Life Cycle Analysis of Food Waste Generated on University Campuses: A Case Study of Montclair State University, New Jersey

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Abstract: Food waste is a critical problem globally with the United States having the second highest food waste generation in the world. Research has shown that about 30 million tons of food is wasted on a yearly basis in the United States, which accounts for almost 40% of the total food produced. This translates to over $160 billion dollars wasted annually in terms of cost. According to the Environmental Protection Agency (EPA), food waste is the highest contributor to municipal landfills. This waste type decomposes overtime to give off methane gas, which has a global warming potential that is 25 times more than carbon dioxide. A study by the National Resources Defense Council (NRDC) indicate that one in eight Americans find it difficult to feed adequately. Meanwhile, the United Nations have found that over 800 million people in the world cannot afford sufficient food. These indicate that there are other issues associated with food waste asides the actual waste issue, some of which include, food insecurity, greenhouse gas emissions, depletion of water, land and energy resources, and economic loss. Addressing the food waste issue on a national scale may be daunting, difficult to manage and ineffective. It is important to be strategic in dealing with the food waste problem in order maximize the productivity of solutions. One way to achieve this is to identify sectors that contribute the most to the nation's total food waste, in terms of volume per capita. Educational institutions can be considered as one of the densely populated places having a large number of people residing or commuting per time. Out of the total amount of food waste generated in the United States, college campuses are said to account for approximately 12%. An average college student discards about 140 pounds of food yearly, while campus dining halls account for 22 million pounds of food waste annually. There are various challenges in addressing food waste generated on university campuses, one of which is the identification of key areas within the food waste life cycle that have the highest impacts on human health and the environment. To properly examine these hotspots, a food waste life cycle analysis is imperative. The aim of this study was to assess the life cycle of food waste generated on University campuses using Montclair State University (MSU) as a case study. Data was obtained from the University Auxiliary services and the analysis was done using Recipe 2016 Mid-Point method in the Sima pro 9.0 LCA software. The results of the study indicated that waste obtained from meat and fish contributed the highest, with a range of 25% to 35% across all impact categories. Also, the life cycle of the food waste generated in MSU contribute mostly to human toxicity and aquatic ecotoxicity. Scenario analysis was also conducted to quantify the impacts of diverting some of the waste generated by composting at various percentages. Results show that composting 30% - 70% of the waste-to-landfill reduces life cycle impacts across all categories by 25% - 50%.

Keywords: Food Waste, Life Cycle Analysis, Universities

Introduction

According to the United States Department of Agriculture (USDA), food waste accounts for 30-40% of total solid waste in the United States. It also doubles as the highest contributor to municipal landfill with about 30 million tons of food waste disposed annually (EPA, 2015). This waste type has become a source of great concern and proffering solutions to curb itis highly important. In an article published by the Washington post (2018), it is estimated that food waste contributes 1lb out of the 4lbs of daily waste generated by an average American. This implies that 25% of total municipal waste is made up of food (Mooney, 2018). Food waste does not only impact food in itself, it affectsseveral other social, economic and environmental factors. These impacts include loss of water and energy resources, higher food production and consumption budgets, contribution to landfill, soil and water contamination, greenhouse gas emissions and food distribution inequity. It is estimated that about 9% of total average food spending ended up as waste in 2010(Neff, *et al.*, 2015). Also, about 35% of freshwater use, 30% of cropland and fertilizer consumption, 2% of the Unites States greenhouse gas emissions and 20% of municipal solid waste after recycling are attributed to food waste(Neff, *et al.*, 2015).

The figures of food waste in Educational Institutions are no different from the general statistics. University campuses across the United Statesgenerate about 3.6 million tons of food waste on a yearly basis (Luecke, 2015). EducationalInstitutions are important because they are considered key contributors to the economic growth of a nation(Jackson, 2016); hence they are long-lasting establishments that would continuously generate waste. Most of the research available on food waste on campus focus onmitigating food waste at the point of service and consumption but not much is available for curbing waste at the point of disposal. This may be as a result of the difficultyinrecognizing major contributors or "hotspots" within afood waste life cycle on campuses. The goal of this study is to conduct a food wastelife cycle analysis (LCA) that would help improve the knowledge of food waste life cycle on University campuses and proffer viable and sustainable food waste management strategies.

Materials and Methods

Study Area

This study was conducted on Montclair State University (MSU) Campus, located in New Jersey, United States. MSU is considered the second largest University in New Jersey with more than 21,000 enrolled students(Best Colleges U.S., 2019). The campus has a total of eleven (11) dining areas that provide food services to resident and commuter students. Some of these dinning areas have multiple food kiosks within them that provide different varieties of food. According to the University Auxiliary services, the food waste generated between October 2018 – March 2019 amounted to 172.43 tonsinthe four (4) major University dining areas. The total period evaluated is equivalent to one semester.

Objectives of Study

Currently, all the waste generatedin the University is sent to landfill; hence there is no data for compost or recycling for food waste.As a result, this study aims:

- To assess the impacts of the life cycle of food waste generated on Campus
- To identify the food waste category with the highest impacts on human health and the environment
- To compare the sustainability of the current food waste management practice in MSU with other options like composting at varying percentages.

Process Flow and System Boundary

The processes involved in the MSU food waste management include waste disposal, central collection of waste within MSU, transport of waste within MSU and transport to landfill. Composting at 30%, 50%, 70% with food waste disposal at landfill are considered in this study as alternative scenarios for food waste management in MSU.

The following assumptions are made for the purpose of this study:

- Food waste is assumed to follow the same process as produced food. The Natural Resources Defense Council (NRDC) has established that 40% of food produced is uneaten, which is then considered as waste(Gunders & Bloom, 2017).
- The classification and proportional values of food waste disposed in MSU is assumed to the same as that obtained from data in NRDC 2017 report(Hoover, 2017) – *see table 1 below*.
- Proportional values of each food type within a waste classification are assumed to be equal. For example, within the dairy and eggs waste classification, the proportion of cheese, eggs, milk, and related dairy are assumed to be equal.
- Although all of the waste from the MSU campus is sent to landfill, the impact of the landfill itself is not included in the scope of this study. The impact of the landfill would greatly outweigh the impacts of the food waste disposal on campus, which would result in a skewed data.

- Trashcans are not included in this study because they are typically used over a long period of time and their impacts are assumed to be negligible.

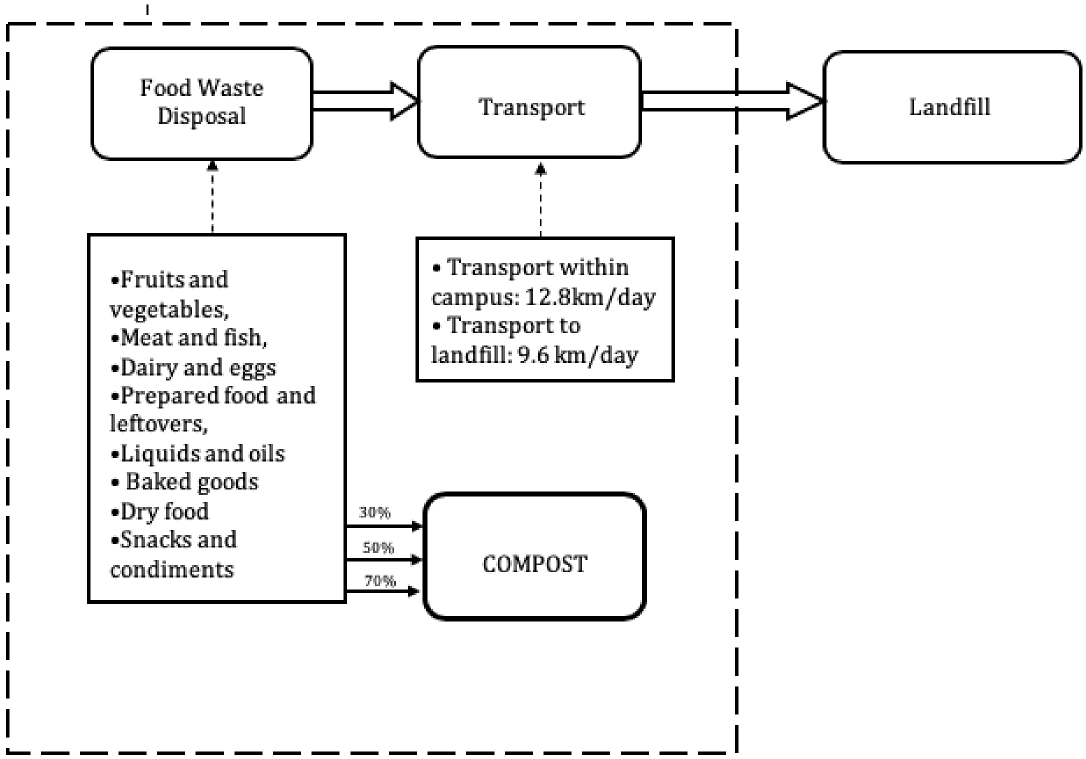


Figure 1: System Boundary of MSU Food Waste Life Cycle

Functional Unit

In this study, the functional unit is defined as the amount of food waste generated on the university campus per day. To obtain this figure, the food waste generated in tons is converted to kg. Total food waste generated over a period of five months is 172.43 tons, which is equivalent to 156,42 kg. Hence, **Functional unit = 1042.8 kg/day**

Table 1: Food waste classification and percentage proportions

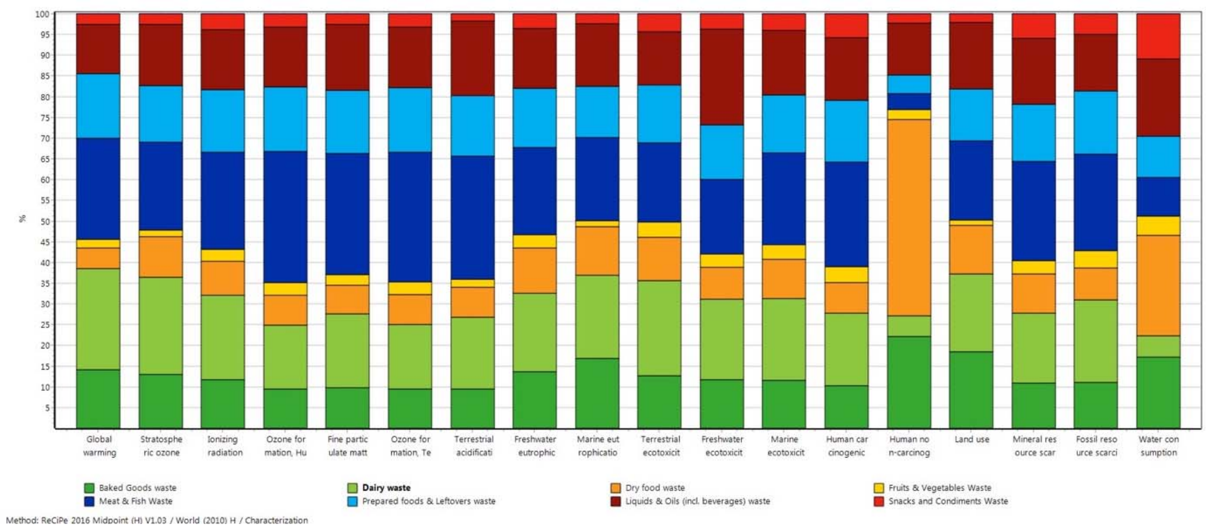
Waste type	Proportions*	Mass (tons)	Mass (kg)	Mass (kg/day)
Dairy	7%	12.1	10949.8	73.0
Liquids & Oils - (includes beverages)	9%	15.5	14078.3	93.9
Fruits & Vegetables	39%	67.2	61005.8	406.7
Prepared Foods & Leftovers	28%	48.3	43799.0	292.0
Meat & Fish	6%	10.3	9385.5	62.6
Baked Goods	6%	10.3	9385.5	62.6
Dry Food	2%	3.4	3128.5	20.9
Snacks & Condiments	3%	5.2	4692.8	31.3
Total				1042.8

*Waste type classification and proportions were derived from general food waste proportion data in the US provided by the natural resource defense council (NRDC, 2017 report on estimating quantities and types of food waste at the city level).

Life Cycle Inventory and Assessment

Data used in this study were obtained from the Montclair State University Auxiliary services and Ecoinventin Sima pro 9.0. The eighteen (18) impact categories included in the ReCiPe 2016 Mid-Point methodwere assessed in this study. These impact categories include global warming, stratospheric ozone depletion, ionizing radiation, ozone formation, formation of fine particulate matter, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human toxicity (carcinogenic and non-carcinogenic), land use, water consumption, mineral resource depletion and fossil resource scarcity.Sima pro 9.0 LCA software was used for the analysis of food waste in this study.

Results and Discussion



Results: Baseline Scenario of Food Waste to Landfill

Figure 2: Life Cycle Impact Assessment of the various categories of Food Waste generated in MSU

The result of the MSU food waste LCA isshown in *fig 2.* According to this result, the impacts of the food waste generated in MSU vary considerably acrossthe eighteen (18) impact categories. Baked goods contributed an average of 13% across all categories while dairy wastehad a mean impact of 15% witha higher impact on global warming at 25%. Although dry food waste contributed an average of 10% across all categories, it has the highest impact on non-carcinogenic human toxicity at 45% compared to all other food waste types. This could be as a result of the fact that gluten has been attributed to the celiac disease, which is described as high intolerance for certain cereal proteins (Vader, et al., 2003). Components of the dry food waste type include wheat grains, oat grains and nuts, which are considered cereal proteins. Prepared food and leftovers contributed an average of13% across all impact categories but had a low impact of5% onnon-carcinogenic human toxicity.Snacks and condiments contributed approximately 3% across board.This is possibly because food waste fromdining areas of MSU wereanalyzedin the study, where condiments are used in small quantities. Also, snacks are typically available at vending machines around campus, not necessarily in dining areas. Liquids and oils had a uniform distribution of impact across all categories, with a mean impact of 15%.Meat and fish waste had a mean impact of 20% contributing the highest across all of the categories except non-carcinogenic human toxicity. Meat waste could be theculprit for this high impact.

Production of meat has been attributed to high greenhouse gas emissions particularlymethane, carbon dioxide and nitrous oxide (Godfray, et al., 2018). It accounts for 80% of greenhouse gases generated in the food sector and almost 25% of total greenhouse gas emissions (Chai, et al., 2019). Other byproducts of meat production including ammonia and nitrate contribute to ecotoxicity, eutrophication and acidification (Godfray, et al., 2018). Meat production is both water and energy intensive throughout the lifecycle of the production process (Djekic, 2015). Rearing livestock, various temperature treatments including boiling roasting, pasteurizing, grinding etc., and transport of meat products require the use of arable land, energy and water resources (Djekic, 2015). Moreover, waste products from meat production process, which include unpalatable products (bones, hair, fats, skin, internals etc.) and meat packaging materials increase the impacts of meat production and consumption on the environment (Djekic, 2015). This also explains the high impact of dairy waste on global warming. Egg, milk and cheese are obtained from livestock, hence, it contributes to high carbon footprint just as in meat production. In terms of human health, meat consumption has been associated with cardiovascular diseases, increase risk of colorectal cancer and type 2 diabetes (Godfray, et al., 2018; Battaglia, et al., 2015).

Fruits and vegetables had the lowest overall impact of 2% across all categories. It is important to note that the fruits and vegetables food waste type had the highest proportion of 34% among other waste types, *see table 1*. Despite this, it had the least effecton thehuman health and the environment.According to Chai, *et al*. (2019), a plant-based diet significantly reduces greenhouse gas emissions, land use, water and energy consumption. This substantiates the result of this LCA study, considering the fact fruits and vegetable had the highest percentage proportion but the lowest impacts. Transportation did not have any visible impacts on any of the categories. This is likely because the return travel distance around campus and to the landfill is only about 14 miles in total per day. Hence, the impact of transport is negligible.

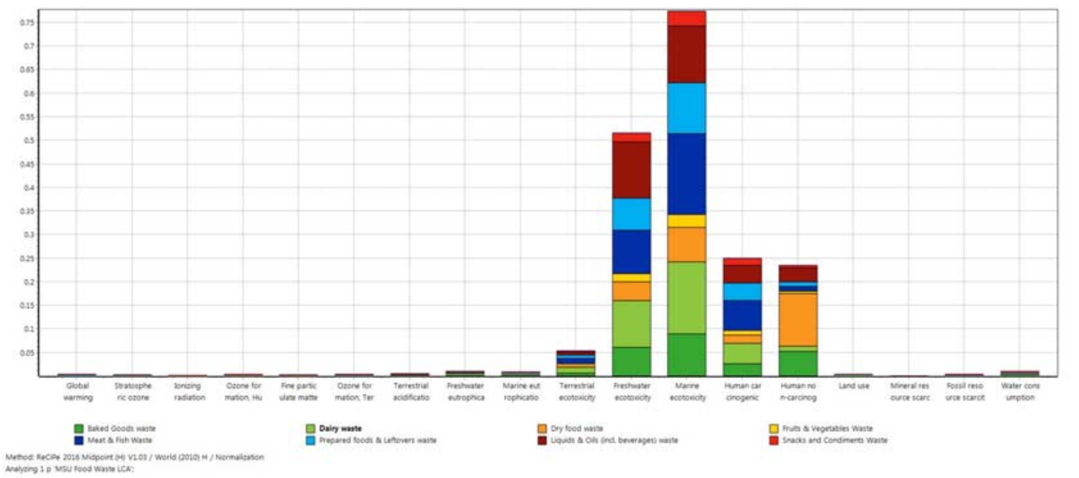


Figure 3: Normalization of food waste generated in MSU

Although the individual impacts of each food waste type wereanalyzed in this LCA as seen in *fig. 2*, hotspots of the total food waste generated on campuswere also identified as seen in the normalization chart in *fig. 3*. The normalization data shows that the hotspots of food waste generated in MSU include freshwater ecotoxicity, marine ecotoxicity and human toxicity. These resultsarejustifiable as the direct impacts on the environment from food waste arise from the use of chemical fertilizers and pesticides. Conventional agricultural systems include the use of chemicals that help protect crops from pesticides and improve productivity. Most of these chemicals, which have toxic properties, leach into groundwater and surface water systems contributing to human and aquatic toxicity (Aktar, et al. 2009).

Scenario Analysis

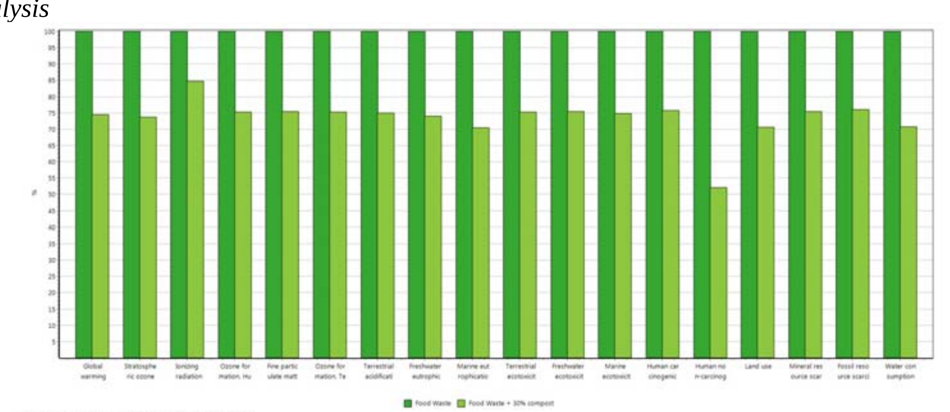


Figure 4: Scenario 1 - 30% of food waste composted and 70% to landfill

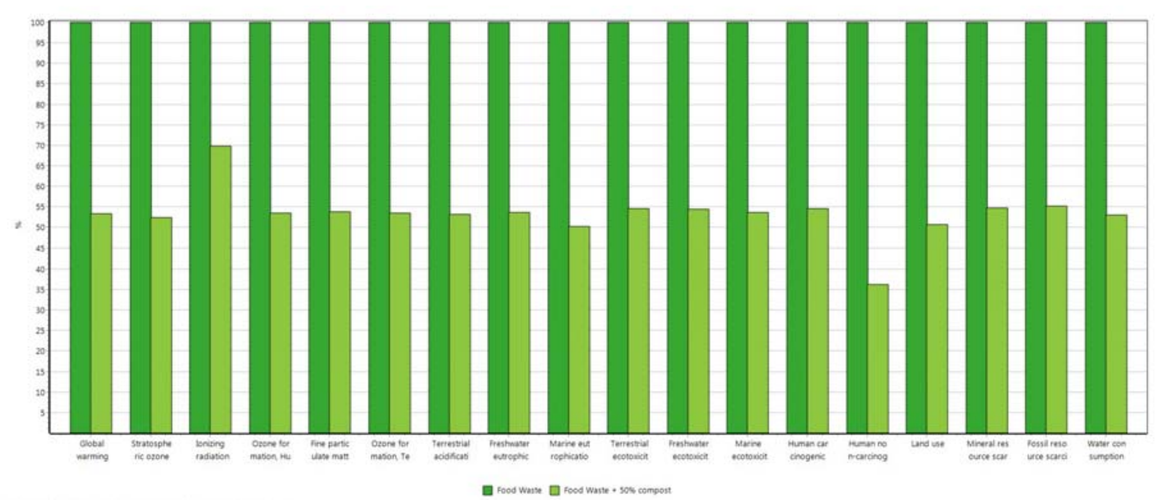


Figure 5: Scenario 2 - 50% of food waste composted and 50% to landfill

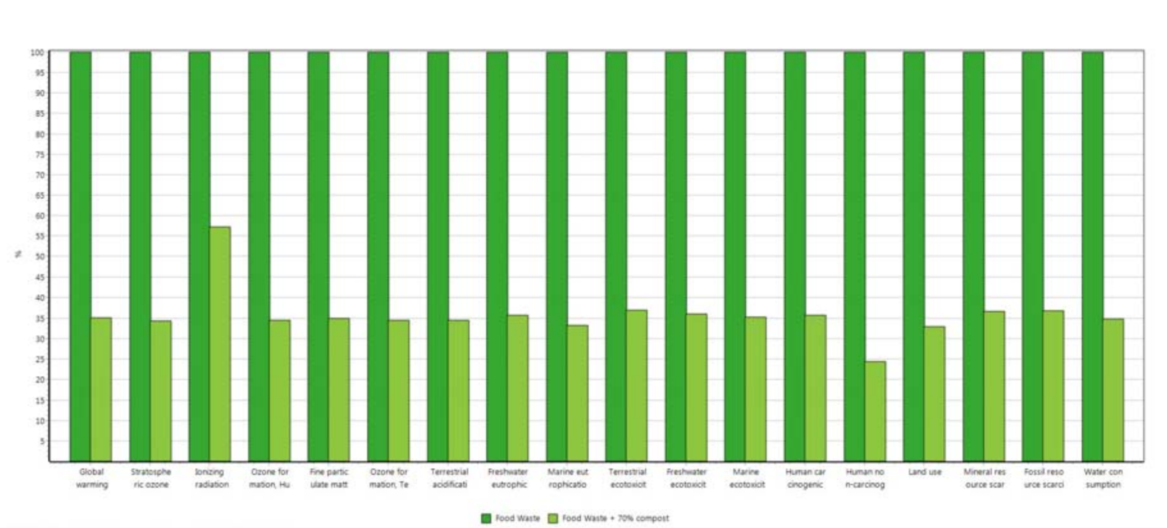


Figure 6: 70% of food waste composted with 30% of food waste to landfill

*Figures 4, 5, and 6*indicate thatthe life cycle impact of combining waste management techniques byadding varying percentages of compost is significantly lower than landfilling all of the food waste. As shown in*scenario 1*, if 30% of the total food waste generated in MSU is composted, there would be a decrease of 28% across all impact categories. While 50% and 70% compost reduce impacts by 50% and 64% respectively across all impact categories. Considering that human toxicity is a critical impact category identified by this LCA, it is important to highlight that there wasa significant decrease in the impacts on human toxicity with a 52% reduction at 30% compost, 35% at 50% compost and 25% at 70% compost. This suggests that composting as little as 30% of the food waste sent to landfill drastically improves food waste life cycle impacts on human health.

Sensitivity analysis with CML-IA method

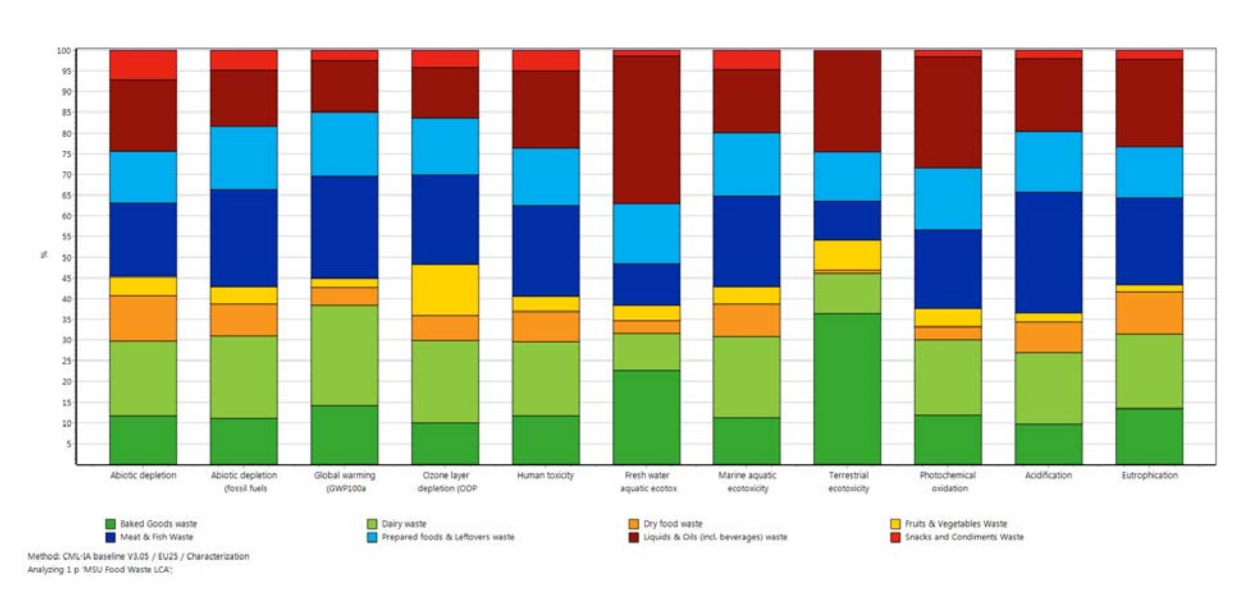


Figure 7: Results of Food Waste LCA using ReCiPe method

A sensitivity analysis was done using the CML-IA method to confirm the reliability of the results of the LCA of food waste in MSU. As shown in *fig. 7*, the results are similar to the results obtained using the ReCiPe method. This confirms that the results of this study are valid and reliable.

Conclusion and Recommendations

This study was conducted to determine the impacts of food waste generated in Montclair State University (MSU) using life cycle assessment (LCA), identify the food waste category with the highest impact and assess the impacts of composting as an additional waste management option. As seen in the results, meat and fish waste had the highest impacts on all categories while fruits and vegetables had the lowest impacts. This highlights that the diet adopted by MSU students is critical to human and environmental health. It is recommended that MSU promotes a shift to more plant-based diet among students. This would not only improve student health; it will also drastically reduce impacts on the environment.

In addition to this, the benefits of compostingat least 30%of the food waste results in adecrease of 28% in life cycle impacts. This percentage reduction increases, as more food waste is composted. Hence, this study suggests that Montclair State University should consider composting their food waste to reduce the amount of food wastesent to landfill.

Moreover, composting has some other benefits. According to the EPA (2015), compostenriches the soil and reduces the need for chemical fertilizers. Composting also mitigates the impacts of food waste on the environment by inhibiting the production of methane gas from food waste that would have otherwise been send to landfill.

References

Aktar, W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: their benefits and hazards . *Interdisciplinary Toxicology, 2*(1), 1-12.

Battaglia, R. E., Baumer, B., Conrad, B., Darioli, R., Schmid, A., & Keller, U. (2015). Health Risks Associated with Meat Consumption: A Review of Epidemiological Studies. *Int J Vitam Nutr Res, 85*, 1-2.

Best Colleges U.S. (2019). *Montclair State University*. Retrieved 2019 йил 7-May, from Best Colleges U.S News Rankings: https://www.usnews.com/best-colleges/montclair-state-university-2617

Chai, B. C., Voort, J. R., Grofelnik, K., Eliasdottir, H. G., Klöss, I., & Perez-Cueto, F. J. (2019). Which Diet Has the Least Environmental Impact on Our Planet? A Systematic Review of Vegan, Vegetarian and Omnivorous Diets. *Sustainability, 11*(4110), doi:10.3390/su11154110 .

Djekic, I. (2015). Environmental Impact of Meat Industry – Current Status and Future Perspectives. *Procedia Food Science.* 10.1016/j.profoo.2015.09.025. .

EPA. (2015). *Facts and Figures about Materials, Waste and Recycling* . Retrieved 2019 йил 7-May, from EPA: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/food-material-specific-data

Godfray, H. C., Aveyard, P., Garnett, T., Hall, J. W., Key, T. J., Lorimer, J., & Pierreh, R. T. (2018). Meat consumption, health, and the environment . *Science*.

Gunders, D., & Bloom, J. (2017). *Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill.* Natural Resources Defense Council (NRDC).

Hoover, D. (2017). *Estimating Quantities and Types of Food Waste at the City Level* . NRDC.

Jackson, A. (2016 йил 18-Aug). *A new study found a promising link between the number of universities in a country and GDP* . Retrieved 2019 йил 7-May, from Business Insider: https://www.businessinsider.com/link-between-universities-in-a-country-and-gdp-2016-8

Luecke, L. (2015). Haste To No Waste: A Multi-Component Food Waste Study in a University Dining Facility. *National Conference On Undergraduate Research (NCUR)* (p. 33). Washington: Eastern Washington University.

Mooney, C. (2018 йил 18-April). The staggering environmental footprint of all the food that we just throw in the trash. *The Washington Post*.

Neff, R. A., Spiker, M. L., & Truant, P. L. (2015 йил 10-June). Wasted Food: U.S. Consumers' Reported Awareness, Attitudes, and Behaviors. (A. S. Wiley, Ed.) *PLoS ONE, 10*(6).

Vader, W., Stepniak, D. T., Bunnik, E. M., Kooy, Y. M., Hann, W. D., Drijfhout, J. W., . . . Koning, F. (2003). Characterization of cereal toxicity for celaic disease patients based on proteins homology in grains. *Gastroenterology, 125*(4), 1105-1113.