Comparing Subnational Ecological Footprints for the United States, 2010

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ABSTRACT

The Ecological Footprint is an environmental impact model widely used in ecological economics. Per capita Footprints are well documented at the national level but there is a dearth in knowledge about per capita Footprints at the subnational level, or comparisons of per capita Footprints between groups within a nation. In this paper, I propose the first complete demographic analysis of Ecological Footprints within the United States using 2010 National Footprint Account data in order to examine environmental burden allocation at the subnational level. For the national average consumer, household expenditures that resulted in the largest Footprints were electricity, public and other transportation, food service, and healthcare. Demographic characteristics, such as race, education, marital status, and housing tenure, are associated with distinct, non-uniform consumption patterns and per capita Footprints for many demographic cohorts differ from the national average. It is important for policy makers in the United States to consider the different causes of consumption heterogeneity and to be able to benchmark industries and consumer products by environmental impact.

KEYWORDS

allocation method, input-output, demographic analysis, population composition, household consumption

INTRODUCTION

The modern Ecological Footprint was formally introduced by William Rees and Mathis Wackernagel in the 1990s (Rees 1992, Rees 1996, Wackernagel and Rees 1997). The Ecological Footprint was designed to represent actual human consumption of biological resources and generation of wastes in terms of appropriated ecosystem area. National Ecological Footprint account methodologies are considered to be well developed and data extracted from these accounts are used as starting points for smaller scale analyses (Collins *et al.* 2006, Kratena 2008, Moran *et al.* 2008, Niccolucci *et al.* 2008). Country-level Footprint assessments have been completed for many nations; some nations have been analyzed multiple times under different methodologies (Haberl *et al.* 2001, Lenzen and Murray 2001, Wackernagel *et al.* 2004a, Galli *et al.* 2012). The most widely used methodology for national Footprint accounting is Global Footprint Network's National Footprint Accounts (NFA), developed and maintained by Global Footprint Network and more than 75 partner organizations (Wackernagel *et al.* 1999). These accounts cover more than 180 nations and extend from 1961 to 2016. The NFA are based on a variety of international and national data sources, including databases from the United Nations Food and Agriculture Organization, the International Energy Agency and the United Nations Statistics Division (FAOSTAT 2007, IEA 2007, UN Comtrade 2010). The National Footprint Accounts follow a specific methodology for expressing Ecological Footprint and biocapacity in terms of 'global hectares': hectares normalized to have world-average biological productivity in a given year (Galli et al., 2007). The ongoing process of improving the quality and accuracy of these accounts is overseen by Global Footprint Network's National Accounts Review Committee, with research contributions solicited from the global community of Footprint researchers.

The National Footprint Accounts can be used to create a consumption allocation model by allocating demand for a given bioproductive area to the consumer responsible for the use of the materials produced by that area. The Ecological Footprint accounts for land use embedded in both domestic production (Ecological Footprint of Production) and international trade (Ecological Footprints of Import and Export). By modeling economic production and consumption as human demand on the Earth's resource regenerative capacity, the Ecological Footprint can describe existing and past relationships between humans and the environment. The Ecological Footprint's inherent relationship to the physical limits of global biocapacity makes it well suited for benchmarking in sustainable development policy (Kitzes *et al.* 2008). It also pushes the field of sustainability target setting beyond anthropogenic greenhouse gas emissions because of its description of total human demand on many different ecosystems and natural resources (Barnosky *et al.* 2012).

Global Footprint Network first constructed National Footprint Accounts for the United States in 1961 and published the latest complete edition for 2010. While there have been some scientific studies in applying the United States NFA to analyses at the city and state level (Moscovici *et al.* 2015, Lawrence and Robinson 2014), there hasn't yet been a comprehensive subnational demographic analysis performed for the US Footprint. A subnational analysis is necessary because with U.S. policy makers will have to find ways to reduce per capita environmental impact due to the nation's pledge to the Paris Agreement (UNFCCC 2015). Without high resolution data on U.S. consumers, policy makers have no way of allocating environmental impact burden accurately and fairly. Subnational analyses are also a recommended focus topic for future Ecological Footprint methodology development (Kitzes *et al.* 2009)

In this paper, I propose the first high resolution demographic analysis that allocates national per capita Ecological Footprints for the United States in 2010 to household consumption expenditures using environmentally extended input-output analysis (Kitzes 2013). This expands upon a Consumption Land Use Matrix methodology employed by researchers allocating United Kingdom Ecological Footprints to household consumption expenditures (Weidmann *et al*. 2006).

METHODS

Disaggregating the U.S Footprint by industry

Ecological Footprint Accounting (Borucke *et al.* 2013) is a resource and emissions accounting tool constructed to measure direct and indirect human demand for planet Earth's regenerative capacity (biocapacity). The Ecological Footprint accounts for demand in six main types of bioproductive areas, each providing different resources and ecosystem services: (1) cropland for plant-based foods and fiber products, (2) grazing land for animal-based foods and other animal products, (3) fishing grounds for fish-based food products, (4) forest land for timber and other forest products, (5) carbon uptake land for absorption of anthropogenic carbon dioxide emissions, and (6) built land representing the physical space occupied by infrastructure and housing. The National Footprint Accounts for the United States are catalogued at the aggregate level (e.g. crop land Footprint) and at the individual classification level (e.g. Bananas). The U.S. NFA uses classifications from FAOSTAT, IEA, and UN COMTRADE depending on the land use type of the Footprint. Figure 1 shows the per capita Ecological Footprint of Consumption for the United States in 2010. I acquired the Ecological Footprint for the United States from the National Footprint Accounts provided by the Global Footprint Network.

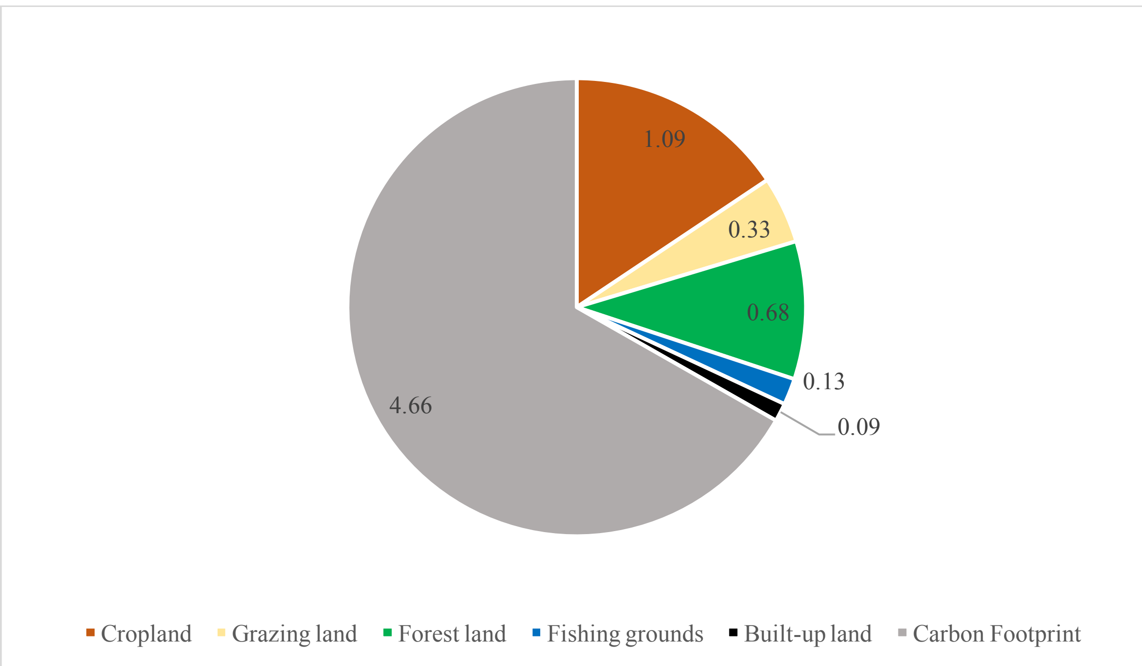


Figure 1. Summary of U.S. per capita Ecological Footprint, 2010. Pie chart showing the per capita Ecological Footprint for the United States in 2010 by land use type. Values are in global hectares.

I disaggregated the Total Use Ecological Footprint (the sum of the Footprints of production and imports) by industry according to a concordance table I constructed to map Footprints and industrial sectors. I built the concordance table from the North American Industry Classification System (NAICS) industry sectors extracted from the U.S. Bureau of Economic Analysis' Benchmark Input-Output Accounts (BEA 2007). I created a direct requirements Footprint vector for 370 NAICS sectors by allocating land use types to the sectors associated with relevant types of resource consumption. This initial allocation process assigns land use to the sectors that are the direct causes of consumption, i.e. the sectors that are the first 'point of entry' where Footprints enter the U.S. economy. I performed all data processing and analysis in the programming language Python and utilized the scientific software packages Pandas and NumPy (E.J. *et al.* 2001, McKinney 2010).

I assigned the Total Use cropland Footprint (1.63 gha/cap) to six plant agriculture NAICS sectors ("Oilseed farming", "Grain farming", "Vegetable and melon farming", "Fruit and tree nut farming", "Greenhouse, nursery, and floriculture production", "Other crop farming") using a many-to-one data model, where I assigned and aggregated many cropland Footprints (catalogued with FAOSTAT classifications) to one NAICS sector.

I assigned the Total Use grazing land Footprint (0.36 gha/cap) to four animal agriculture NAICS sectors ("Beef cattle ranching and farming, including feedlots and dual-purposes ranching and farming", "Dairy cattle and milk production", "Animal production, except cattle and poultry and eggs", "Poultry and egg production") using multiple data models. For "Animal production, except cattle and poultry and eggs" I used a many-to-one data model, where I assigned and aggregated many grazing land Footprints (catalogued with FAOSTAT classifications) to one sector. For "Poultry and egg production", I assigned the associated fish Footprint, embedded in the grazing accounts, to chicken consumption because it is not accounted for in the fishing grounds Footprint. For "Beef cattle ranching and farming, including feedlots and dual-purposes ranching and farming" and "Dairy cattle and milk production" I used a weighted allocation of the grazing Footprint FAO classification "Cattle" using cattle inventory data for 2010 from the National Agriculture Statistics Service (NASS 2010).

I assigned the Total Use fishing grounds Footprint (0.18 gha/cap) completely to "Fishing, hunting, and trapping", using a many-to-one data model, where I assigned and aggregated many fish Footprints (catalogued with FAOSTAT classifications) to one NAICS sector.

I assigned the domestic production carbon Footprint (4.39 gha/cap) to all 370 sectors using a one-to-many data model, where I split each carbon Footprint (catalogued with IEA classifications) amongst many NAICS sectors. Environmentally-extended input-output analysis requires that the Total Use Footprint be used in the initial allocation, however, due to time constraints, I used the domestic production carbon Footprint instead, and did not capture the carbon dioxide embedded in imports (Kitzes 2013). In the 2010 U.S. National Footprint Accounts, the carbon Footprint of imports and exports are the same value, therefore, only using the Footprint of domestic production for initial allocation shouldn't have a significant impact on my results.

I assigned the Total Use forest Footprint (0.88 gha/cap) completely to "Forestry and logging" using a many-to-one data model, where I assigned and aggregated many forest Footprints (catalogued with FAOSTAT classifications) to one NAICS sector. The Ecological Footprint for built land (0.09 gha/cap) includes hydropower and infrastructure and I disaggregated it across 370 NAICS sectors evenly, assuming that all economic activities use built infrastructure equally.

After I allocated all subfootprints to NAICS sectors, I divided each sector's total Ecological Footprint by the 2010 United States population (303.9 million people) to derive the per capita Footprint for that sector.

This initial allocation constitutes an expansion of national environmental accounts using Ecological Footprints. The Ecological Footprints were derived in a way that represents the direct ecological requirements of all industry sectors, i.e. the environmental pressures caused by land appropriation and carbon dioxide emissions of U.S. production activities and imports. However, such an account does not yet take into account the transactions and subsequent flow of resources between industrial sectors. I used input-output analysis to reallocate footprints across NAICS sectors.

Reallocation of Footprint using input-output analysis

To begin my input-output analysis, I calculated the direct intensity vector (f) by dividing NAICS sectors' total output in USD (X) by their total Ecological Footprint (EF):

$$f = \frac{EF}{X}$$

The direct intensity vector represents the land area required to produce one dollar (USD) of output for a sector. This allows me to benchmark sectors by appropriation of ecological capacity per dollar, however it doesn't yet take into account the interaction and transactions between sectors. I calculated the total intensity vector (F) by post-multiplying the direct intensity vector (f) by the Leontif inverse (L), extracted from the Total Requirements Table from the Benchmark Input-Output Accounts (BEA 2007):

$$F = f \cdot L$$

The Leontif inverse represents the relationships between sectors as the USD value of input from other sectors required to produce one USD of output. The total intensity vector represents all ‘upstream’ land use associated with one USD of final output for a NAICS sector.

I then calculated the Ecological Footprints associated with sectors (EF^{FD}) by post-multiplying the total intensity vector (F) by the final demand of household consumption (Y) for all sectors, as calculated before:

$$EF^{FD} = F \circ Y$$

EF^{FD} represents the appropriated ecological capacity that flows through a NAICS sector to household consumption activities. However, this vector sums up to a value that is less than the original per capita Ecological Footprint because household consumption demand is only a fraction of total demand for a sector. In the input-output accounts, most of the final demand for an NAICS sector is allocated to other sectors and capital investments, hence environmental burden gets allocated primarily to producers. Because I am creating a consumption-based allocation model, which assumes that all environmental burden passes to the consumer through the products they purchase from producers, I scaled EF^{FD} up to Footprint values that are consistent with the U.S. NFA.

Allocating Footprints from industries to expenditures

I then allocated the Footprints of household consumption from NAICS sectors to consumer expenditure classification using another concordance table I constructed to map NAICS sectors to Consumer Expenditure Survey expenditure classifications (BLS 2014). The Consumer Expenditure Survey provides data on American consumers’ average annual expenditures, income, and consumer characteristics. Consumers’ average annual expenditures are divided into 76 basic classifications with 103 total classifications (including aggregate classifications). Before I performed the allocation, I divided the national average consumer's expenditures by its average household size to get per capita expenditures.

In order to allocate footprints to consumer expenditures for the national average consumer (EF^{EXP}), I multiplied EF^{FD} component-wise by expenditures as a proportion of total expenditures mapped to a NAICS sector (R), and then by expenditures as a proportion of total average annual expenditures (P):

$$EF^{EXP} = EF^{FD} \circ R \circ P$$

EF^{EXP} is a complete representation of the U.S. per capita Footprint disaggregated by BLS expenditure classifications. This is also known as a Consumption Land Use Matrix (CLUM) because it associates consumption activities with the Footprints required to sustain them. This is an expansion of the Production Land Use Matrix (Moran *et al.* 2009).

Calculating per capita Footprints for U.S. demographic cohorts

In order to calculate subnational Consumption Land Use Matrices, I used the expenditure data in the Consumer Expenditure Survey for the following demographics and their respective cohorts:

- Age of reference person
    - Under 25 years; 25-34 years; 35-44 years; 45-54 years; 55-64 years; 65-74 years; 75 years and older
- Composition of consumer unit
    - Married couple, no children; Married, oldest child under six; Married, oldest child 6 to 17; Married, oldest child 18 or over; One parent, at least one child; Other married couple; Single person and other
- Highest education level of any member
    - Less than high school; High school graduate; High school with some college; Associate's degree; Bachelor's degree; Master's, professional, doctorate
- Hispanic or Latino origin of reference person

    - Hispanic or Latino; Not Hispanic or Latino
- Income before taxes
    - Less than $5,000; $5,000 - $9,999; $10,000 - $14,999; $15,000 - $19,999; $20,000 - $29,999; $30,000 - $39,999; $40,000 - $49,000; $50,000 - $69,999; $70,000 and more
- Race of reference person
    - White and all other races; Asian; Black or African-American
- Region of residence
    - West; Midwest; Northeast; South
- Housing tenure and type of area
    - Renter; Home-owner with mortgage; Home-owner without mortgage; Rural; Central City; Other Urban

I created the demographic cohorts' CLUMs by multiplying the national average CLUM by each cohort's expenditures as a proportion of the national average consumer's total expenditures (P'):

$$CLUM' = P' \times CLUM$$

P' represents a demographic cohort's expenditures as a proportion of all consumers' (national average) total average annual expenditures, similar to how P represents all consumers' expenditures as a proportion of all consumers' total average annual expenditures. CLUM' represents the consumption land use matrix for a demographic cohort. This method allows for demographic cohorts that have total average annual expenditures differing from the national averages to have different total Ecological Footprints as well.

RESULTS

National per capita Footprint

The Consumption Land Use Matrix for the average American consumer (total 6.98 gha/cap) shows the distribution in Footprint allocation across expenditures (Appendix A). At the individual classification level, the five largest consumption Footprints are "Public and other transportation" (1.1 gha/cap), "Electricity" (0.6 gha/cap), "Other household expenses" (0.4 gha/cap), "Food away from home" (0.4 gha/cap), and "Health insurance" (0.3 gha/cap). Figure 2 displays the aggregate expenditure categories and the Footprints associated with them. At the aggregate level, "Food" (2.0 gha/cap), "Housing" (1.9 gha/cap) and "Transportation" (1.5 gha/cap) dominate the average American consumer's Footprint, accounting for 29%, 28%, and 21% of the total Footprint respectively. "Apparel" (0.4 gha/cap) and "Health" (0.5 gha/cap) are the least contributing components, only accounting for 13% of the total Footprint combined.

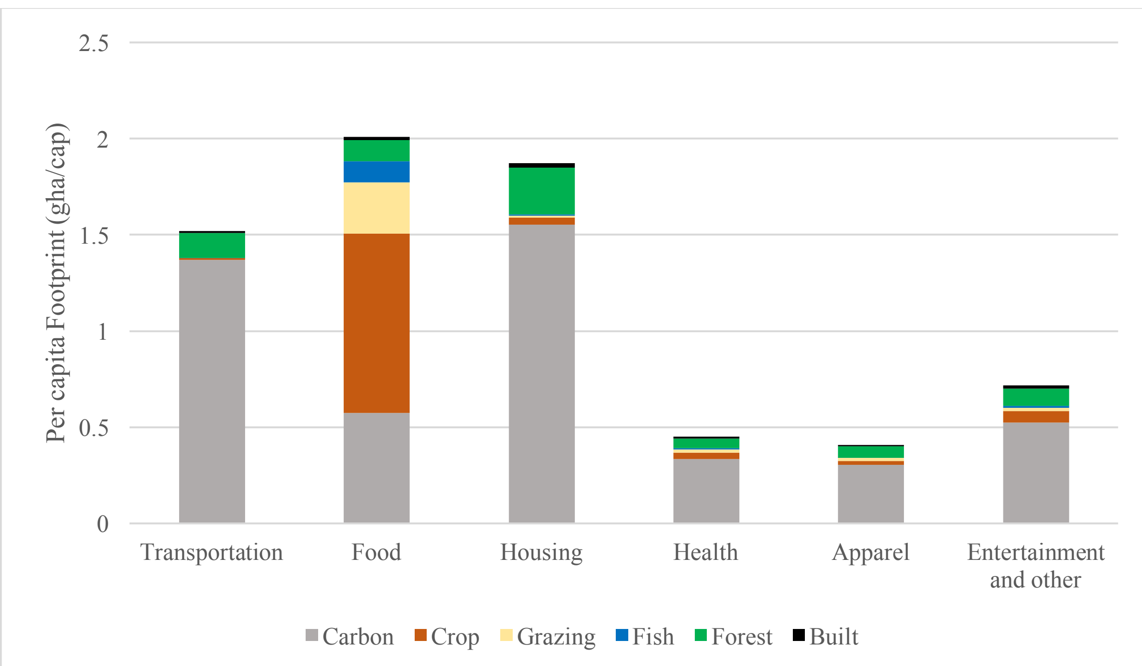
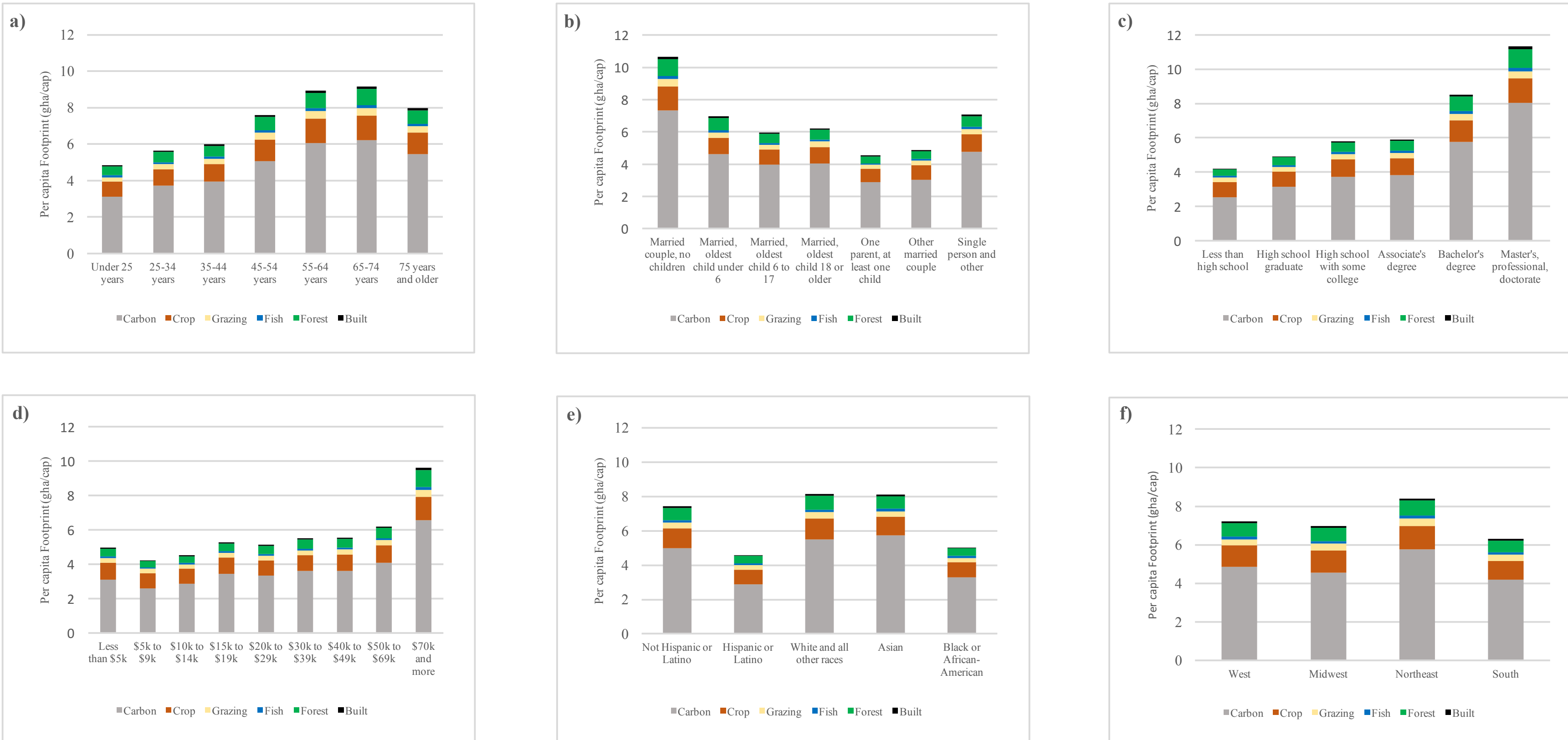


Figure 2. Summary of U.S. national average Consumption Land Use Matrix, aggregated classifications. Stacked bar chart showing the U.S. national average per capita Ecological Footprint's distribution across household consumption expenditures.

Demographic cohort per capita Footprints

Total per capita Footprints

Total per capita Ecological Footprints for demographic cohorts varied notably from the national average. Figure 3 summarizes the differences in total per capita Ecological Footprints for the seven demographics and their respective cohorts. The demographic cohorts that had the largest per capita Footprints were ‘Married couple, no children” (total 10.6 gha/cap), “Other Urban” (total 7.4 gha/cap), “Bachelor’s degree” (total 8.5 gha/cap), “$70,000 and more” (total 9.6 gha/cap), “55-64 years” (total 8.9 gha/cap). The demographic cohorts with the smallest per capita Footprints were “Hispanic or Latino” (total 4.6 gha/cap), “$40,000 – $49,999” (total 5.5 gha/cap), “$5,000 - $9,999” (total 4.2 gha/cap), “Married, oldest Child 6-17” (total 6.0 gha/cap) and “One parent, at least one child under 18” (total 4.5 gha/cap). The demographic cohorts that were similar to the national average per capita Footprint were “Married, oldest child under 6” (total 7.0 gha/cap) and “Midwest” (total 7.0 gha/cap).



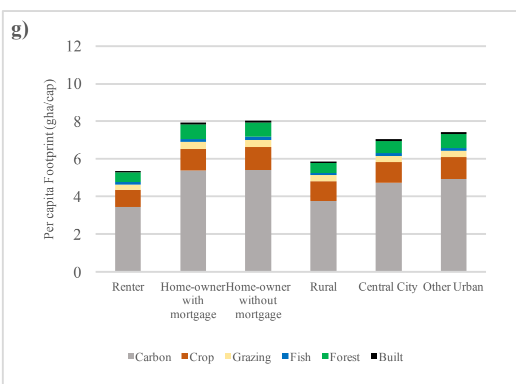


Figure 3. Variation in total per capita Footprint by demographic cohort. Panel of stacked bar charts showing the differences in per capita Ecological Footprints for each demographic: a) Age of reference person; b) Composition of consumer unit; c) Highest education of any member; d) Income before taxes; e) Hispanic or Latino origin *and* Race of reference person; f) Region of residence; and g) Housing tenure and type of area.

Comparison of demographic cohorts CLUMs to the national average

Age of reference person. Footprints associated with expenditure classifications tend to increase from younger to older consumers, however, they peak at “65-74” and dip at “75 years and older”. The Footprint distribution across expenditures for cohorts by age generally follow the national Footprint distribution, with the exception of “Health Insurance”, which increases with age at a faster rate than all other expenditures.

Composition of consumer unit. Married consumers tend to have overall larger per capita Footprints than unmarried consumers. “Married couple only”, that is, married consumers without children, have the largest per capita Footprint of the demographic (total 10.6 gha/cap) while “One parent, at least one child under 18”, that is, single parents, have the smallest per capita Footprint of the demographic (total 4.5 gha/cap). The distribution of Footprints across consumer composition cohort’s expenditures roughly resembles the national Footprint distribution, with the exception of “Married couple, oldest child under 6”, which has a very large “Personal services” (1.2 gha/cap) Footprint.

Highest education of any member. Consumers with a college degree have larger per capita Footprints than consumers who have a high school degree only or less. “Master’s, professional, doctoral degree” has the largest per capita Footprint of the demographic (total 11.3 gha/cap) while “Less than high school graduate” has the smallest per capita Footprint of the demographic (total 4.2 gha/cap). The distribution of education cohorts’ per capita Footprints are fairly similar to the national average Footprint distribution, with no notable exceptions.

Hispanic or Latino origin of reference person. “Hispanic or Latino” (total 4.6 gha/cap) has a smaller Footprint than “Not Hispanic or Latino” (total 7.4 gha/cap). Hispanic cohorts’ per capita Footprint distributions are fairly similar to the national average Footprint distribution, with no notable exceptions.

Income before taxes. Consumers' per capita Footprints increase with income. Income cohort per capita Footprint distributions are fairly similar to the national average Footprint distribution, with no notable exceptions.

Race of reference person. "White and all other races" (total 7.5 gha/cap) and "Asian" (total 8.1 gha/cap) per capita Footprints were higher than "Black or African-American" Footprints (total 5.0 gha/cap). Race cohorts' per capita Footprint distributions roughly resembled the national average Footprint distribution, with the exceptions that "Asian" had a "Public and other transportation" (2.3 gha/cap) Footprint that was higher than other cohorts with similar average annual expenses, and "Black or African-American" had an "Electricity" (0.7 gha/cap) Footprint that was slightly larger than the "Public and other transportation" (0.6 gha/cap) Footprint. The national average Footprint distribution has a "Public and other transportation" Footprint larger than their "Electricity" Footprint.

Region of residence. The "Northeast" (total 8.4 gha/cap) and "West" (total 7.2 gha/cap) region cohorts had larger per capita Footprints than the "Midwest" (total 7.0 gha/cap) and "South" (total 6.3 gha/cap) cohorts. Region cohorts' per capita Footprint distributions roughly resemble the national Footprint distribution with the exception of "South", where the "Electricity" (0.8 gha/cap) Footprint is larger than the "Public and other transportation" (0.7 gha/cap) Footprint.

Housing tenure and type of area. "Rural" (total 5.7 gha/cap) has a smaller Footprint than "Central city" (total 7.0 gha/cap) and "Other Urban" (total 7.4 gha/cap). "Renter" (total 5.3 gha/cap) has a smaller Footprint than "Home-owner with mortgage" (total 7.9 gha/cap) and "Home-owner without mortgage" (total 8.0 gha/cap). Tenure cohort per capita Footprint distributions slightly resemble the national Footprint distribution, with the exception of "Rural", which has a smaller "Public and other transportation" (0.5 gha/cap) Footprint than other cohorts with similar average annual expenditures.

DISCUSSION

These findings show that the per capita Ecological Footprint for the United States is different depending on what demographic characteristics a consumer possesses. On the consumer's side, affluence is a driving factor for differences between total per capita Footprints across demographic cohorts. On the producer's side, differences in technology and resources used to produce a product, or expenditure intensity, creates the differences in per capita Footprint distributions across demographic cohorts.

Variation in total expenditures

Consumers with access to more money have the ability to spend more and thus consume more. This increase in consumption expenditures leads to increased environmental impact. Indicators of affluence like college degrees, marriage, homeownership without a mortgage, were also indicators of large Ecological Footprints.

Many demographics with large per capita Footprints have overall larger average annual expenditures. However, on a classification-by-classification level, large expenditures in any one classification does not necessarily result in a large Footprint for that classification. The expenditure classifications with the largest expenditures for the national average consumer included payments to pension plans and social security, rent payments, mortgage payments, and gasoline. However, the Footprint of investments to retirement or rent and mortgage payments were relatively small, because of the weak association of these payments to direct resource use. The expenditure classifications with the smallest expenditures for the national average consumer included payments for vehicles other than cars and trucks, food prepared by consumers on out of town trips, and clothing for children under 2 years. However, due to the direct association of food and clothing to agricultural land use, these small expenditures carried a relatively larger impact on crop land Footprints. In order to determine the impact of the total dollar expenditure for a classification, the Footprint intensity of that classification has to be considered.

Variation in expenditure intensity

The variation in expenditure intensities played a major role in determining the differences amongst demographic cohort total per capita Footprints. The expenditure intensity of a BLS classification is determined by the intensities of the industries mapped to the expenditure, i.e. products produced by industries that carry larger environmental impacts will have larger environmental impacts themselves. Variations in expenditures for BLS classifications with smaller intensities across demographic cohorts resulted in smaller variations in Footprint. The opposite is also true: variations in expenditures for BLS classifications with large intensities resulted in larger variations in Footprint. Differences in expenditures in key, high intensity classifications resulted in the largest differences in per capita Footprints across demographic cohorts. The BLS classifications with the largest expenditure intensities included public transportation, food consumed away from home, and all major meat products. These large intensity classifications, coupled with moderate to high expenditures, are the reason why food and transportation dominate the per capita Footprint. The BLS classifications with the smallest expenditure intensities included payments for used cars and trucks, household products that are not major appliances, and payments towards pension plans and social security. The low intensity of these classifications, especially financial investments, explain why regardless of large expenditures in these categories, the Footprint is relatively small.

Limitations

The input-output analysis I performed is a simplified model of the U.S. economy. This model assumes that environmental impact burden is assigned completely throughout the economy with no transformations and that burden is disaggregated to the sectors in the manner that I specified in my concordance tables. There are also discrepancies in the study years for my data sources, NFA was 2010, BEA was 2009, and BLS was 2014. My model is also limited in its ability to address intersectional identities, meaning that while I can explore Footprint variations within demographics, I cannot explore the overlap between them (e.g. Asian AND single parent households). This overlap also prevents me from performing statistical analysis between demographic cohorts; while each cohort is independent of one another within a demographic, they are not independent between demographics. Finally, I am limited by the resolution of the data. While uncovering consumption heterogeneity is a good start, I could make stronger conclusions about the per capita Footprint distributions if I could increase the resolution of the Consumption Land Use Matrix. For example, I could potentially make an inference about the intensity of airplane travel and its association with the category "Public and other transportation" if air travel was disaggregated from bus and rail travel.

Future Research

I strongly recommend that future researchers focus on creating grounded, standardized concordance tables between FAOSTAT and NAICS, and between NAICS and CEX classifications. These concordance tables can be used for future demographic analysis of U.S. per capita Footprints and can be instrumental in constructing a subnational time series (Wackernagel *et al.* 2004b). Since the inception of this study, the Global Footprint Network has compiled U.S. Footprint data at the state level; integrating that into a demographic analysis would be a logical next step.

Conclusion

Per capita, subnational Ecological Footprints are a robust, intuitive measure of ecological capacity appropriation by household consumers. By linking consumer purchases to land use type using input-output analysis, I was able to generate a clearer picture about how differences in expenditure patterns across demographics leads to differences in environmental burden associated with consumption. U.S. environmental policy makers need to take into account differences in environmental impact between demographics in order to efficiently and effectively craft regulations that will achieve the goal of reducing our environmental impact. Uniform policies that assign externality cost to all consumers equally are unfair and inefficient because they will burden consumers with less affluence and will fail to regulate consumers with more affluence. Directly targeting products with high intensities and low costs (e.g. processed fruits and vegetables) will harm consumers that don't have the income to afford lower intensity, higher cost products (e.g. fresh fruits and vegetables). Wealthier consumers will be able to shift their expenditures from the targeted products to other alternatives, without necessarily reducing their total annual expenditures. A more efficient policy approach would involve regulating the industries that produce high intensity products, either through technological standards or sourcing regulation. By selectively targeting industries with high Footprint intensities, policy makers will be able to reduce the intensities of the products that people consume and reduce per capita Footprints.

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APPENDIX A: U.S. National Consumption Land Use Matrix

	Total expenditure ($)	Carbon Footprint (gha)	Real land Footprint (gha)	Total Ecological Footprint (gha)
Cereals and cereal products	72	0.01	0.02	0.03
Bakery products	141.6	0.04	0.1	0.14
Beef	90	0.02	0.14	0.15
Pork	70	0.01	0.11	0.12
Other meats	48.8	0.01	0.08	0.09
Poultry	70.4	0.03	0.1	0.13
Other dairy products	108.8	0.03	0.1	0.14
Fresh fruits	111.2	0.01	0.11	0.12
Processed fruits	46	0.01	0.06	0.07
Processed vegetables	53.2	0.01	0.06	0.07
Sugar and other sweets	56.8	0.01	0.02	0.03
Miscellaneous foods	284.8	0.05	0.13	0.19
Nonalcoholic beverages	150.8	0.03	0.02	0.05
Food prepared by consumer unit on out-of-town trips	19.2	0.07	0.01	0.08
Food away from home	1064.4	0.17	0.21	0.38
Alcoholic beverages	180	0.03	0.03	0.06
Mortgage interest and charges	1213.2	0.08	0.01	0.09
Property taxes	739.6	0.05	0.01	0.06
Rented dwellings	1388.8	0.09	0.02	0.1
Other lodging	265.6	0.02	0.01	0.03
Natural gas	170.8	0.02	0	0.02
Electricity	588	0.63	0.01	0.64
Fuel oil and other fuels	61.2	0.01	0	0.01
Water and other public services	207.2	0.02	0.01	0.03
Personal services	133.2	0.12	0.06	0.18
Other household expenses	312.8	0.35	0.04	0.39
Laundry and cleaning supplies	60.4	0.03	0.01	0.04
Other household products	144	0.01	0	0.01
Postage and stationery	52.4	0.03	0.05	0.09
Household textiles	36.4	0.02	0.01	0.02
Furniture	144.8	0.04	0.07	0.11
Major appliances	83.2	0.01	0	0.01
Small appliances, miscellaneous housewares	41.6	0.02	0.01	0.02
Miscellaneous household equipment	280.4	0.01	0.01	0.03
Apparel, Men 16 and over	122.8	0.05	0.01	0.06
Apparel, Boys 2 to 15	35.6	0.01	0	0.02
Apparel, Women 16 and over	211.2	0.08	0.02	0.1
Apparel, Girls 2 to 15	42	0.02	0	0.02
Children under 2	29.6	0.01	0	0.01
Footwear	133.2	0.07	0.05	0.12
Other apparel products and services	95.2	0.07	0.02	0.09
Cars and trucks, new	642	0.17	0.1	0.27
Cars and trucks, used	682.8	0.02	0	0.03
Other vehicles	16.4	0.01	0.01	0.02
Gasoline and motor oil	1028.4	0.09	0.01	0.1
Maintenance and repairs	329.6	0.03	0.01	0.04
Public and other transportation	217.2	1.04	0.02	1.06
Health insurance	1002	0.26	0.08	0.34
Drugs	188.4	0.07	0.03	0.1
Audio and visual equipment and services	400.4	0.06	0.02	0.08
Pets	192.8	0.01	0.03	0.04
Toys, hobbies, and playground equipment	50.8	0.04	0.02	0.05
Other entertainment supplies, equipment, and services	151.2	0.07	0.02	0.09
Personal care products and services	240.8	0.01	0	0.02
Reading	40.4	0.02	0.01	0.03

Education	457.2	0.06	0.02	0.09
Tobacco products and smoking supplies	126	0.01	0.01	0.02
Miscellaneous	273.2	0.11	0.03	0.13
Cash contributions	716	0.04	0.01	0.05
Pensions and Social Security	2092.4	0.08	0.03	0.11
Total	**18009.2**	**4.61**	**2.19**	**6.82**

Figure A1. U.S. National CLUM. Table showing the expenditures, carbon footprint, real land footprint, and total ecological footprint for all individual consumer expenditure survey expenditure classifications.