 39952 Ibs CO2  |

GHG emission for electricity = 1.672 Ibs/kWh [Source: Student Sustainability Committee]

GHG emission for propane = 12.43 Ibs/gallon [Source: Student Sustainability Committee]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Waste  | Weight (Ibs/yr) | Transport (mi/yr) | GHG Emission (Ibs CO2) |
| Vermi-composting |  Landfill |  Synthetic fertilizers |
| Transport | Leaves | 15600  | 15.2 (ULRC) | 46.22 (7.3 mi/gal; 22.2 CO2Ib/gallon) | 3539.52  | 0.0547  |
|  | Vegetable waste | 9100  | 712.8 (Busey) | 2167.69  |
| Operation | 3498 - 3995.2 |
| Total | 5711.91 - 6209.11 |

GHG emission for propane = 12.43 Ibs/gallon [Source: Student Sustainability Committee]

GHG emission for diesel = 22.2 Ibs/gallon [Source: Student Sustainability Committee]

Carbon coefficient for LPG (propane) = 12.43 Ibs/gal [Source: [U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009](http://www.epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html) (EPA 2011)]

Single-unit truck average miles traveled per gal of fuel is 7.3. ( [Federal Highway Administration's Highway Statistics 2007](http://www.fhwa.dot.gov/policyinformation/statistics/2007/pdf/vm1.pdf))

US EPA Landfill Net Emission Factors: National Average for food scraps and leaves = 0.69 + (-0.56) = 0.13 MT CO2 E/ Ton

GHG Costs CO2 equivalents for synthetic fertilizer (Mt/ac/yr) (amount of CO2 produced during the manufacturing process) = 0.03 [Source: Michigan State University]

 Same as the cost analysis, I assume that the vermicomposting project accounts for 10% of the GHG emissions of the greenhouse in terms of electricity and propane used for heating. The total GHG emissions from the vermicomposting is higher than landfill.

 The evaluation focuses on the cost-benefit analysis and environmental impacts in terms of greenhouse gas emission. The life-cycle analysis of construction materials is not included. The cost analysis is based on the first year expense and benefits. Therefore, the harvesting, maintenance, and replacement costs are not included as well. For the estimates of greenhouse gas emissions, the transport of greenhouse materials especially the shipping of greenhouse from other state is not calculated. The potential greenhouse gas emission during composting process is also excluded. Besides, the comparison between application of synthetic fertilizers and vermicompost in terms of the GHG emissions is not done. The greenhouse gas emission for the shipping of synthetic fertilizer before the use of vermicompost is not calculated as well.

Future Plan

* The future plans stated by Zackary Grant include research, ways to reduce transport and greenhouse gas emissions, education, and outreach. The future research will focus on getting the right ratio of compost and soil mixture. Sample will be tested for pH, nutrients content, and contaminants before applying it. There will be educational tours and other outreach programs. Besides, Zack is planning to get leaves from university land and use biomass energy to replace propane. There is no plan to expand the project.

Recommendation

 It is recommended to do a complete evaluation on this project. Some of the factors to be considered are the life cycle analysis, maintenance costs, monitoring plan, and a more accurate cost analysis and GHG emission estimates.

 The life cycle analysis should consider the greenhouse plastics and other greenhouse parts, propane tank, vermicomposting unit, equipments, and waste can. The plastics have to be replaced every 5-6 years and the propane has to be replaced every year. These require maintenance costs. There may be additional costs depending on the worm population, weather, and changes in costs of electricity, water and propane. Furthermore, the future plans on getting leaves from university land and replacing propane with biomass energy to heat the greenhouse will greatly affect the cost spent each year and the greenhouse gas emissions.

 The monitoring of vermicomposting should include temperature, moisture content, worm population, waste processing rate, percentage of waste composted, quality of vermicompost, greenhouse gas emissions, yield, quality of produce, compost stability, and soil quality.

Conclusion

 In conclusion, the vermicomposting project has many data needed to be collected to further investigate the effectiveness of this project in fulfilling the sustainability goals. In current stage, the estimated GHG emissions shows the need to reduce the transport and propane and electricity usage to reduce the carbon footprint. Other factors should also be considered in future evaluation.

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