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Colorado State University Nitrogen Footprint FY21 Research Report

SUPER Program:
Skills for Undergraduate
Participation in Ecological Research

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Skills for Undergraduate Participation in Ecological Research

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Abstract

The rise in nitrogen pollution is causing devastating impacts on the air and water quality, eutrophication of bodies of water and coastal regions, stratospheric ozone depletion, and climate change. As a part of CSU's sustainability effort, the Nitrogen Footprint team has calculated and analyzed the nitrogen footprint for the 2021 fiscal year. A nitrogen footprint calculates the reactive nitrogen from food production and consumption, utilities, transportation, fertilizer, research animals, and agriculture. We contacted CSU Housing and Dining staff to collect information on food purchases. To address our research question, we processed the data by formatting the raw data and uploading it to SIMAP in accordance with the instructions provided by the Nitrogen Footprint team to calculate the Nitrogen Footprint data for the entire fiscal 2021 year for making future reduction recommendations. We expect to compare the differences in nitrogen footprints between this year and previous years, and create pie and bar charts to compare the entire emissions and categories in food, utilities, fertilizer, etc. Food Purchase is CSU's largest source of nitrogen waste and is one of the easiest ways the research can be applied for recommendations for nitrogen reduction.

Introduction

Universities are large sources of nitrogen waste and in pairing with the N waste of the cities they are in and the other concentrated human activities, the pollution can cause devastating environmental damages. Colorado State University recognizes the negative effect of its nitrogen footprint and set a goal of decreasing the nitrogen footprint in 2014 (Kimiecik et al., 2017). Although the N reduction goal was only formalized in the 2020 CSU Sustainability Plan. Set in place by Stacey Baumgarn putting language to reduce CSU's N footprint in the plan as a result of SUPER students' work. To make strides towards its sustainability goals, as a large land grant university, CSU calculates its nitrogen footprint to track and find areas to reduce the nitrogen footprint. Food production and consumption, utilities, transportation, fertilizer, agricultural animals, and agriculture are some of the sources of CSU's nitrogen (N) waste. For this project, the CSU's nitrogen footprint was calculated for fiscal year 21 (07/01/2020 - 06/30/2021). This nitrogen footprint calculation has its backing from the work of ecologists and researchers from multiple universities and expands on the previous years' calculations (Leach et al., 2013, Castner et al., 2017).

Stakeholders

The main stakeholders for the nitrogen footprint project are CSU faculty, staff, and students, Agricultural Experiment Stations and other research facilities around Colorado, and the operational offices of CSU, including Housing and Dining Services (HDS), Facilities Management, Facilities Maintenance, and Fleet Services, as well as the President's Sustainability Commission, and Laboratory Animal Resources.

Glossary

Nitrogen footprint: Nitrogen footprint refers to how much reactive nitrogen is emitted from an institution as a product from the institution's usage of resources. It is a tool used to measure nitrogen from all sources, including the production, processing, and ingestion of food, public utilities, transportation, fertilizers, agricultural animals and agriculture.

Unreactive nitrogen: Di-nitrogen nitrogen gas makes up 78% of Earth's atmosphere, but is an inactive element because of the very strong triple bond N≡N bond between nitrogen atoms. Given the position of the nitrogen atom in the periodic table, this strong trivalent bond requires a large amount of energy to break before the nitrogen atom can react with other atoms.

Reactive nitrogen: Reactive nitrogen, including ammonia or nitrate, includes every molecule of nitrogen with biological, photochemical, or radiological activity (Erisman et al., 2018). Reactive nitrogen is essential to humankind's livelihood because it is the major ingredient in DNA and proteins. It is not only a by-product of energy consumption but also crucial for the making of food and all biological processes. It also can cause a large range of human and environmental health concerns, including acid rain, smog, accelerated growth in terrestrial ecosystems, soil leaching, and algal blooms (Castner et al., 2017), as shown in *Figure 1*.

Figure 1.

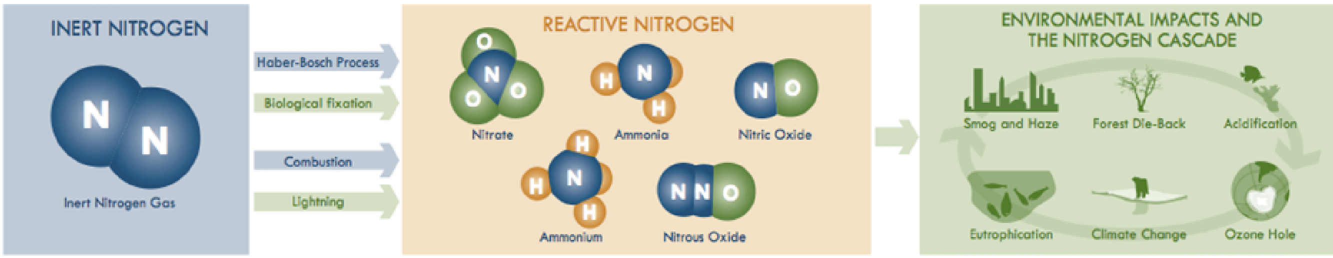

Figure 1. The nitrogen cycle, from inert nitrogen converted to reactive nitrogen to the impacts on the environment. Copyright Andrew Greene 2011.

SIMAP: SIMAP (https://unhsimap.org) is a carbon and nitrogen-accounting platform website where campus-wide sustainability can be tracked, analyzed, and improved. It can be used for tracking and calculating the nitrogen and carbon footprints of campuses. Once the data are uploaded, SIMAP uses its emission factor data to estimate the emissions from the data entered.

Background

CSU is a part of the Nitrogen Footprint Network established in 2014. The NFT Network consists of twenty US and international institutions that have committed to assessing their own nitrogen footprints and reducing the NFT. The nitrogen footprint tool was first developed by Dr. Alison Leach for the University of Virginia and was expanded to other colleges. The N-print tool was expanded over time to include C accounting, and now SIMAP is the software that calculates the nitrogen and carbon footprint for institutions. SIMAP gathers the weight of items that produce an N-print including food purchases, transportation/commuting, fertilizer use, and animal research, and uses an emission factor to estimate the N-print from the reported data. The official software's website is https://unhsimap.org/.

During FY21 dining rooms and halls were closed to seating and only offered to-go meals due to COVID-19 restrictions. It completely changed dining services on campus, not to mention everything else.

Study area boundaries

Because reactive nitrogen causes a large number of human and environmental health problems (Castner et al., 2017), and reactive nitrogen production is associated with humans and causes serious impacts on the consumption of food, energy, etc., CSU, as one of the campuses that produce food and energy-related impacts, is committed to developing in sustainability to reduce campus problems caused by Nr. Colorado State University was an early adopter of the nitrogen footprint method to calculate the school's N pollution (Kimiecik et al., 2017), and its Nitrogen Footprint Project was first launched in 2016 to develop strategies to reduce Nr and raise awareness of the environmental impact of reactive Nr (Kimiecik et al., 2017). CSU has committed to sustainability and to 100% renewable energy by 2030 (Miyamoto & Dollard, 2021). This means that CSU must meet high standards of campus sustainability in all measurement categories, which is why we continue to study the nitrogen footprint. Our study site is primarily our main campus, which is represented in *Figure 2* by the land covered, but CSU owns and manages a 1,433-acre foothills campus, 1,575-acre agricultural campus, 1,177-acre Pingree Park mountain campus, and 4,038 acres of land for research centers and Colorado State Forest Service stations outside of Larimer County which map is not displayed.

Figure 2.

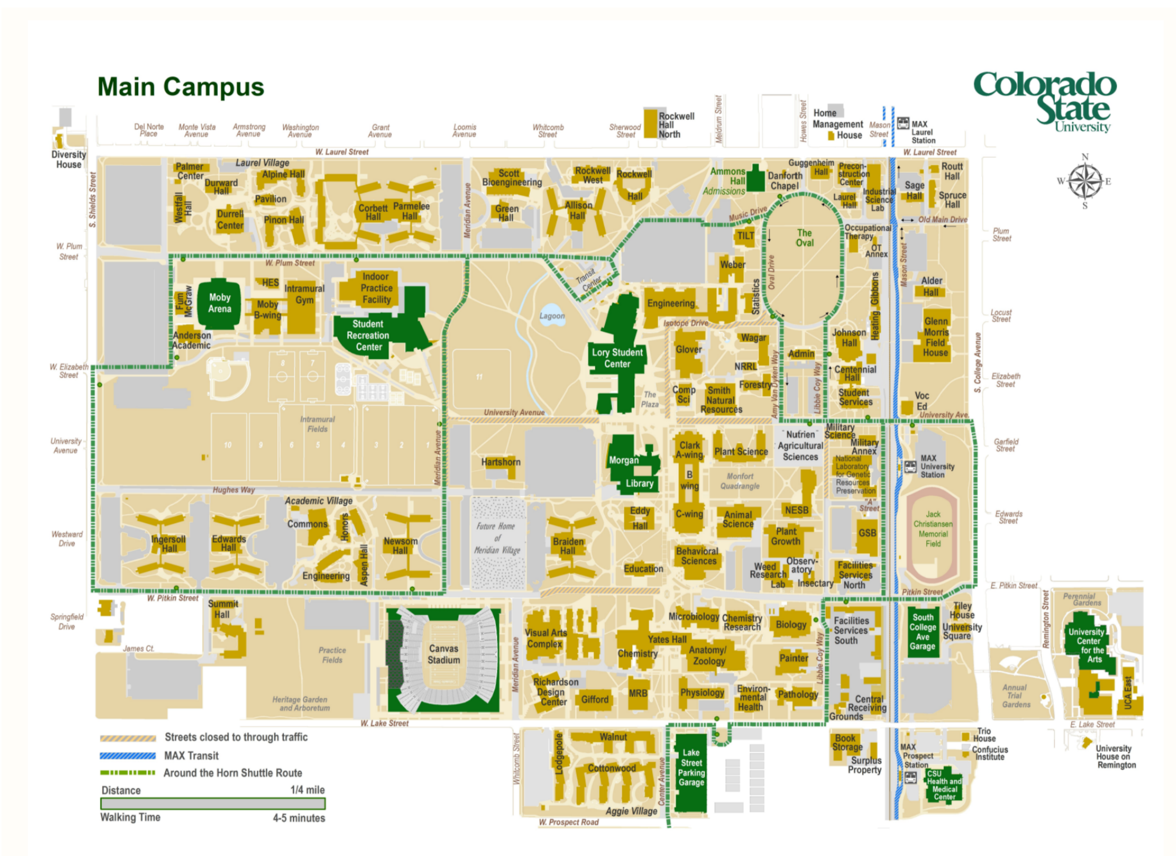

Figure 2. Map of Main Campus at CSU in Fort Collins, Colorado (CSU).

Previous work

Research and calculations from previous years have shown that the main sources of the CSU's nitrogen footprint are food purchases and utilities. Based on previous research team analyses of Housing and Dining food procurement data and research animal inventories, as well as data provided on transportation and energy consumption, researchers calculated the total nitrogen footprint of the campus. Unlike previous years, the nitrogen footprint for FY20 used October and April and excluded February in order to better represent the change in purchasing for the university that closed at the end of March due to COVID-19. The FY20 footprint is much lower than the FY19 footprint due to the unique circumstances of the 2020 campus closures.

Gaps in knowledge

People don't know that energy use, food consumption, and transportation create nitrogen waste, nor do they know that nitrogen has such a huge impact on our environment and physical health. More remarkable is that people aren't aware that calculating nitrogen footprint is important in making decisions to protect the environment because without any reports on nitrogen and its impacts we wouldn't be aware of the issue and how much to reduce waste. In order to compensate for these, people need to take the opportunity to improve themselves by studying and learning about relevant knowledge. In addition, people need to be curious and research the topics that they feel like they know very little about. Another gap in knowledge is the emissions intensities of reactive N differences between animal and vegetable-based products which many individuals do not know. According to Figure 3, based on the "The nitrogen footprint of food products in the European Union" report the range of gram N per kg of animal products was 0-350, whereas the range of gram N per kg of vegetable products was 0-15, meaning on average animals products have the highest intensity of reactive N.

Figure 3.

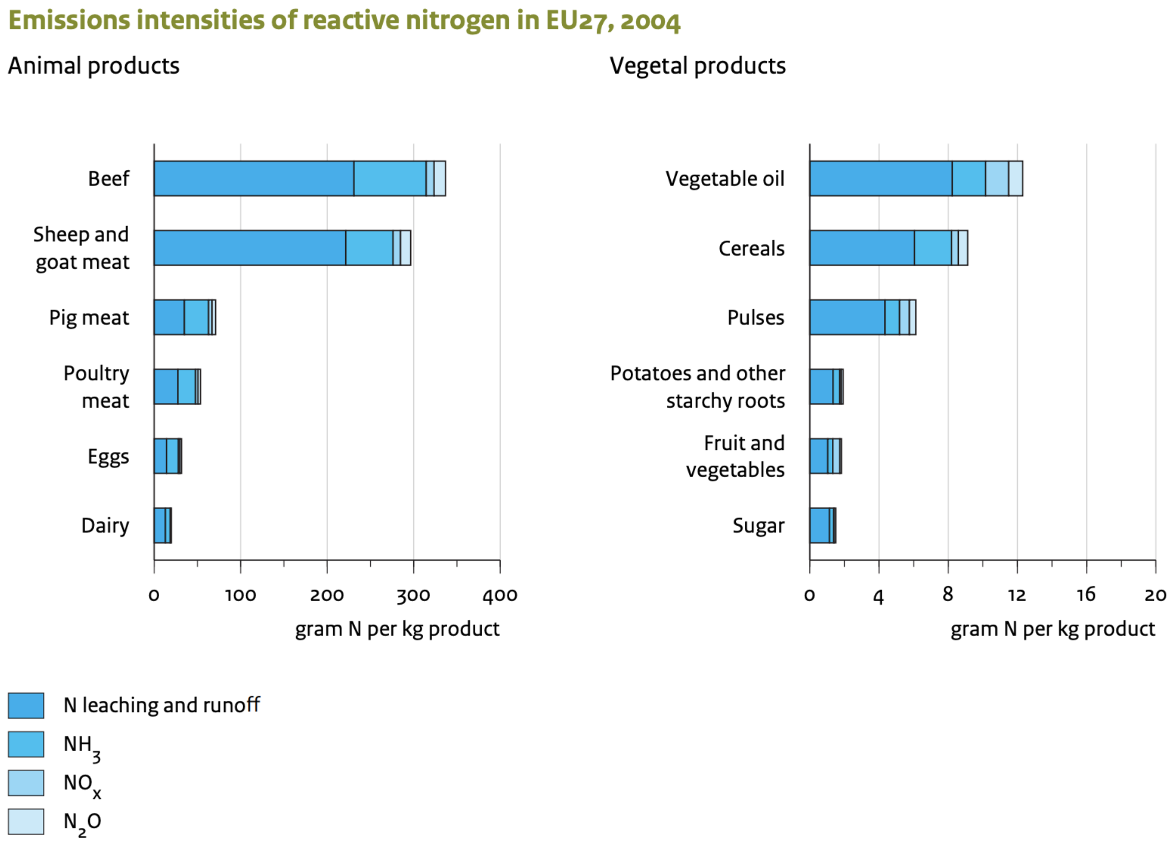

Figure 3. Emission intensities per kg food product for N_2O, NO_x, NH_3 and N leaching and run-off for the twelve main food commodity groups (six animal products, left; six vegetable products, right), based on the CAPRI-model (Leip et al., 2014). Note differences in scale between the two figures.

Research questions

What is Colorado State University's Nitrogen Footprint for the fiscal year 2021? Did CSU Housing and Dining reduce the Nitrogen Footprint in the Food Purchases category after last year's team's recommendations?

Expected outcome, or research (null) hypothesis:

The CSU Nitrogen Footprint for the fiscal year 2021 shows Housing and Dining Services attempts at N reduction have made no difference in reducing the Nitrogen Footprint.

Emergent hypothesis:

The emergent hypothesis is the Nitrogen Footprint for the fiscal year 2021 shows Housing and Dining Services were successful at reducing the Nitrogen Footprint.

Explanation:

After Housing and Dining met with last year's SUPER students to discuss future N-print reductions, they stated they would like to reduce food purchases N-print by 5%, but didn't formalize a plan. Since HDS didn't set a date to start N-print reduction, they most likely didn't enact any N reduction plans. As well as, HDS had to handle the difficulties of feeding a university during COVID-19, most likely affecting plans for future transitions. With all consideration, the FY21 food N-print will not be less than FY20.

Methods (Figure 4)

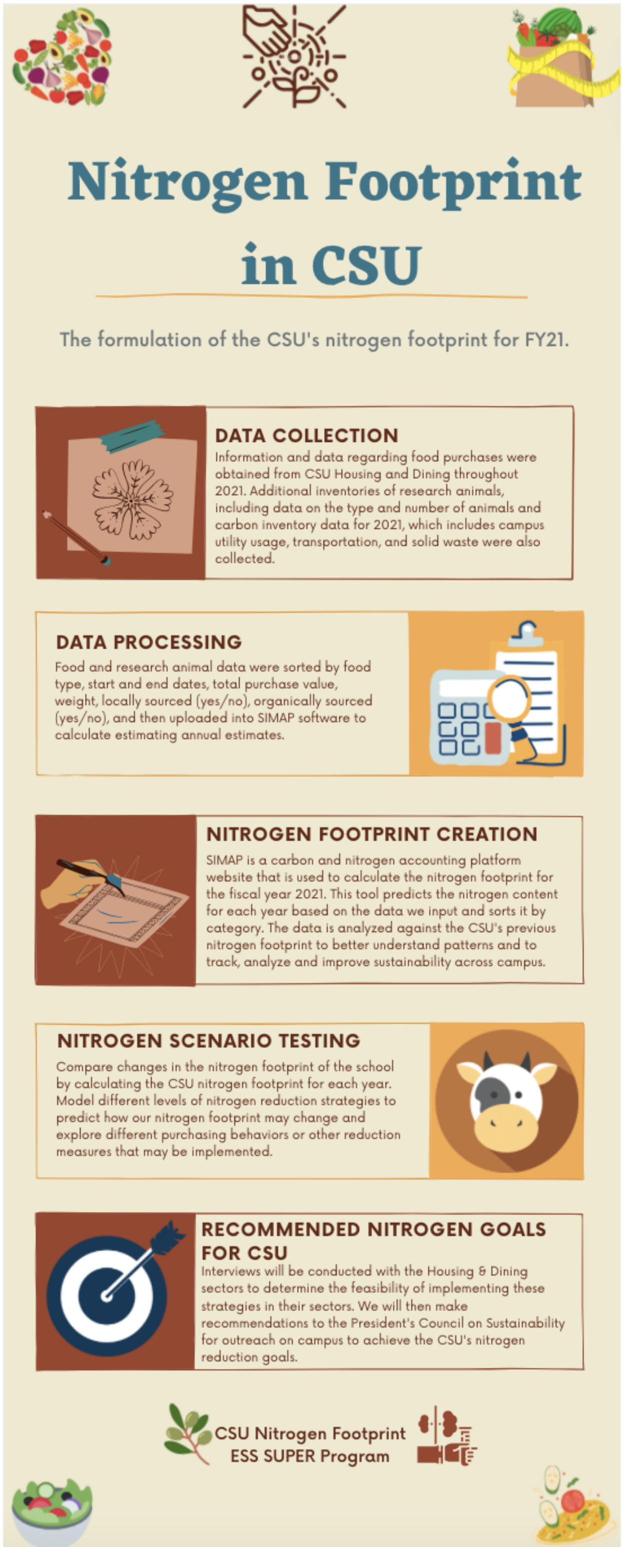

Figure 4. Methods Infographic depicting the process of creating the FY21 N footprint.

Data Collection

We contacted Mary Liang and Joseph Hostetler in the CSU Housing and Dining Department, to gather information on food purchases, which included the name of the item, weight, quantity, package size, vendor, dining unit, price per item, and received date (*Figure 4*). In addition, we obtained a list of research animals from CSU that included data on the types and numbers of animals, as well as carbon inventory data for 2021 from Stacey Baumgarn in Facilities Management that included campus utility use, transportation, and solid waste. This year we acquired data for the entire fiscal year 2021 in anticipation of calculating and comparing the data to provide valid and comparable information for future nitrogen reduction recommendations.

Data Entry and Processing

We processed the procurement data from Housing and Dining by formatting the raw data according to the instructions provided by Dr. Alley Leach and the Nitrogen Working Group. We downloaded the data for all of 2021, uploaded it to Google Drive. Unique values were identified by using the 'remove duplicates' tool to identify the unique items. The VLOOKUP formula was then used to identify the Itemid, Receiveunit, Unit name, Rcvdate, and Rcvprice. To find the total amount, the SUMIF formula identified the total purchases and then the 'sort by descending' option organized the highest dollar amount to the least. All purchases greater than $3000 were further analyzed. The total weight is calculated in different units including kilograms, pounds, and US Gallons; we converted them all to kg. The items were categorized based on food type for SIMAP and included Beef, Pork, Chicken, Cheese, Eggs, Milk, Liquids, Grains, Fish, Fruits, Nuts, Oils, Beans, Spices, Potatoes, Coffee and Tea, Sugars, and Vegetables. For food to belong in a category, the category needed to make up at least ⅓ of its overall weight. Because SIMAP requires food data in a specific format, we uploaded the specific template to Google Drive and converted all food weights to kilogram, pound, or US gallon. In order to facilitate the calculation and processing, we converted all weights to kilograms and entered them into the SIMAP template. After processing and validating the data for these categories, it was uploaded to SIMAP as the food portion of the nitrogen footprint. CSU Housing and Dining provided data that included the item, weight, number received, date received, whether the item was from a local source, and whether it was organic. The list of CSU research animals including the type and number of animals and the remaining data was obtained from Stacey Baumgarn in Facilities Management.

Data Analysis by SIMAP Calculations

The analysis of the nitrogen footprint data occurs in SIMAP software, which was taken from the total number of meals served in the cafeteria over the course of a year to collect food information to be used in conjunction with CSU's carbon footprint study.

Results

The results that are documented are preliminary because when compared to previous years' results there are significant differences that require further analysis in order to produce valid results. The FY21 total nitrogen footprint is 164.73 N metric tons. 36.3% of the total footprint is from food purchases, represented in *Figure 5*. In FY21 the food N footprint is 35.2 N metric tons less than in FY20, whereas the overall nitrogen footprint is 44.32 N metric tons less than in FY20. FY21's CO2 footprint from food was 2291.16 N metric tons less than FY20. See *Figure 6*. Although the FY21 total food N footprint was less than FY20 we will discuss how the meals purchased for FY21 dropped 50.4% from last year's meals purchased affecting the total nitrogen per meal served.

Figure 5.

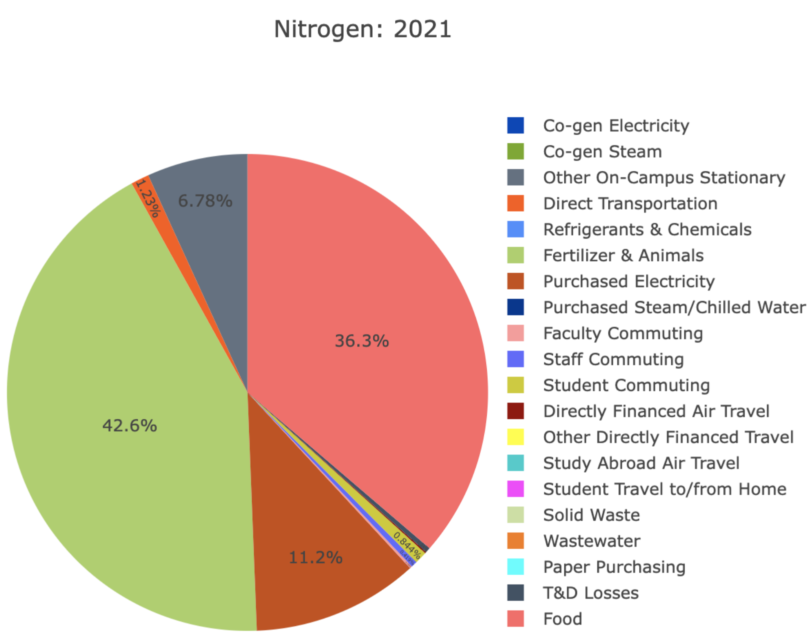

Figure 5 is a pie chart representation of the FY21 Nitrogen Footprint divided in the nitrogen sources.

Figure 6

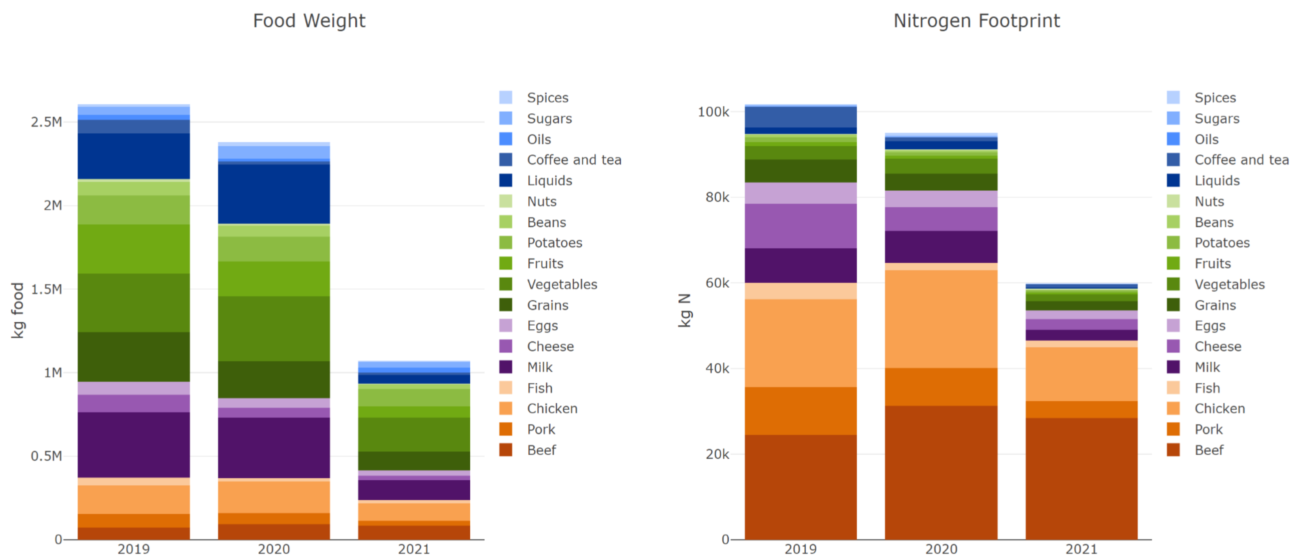

Figure 6 is the stacked bar charts representing the comparison of the 2019, 2020 and 2021 nitrogen footprints.

As shown in *Figure 7*, when looking at the food categories by weight in the left pie chart, the largest categories are vegetables, milk, and grains (18.9%, 11.1%, and 10.7% respectively). Weight per food category does not translate equally in terms of the nitrogen footprint. For nitrogen usage, the largest categories are, shown in the right pie chart, beef, chicken, and pork (47.6%, 21%, and 6.62% respectively).

Figure 7

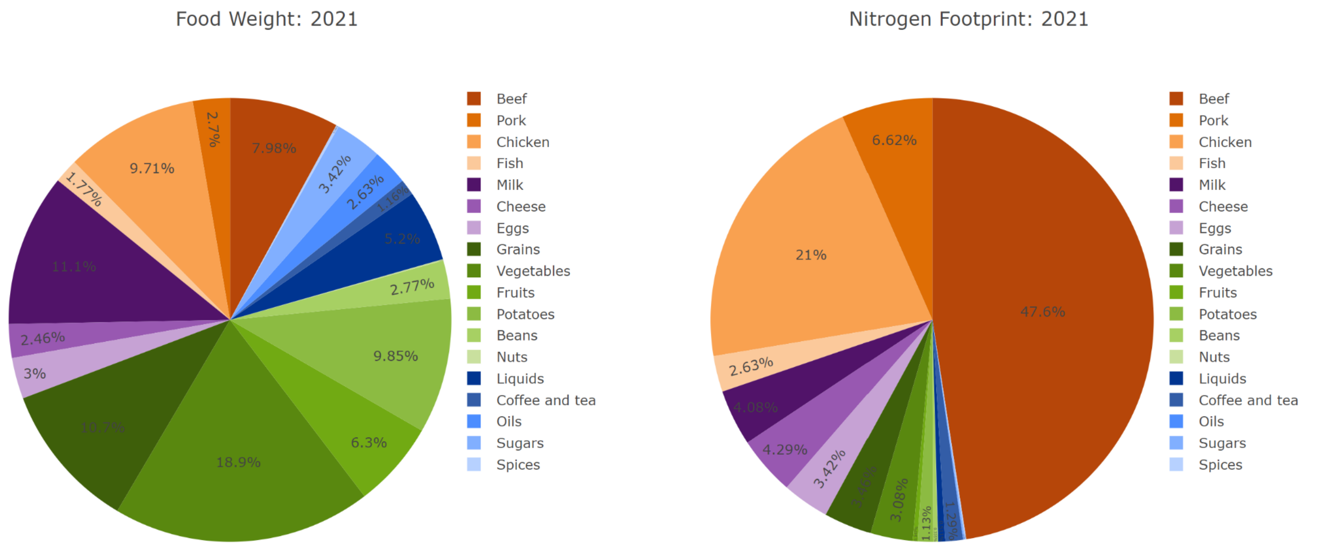

Figure 7 is the pie chart representation of the FY21 Food Weight and Nitrogen Footprint for the food categories.

Represented in *Figure 8*, is the ratio of food nitrogen footprint per meal served for FY19-FY21. Where the total food N footprint was divided by the total meals served for each year. As shown in the figure, FY21 food N footprint is substantially larger than previous years growing by 80% from FY20 to FY21. Where it was observed that FY21 meals served was 50.4% less than FY20.

Figure 8.

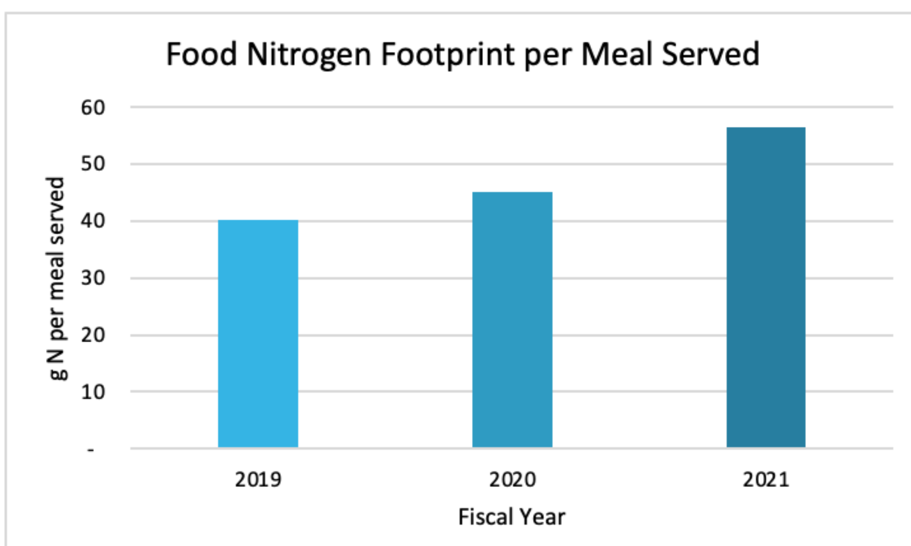

Figure 8 illustrates the ratio of Food Nitrogen Footprint and Meal Served for the fiscal years from 2019 to 2021.

After an analysis of the percentage of total weight by food category for FY19-FY21, *Figure 8* shows significant differences between FY21 compared to FY19 and FY20. Comparisons of the percent by food category between years raise questions and cause the data to be preliminary until we check whether these differences are correct or due to calculation errors. Beef purchases have doubled in percentages and chicken purchases have increased 2% from FY20 whereas fruit purchases decreased by 3% and a 4% decrease in milk purchases from FY20.

Table 1.

Table 1 illustrates the percentage of total of weight by food category and year.

% of total weight by food category and year			
Category	2019	2020	2021
Beans	3%	3%	3%
Beef	3%	4%	8%
Cheese	4%	2%	2%
Chicken	7%	8%	10%
Coffee and te	3%	1%	1%
Eggs	3%	3%	3%
Fish	2%	1%	2%
Fruits	11%	9%	6%
Grains	11%	9%	11%
Liquids	10%	15%	5%
Milk	15%	15%	11%
Nuts	0%	0%	0%
Oils	1%	1%	3%
Pork	3%	3%	3%
Potatoes	7%	6%	10%
Spices	0%	1%	0%
Sugars	2%	3%	3%
Vegetables	13%	16%	19%

Discussion

Based on results data and graphs in SIMAP, FY21 results show a reduction in the overall nitrogen footprint, as projected in the assumptions. However, this decrease is likely due to the campus being largely closed throughout the year due to COVID-19, students and employees have reduced the number of meals and commuting times to campus. And as we calculated the data for the whole FY 2021, compared with previous years only in March, April, and May, it was limited in some aspects, the overall reduction has also become substantial due to COVID-19 as well. The carbon footprint also shows a small downward trend, with the largest differences being in Directly Financed Air Travel, followed by Purchased Electricity. For the nitrogen footprint, the most significant decrease was in food; the energy footprint decreased only slightly, as most buildings on campus continued to operate as usual. Regarding meat, the nitrogen footprint of chicken, pork, fish and beef has been reduced compared to the past. However, because the nitrogen footprint of beef products is very large, the huge potential for reducing beef purchases is still very valuable. In addition, liquids, including Coffee and tea and Milk also showed a downward trend this year.

This year's calculations help us understand what a normal CSU annual footprint baseline is as the basis for CSU's reduction strategy because it can be used for comparing COVID-19 affected years vs not. Also since this year's calculation is for a full year compared to the previous three calculations and counts purchases over $3,000, it provides a good comparison for each subsequent year's data. Compared to previous years, some items, such as spices, may have been purchased in bulk in one of our sample months but not in others, and items that may have been purchased in bulk over several months are not counted, FY21's data is relatively objective and accurate.

As mentioned previously, the results are preliminary because they are significantly different from previous years, which arouses questions to be answered before we can validate the data. The FY21 meal served dropped a little more than 50% from FY20, but why has the nitrogen footprint per meal served increased by 80% from last year? According to Stacey Baumgarn, the majority of food served at the dining halls was prepared food packaged for dorm/home eating and CSU held no outside event (meals served there). This brings forth questions for CSU Housing and Dining Services. How did the number of students living and occupying CSU Housing change from previous years? Did the food menu change from previous years to accommodate the packaged meals? Possibly serving more animal protein and fewer side items (vegetables, fruits, grains) considering how the package meal sits sometime before someone picks it up and side items might get soggy or not up to food service standards. According to Figure 9, FY21 beef weight doubled from FY20 and chicken weight increased by 2%. What caused these increases in animal protein?

For the next steps in FY21, we will share these results with HDS and compare FY21 findings to their results and understanding, then follow with a discussion on how to validate them. Since we have found that beef, even if it has a small percentage of the food weight, can have a very large nitrogen footprint, we recommend reducing the amount of beef consumed and purchased in favor of other meats or vegetables instead. For the vegetable section, we have seen a decrease in vegetable consumption and purchases this year as well, and since we are not sure if this is due to COVID-19, we are still recommending purchasing a larger percentage of vegetables-based products for next year's purchases.

Regarding CSU, we can raise awareness on campus and recommend that students and staff take action to change their thinking, including reducing their meat and protein diets and increasing their vegetable intake. A plant-based educational outreach program could be the step that can influence individual food choices and demands. A report “Implementing Meatless Monday in Food Service Operations: Best Practices” from Johns Hopkins guides the many dynamics of establishing a reduction of animal products at universities. It states that education among the members of the institution is a vital component of the implementation of the campaign, the most effective educational outreach is peer to peer (“Implementing Meatless Monday in Food Service Operations: Best Practices,” n.d.).

In addition, in terms of transportation, driving less and using public transportation more often will help reduce both the nitrogen and carbon footprints. The university can also choose energy-efficient alternatives when purchasing teaching tools and lighting. The power gathered from the little things students can do to help reduce their nitrogen footprint can also help. As well as, learning to understand the impact of nitrogen footprint and its solutions, participating in environmental activities, turning off the lights when leaving the classroom, using paperless writing, and setting appropriate temperatures for air conditioning in the dormitory.

Conclusion

The nitrogen footprint of Colorado State University in FY21 is 164.73 N metric tons in total, with the food nitrogen footprint of 59.85 N metric tons; CSU can use this calculation and our projections to build a long-term strategy to mitigate nitrogen in the Housing and Dining department. Stakeholders, including students and faculties, can start small by changing eating habits to eat energy-efficient foods and choose more plant proteins; reduce food waste and buy only what they need; and choose organic to better recycle nitrogen.

Acknowledgments

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Appendix 1

Methods:

1. Data Collection

We contacted CSU Housing & Dining to collect food purchasing information including the item, weight, received quantity, date received, if the item was locally sourced, or if it's organic. We obtained the research animal inventory including mice, reptiles, chickens, birds, cows, pigs, etc, for CSU; these data include the animal type and the amount. The FY21 carbon inventory data were received from Stacey Baumgarn in Facilities Management, including campus utility usage and transportation data.

2. Data Entry and Processing

We processed purchasing data from Housing and Dining because SIMAP requires food data in a certain format, and we edited the raw data to match these requirements.

Spreadsheets: instructions provided by Alley Leach, Ph.D., and the Nitrogen Working Group. Data entry and processing were completed by Laura Lenhart and Xiaowen Sun.

1) **Pre-processing**: Download 2021 fiscal year's data, rename each file, and create a new tab for data extraction.
2) **Identify Unique values**: Rename the tab 'Unique Values' and copy and paste the item name into this tab. Use the 'remove duplicates' tool to identify all unique items. Using the VLOOKUP formula identifies Itemid, Receiveunit, Unit name, Rcvdate, and Rcvprice.

   Example Format =vlookup(A2,'FY21 RAW'!A:H,2,FALSE)

   (itemName, The entire table to choose from, row in the table to look for value, always FALSE)

3) **Find Total Amount**: Using the SUMIF formula to identify the total amount of items purchased and the total purchase amount. Use the 'Sort by descending' option to organize from the highest dollar amount to the least. After sorted copy-paste all data in a new tab 'AS VALUES'. 300 rows, the cut-off price of $2,915.10, in purchases will be analyzed.

4) **Identify total weight**: To calculate the total weight, create a new column and label 'total weight' then multiply the rvqty by Receive unit for each item. Create a separate column for the units: lbs, ounces, or kg.
5) **Identify Food type**: Using SIMAP categories of Beef, Pork, Chicken, Cheese, Eggs, Milk, Liquids, Grains, Fish, Fruits, Nuts, Oils, Beans, Spices, Potatoes, Coffee and Tea, Sugars, and Vegetables, use drop-down menus to select the up to 3 main categories that fit each item.
6) **Enter data into SIMAP:** Copy-paste relevant columns into the SIMAP template for processing.
7) **Run SIMAP simulations**: Using SIMAP's simulation tool, we will project CSU's footprint across the months we didn't gather data for. We will also run simulations on how different food purchasing methods would affect the footprint.

3. Data Analysis

For the nitrogen footprint, data analysis occurs in the SIMAP software; this is a platform for tracking and calculating campus nitrogen and carbon footprints. Deciding the boundaries is important for the calculations for footprints for this project only the CSU dining halls. These tools tracts all scope 1, 2, 3 reactive nitrogen from the major pollutant sources agriculture, transportation, and uses food information collected with the total number of meals served in one year. This information from the dining hall is used in combination with research collected for CSU's carbon footprint.

4. Data Interpretation

We will be creating pie charts to see the distributions of food type by weight. We are computing the total reactive nitrogen produced in the FY21 by Colorado State University. To visualize which sources have the greatest impact on the nitrogen footprint we will create pie charts to compare food, utilities, fertilizer, etc. We will also create bar graphs to compare 2021's emissions to previous years.