nature cities

Article https://doi.org/10.1038/s44284-023-00023-3

Comparing the carbon footprints of urban and conventional agriculture

In the format provided by the authors and unedited

Supplementary materials

Contents

Supplementary Figures and Tables

Figure S1a: Unabridged version of Figure 1, panel 1*

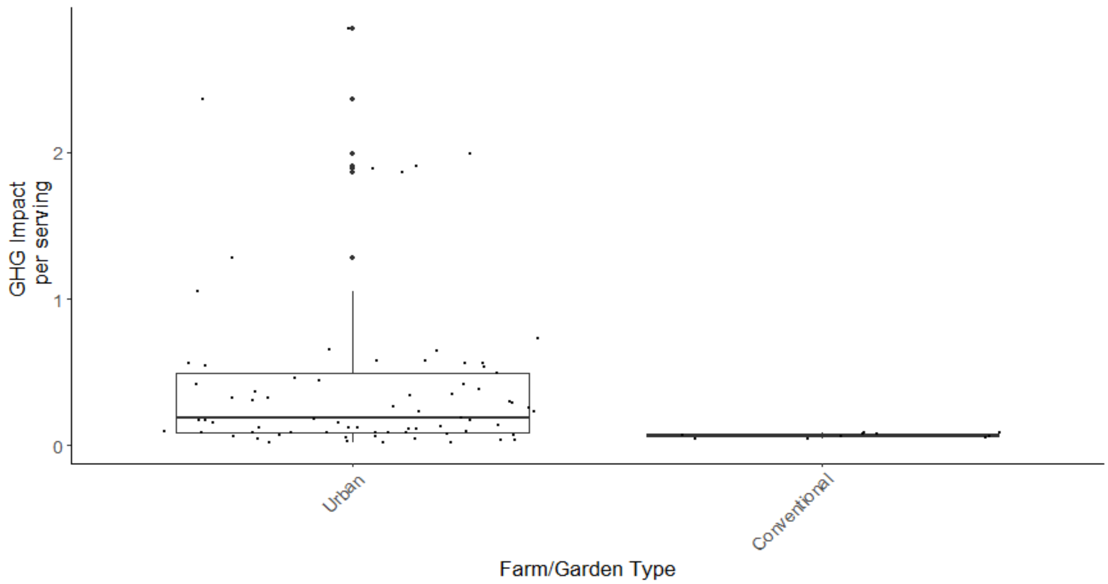
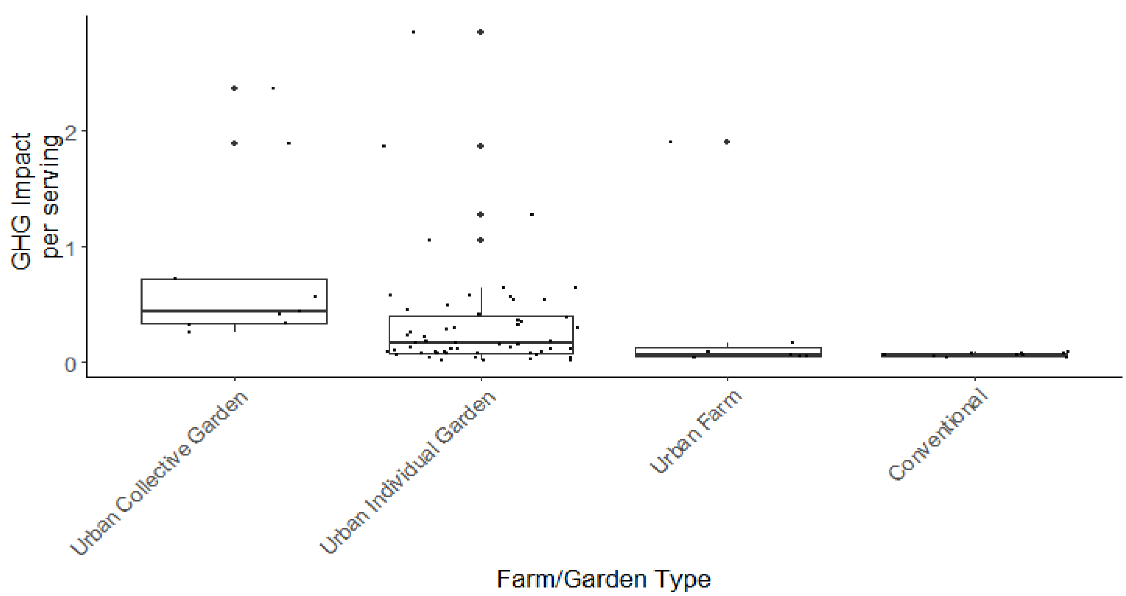


Figure S1b: Unabridged version of Figure 1, panel 2*



*All statistics and data identical to Figure 1 in manuscript - abridged version presented in manuscript for reader's ease.

Figure S2: Results across case study countries

Across countries, urban agriculture is consistently more carbon-intensive than conventional agriculture

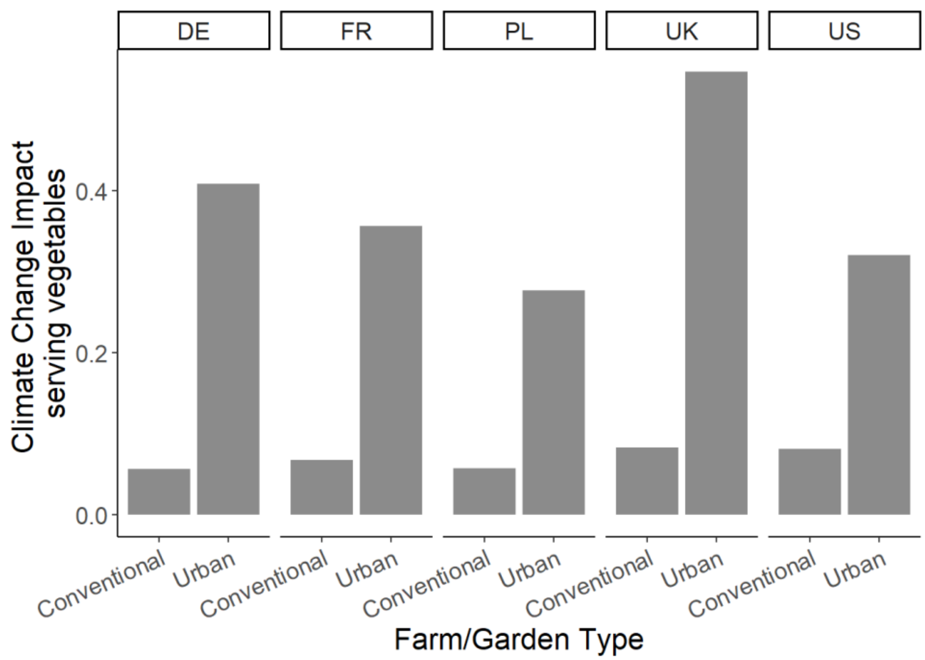


Figure S3. Infrastructure impact allocation sensitivity

Results are somewhat sensitive to percent of infrastructure allocated to food, but only extreme scenarios change directionality. This change of directionality depends on ignoring impacts from supplies and irrigation. Error bands represent the interquartile range of UA sites analyzed; black line represents median.

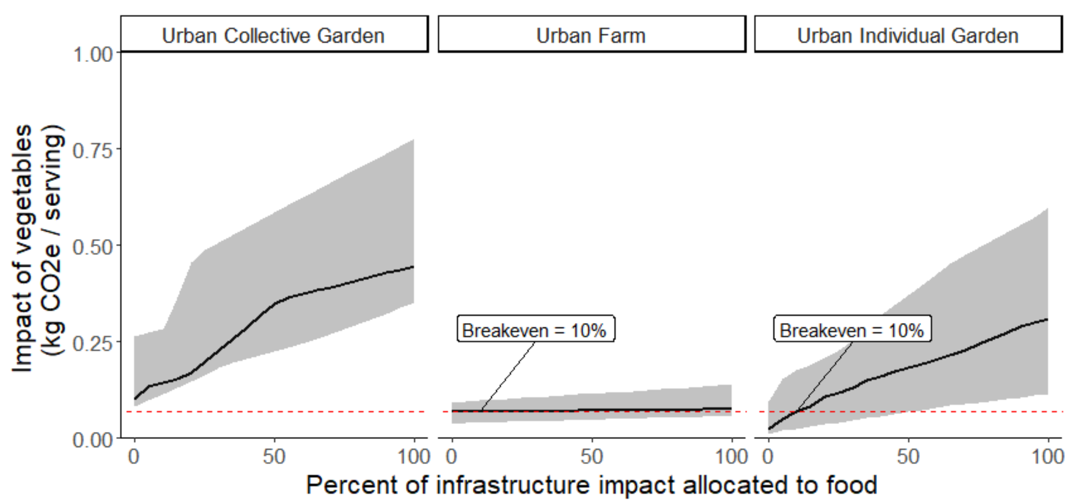


Table S1. Results sensitivity to method of allocation

Method of allocation did not affect directionality of results. Even for tomatoes, the average urban crop is still more carbon-intensive than the average conventional crop even for relatively friendly allocation schemes (e.g., calories)

crop	Conventional results	Calories allocation	Economic allocation	Mass allocation	Nutrient allocation (NRF 9.3)	Calories vs. Economic	Calories vs. Mass	Calories vs. NRF	Economic vs. Mass	Economic vs. NRF	Calories vs. Conventional	Economic vs. Conventional	Mass vs. Conventional	NRF vs. Conventional
Apples	0.0407	0.487	0.332	0.355	0.145	1.46	1.37	3.35	0.936	2.29	12	8.17	8.72	3.57
Beans	0.0529	0.668	0.37	0.225	0.412	1.81	2.97	1.62	1.64	0.898	12.6	6.99	4.25	7.79
Cabbage	0.0235	0.106	0.0731	0.168	0.241	1.45	0.629	0.438	0.435	0.303	4.49	3.11	7.14	10.2
Carrots	0.0349	0.458	0.17	0.295	0.34	2.69	1.55	1.35	0.576	0.5	13.1	4.87	8.45	9.73
Melons	0.0617	0.152	0.131	0.422	0.136	1.17	0.361	1.12	0.31	0.962	2.47	2.12	6.84	2.2
Onions	0.05	0.507	0.237	0.417	0.247	2.14	1.21	2.06	0.568	0.961	10.1	4.74	8.35	4.93
Potatoes	0.0497	0.758	0.11	0.323	0.186	6.87	2.34	4.06	0.341	0.592	15.2	2.22	6.5	3.75
Salad Greens	0.0448	0.134	0.422	0.274	0.232	0.318	0.489	0.578	1.54	1.82	3	9.41	6.12	5.18
Tomatoes	0.27	0.287	0.422	0.419	0.384	0.678	0.685	0.747	1.01	1.1	1.06	1.56	1.55	1.42

Table S2. Sensitivity of model to air freight

Food miles, particularly in the form of air freight, have long been a key refrain of calls for expanded local food production. In order to assess the relevance of these claims, we test the sensitivity of our model to air freight. Overall, we do find that targeting air freighted goods may be a useful strategy for improving the carbon-competitiveness of UA.

Shipping method	**Average conventional vegetable impact (kg CO2eq/serving)**	**p-val for carbon comparison: (asterisk indicates a statistically significant different)**			
		UA overall	Community gardens	Urban farms	Individual gardens
Container ship	0.07	<<0.001*	0.02*	0.33	<<0.001*
Air freight	0.22	0.02*	0.04*	0.66	0.17

Table S3. Correlation between climate impacts and gardener behaviors

Correlation table of environmentally friendly behaviors and climate friendly gardens. No broadly environmentally friendly behaviors are highly correlated with carbon footprint at our UA sites.

	Climate friendly garden on average?	Number of scenarios where garden is climate friendly	Size Of Production Site	Percent of site left permeable	Presence of solar panels on site	Percent of irrigation water derived from rainwater	Amount of synthetic fertilizer used	Stated goal of environmental friendliness
Climate friendly garden on average?	1	0.8059788	-0.0579477	0.1033427	-0.0619512	-0.0272534	-0.0602916	-0.1901718
Number of scenarios where garden is climate friendly		1	-0.0719002	0.1687473	-0.1259571	-0.0692971	0.078708	-0.3208775
Size Of Production Site			1	-0.0779372	0.0152247	-0.1311053	0.3037297	0.0731325
Percent of site left permeable				1	-0.0169064	-0.0421619	0.0851614	-0.3202703
Presence of solar panels on site					1	-0.0981059	-0.0423903	0.0208823
Percent of irrigation water derived from rainwater						1	-0.0430165	0.1437336
Amount of synthetic fertilizer used							1	-0.0902288
Stated goal of environmental friendliness								1

Table S4. Top contributors to climate change impacts

Most important supply and infrastructure component counts – counts of farms where they were the highest impact feature

Component	Number of farms on which this is the most important source of impacts
Compost...Homemade	22
Compost...Industrial	1
Compost.Bins	7
Garden.House	13
Greenhouses	1
Irrigation.pipes	2
Manure...solid	1
Pathway	1
Pavement	1
Pesticide	2
Poles.or.supports	1
Potting.soil	2
Raised.Beds	5
Soil.or.substrate	2
Synthetic.fertilizer	5
Water.Tank	1
WaterUse_2019	6

Table S5. Nutrient impacts by farm/garden type

Comparing synthetic fertilizer use by UA and conventional agriculture. Use varies by growing format, but urban farms, collective gardens, and individual gardens all use fewer synthetic fertilizers than conventional agriculture.

Nutrient	Baseline: Conventional agriculture (g/serving) [n = 279]	Average urban agriculture (g/serving) [n = 73]	Urban Farm (g/serving) [n = 7]	Urban collective garden (g/serving) [n = 9]	Urban individual garden (g/serving) [n = 55]
Nitrogen (N)	0.88	0.06	0.18	0.00	0.05
Phosphorus (P)	1.4	0.04	0.14	0.00	0.03
Potassium (K)	0.99	0.05	0.23	0.00	0.04

Table S6. UA Impact results if compost is assumed to be a carbon benefit

Sensitivity test of carbon footprint of compost. If we assume that home composting is a net carbon benefits, we still detect the same significant differences found in the original assessment. See methods for more discussion. Significance reflects a two-sided t-test.

group1	group2	n1	n2	statistic	df	p	p.adj	p.adj.signif
Conventional	Urban Collective Garden	10	9	-2.8982388	8.028981	0.02	0.04	*
Conventional	Urban Farm	10	7	-0.9167573	6.011151	0.395	0.395	ns
Conventional	Urban Individual Garden	10	55	-3.0411179	55.330387	0.004	0.011	*

Summary of Online Supplementary Materials

This summary is replicated in the ReadMe available with the online materials at https://doi.org/10.7302/yjtn-gq37.

Date: 8 December, 2023

Dataset Title: Data for: Comparing the Carbon Footprints of Urban and Conventional Agriculture

Dataset Creators: Jason K. Hawes, Benjamin P. Goldstein, Joshua P. Newell, Erica Dorr, Silvio Caputo, Runrid Fox-Kämper, Baptiste Grard, Rositsa T. Ilieva, Agnès Fargue-Lelièvre, Lidia Poniży, Victoria Schoen, Kathrin Specht, Nevin Cohen

Dataset Contact: Jason K Hawes, jkhawes@umich.edu or jasonkhawes@gmail.com

Introduction: Urban agriculture (UA) is a widely proposed strategy to make cities and urban food systems more sustainable. However, its carbon footprint remains understudied. In fact, the few existing studies suggest that UA may be worse for the climate than conventional agriculture. This is the first large-scale study to resolve this uncertainty across cities and types of UA, employing citizen science at 73 UA sites in Europe and the United States to compare UA products to food from conventional farms. The results reveal that food from UA is six times as carbon intensive as conventional agriculture (420g vs 70g CO2 equivalent per serving). Some UA crops (e.g., tomatoes) and sites (e.g., 25% of individually-managed gardens), however, outperform conventional agriculture. These exceptions suggest that UA practitioners can reduce their climate impacts by cultivating crops that are typically greenhouse grown or air-freighted, maintaining UA sites for many years, and leveraging waste as inputs.This database contains the necessary reference material to trace the path of our analysis from raw garden data to carbon footprint and nutrient results. It also contains the final results of the analyses in various extended forms not available in the publication. For more information, see manuscript at link below.

(Introduction partially quoted from Hawes et al., 2023)

Methods:

Data collection Urban agriculture input and output data were collected via citizen science at 72 urban farms and gardens in the US and Europe. See Caputo et al., 2021 or Dorr et al., 2023 for more information.

Life cycle impact assessment Material inputs were converted to carbon emissions data using EcoInvent 3.0. This is replicable with the material impacts dataset available with the code included in this database. Nutrient analysis was conducted via material flow analysis. See linked manuscript methods for details.

Impacts allocation Carbon and nutrient impacts were allocated to crops produced by each urban agriculture site, with a portion of impacts also allocated to social benefits. See manuscript for details.

Comparison to conventional agriculture Conventional agriculture impacts were identified via literature review. See manuscript methods for details. Conventional agriculture dataset is available attached in raw form, which may be converted to crop and country impact values via attached code.

File inventory:

Urban Agriculture Impact Assessment data - Zipped folder:

- Farm Level Impact Assessment: Impact assessment data are first compiled at the farm level. This folder contains the farm-level results generated during the sensitivity analysis, as well as a codebook to guide the user in interpreting the results file.

- Crop level Impact Assessment dataset: Impact assessment data are also compiled at the crop level, meaning that farm-level impacts are allocated to individual crops. This folder contains the crop-level results generated during the sensitivity analysis, as well as a codebook to guide the user in interpreting the results file.

- Anonymized Full: Full scenario analysis containing impacts data for each UA site across all simulations - can be replicated with SI code.

Nutrients data - Zipped folder:

- Contains three files with conventional nutrient results for N, P, and K – recorded in kg. Also contains SyntheticNutrientsAtFarmLevel.csv, which records synthetic nutrients used on UA sites – recorded in kg

Conventional crops impact assessment dataset - Excel format:

- More than 1,000 assessments of conventional agriculture were compiled as part of the effort to compare our urban food products to relevant local conventional crops. This Excel workbook contains those data, as well as a summary sheet identifying the relevant crop-country combinations, and a codebook to guide the user in interpreting the database. Also available as an input to the code, but this is a version you can manipulate without fear of disrupting the code.

Farmer/Gardener Survey

- This survey was conducted with farmers, gardeners, and organizational staff at each of the UA sites we studied. See Kirby et al. for more details.

Raw data files and R code – SI Code and Inputs.zip:

R is used to generate the farm- and crop-level impact assessments from raw inventories of crop yield, supply input, infrastructure on-site, and other various data about each UA site. This folder contains the anonymized and cleaned raw data files as well as the R code used to transform them into the impact results shared above. The folder also contains an assortment of spreadsheets used to communicate key-value combinations to R or to input relevant USDA or impact data to R. We strongly recommend that you don't make any edits to the input data unless you intend to make major revisions to the program. For simple replication, download the entire zip file, store it somewhere with a relatively short folder directory, and then run everything. Making changes to the inputs can have unforeseen consequences because of the complicated and interconnected nature of the code.

Contents of zip file:

1) Cleaned and anonymized inventory data
    a) crops.csv – Presents basic inventory of crop production on the farms and gardens we studied.
    b) farms.csv – Basic information, including selected survey results, for each farm or garden.
    c) growLog.csv – Tracks inputs and outputs in detail, was used in AirTable to associate supplies and crops with different farms, gardens, and infrastructures – used in this program to track harvest and irrigation over time.
    d) infrastructure.csv – List of infrastructure cataloged on each farm or garden.
    e) supplies.csv – List of supplies used on each farm or garden.
2) R code
    a) Data processing and sensitivity analysis.Rmd – Data processing file customized to run with the anonymized data provided here. Produces the outputs that the LCA Final Figures file needs to run.
    b) LCA Final Figures.R – Processes the Farm-Level and Crop-Level data in order to produce the figures, tables, and statistical tests presented in the manuscript.
3) Other data files:
    a) Scenario Outputs folder – Empty folder where the outputs from Data processing and sensitivity analysis.Rmd file are programmed to go
    b) SimaProImpactAssessment folder – A number of files containing raw midpoint indicator results from SimaPro. Cannot be used to back-calculate original inventories.
    c) Conventional Ag Data Summary.xlsx – The results of our review of conventional ag LCAs. Guide to sheets:
        i) All Crops Impact Data – Impact data from other studies
        ii) Crop Impact Codebook – Guide to the variables on the All Crops Impact Data sheet
        iii) Travel – Distance used in this study, largely extracted from online routing tools.
        iv) FPED Equivalents – FPED equivalents for internal reference. Same as USDA data below.
        v) Top 5 – Original List – Original top 5 crops studied as point of reference.
    d) Crops_AllocationCodebook – xlsx and csv – Two of the same file, the csv can be used if your directory is too long for read_xlsx, but the code isn't set up to do this. Mostly included as an example of how to get around that glitch, but it would still take a lot of coding if you do try to move from read_xlsx to read.csv. Allocation codebook itself is used to associate crops with USDA names.

e) FICRCD, FPED, FNDDS – Three files with USDA data for import
f) LCA Codebook – Matches the UA site materials to EcoInvent materials.

Discipline: Industrial ecology; Other: Agriculture

Keywords: Community garden; Individual garden; Urban farm; Carbon footprint; Nutrient use

For more information and to cite this work, see related manuscript:

Hawes, J. K., Goldstein, B. P., et al. (2023). Comparing the Carbon Footprints of Urban and Conventional Agriculture. Nature Cities

Dataset citation:

Hawes, J.K., Goldstein, B.P., Newell, J.P., Dorr, E., Caputo, S., Fox-Kämper, R., Grard, B., Ilieva, R.T., Fargue-Lelièvre, A., Poniży, L., Schoen, V., Specht, K., Cohen, N. Data for: Comparing the Carbon Footprint of Urban and Conventional Agriculture. [Data set], University of Michigan - Deep Blue Data. https://doi.org/10.7302/yjtn-gq37