Using Carbon and Nitrogen Footprints to Advance UHM Sustainability

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Human activities have greatly altered the planet's nitrogen and carbon cycles. Combustion of fossil fuels and land use changes that reduce ecosystem carbon stocks have increased atmospheric carbon dioxide concentrations, resulting in climate change. The invention of chemical fixation of inert dinitrogen (N_2) has increased all other forms of reactive nitrogen in the environment. While essential to life, excessive reactive nitrogen cascades through the land, air, and water and contributes to multiple consequences for environmental and human health. Many universities and colleges have sustainability goals aimed at reducing their contribution to carbon and nitrogen pollution. However, making informed decisions on which actions to take is a challenge and evaluating the impact of those actions remains a challenge for institutional sustainability. We conducted the first nitrogen and carbon footprint assessment for the University of Hawai'i at Mānoa (UHM) to quantify the amount of reactive nitrogen and carbon dioxide released into the environment as a result of its activities. Purchased electricity and food were the largest contributors of UHM's nitrogen footprint, and purchased electricity and commuting transportation contributed most to the carbon footprint. We calculated scenarios within each sector to project the impact of potential actions on UHM's carbon and nitrogen footprint, and we identified opportunities to refine data collection and analysis for future footprint assessments. This research provides a comprehensive baseline of UHM's carbon and nitrogen footprint, which can be used to support and guide the university's sustainability goals.

I graduated in Spring 2019 with a B.S. in Natural Resource and Environmental Management and a B.A. in Geography and Environment. In the future I intend on furthering my education in the field of Urban and Regional Planning. This article discusses how Carbon and Nitrogen Footprints can be used to benchmark and track progress towards institutional sustainability. I learned that quantifying these footprints can be a challenging task since the results are heavily dependent on the current systems in place to track the necessary information. Therefore, if institutions are committed to benchmarking and tracking sustainability goals, improvements must be made to the accuracy and inclusiveness of these data tracking systems.

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Introduction

Human activities have greatly perturbed Earth's biogeochemical cycles, including local to global flows of carbon and nitrogen (Steffen et al., 2015). Major anthropogenic changes to the carbon cycle include the burning of fossil fuels, land use and changes in land use, deforestation, livestock production, fertilization, industrial processes, and waste management (IPCC, 2018, forthcoming). These activities have resulted in a rapid rise in atmospheric concentrations of carbon dioxide (CO_2), which is the primary anthropogenic greenhouse gas (GHG) and a major driver of climate change (IPCC, 2018, 546). The global average temperature has been rising at a rate of 1.7°C per century since 1970 in spite of a prior long-term decline of 7,000 years and average global temperature warming from anthropogenic emissions has reached approximately 1°C above pre-industrial in 2017 (Allen et al., forthcoming).

Nitrogen is the building block of amino acids and is an essential element to all known life. The largest pool of nitrogen is atmospheric dinitrogen (N_2), which is unreactive except to a few specialized organisms that fix N_2 into reactive forms of nitrogen, like ammonia (NH_3). Reactive nitrogen takes many forms as it travels through biotic and abiotic reservoirs on the land, sea, and air. Like carbon, the global nitrogen cycle has also experienced dramatic changes. Human activities that combust fossil fuels also release gaseous forms of nitrogen, including nitrous oxide (N_2O) and nitrogen oxides (NO_x), which contribute to climate change and air pollution, respectively. The process of producing chemical fertilizer, known as the Haber-Bosch process, breaks the strong triple bond of atmospheric N_2 and transforms it into reactive forms that can be taken up by crops or move through the environment. These actions have more than doubled the amount of reactive nitrogen, which cascades through the environment in different forms contributing to poor water quality, smog, ozone depletion, and climate change. Just as human activities have disrupted Earth's carbon and nitrogen cycles, changes to our activities are critical in solving these wicked problems.

Small islands, coastal regions, mega cities, and high mountain ranges are among those most affected by anthropogenic induced global temperature rise, and warm-water tropical reefs are especially at risk of severe impacts (Allen et al., forthcoming). The small islands with many coastal cities ranging in population size and density and surrounded by warm-water tropical reefs that comprise Hawaiʻi make it a region of high risk for severe impacts due to climate change. Hawaiʻi's geographical isolation, dependence on imported goods, limited land area, and reliance on a service-based economy presents challenges for a sustainable future (Hawaiʻi 2050 Sustainability Plan: Charting a Course for Hawaiʻi's Sustainable Future, 2008). A better understanding of Hawaiʻi's impact on global carbon and nitrogen cycling can help to identify opportunities for a more sustainable path forward.

Nitrogen and carbon footprints quantify the amount of reactive nitrogen and carbon dioxide released into the environment as a result of a country, state, or institution's activities (Compton et al., 2017; Leach et al., 2017). By measuring their carbon and nitrogen footprints, large institutions such as universities, government agencies, non-profit organizations, and businesses can determine their impact on the environment and identify the most effective strategies to reach their sustainability goals (Leach et al., 2017). The University of Hawaiʻi (UH) is poised to become a more sustainable institution as a result of Hawaiʻi Revised Statutes (HRS) 304a-119 and Executive Policy (EP) 4.202. HRS 304a-119 calls for net-zero energy use by January 1, 2035 across the UH system. To reach this goal, various components such as energy efficiency, generation, and social initiatives will be managed (Annual Report on Net-Zero Energy for the University of Hawaiʻi, 2017). EP 4.202 references the native Hawaiian culture and knowledge as a foundation to developing unique and sound responses to sustainability and climate change challenges. It outlines UH's mission and executive policies for system sustainability through establishing mechanisms for goal implementation, campus strategic planning, providing system-wide metrics and targets for improved efficiency and waste reduction, tracking methods, saving re-investment strategies, and the establishment of university-wide sustainability values.

However, these sustainability goals and policies cannot be realized until baselines for current carbon and nitrogen emissions are determined. Estimating all UH campuses' carbon and nitrogen emissions, for example, is a challenging task. This study estimates the carbon and nitrogen footprints of only the University of Hawaiʻi at Mānoa (UHM) campus since it is the largest of the UH system campuses. Due to its size, UHM is expected to have the greatest emissions across the UH system. Therefore, quantifying UHM's nitrogen and carbon footprint will represent the majority of the UH system's contribution. Additionally, footprinting performed at UHM can serve as a model for other campuses in the system and other institutions in the State.

Purpose of this Project

The University of Hawaiʻi at Mānoa is a 320 acre medium-sized, 4-year, public coed university located in the large city of Honolulu on the island of Oʻahu. Numerous facilities and buildings support this campus, including various residence halls, student apartments, faculty housing, food courts, residence dining halls, a gym, a stadium, two multi-level parking structures, and numerous multi-functional buildings. As of fall 2017, UHM's total enrollment was 17,612 students with the majority being undergraduates and with a student-to-faculty ratio of 12:1. Of those undergraduate students, 67% were in-state, 31% were out-of-state, and 2% were international (NCES, 2018). The University is also an R1, research university, consistently ranked amongst the top 15 R1s internationally in recognition of the high-quality earth and environmental sciences programs. UH Mānoa also has a NCAA Division 1 athletic program with 21 women's, men's, and coed teams (University of Hawai'i at Mānoa, 2019).

Quantitative data about various activities including transportation, utilities, food production and consumption, research animals, agriculture production, and landscape services can be analyzed using the Sustainability Indicator Management & Analysis Platform (SIMAP) created by the University of New Hampshire in collaboration with the University of Virginia and the U.S. Environmental Protection Agency (EPA). SIMAP estimates the nitrogen and carbon footprints that result from these activities. Previous tools include the Nitrogen Footprint Tool, created by the University of Virginia, and CarbonMAP, created by the University of New Hampshire, that have been combined to create SIMAP ("Campus Calculator Home", 2018). The Nitrogen Footprint (NFT) Network oversees the maintenance and development of SIMAP for multiple institutions around the globe. The University of Hawai'i at Mānoa has been part of this network since 2016. SIMAP was released in late 2017 and can be used to analyze a range of potential reduction scenarios. For this study, the initial calculations were made using the Nitrogen Footprint Tool and transitioned to SIMAP to calculate UHM's 2016 and 2017 nitrogen and carbon footprints.

This paper outlines how the data needed to calculate UHM's carbon and nitrogen footprints for fiscal year 2016 and 2017 was collected; presents UHM's carbon and nitrogen footprints for 2016 and 2017; investigates the potential for reducing various activities that might make a significant difference to these footprints; details steps that can be taken to improve the availability and accuracy of the data used by SIMAP; and offers suggestions for customizable data calculation with SIMAP to enable institutions facing challenges similar to those faced by UH to make SIMAP more useful internationally.

Methods

Calculating UHM's carbon and nitrogen footprint required that boundaries be established to clearly define what is and is not included. These boundaries can be broken down into scopes that organize different sectors of activities by direct and indirect production of emissions. Scope 1 includes emissions resulting from on-campus institutionally owned and operated equipment. This includes stationary fuels, transport fuels, fertilizer, animals, and refrigerants and chemicals. Scope 2 accounts for emissions produced indirectly as the result of purchased electricity. This includes purchased electricity and custom fuel mix. Scope 3 includes all other institutional activities and consumption that indirectly release emissions, including commuting, business travel, study abroad travel, student travel to and from home, food, paper, and waste/wastewater (Reguera et al., 2017). For this study, the system boundaries are restricted to the main UH Mānoa campus for fiscal years 2016 and 2017 excluding all off-campus research and cooperative extension facilities.

Utilities Data

The 2016 data for utilities use came from the Hawaiian Electric Company (HECO), the provider of UHM's electricity, 2017 Power Facts Report. It summarized megawatt hours (MWh) from oil, coal, biomass, PV and solar thermal, wind, biofuels, as well as customer-sited grid connected sectors and was used to determine the relative fuel mix that generates O'ahu's electricity. The average fuel mix for O'ahu was used to estimate the utility portion of the footprints, assuming that UHM's fuel mix is the same and the e-grid was the Hawaii Islands Coordinating Council (HICC) O'ahu. The relative fuel mix for O'ahu was applied to UHM's average usage per day of 320 megawatts and all the institution's utilities were assumed to be included.

The 2017 data came from the UH Mānoa Energy & Demand Report by Miles Topping and Jonathan Kutsunai, 2018. The utility energy use from 6/01/2016 to 7/01/2017 was profiled, with averages calculated across the entire period, including summer months and holidays. The weekday average energy use in kilowatt hours (kwh) per day and weekend average total energy MWh use was scaled up by multiplying average by the total number of weekdays and weekend days to estimate a yearly total. Weekdays had higher average daily energy usage compared to weekend days. Yearly totals for weekdays and weekends were summed to obtain a yearly total of 116,705 MWh for 2017. The total was then loaded into SIMAP's Purchased Electricity category and the HICC O'ahu grid was selected for the relative fuel mix (Topping & Kutsunai, 2018).

Transportation Data

The transportation sector includes transport fuel, staff/faculty commuting, student commuting, and directly financed air travel. Direct transportation fuels are included in scope 1, while staff/faculty commuting, student commuting, and directly financed air travel are included in scope 3. The data used includes stationary fuel such as gasoline and diesel fuel tank purchasing records for fleet vehicles (J. Perreira, personal communication, 2017 & 2018), and parking permit pass purchases (K. Yamamoto, personal communication, 2017 & 2018). We also included sports team travel flights, which were estimated using information on location and minimum distance to away games. We assumed all flights were direct flights and took the most direct route. UHM has on-campus fuel tanks that are refilled periodically and fuel purchase invoices were used to calculate the total amount of fuel purchased for 2016 and 2017. This data set is used to account for direct transportation.

Commuter services tracks the type and amount of vehicle parking permits purchased. The permit types include single occupant cars, carpools, mopeds, and bus passes for faculty/staff and students. Other forms of commuter travel such as neighborhood parking, campus shuttles, biking, and walking were not included due to a lack of sufficient data and/or established tracking methods. The University of Hawai'i at Mānoa Existing Conditions Report Campus Transportation and Demand Management Plan, 2011, contained survey based estimates of commuter travel miles and were used for this study. Faculty/staff were assumed to make one round trip with an estimated fifteen-mile radius for 218 days. Students were assumed to make 1 trip with an estimated ten-mile radius for 218 days. The 218 days account for fall and spring semesters, excluding holidays and weekends. All commuting assumptions about number of trips, miles traveled, and number of days, along with the number of each type of purchased permit, were entered into SIMAP to calculate staff and student commuting, respectively.

Directly financed air travel includes sports team travel. Faculty, student, and other school related travel was excluded due to the lack of available data. All male, female, and co-ed sports teams were included individually based on the number and location of away games found on the UHM athletics website (https://www.hawaiiathletics.com). The major airport nearest to the game location was used along with the estimated/average one-way miles from Daniel K. Inouye International Airport. Totals for miles traveled equaled the sum of miles used for each away game multiplied by two to account for a round trip. If the flight is assumed to be one way, the miles were added to the total miles and not multiplied by two to indicate that no round trip was taken. Assumptions made:

- If dates are consecutive or only 1–2 days are between the games and they are within the same state, travel was assumed to be only to this location. No return flight to O'ahu, Hawai'i was taken in between those games and were counted as only 1 round trip.
- If dates varied by 1–2 days and varied in location, travel was assumed to be from a previous location and no round trip was taken back to O'ahu, Hawai'i. Various one-way flights, at least 500 miles apart, were assumed to occur.
- If locations are within the same state and varied by 1–2 days the assumption was made that no flights were taken between locations. However, if one game is in Southern California and the other in Northern California, with at least a flying distance of 500 miles, the assumption was made that a one-way flight was taken instead of driving. In Hawai'i if a game was not on the same island, it was assumed a round trip flight was taken.
- If the event for travel is an invitational or tournament on multiple days, the assumption was made that no round trip flights were taken in-between event dates and only one round trip was included.
- All flights were assumed to take the most direct route using the Google Maps, measure distance tool and milecalc.com.

Food Data

For fiscal year 2016, the Hale Aloha Cafe food purchasing invoices for January 2016 were logged into an excel-based food invoice log. Information about food type and weight was converted into the SIMAP food template, scaled, and uploaded to SIMAP. Since the data set was only for one month of food invoices from one cafe out of three on-campus cafes, the total food weight per category was scaled to three cafes for nine months. Summer months were excluded because two out of three cafes are generally only for residents and summer sessions are not busy enough for purchasing records to be similar to those during the semesters. The total food weight per category was scaled by weight in SIMAP as capturing 35% of the total food for UHM. This percentage was chosen based on the assumption that a substantial quantity of food was not accounted for because the raw data was either illegible and/or did not contain units/quantities that could be converted into weights. The percentage also accounts for food data that was not captured such as non-Sodexo operated eateries (i.e. Paradise Palms cafe, food trucks) and inaccessible information (i.e. Starbucks, Safeway, Jamba Juice).

A similar methodology was used for food data collected in 2017. However, inventory sheets that already compiled the food items into various types and weights were used. Inventory sheets were logged into the SIMAP food template, scaled to three cafes and nine months, uploaded to SIMAP, and scaled in SIMAP to 35% weight accounted for.

The change of methodology from 2016 to 2017 data collection is apparent in the 2016 and 2017 food footprints. Multiple issues arose with the 2016 data, due to the lack of information about the weight of food items. The 2017 approach addressed this issue because food items were sorted into categories with total weights. However, there still were some inquiries that lacked weight information. Inventory lists also cut back on the time it took to decipher and sort through each scanned invoice.

Fertilizer Data

The data includes information on the fertilizer used on the main lawns and in the nursery, which maintains plants for various University activities. The total amount of nitrogen in Sustane 4-6-4 (N-P-K) is 4% with 100 pounds being used annually in the nursery, resulting in 4 lb of N annually. For Sustane 10-2-10, 400 pounds is used about every other year and the nitrogen percentage of 10% means 40 lb equivalent of N is used every other year. Both fertilizers used were organic thus virtually no new N was introduced into the nitrogen cycle, through the creation of synthetic fertilizer, and the N from the organic source was recycled back into the nitrogen cycle to reduce the fertilizers' footprint (R. Adams & D. Strauch, personal communication, 2017). In order to strengthen the data set, information from other areas on campus not under the UH Mānoa Building and Grounds Management department should be collected. Such areas could include Lyon Arboretum, which is associated with UHM, and UHM owned and operated research farms.

Reduction Scenarios

Various scenarios were analyzed based on areas of UHM's C&NFT that showed potential for reduction. These scenarios were also selected based on the scenario options provided by SIMAP and the NFT Network through beta-testing. The purpose of these scenarios is to demonstrate the impact such decisions (i.e. composting, changing food purchases, installing solar, and reducing energy consumption) can have on UHM's total C&NFT and therefore influence decision makers.

Sodexo owned and operated eateries on the UHM campus currently contract Eco Feed to take dining waste. A scenario for composting 300 imperial tons of dining waste demonstrates the impact to UHM for the 2016 & 2017 C&NFTs if dining waste produced annually was composted on campus instead of contracting a third party to haul it away. This scenario assumes that composting takes place on-campus and the resulting compost is used as a soil amendment on-campus.

Emissions resulting from food consumption can be mitigated either by reducing food waste or by substituting for food that is grown with smaller nitrogen and carbon footprints. Various food replacement options were explored to determine their impact. This scenario also used an excel-based tool provided by the NFT Network at the 5th Annual NFT Conference for beta-testing in 2018. The UHM 2017 C&NFT results were used as the baseline year because of the change in methodology for the food sector. The food category replacement options replace a percentage of certain food categories with others while taking into consideration growth rates. Linear population growth (3.70%) for the food projection rate and standard growth rate (3.00%) for the non-food projection rate were included. A baseline year of 2017 and projection year of 2035 was selected and five different options were investigated.

Solar infrastructure also has mitigation potential for UHM. A scenario that adds two megawatt hours solar demonstrates the impact it will have UHM's C&NFT. This scenario was analyzed by changing the purchased electricity category in SIMAP, adding 2 MWh PV solar, for both 2016 & 2017 C&NFTs. The solar scenario assumes that these changes to the utilities sector would be accomplished using a power purchase agreement.

This scenario uses an excel-based tool provided by the NFT Network at the 5th Annual NFT Conference for beta-testing. Reductions were made to the electricity, fleet gasoline, and fleet diesel usage categories with the baseline year equal to the footprint for the 2017 UHM C&NFT results. Three different options were tested. Option 1 is the small reduction between 10% and 20%, option 2 is the medium reduction between 20% and 30%, and option 3 is the large reduction between 30% and 40%.

Results

UHM's total footprint for January 1 to December 31, 2016, was 83 net metric tons (mt) of released, reactive nitrogen (N) and 90,600. net greenhouse gas metric tons carbon dioxide equivalent (GHG MTCDE) (Table 1). For fiscal year 2017 the total footprint was 110 net mt N and 89,506 net MTCDE (Table 1). The two largest contributors for both the 2016 and 2017 nitrogen footprints were purchased electricity and food (Figure 1). The two largest contributors for the 2016 and 2017 carbon footprints (CFT) were purchased electricity and commuting, combined staff and student commuting, excluding the transmission and distribution (T&D) losses category which accounts for the inefficiency of production by the energy provider (Figure 2).

Although the methodology changed from the 2016 to 2017 footprints, the results did not change drastically. The utilities sector includes the purchased electricity category, included in scope 2. For 2016, purchased electricity contributed to 43 mt N, 52% total N, (Figure 1) and 78,529 GHG MTCDE, 86.68% total GHG MTCDE (Figure 2). For 2017, purchased electricity contributed to 43 mt N, 39.48% total N, (Figure 1) and 70,956 GHG MTCDE, 79.28% total GHG MTCDE (Figure 2).

For fiscal year 2016 the various methods of transportation contributed a total of about 3 net mt N and 5,370. net MTCDE. Staff commuting contributed to 1.62 mt N and 3,103 GHG MTCDE. Student commuting contributed to 0.76 mt N and 1,490. GHG MTCDE. Direct transportation contributed to 0.3 mt N and 452 GHG MTCDE. Directly financed air travel contributed to 0.04 mt N and 325 GHG MTCDE (Figure 1 & 2). For fiscal year 2017, these contribute a total of about 5 net mt N and 10,703 GHG MTCDE. Staff commuting contributed to 2.92 mt N and 5,784 GHG MTCDE. Student commuting contributed to 1.98 mt N and 4,022 GHG MTCDE. Direct transportation contributed to 0.38 mt N and 596 GHG MTCDE. Directly financed air travel contributed to 0.04 mt N and 300. GHG MTCDE (Figure 1 & 2).

For fiscal year 2016, food contributed to 34 mt N (Figure 1) and 2,411 GHG MTCDE (Figure 2). The top five largest

Table 1 University of Hawai'i at Mānoa Carbon and Nitrogen 2016–2017 results by fiscal year and scope.

	SCOPE 1		SCOPE 2		SCOPE 3			
YEAR	TOTAL N (MT)	TOTAL MTCDE	TOTAL N (MT)	TOTAL MTCDE	TOTAL N (MT)	TOTAL MTCDE	NET N (MT)	NET MTCDE
2016	0.3	452.13	43.42	78,529.48	39.12	11,618.46	82.83	90,600.07
2017	0.39	596.24	43.38	70,956.20	66.12	17,953.61	109.89	89,506.05

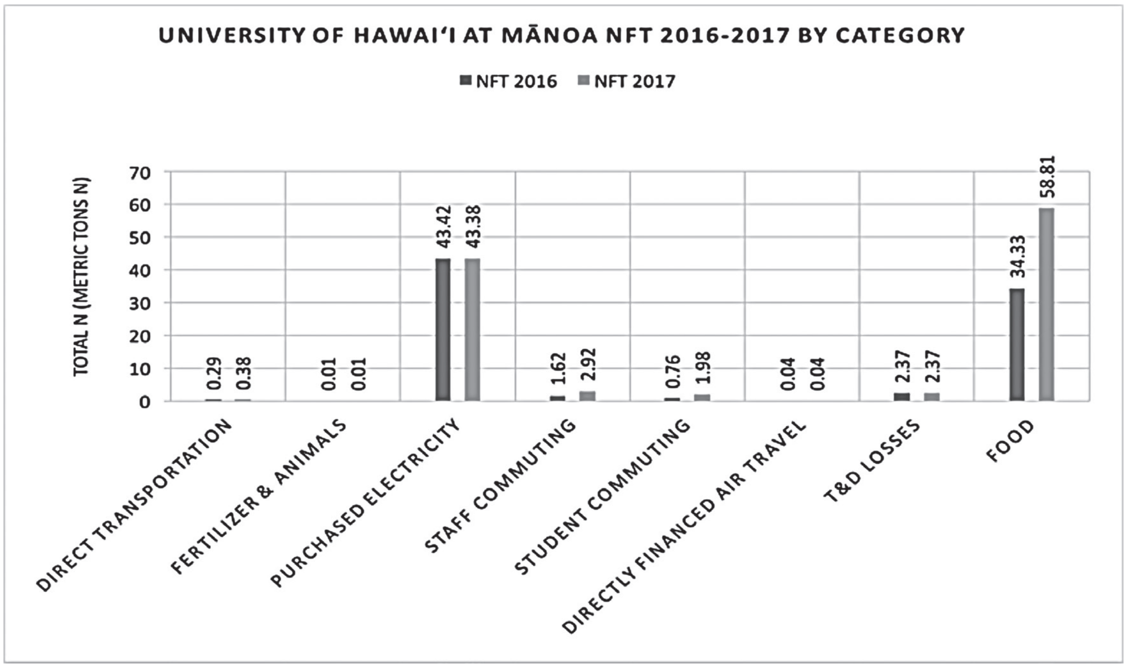

Figure 1 University of Hawai'i at Mānoa Nitrogen Footprint (NFT) 2016 & 2017 total mt N by category.

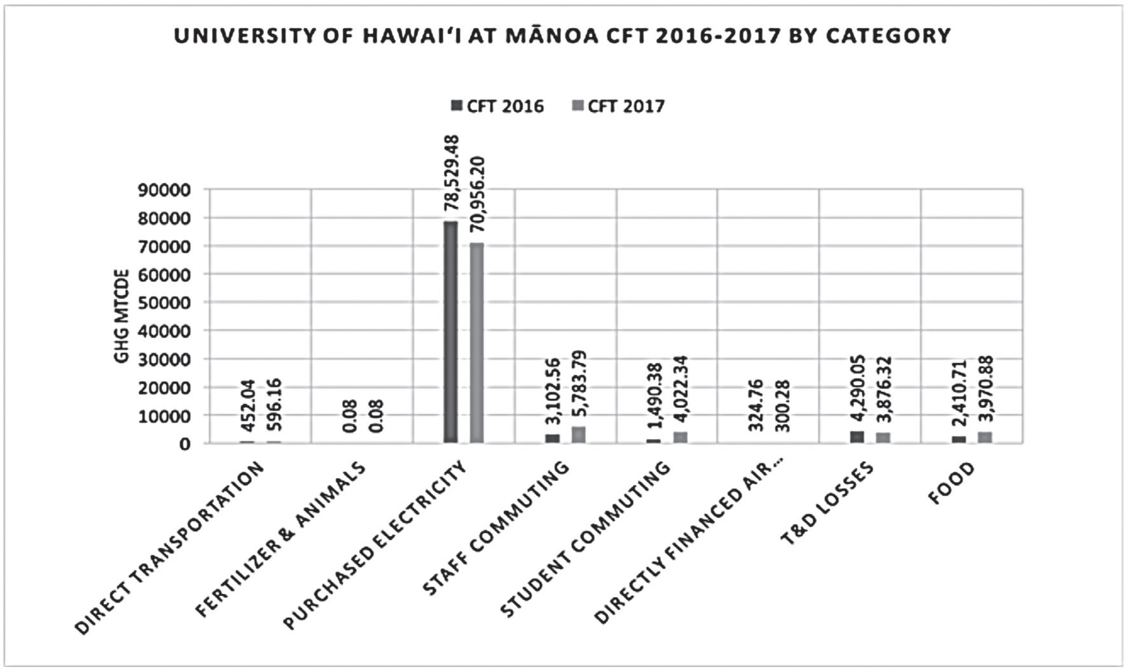

Figure 2 University of Hawai'i at Mānoa Carbon Footprint (CFT) 2016 & 2017 total GHG MTCDE by category.

contributions (kg N) to overall food footprint came from the following food types.

1. Beef
2. Chicken
3. Milk
4. Pork
5. Eggs

For fiscal year 2017, food contributed to 59 mt N (Figure 1) and 3,971 GHG MTCDE (Figure 2). The top five largest contributions (kg N) to the overall food footprint came from the following foods types.

1. Beef
2. Chicken
3. Grains
4. Eggs
5. Pork

For both years, beef was the top contributor to the amount of kg N released as the result of its production followed by chicken. Overall, meat and animal byproducts were the greatest contributors with the exception of grains in the 2017 food footprint (Table 2). The fertilizer sector includes fertilizer data only. For 2016 and 2017, fertilizer contributed to 0.01 mt N and 0.08 GHG MTCDE (Figure 1 & 2).

Table 2 UHM Food Production (kg N) for Fiscal Year 2016 & 2017.

YEAR	FOOD CATEGORY	PRODUCTION (KG N)
2017	Beef	18,274
2016	Beef	8,877
2016	Chicken	7,208
2017	Chicken	7,063
2017	Grains	5,382
2017	Eggs	5,103
2017	Pork	4,848
2016	Milk	4,764
2017	Milk	4,485
2017	Cheese	3,027
2016	Pork	2,686
2017	Coffee & Tea	2,342
2017	Spices	2,236
2016	Eggs	2,089
2016	Fish	2,022
2016	Cheese	2,012
2017	Vegetables	1,877
2016	Liquids	1,748
2016	Grains	1,317
2017	Fish	1,182
2017	Liquids	1,179
2016	Vegetables	811
2017	Potatoes	580
2017	Beans	483
2017	Fruits	273
2017	Nuts	245
2016	Fruits	207
2017	Sugars	204
2016	Potatoes	193
2016	Beans	161
2016	Spices	128
2016	Coffee & tea	43
2017	Oil	28
2016	Sugars	27
2016	Nuts	27
2016	Oils	6

Reduction Scenarios

The 2 MWh solar scenario results in a reduction to the purchased electricity category and overall footprint. For 2016, 2 MWh solar contributed to a reduction of 1.35 GHG MTCDE (0.0015% net reduction) and 0 mt N. For 2017, 2 MWh solar contributed to a reduction of 1.22 GHG MTCDE (0.0014% net reduction) and 0.01 net N (0.01% net reduction) (Table 3).

Composting does not contribute to reducing any specific category, though it did result in a reduction in the net footprints. For 2016, 300 imperial tons (304.814mt) of dinning waste composted led to a reduction of 98.79 net MTCDE (0.11% net reduction) and 3.16 net N (3.82% net reduction). For 2017, the composting scenario led to a reduction of 98.78 net MTCDE (0.11% net reduction) and 3.17 net N (2.88% net reduction) (Table 3).

The selected energy source type reduction usage categories affected the direct transportation category for the gasoline and diesel reduction and the purchased electricity category for the electricity consumption. Option 1, led to a reduction of 89 GHG MTCDE and 0 mt N for direct transportation and 11,837 GHG MTCDE and 0 mt N reduction for purchased electricity (Figure 3 & 4). This option reduces the net footprints by 0.18 mt N (0.16% reduction) and by 11,926.41 MTCDE (13.32% reduction) (Table 3). Option 2, led to a reduction of 119 GHG MTCDE and 0 mt N for direct transportation and 19,728 GHG MTCDE and 10 mt N reduction for purchased electricity (Figure 3 & 4). Overall, option 2 reduces the net footprints by 10.94 mt N (9.96% reduction) and by 19,877.35 MTCDE (22.21% reduction) (Table 3). Option 3, led to a reduction of 208 GHG MTCDE and 0 mt N for direct transportation and 27,619 GHG MTCDE and 15 mt N reduction for purchased electricity (Figure 3 & 4). This option reduces the net footprints by 15.32 mt N (13.94% reduction) and by 27,828.29 MTCDE (31.09% reduction) (Table 3).

Table 3 UHM Reduction Scenarios: 2 MWh Solar, 300 Imperial Tons Dining Waste Composted, Energy Source Type Reduction.

SCENARIO	OPTION	DESCRIPTION	NET N (MT)	REDUCTION N (%)	NET MTCDE	REDUCTION NET MTCDE (%)
2 MWh Solar	2016 No Solar		82.83	–	–	–
	2016 Solar		82.83	0.00	0.00	0.0015
	2017 Solar		109.89	–	–	–
	2017 No Solar		109.88	0.01	0.01	0.0014
300 Imperial Tons Dining Waste Compost	2016 No Compost		82.82	–	–	–
	2016 Compost		79.66	3.16	3.82	0.11
	2017 No Compost		109.89	–	–	0.00
	2016 Compost		106.72	3.17	2.88	0.11
Energy Source Type Reduction	2017 Baseline		109.89	–	–	–
	1	10–20% Reduction	109.71	0.18	0.16	13.32
	2	20–30% Reduction	98.95	10.94	9.96	22.21
	3	30–40% Reduction	94.57	15.32	13.94	31.09

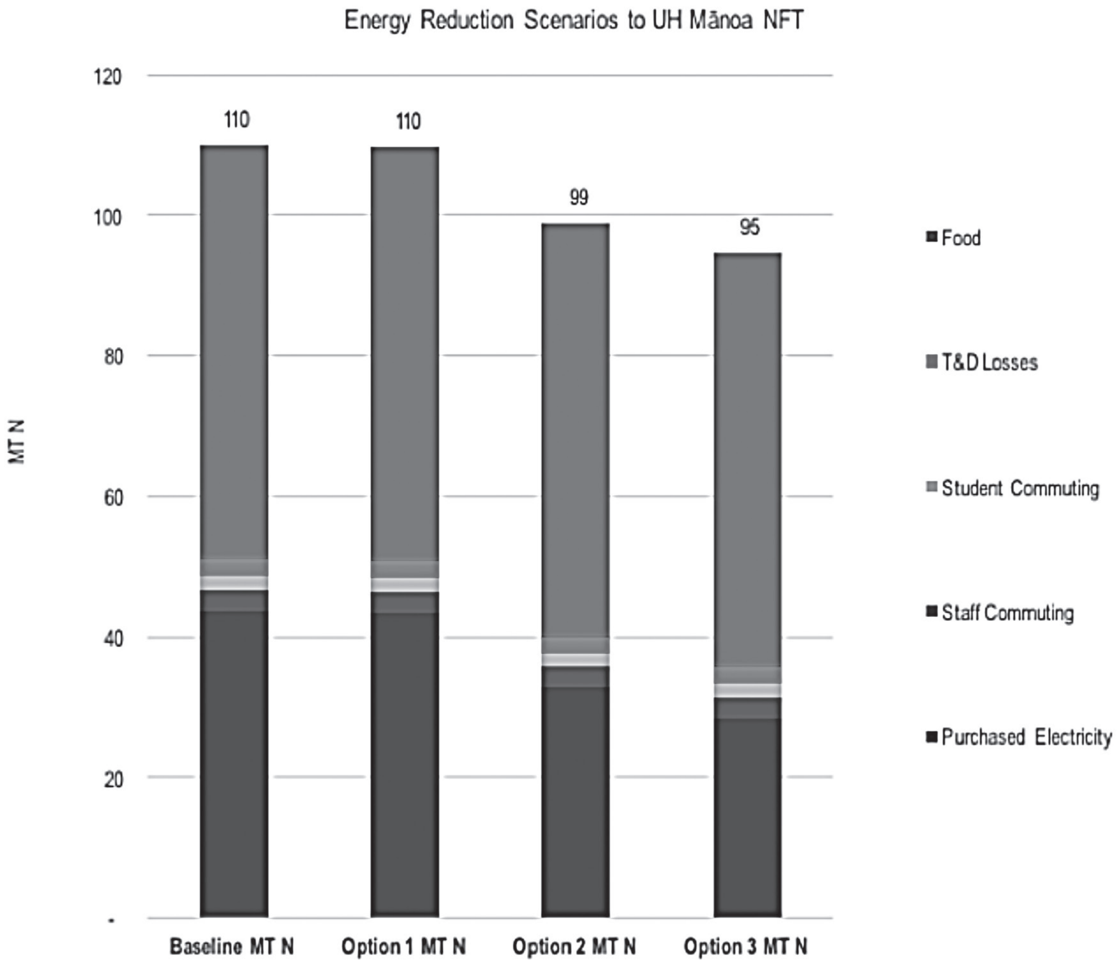

Figure 3 UHM NFT energy reduction scenarios (mt N). Baseline year is 2017. Option 1 is the small reduction (10–20% reduction). Option 2 is the medium reduction (20–30% reduction). Option 3 is the large reduction (30–40% reduction). Reduction scenarios made to purchase electricity, fleet gasoline usage, and fleet diesel usage.

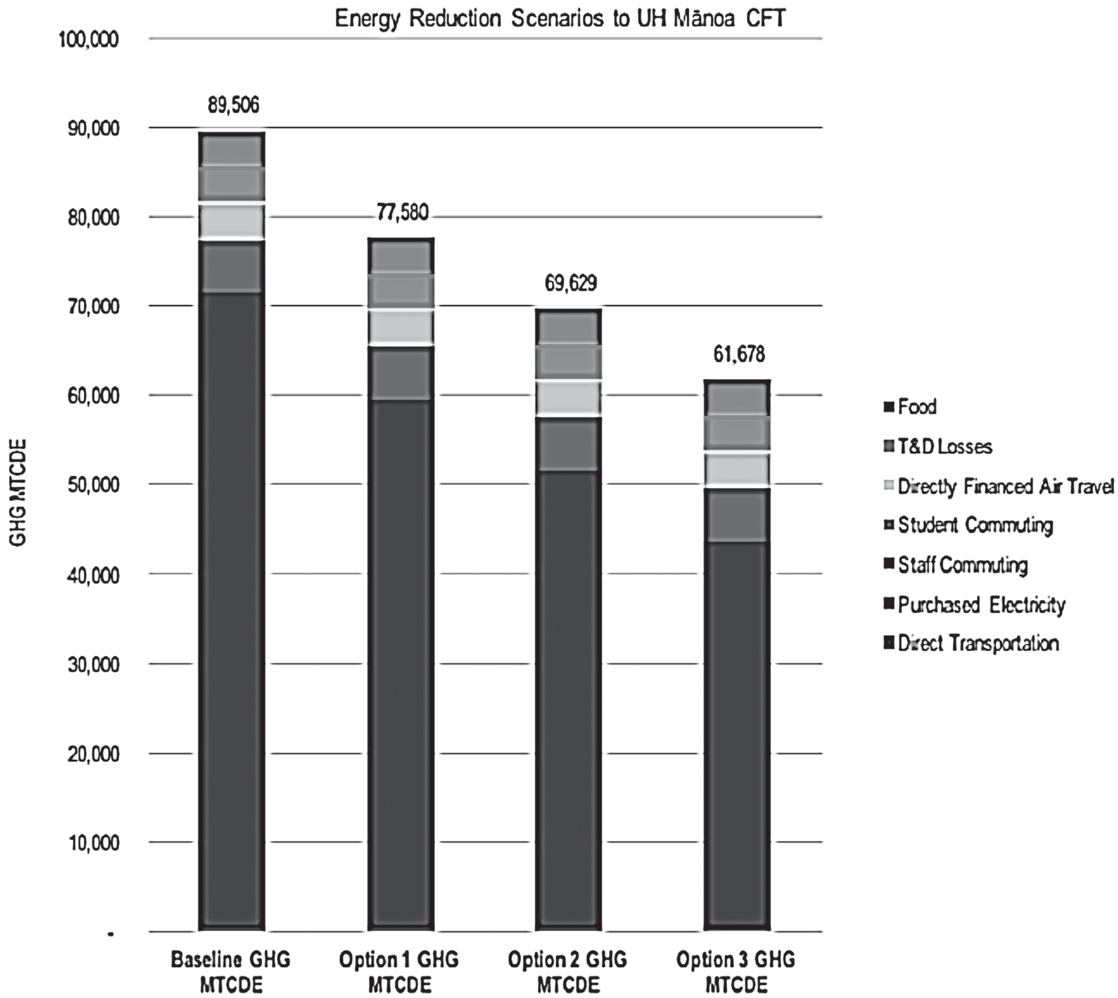

Figure 4 UHM CFT energy reduction scenarios (GHG MTCDE). Baseline year is 2017. Option 1 is the small reduction (10–20% reduction). Option 2 is the medium reduction (20–30% reduction). Option 3 is the large reduction (30–40% reduction). Reduction scenarios made to purchase electricity, fleet gasoline usage, and fleet diesel usage.

Food Category Replacements Scenarios

Option 1 resulted in a 3.18% reduction from the NFT baseline and a 0.39% reduction from the CFT baseline to the projection year. Option 2 resulted in a 54.27% increase from the NFT baseline and a 53.85% increase from the CFT baseline to the projection year. Option 3 resulted in a 3.33% reduction from the NFT baseline and a 0.41% reduction from the CFT baseline to the projection year. Option 4 resulted in a 53.24% increase from the NFT baseline and a 53.77% increase from the CFT baseline to the projection year. Option 5 resulted in a 0.03% reduction from the NFT baseline and a 0.04% reduction from the CFT baseline to the projection year (Table 4).

Discussion

The University of Hawaiʻi at Mānoa's carbon and nitrogen footprints for 2016 and 2017 were similar. The 2017 nitrogen footprint was 27 net mt more than the 2016 footprint (Table 2) and the 2017 carbon footprint was 90,600 kg N more than the 2016 footprint (Table 2). These baseline results provide a foundation to assess what progress has been achieved and identify the greatest potential for emission reductions. Inferences can also be made on how much other UH system campuses are emitting in relation to their operation size and UH Mānoa's operation size.

Nitrogen and carbon footprints also reflect the quality of

Table 4 Food Category Replacement Scenarios

Food Category Replacements		2017 Baseline				2035 Projection				Change from Baseline to Projection (%)	
		Business as Usual		Option		Business as Usual		Option			
Option	Description	Net N (MT)	Net MTCDE	Net N (MT)	Net MTCDE	Net N (MT)	Net MTCDE	Net N (MT)	Net MTCDE	Nitrogen	Carbon
1	30% of beef replaced with chicken; no linear population growth; no standard growth rate	109.89	89,506.05	106.40	89,154.71	109.89	89.505.05	106.40	89,154.71	–3.18	–0.39
2	30% of beef replaced with chicken; linear population growth; standard growth rate	109.89	89,506.05	106.40	89,154.71	176.68	138,342.29	169.53	137,701.46	54.27	53.85
3	30% of beef & pork replaced with chicken; no linear population growth; no standard growth rate	109.89	89,506.05	106.23	89,135.41	109.89	89,506.05	106.23	89,135.41	–3.33	–0.41
4	30% of beef replaced with chicken; linear population growth; standard growth rate	109.89	89,506.05	106.23	89,135.41	176.68	138,342.29	168.39	137,633.57	53.24	53.77
5	30% local food; no linear population growth; no standard growth rate	109.89	89,506.05	109.86	89,470.31	109.89	89,506.05	109.86	89,470.31	0.03	–0.04

the data used to construct them. Throughout this project various unknowns were encountered that required that assumptions be made. The 2016 utilities sector assumes that Oʻahu's relative fuel mix can be applied to UHM's relative fuel mix because HECO is the major energy supplier for Oʻahu and UHM. The 2017 utilities data assumes that the averages for weekdays and weekends during the data time frame of 6/01/2016 to 7/01/2017 can be applied for the 2017 fiscal year calculations. The entire year of 2017 and the averages were also influenced by consumption in 2016.

The sector that required the most assumptions to be made was the transportation sector. The data for this sector fails to capture commuters that use modes of transportation which are difficult to analyze using the current methodology. For example, commuters park in the surrounding neighborhood or pay by the day to park in the parking structure and in various parking lots on campus. Uncertainties also exist about the amount of student air-travel, study abroad travel, and faculty travel. To improve transportation data, travel for commuters that drive to campus and park in the surrounding area or park on campus is needed as well as sports team travel transportation purchases/documentation. Data would also need to include students using the bus and other modes of transportation to campus. To extend the scope of transportation methods included in the UHM boundaries, efficient data collection methods need to be established to capture faculty air travel, student air travel, study abroad travel, and fuel usage for fleet vehicles besides on-campus fuel tanks. Possible improvements to SIMAP could include options to distinguish between the use of electric vehicles from traditional gasoline operated automobiles since island locations make electric vehicles more feasible and cost effective.

The other sector for which many assumptions were made was the food sector. Uncaptured data from other food vendors on-campus such as Paradise Palms Food Court, food trucks, and Sodexo contracted eateries is likely to be significant. Scaling for the data based on one month of information from one eatery fails to capture the variation in purchasing based on time of the year and overall differences in demand between the various eateries. Inventory lists from all eateries and other food sources, such as vending machines, are also needed. SIMAP currently lacks the ability to change the method of food transportation and food miles traveled, relying on food trucks and average U.S. food miles now. Hawaiʻi's food transportation is by cargo ship with an average distance close to 2,500 miles traveled, which is expected to increase UHM's footprint, if accounted for. Potential improvements to SIMAP that could account for this variation are customizable food transportation methods, fuel sources, and average miles transported. Improvements that capture the impact of sourcing local food in which the food transportation type, fuel source, and average miles transported would be included and customizable are also desirable. A feature to select the region that food is being imported from could also be added in to account for the impact geographical variance of imported food has on the footprints.

The fertilizer sector fails to capture all applications on-campus because it includes only the main lawns and nursery. Also, the amount applied on-campus is not significant enough to impact the footprints as a whole. If research farms and UH agricultural programs were included this would increase the footprints.

Overall, minimizing the amount of assumptions made; obtaining more accurate data; and developing customizable data calculation in SIMAP is expected to increase UHM's C&NFT for all sectors. Data tracking methods also need to be established institutionally. The system boundaries could be extended to off-campus facilities to capture all UH owned and operated facilities. This will enable a more holistic calculation of the UH system and can be extended out to other UH system universities and community colleges. SIMAP could also improve the data capturing capabilities of small island institutions in comparison to the current preset metrics in SIMAP used for U.S. institutions on the continent.

The most effective way to improve the data in order to create a more accurate and comprehensive UHM C&NFT requires a multi-step approach. First, the current methods of data tracking/collection need to be improved upon. This entails improving UHM administrative support and stakeholder collaboration. At the same time the process of data collection needs to be streamlined to ensure that data is easily tracked and reported. Therefore, in order to have effective, well executed, and permanent change the current system of tracking, communication, and reporting of data pertaining to UHM's institutional footprints needs to be reshaped. At the same time, this data should be made available across the system to facilitate all efforts to investigate reduction scenarios.

Conclusion

Hawaiʻi's proactive stance to addressing sustainability and climate change resilience through policy and goal setting has left institutions with the task of meeting these goals. Calculating carbon and nitrogen footprints allows progress to be benchmarked and reduction scenarios to be examined. The University of Hawaiʻi is one of Hawaiʻi's largest stakeholders and the University of Hawaiʻi at Mānoa alone released 83 mt N and 90,600 MTCDE in 2016 and 110 mt N and 89,506 MTCDE in 2017 (Table 2). The largest contributors were purchased electricity and food, and commuting transportation (Figure 1 – 4). The individual reduction scenarios analyzed here resulted in minor reductions to UHM's carbon and nitrogen footprints as a whole (Table 3), suggesting the need for actions to be taken across all sectors. To have a bigger impact on reducing UH's footprints, a better understanding of how much the UH system is emitting holistically is needed through institutionalizing a system to improve data collection while establishing a repeatable consistent method for tracking changes through time. This includes extending data collection and tracking to all University of Hawai'i institutions and carefully analyzing various reduction scenarios across the system to find the most cost-effective options. SIMAP has the potential to do just that and more if integrated across the UH system. SIMAP can also be improved by adapting the tool for use by institutions in other settings that are geographically isolated and highly dependent on imported goods. Incorporating more calculation options associated with transporting food and people, in addition to various energy sources, will make SIMAP more useful across the globe. Detailed understanding of the challenges institutions face in becoming sustainable is essential.

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