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The Nitrogen Footprint Tool Network: A Multi-Institution Program To Reduce Nitrogen Pollution

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Abstract

Anthropogenic sources of reactive nitrogen have local and global impacts on air and water quality and detrimental effects on human and ecosystem health. This article uses the Nitrogen Footprint Tool (NFT) to determine the amount of nitrogen (N) released as a result of institutional consumption. The sectors accounted for include food (consumption and upstream production), energy, transportation, fertilizer, research animals, and agricultural research. The NFT is then used for scenario analysis to manage and track reductions, which are driven by the consumption behaviors of both the institution itself and its constituent individuals. In this article, the first seven completed institution nitrogen footprint results are presented. The Nitrogen Footprint Tool Network aims to develop footprints for many institutions to encourage widespread upper-level management strategies that will create significant reductions in reactive nitrogen released to the environment. Energy use and food purchases are the two largest sectors contributing to institution nitrogen footprints. Ongoing efforts by institutions to reduce greenhouse gas emissions also help to reduce the nitrogen footprint, but the impact of food production on nitrogen pollution has not been directly addressed by the higher education sustainability community. The Nitrogen Footprint Tool Network found that institutions could reduce their nitrogen footprints by optimizing food purchasing to reduce consumption of animal products and minimize food waste, as well as by reducing dependence on fossil fuels for energy.

Introduction

Anthropogenic losses of reactive nitrogen (Nr; all nitrogen species except N_2) to the environment cause negative impacts to human and ecosystem health. Anthropogenic reactive nitrogen is created during the burning of fossil fuels for energy (nitrogen oxides (NOx) and nitrous oxides (N_2O)), by the Haber-Bosch process (ammonia (NH_3)), and from

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cultivation-induced biological nitrogen fixation for food production. On a global basis, these activities exceed natural rates of reactive nitrogen creation by up to a factor of four to five; in the United States it is up to a factor of 10.[1] The addition of reactive nitrogen to the environment has been an important factor in increasing food production and providing energy for a growing human population. However, the unintentional release of reactive nitrogen into the environment also leads to a number of detrimental impacts, including smog, acid rain, forest dieback, eutrophication, biodiversity loss, stratospheric ozone depletion, and an enhanced greenhouse effect.[2] While research to improve nitrogen efficiency at the producer level is ongoing,[3] the role of consumer choice must be explored, especially on the scale of institution consumption.

Nitrogen (N) footprints are indicators of how an entity's activities contribute to the negative effects of excess reactive nitrogen. This article presents the N footprint for seven institutions of higher education and research, which are the first institutions to calculate their N footprint since the institution nitrogen footprint model was developed. A Nitrogen Footprint Tool (NFT) was used to quantify the reactive nitrogen pollution generated by these institutions and to test scenarios on how to decrease the reactive nitrogen pollution.

Institutions of higher education and research vary in several characteristics: physical size; geographical location; population of residential and nonresidential students, faculty, and staff; and research activities. All of these variables shape the extent of an institution's N footprint. Each institution shares common reactive nitrogen sources that are captured in the sectors of the NFT: utilities, transportation, food production, food consumption, fertilizer use, management of research animals, and agricultural research.[4]

Many institutions of higher education and research already track and manage their carbon footprint to address sustainability goals related to climate change. The Campus Carbon Calculator™ has been used by thousands of institutions of higher learning to calculate their institution's carbon footprint.[5] Many users are signatories of the Second Nature Carbon Commitment (formerly known as American College and University Presidents' Climate Commitment) to make their campuses climate neutral by reducing and offsetting greenhouse gas emissions.

While the reduction of greenhouse gas emissions by institutions is an important goal for addressing global climate change, the carbon footprint metric addresses only one aspect of environmental impact. The N footprint adds value to an institution's environmental stewardship efforts by addressing a broader range of environmental impacts and by identifying the activities and areas of consumption that integrate multiple sustainability goals. The effort and cost to perform a N footprint analysis and drive reduction strategies involve the collaboration of students, staff, and faculty over the course of a semester or year. Not only does the N footprint add an extra method of analysis to existing institution sustainability efforts, it can strengthen the argument for reduction strategies that address waste management, energy conservation, sustainable purchasing, and more.

The Nitrogen Footprint Tool for institutions was developed at the University of Virginia, which was the first to calculate its N footprint in 2010 and the first to adopt a nitrogen footprint reduction goal in 2013.[4] As part of a project supported by the Environmental Protection Agency (EPA) program, Sustainable and Healthy Communities, the NFT has been applied to additional institutions that make up the Nitrogen Footprint Tool Network. The goals of the NFT Network are to communicate and improve outreach for the N footprint concept and to improve the NFT for applicability to a wider range of institutions through an intensive beta-testing process.

This article presents the N footprints for the institutions that make up the first cohort of beta-testers: Brown University, Colorado State University (CSU), Dickinson College, Eastern Mennonite University (EMU), Marine Biological Laboratory (MBL), University of New Hampshire (UNH), and University of Virginia (UVA).

In addition to the institutions discussed here, an additional 13 institutions in and outside the United States have begun N footprint calculations using the NFT. This diverse group represents a range of campus sizes, populations, locations, and types, so as to strengthen the NFT and make it widely useful. Feedback and collaboration within the NFT Network have led to improved materials and methods for the calculation of institution N footprints, as well as new projects to further study institution N footprints and devise creative reduction strategies. This article discusses how the NFT has been implemented at seven institutions, reports and discuss the results, and presents the opportunities

each institution has for reducing its N footprint.

Methods

A nitrogen footprint reflects the reactive nitrogen released by all the primary activities and consumption of resources by an institution. The system bounds are set based on institutional properties and services. Many colleges provide housing and meal plans for a large part of their population, so students' consumption of food and energy is included in the N footprint. However, if part of the population's food and energy consumption occurs off-campus (e.g., students living in apartments), this data is not captured in the footprint.

The sectors of the Nitrogen Footprint Tool include food production, food consumption, utilities, transportation, fertilizer, research animals, and agriculture. Calculation methods for all but the agriculture sector are described in Leach et al.[4] The most recent version of the NFT can be found online, as published by the EPA.[6]

The agricultural research sector accounts for farm inputs such as fertilizer and livestock feed as well as outputs, including farm products and exported waste (e.g., compost). While some reactive nitrogen associated with research farms may cycle within an institution's system bounds in the forms of agricultural products and compost, any nitrogen inputs to research farms that are lost to the environment are included in the N footprint.

The NFT contains standard emission and conversion factors, including stationary and non-stationary fuel emission factors and virtual nitrogen factors for food production.[4]

A virtual nitrogen factor (VNF) is the ratio of the nitrogen released to the environment during production to the nitrogen content of that food.[7]

Data inputs for the calculation are entered by sector. Utilities and transportation consumption data can typically be collected from an institution's carbon footprint calculator. The data used for food production and consumption consist of dining services' inventories of ingredients purchased, amount of food composted or donated, and a nitrogen removal factor from a local wastewater treatment plant.

Results

The institutions included in this study vary in size (population, gross square footage of campus), mission (a research institution, small liberal arts colleges, large research universities), and location across the United States. There is a broad distribution of N footprint results—from 7.5 metric tons N at MBL to 444 metric tons N at UVA (Figure 1; Table
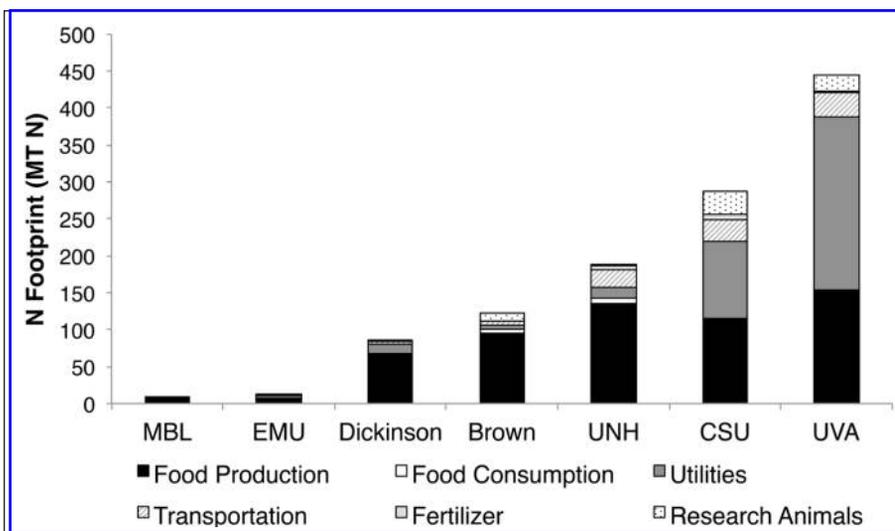

Figure 1. Total institution N footprint results divided by sector.
*Although CSU calculated its agricultural research N footprint, it is not shown here due to its size and for comparability with other footprint calculations.

| **Table 1**. Background Information and Results for the Seven Institutions Included in This Article				
	Location	Population (Full time equivalent)	Total N Footprint (MT N)	Per Capita N Footprint (kg N per FTE)
Marine Biological Laboratory	Woods Hole, MA	300	7.5	23
Eastern Mennonite University	Harrisonburg, VA	1,600	12	7
Dickinson College	Carlisle, PA	3,200	85	27
Brown University	Providence, RI	7,900	123	16
University of New Hampshire	Durham, NH	16,500	186	11
Colorado State University	Fort Collins, CO	31,400	287	9
University of Virginia	Charlottesville, VA	35,900	444	12
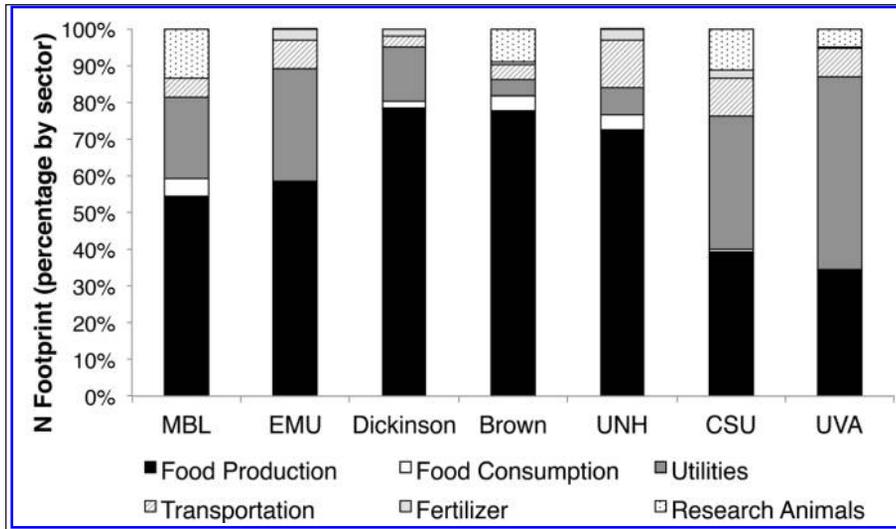
Figure 2. Institution N footprint sector contributions to total footprints, by percentage.
*Although CSU calculated its agricultural research nitrogen footprint, it is not shown here due to its size and for comparability with other footprint calculations.

1). While food production is the dominant sector for five out of seven institutions (50% on average), the utilities sector at UVA and the agriculture sector at CSU are deviations from this trend (Figure 2). Utilities is the second-largest sector, contributing 33 percent on average. Reflecting the variety in sizes and missions of the institutions, per capita N footprints ranged from 7 to 29 kg N.

The following individual assessments lay out the N footprint for each institution, features of consumption and operations that contribute to the N footprint, and plans to implement reduction goals and strategies.

Marine Biological Laboratory

The largest sector of the Marine Biological Laboratory's (MBL) N footprint is food production, at 4.1 metric tons N (55% of total). Utilities is the second-largest sector, releasing 1.7 metric tons N (22% of total). Some research conducted by the MBL involves fertilization studies; it is estimated that these studies released 12 metric tons N during the 2014 calculation year, which is larger than the total nitrogen footprint from consumption and operations. This fertilizer component was not included in the final N footprint because the extent of fertilizer studies varies from year to year, and it is considered part of the institution's vital research mission. The food production contribution to the N footprint is relatively low because the MBL does not have residential students or staff for most of the year, so they are providing less food per capita than other institutions in this study. Scenarios that have been analyzed for reducing MBL's N footprint include composting 75 percent of food waste, which would reduce the N footprint by 0.1 metric tons N, and adopting energy efficiency strategies.

Table 2. The Results of Each Institution's N Footprint Calculation by Sector and Total, Given in Metric Tons Nitrogen (MT N) Released to the Environment

Sector	Brown Total N Footprint (MT N)	CSU Total N Footprint (MT N)	Dickinson Total N Footprint (MT N)	EMU Total N Footprint (MT N)	MBL Total N Footprint (MT N)	UNH Total N Footprint (MT N)	UVA Total N Footprint (MT N)
Food Production	96	113	66	6.6	4.1	135	152
Food Consumption	4.8	2.2	1.8	0.06	0.3	7.5	1.8
Utilities	5.5	104	13	3.5	1.7	14	233
Transportation	5.4	30	2.5	0.9	0.4	24	34
Fertilizer	7.5	7.0	1.6	0.4	0.004	6	1.8
Research Animals	11	32	0	0.01	1.0	0.03	22
Agriculture	0	768	0	0	0	0	0
Total	123	1,056	85	11	7.5	186	444

Eastern Mennonite University

Sustainability efforts on the Eastern Mennonite University (EMU) campus include student gardens, an on-campus composting facility, waste reduction programs, lighting and energy efficiency upgrades, on-campus solar arrays, and three LEED Gold-certified residence halls. Despite having such an energy-efficient campus, the N footprint for utilities is relatively high (30% of the total) because coal is a dominant fuel source for the regional electricity grid. The transportation sector also makes up a higher portion of the total N footprint (9%) than that of other institutions because commercial air travel is included in the footprint due to EMU's requirement for all students to study for one semester in a non-Western European culture. These factors make the food production sector's contribution slightly smaller (57%) than other institutions, but it is still the largest sector. EMU's per capita N footprint is the smallest of all institutions in this study.

Strategies that are already in place show significant reductions from what the footprint could be, such as the composting program (3% reduction) and tertiary sewage treatment (4% reduction). An additional food scenario being considered is replacing 20 percent of beef with chicken, which would result in a 5 percent reduction. Additional reductions may result from a switch of utility fuel from coal to natural gas and an increase in renewables, improving the N footprint of purchased electricity in Virginia.

Dickinson College

Food production and sewage make up 80 percent of Dickinson's 85 metric tons N footprint. The remainder is made up of utilities (15%), transportation (3%), and fertilizer application (2%). Of the virtual nitrogen calculated for food, 70 percent was from meat, and 87 percent of the total was from animal products. Though the footprint from food production seems high compared to other institutions, 94 percent of Dickinson's students live on campus and have full meal plans. This is important to note because the food footprint of an institution does not account for all meals consumed by the population of the institution, only food purchased and provided by the institution. In addition, the college hosts summer programs that bring several hundred middle school and high school students to live on campus and eat in its dining hall. In consequence, the number of meals served per full-time student is high relative to institutions that have a smaller portion of their students living on campus with full meal plans or that do not have a significant summer population.

Scenario analyses were performed for Dickinson College for a number of nitrogen reduction measures.[8] The most impactful measures are those targeting food purchases and dietary choices and sourcing electricity from renewables. Reducing food purchases by 25 percent through more efficient food purchases and inventory management would reduce Dickinson's N footprint by 20 percent, and substituting nonmeat protein sources for 25 percent of meat purchases would reduce the footprint by an estimated 12 percent. A new 3 megawatt solar array that is scheduled to be installed in 2017 will reduce Dickinson's carbon footprint by roughly 10 percent and nitrogen releases by 3 percent.

Policy packages that combine multiple measures that are considered to be feasible and cost-reducing are estimated to have the potential to reduce Dickinson's N footprint by 15 percent or more.

Brown University

With an urban campus in the northeastern United States, Brown faces different constraints with respect to its N footprint, particularly the fact that it does not provide fleet transportation for students and much of the student population lives and boards on campus. The food production sector was the largest contributor (78%) to Brown's total N footprint, while fossil fuels used for transportation and utilities contributed 8 percent of the total, research animals 9 percent, food consumption 4 percent, and on-campus fertilizer 1 percent. The small contributions of utilities and transportation reflect the dependence on natural gas in the New England regional electricity grid, the relatively small campus size, and lack of large numbers of student commuters. A sewage treatment nitrogen removal rate of 79 percent kept the contribution of the food consumption sector small. Brown's biological and medical research program uses a relatively large proportion of research animals in comparison with other institutions in general, but the number is comparable to institutions that have similar research programs (e.g., CSU and UVA).

Over the past 10 years, Brown University has taken aggressive steps to reduce its environmental footprint and engage in sustainability education and community outreach. A greenhouse gas emissions reduction goal of 42 percent below 2007

baseline levels by 2020 was set, and resulted in new standards and investments in energy efficiency. An upcoming composting initiative motivated, in part, from the passage of state law requiring diversion of food waste from landfills is expected to divert 450 metric tons of organic waste per year from landfills.

At Brown, a set of scenarios that includes a 5 percent reduction in commuting, a 5 percent reduction in utilities, 80 percent composting of food waste, replacing 10 percent of beef served in dining halls with chicken, increasing food donations to 8 percent, and purchasing local food would result in a 5 percent reduction in the total footprint.

University of New Hampshire

Food production is by far the largest sector of the University of New Hampshire's (UNH) N footprint, releasing 135 metric tons N and comprising 73 percent of the total footprint. Food consumption (8 MT N), transportation (24 MT N), utilities (14 MT N), and fertilizer (6 MT N) are smaller sources. The utilities sector is a relatively small portion (8%) of the total footprint because most of the energy used to heat and power the campus is derived from an on-campus cogeneration facility, which uses processed methane gas from a local landfill as a fuel source. For purchased electricity, the fuel mix for regional electricity production relies primarily on natural gas, which has a lower N footprint than other fossil fuel sources.

Scenario analysis at UNH has focused on food because the university has already established a goal to achieve carbon neutrality by 2100. Achieving this goal will also sub-

stantially reduce the already small utilities and transport N footprints. Exploratory scenario analysis has calculated the effect of the following scenarios: composting all food waste (2% reduction), replacing 25 percent of beef purchases with chicken (3% reduction), reducing food waste by 25 percent (3% reduction), and replacing 10 percent of meat protein with vegetable protein (12% reduction). UNH is currently reviewing scenario and projection results to set a N footprint reduction goal.

Colorado State University

CSU is a land-grant university, and therefore has an agricultural research sector in its N footprint, which includes the fertilizer for crops and the reactive nitrogen released from livestock. CSU's footprint without agricultural activities is 287 metric tons N, but with agricultural activities included it is 560 metric tons N. Agriculture makes up the largest sector of the footprint with 273 metric tons N (49% of the total) being released by crop and livestock production. Food production and consumption together make up 20 percent of CSU's N footprint, making it the second-largest sector, after agriculture. Utilities and transportation make up 19 percent and 5 percent, respectively. Research animals, many of which are associated with the veterinary school, make up 6 percent of the total footprint.

CSU already has tertiary sewage treatment, a climate action plan on a path toward carbon neutrality by 2050, and an aggressive alternative transportation plan for bicycle and mass transit. Xeriscaping could reduce fertilizer application on campus, and food labeling and a Meatless Mondays campaign will help

on-campus consumers shift toward a less nitrogen-intensive diet; an expanded composting program will divert food waste.

University of Virginia

UVA was the first institution to calculate its N footprint in 2010.[4] UVA's utilities sector makes up 52 percent of the total N footprint, and UVA is the only institution in this cohort where the utilities N footprint is larger than that of food production. This is due to the fuel mix for the local electricity grid, which is 46 percent coal, as well as on-site fuel use, which also depends on coal burning. Food production is the second-highest contributor to the university's footprint, and it is driven by more than half the student population purchasing meal plans.

UVA's N footprint reduction goal of 25 percent by 2025, relative to a 2009 baseline, is supported by the actions of the university's Office for Sustainability and the Nitrogen Working Group. Current projections for campus growth and energy use would increase the N footprint, but strategies including purchasing renewable energy, energy efficiency improvements, campus heat plant fuel switching, and transportation management will contribute to substantial reductions before 2025. A set of updates to the wastewater treatment plant in Charlottesville resulted in an immediate decrease from the 2010 footprint. Strategies for reducing the food N footprint include implementing vegetarian-themed meals at dining halls, launching a food labeling campaign to educate consumers about the environmental impact of their food choices, working to reduce the overall amount of meat served in dining halls, and minimizing food waste.

Discussion

Institution Nitrogen Footprints

Institution N footprints highlight how community activities impact the global nitrogen cycle through food production and fossil fuel burning. These activities have broad environmental impacts beyond nitrogen, and can also be quantified in terms of carbon, water, and land use footprints.[9,10] The use of multiple footprint metrics could be a powerful tool for understanding the ways that actions connect to various environmental issues (climate, ecosystem health, human health).[11,12] Currently, the Nitrogen Footprint Tool is being integrated into the Campus Carbon Calculator™, which will allow institutions to track and manage their carbon and nitrogen footprints together.[12] Institutions that quantify their nitrogen footprints are able to understand the broader significance of sustainability strategies that affect their consumption of energy and food.

Food production has been shown to be a significant sector for institution nitrogen; it is the largest contributing sector at five of the seven institutions in this study. The N footprint of institutional food consumption is driven largely by the purchase of animal products that release more reactive nitrogen to the environment than plant sources of protein. Institutions that model reductions in beef and meat purchasing see reductions in their N footprints. Another driver of the food N footprint is food waste: Any food that is not consumed or recycled by composting or food donation ends up in a landfill and therefore releases more reactive nitrogen to the environment.

The impact of the utilities sector is seen most prominently at UVA and CSU, where coal is an important source of fuel for the local electricity grid and on-site heating. Other universities have higher proportions of no emission and lower-emitting fuel sources in local electricity grids and on-site.

The one institution that has calculated the N footprint of its agricultural sector (CSU) found that this sector was by far the largest contributor to its N footprint. This sector is similar to the food production sector in that it captures reactive nitrogen lost to the environment as a result of crop and livestock production. However, the agriculture sector footprint results from the university's research and education missions rather than directly from food consumption, and so it cannot be treated the same way as food purchasing for management and N footprint reduction. CSU's agricultural activities might provide an educational model for implementing best management practices and precision farming.

The per capita N footprint varied quite a bit across institutions, from 7 to 29 kilograms of nitrogen per person. Some of the variation could be explained by the proportion of meals eaten on campus, such as at Dickinson where a very high proportion of meals are consumed on campus (94%). However, all of the N footprints were much lower than the value of 39 kg N per capita per year, the amount estimated for the average U.S. citizen.[7] This could in part reflect the fact that the campus footprint does not represent the entire annual footprint for all community members. But this also may represent differences in diet, as well efficiencies of scale that occur in

transportation and utilities within institutions.

Reduction Strategies

The Nitrogen Footprint Tool offers the ability to calculate business-as-usual projections for future years and to evaluate the impact of specific reduction strategies. Though the scenarios included in the NFT are not all-encompassing, they represent the approaches that are seen as strategic and achievable for institutions within the NFT Network. The scenarios associated with energy are designed to align with management strategies that are possible or planned to reduce an institution's carbon footprint. The projected percentage reduction in fossil fuel use from a carbon footprint is used to predict the reduction in an institution's N footprint. This indirect modeling allows users of the NFT to focus on strategies unique to the N footprint, which focus primarily on food. There are several strategies that can be implemented to reduce the reactive nitrogen released as a result of institutional food purchases, consumption, and waste. Many strategies for reducing the institution nitrogen food footprint align with existing sustainability programs, including the Real Food Challenge, the Food Recovery Network, and initiatives such as Meatless Mondays.[13,14,15]

Reducing the amount of food waste going to landfills is a sustainability goal that can be met through several strategies. First, food waste itself can be addressed upstream by various methods to drive down overall food purchasing. Then, any remaining food waste can be diverted to compost or food donation.

Food purchasing changes can also reduce the N footprint. Since beef production has the largest virtual N footprint, one strategy swaps out a percentage of beef purchased with chicken. A Meatless Mondays scenario swaps out a set number of meat-based meals with vegetarian meals.[14] Organic and sustainable food production practices can change the amount of reactive nitrogen lost during food production, and the NFT includes scenarios in which a certain percentage of food purchases are organic or sustainable. Preliminary study suggests that the N footprint of organic food production does not differ vastly from that of conventional food production practices; therefore, a strategy of purchasing more organic food will likely have little impact on the overall institution N footprint, other environmental benefits notwithstanding.[16]

The sustainable food production scenario assumes that food producers use currently available technology to reduce farm nitrogen losses.[12] Although this scenario has a noticeable impact on the N footprint, sustainable farming practices are difficult to track and verify. The NFT can also calculate the impact of local food by reducing the number of food miles (the distance food is transported from production to consumer) associated with each product. However, local food purchasing has a negligible impact on the food N footprint because the amount of reactive nitrogen released during food transportation (NOx and N_2O) is much lower than the reactive nitrogen released during food production.

Energy scenarios align the N footprint with goals for reducing consumption and reducing greenhouse gas emissions by strategies such as fuel-switching, for example replacement of coal with natural gas that has a lower nitrogen release. Energy reduction goals are already an important part of all institutions' sustainability plans, and N footprint scenarios modeled on carbon footprint reductions often result in a large reduction in the N footprint. (For a comparison of average nitrogen footprint reductions from food and energy scenarios, see Leach et al.[12])

Institution Nitrogen Footprint Reduction Goals

Currently, UVA is the only institution to have a N footprint reduction goal approved by its governing body, the Board of Visitors. However, each institution in the Nitrogen Footprint Tool Network has identified actions to reduce its N footprint and some are working toward implementing institution-wide reduction goals. UNH plans to set a N footprint reduction goal in 2017 with the support of the UNH Sustainability Institute and Ecosystem Task Force, which will align with its carbon neutrality goal by 2100. Brown University plans to set a N footprint reduction goal after further assessment of scenarios that might have a larger overall impact. Current plans for EMU's N footprint call for a 20 percent reduction by the end of 2020. Colorado State University plans to address its N footprint with an official reduction goal, which will integrate the strategies from its Climate Action Plan with several actions focused on the N footprint.[17]

Food and energy reduction strategies are both important components of managing an institution N footprint. Since energy reduction strategies for N footprints closely align with those aimed at reducing greenhouse gas emissions and are already part of many institutions' GHG reduction goals, the NFT adds the ability to address the N footprint of food consumption and other activities with tangible reduction goals. Purchasing local food, though it provides other benefits, does little to reduce an institution's N footprint. The food purchasing strategies with the greatest potential impact are reducing animal products purchases and increasing purchases of sustainably produced food. How to implement these strategies at an institutional level will take further discussion with food providers and education for consumers, but could be addressed with sustainable food purchasing goals that are in agreement with N footprint reduction strategies. Strategies around food, especially, can be driven by outreach and conversation within the student body about the impact of food consumption choices and food waste. Beyond the reduction strategy scenarios included in the NFT, institutions may have the option to purchase nitrogen offsets.

While reduction actions often require cost and effort, many can be achieved at low cost and with the effort of student volunteers. Certain strategies may even contribute to cost savings. Renewable energy production and building energy efficiency improvements often have large up-front costs and long-term savings potential. Waste reduction and consequent efficiencies in purchasing for food and other materials have the potential for cost savings in the short term. Addressing institution carbon and nitrogen footprints simultaneously can strengthen the

argument for up-front sustainable energy costs, while short-term cost savings can also be achieved by driving food consumption changes with outreach and awareness. Reduction efforts at the institutions included in this article are discussed in greater detail elsewhere.[8,11,17]

How to Get Involved

The NFT project is transitioning to a new model for participation that will be open to many more institutions by the end of 2017. The Microsoft Excel-based version of the tool, available online,[6] can be downloaded and used for free. A new version of the NFT will be online as part of a combined carbon and nitrogen footprint tool for institutions, which is supported by the UNH Sustainability Institute.[12]

Conclusion

The Nitrogen Footprint Tool has proved capable of assessing the environmental impact of a diverse group of institutions, and it highlights the importance of food and fuel consumption. The nitrogen footprint of food production was the largest contributing factor to the institution total for five of the seven institutions. At CSU, agriculture comprised a very large component of the overall nitrogen footprint (49%), revealing the importance of accounting for research activities. The consumption of fossil fuels, especially coal, drives a large portion of institution nitrogen footprints, making utilities the largest component of the N footprint at UVA, for example.

Food and fuel consumption are the two areas in which sustainability programs have the largest opportunity to decrease an institution's

N footprint. Currently, widespread programs to reduce greenhouse gas emissions address the energy component of the N footprint, but there are no consistent or significant efforts to reduce the impact of food consumption. Institutions, because of their buying power and common mission of education, have a large role to play in shifting diets and food production systems to be more sustainable. The NFT can be used to determine the most impactful management strategies. Because the tool measures nitrogen emissions from all institutional sources, it can identify unique reduction opportunities for any user.

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