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An urban university's ecological footprint and the effect of climate change

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ABSTRACT

Ecological footprint analysis (EFA) has been used since the early 1990s as a measure of sustainability for geographical regions, products, and activities. EFA is used as a measure of land and water ecosystems needed to provide the resources for a given population and process the waste that it produces in a globalized metric (global hectares), generally on an annual basis. As institutions seek ways to become more sustainable they have used a variety of metrics, ranking systems, and indicators to evaluate their baseline and progress towards those goals. An EFA for a large urban public university, the University of Illinois at Chicago (UIC), was calculated as 97,601 global hectares (2.66 global hectares per total faculty, staff and students). The breakdown of sources is energy for the built environment (73%), transportation and commuting (13%), materials and waste (12%), and food (3%). UIC's ecological footprint to actual landprint ratio has a value of 1005 which is 1–2 orders of magnitude higher than the other campuses that have performed EFAs. This is an indicator of the urban nature of the campus since the land resources in an urban environment are limited and the activities tend to be denser. A sensitivity analysis to examine the effect of climate change events on the footprint indicated that, if all other factors are held constant, climate change will increase the ecological footprint of UIC.

1. Introduction

Colleges and universities are institutions that have large facilities encompassing many functions of a small community such as housing, laboratories, recreational facilities, transportation and grounds operations, agricultural activities, and office and classroom buildings. Large universities operate like small towns with a significant environmental impact can be at the local level. As institutions such as universities move to become more sustainable ways to measure progress are being sought such as greenhouse gas emissions and ecological footprint analysis (EFA).

EFA has been proposed as a measure of sustainability since it expresses results in terms of the biophysical limits of resources used. The ecological footprint is an aggregate measure that represents the amount of biologically productive land and water area required to provide resources consumed and assimilate waste produced by a given entity (Conway et al., 2008). There is a benefit to having a single value (equal to land area required) that reflects resource use patterns (Constanza, 2000). The use of ecological footprinting in combination with a social and economic impact assessment can provide a measure of sustainability's triple bottom line (Dawe et al., 2004), the footprinting process can help find some of the "hidden" environmental costs of consumption that are not captured by techniques such as cost-benefit analysis and environmental impact (Venetoulis, 2001), and using the ecological footprint, an assessment can be made of where the largest impact comes from (Flint, 2001). EFA specific to a university campus can also be used to compare various footprint reduction scenarios using a common measure.

A number of campuses have published EFA studies (Burgess and Lai, 2006; Conway et al., 2008; Dawe et al., 2004; Flint, 2001; Li et al., 2008; Venetoulis, 2001; Wright, 2002), however, only one study involving a large public university (Ohio State, Janis, 2007) is available, and no university in a large urban area has published a comprehensive EFA. Densely populated regions can have footprints hundreds of times larger than their geopolitical area (Rees and Wackernagal, 1996). This study was undertaken in order to evaluate the ecological footprint of an urban, public university in the United States. Climate change studies have predicted that global warming will lead to significant changes in average temperatures by mid-century as well as change in weather patterns such as rainfall (Meehl et al., 2007). In the East-North Central region, where Chicago is located, climate warming is likely to reduce consumption of heating fuel more than it increases the consumption of electricity, meaning there could be an overall decrease in energy consumption (Hadley et al., 2004). This study also examines the potential effect of those climate change scenarios on the EFA of an institution.

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Table 1
Comparison of ecological footprints for colleges and universities.

	Campus								
	University of Illinois at Chicago	University of Redlands	University of Newcastle	Holme Lacy College, UK	Northeastern University, China	University of Toronto at Mississauga	Colorado College	Kwantlen University College	Ohio State University, Columbus
Year	2008	1997	1999	2001	2003	2005	2006	2006	2007
Ecological footprint, ha	97,601	5700	3592	296	24,787	8744	5603	3039	650,666
Ratio EF to land area	1005	40	26	1.23	50	97	154	81	916
Per capita	2.66	0.9	0.19	0.57	1.06	1.07	2.24	0.33	8.66
Energy	72.66%	49.50%	47%	19%	67.97%	69.40%	87%	28.90%	23.30%
Transportation	12.60%	32.50%	46%	23%	0.08%	16.10%	1.40%	53%	72.24%
Materials and Waste	11.83%	12.50%	2%	32%	5.74%	4%	na	na	4.46%
Paper	na	na	na	na	2%	na	na	7.20%	na
Food	2.60%	na	2%	25%	21.80%	9.20%	10%	9.60%	na
Built-up land	0.18%	na	2%	1%	0.44%	1.20%	na	1.10%	w/transport
Water	0.14%	5%	1%	w/built-up land	2%	0.20%	1%	0.16%	na
Source		Venetoulis (2001)	Flint (2001)	Dawe et al. (2004)	Li et al. (2008)	Conway et al. (2008)	Wright (2002)	Burgess and Lai (2006)	Janis (2007)

2. Ecological footprint

2.1. Methodology

The University of Illinois at Chicago (UIC) is a public research university located near the center of the third largest metropolitan area in the United States and is the largest university in the Chicago area (UIC News Bureau, 2009). Geographically, the scope included only the UIC Chicago main campus east and west sides (see map in supplemental information). The campus population in FY2008 consisted of 20,125 full-time students, 5000 part-time students, 2574 faculty, and 8941 staff. The total land area is 97 hectares and the built environment which is comprised of the building footprints, parking lots, roads and impermeable pavements totals 608,863 square meters. Data for this study were collected from numerous university sources (see supplemental information). Rainfall data for FY08 were obtained from the National Weather Service site nearest to UIC (National Weather Service, 2009).

The calculations were based on Wackernagel and Rees' ecological footprinting procedure (1996), a component-based calculation which examines individual products and services for their cradle-to-grave resource use and waste, and results in a factor for a certain unit or activity (e.g., ha-year/ton or ha/passenger-km) (Chambers et al., 2000). The latter is best suited for universities since the compound methodology only accounts for the ecosystem area used by producers of a good and not other land/water used by the supply chain (Rees, 2003). See supplemental information for further details.

2.2. Results

The ecological footprint in global hectares totaled 97,601 gha for FY2008. Table 1, column 1 shows the contribution of each component by percentage. The energy footprint is the largest and consists of 49,158 global hectares (gha) from onsite power generation and 21,758 gha from purchased electricity. The next largest component is transportation which can be broken down 1619 gha from the campus fleet and 47,538 gha from commuting. Materials and waste make the next largest contribution comprised of 7216 gha from waste and 4331 gha from recycled waste. Calculations are found in supplemental information. Food is the fourth largest component of the ecological footprint, 4193 gha. The results of the two method-

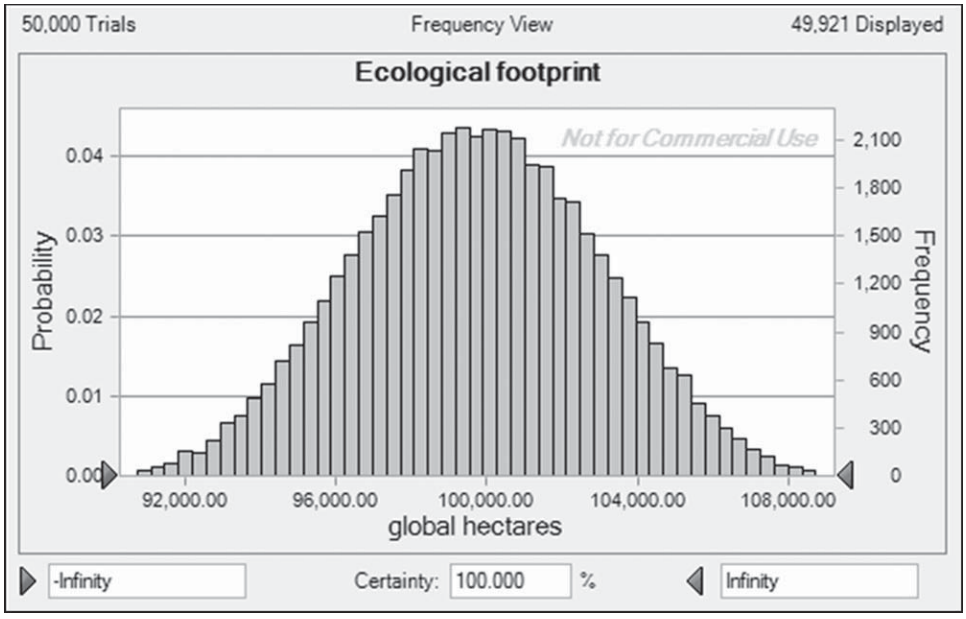

Fig. 1. Sensitivity analysis of the effects of climate change on UIC's EFA.

ologies that were used showed that the more detailed method always produced an overall result that falls between the higher and lower result for the simpler method. For instance the hospital foodprint was 1019, 1956 and 1384 gha of the low, high, and detailed methods, respectively. Water and built-up land make up the smallest portion of the footprint.

3. Climate change simulation

The purpose of the simulation was to examine what the potential effects of climate change alone might have on the ecological footprint of UIC, assuming all other conditions remain the same, including the mix of purchased electricity from the grid versus generated. The change in rainfall is from average annual rainfall from the baseline period. It is assumed that the increase in electricity consumption in summer is due only to the need for chilled water and other air conditioning. There is no growth in the campus population and food and commuting habits remain the same.

Chicago-area specific climate change scenarios from the Chicago Climate Impacts Report of the Chicago Climate Action Plan (CCAP) were used as a point of departure (2008). Different models of climate show some degree of variability, but in general, they suggest that the range of precipitation will vary from a decrease of 2% to an increase of up to 10% by mid-century in the Chicago region relative to the reference period of 1961 to 1990. By extrapolation from the Intergovernmental Panel on Climate Change models (Meehl et al., 2007), we assume that as of 2008 there has been an increase of at least 0.5 °C and thus from 2040 to 2069, temperature changes will increase a further 1 to 4.5 °C. Temperature changes are expected to change demands on the heating and cooling systems. We assumed that an increase in electricity consumption to provide for increased cooling needs would result in increased purchased electricity, and that a decrease in cooling needs would result in a corresponding reduction in natural gas consumption by on-campus power plants.

Monte Carlo sensitivity analysis was performed with independent variables set for rainfall, purchased electricity, and power plant natural gas, using a triangular distribution of the lowest, highest and 2008 value. The final distributions were the result of multiple runs ($n = 50{,}000$). The results of UIC's EFA are displayed in supplemental information and Fig. 1. The distribution of values for $p = 0.02$ is between about 95,600 to 104,000 gha.

4. Discussion and conclusions

In comparison to the GHG emissions for UIC where buildings comprise 83%, transportation 16%, and waste 1% (Klein-Banai et al., 2010), the EFA shows buildings contributed 73%, transportation 13%, materials and waste 12% and food 3%. Thus EFA methodology gives larger weight to waste than GHG emissions since it accounts for the impact of the assimilation of waste as well as the consumption of resources including food.

An examination of the components of the foodprint displayed on a weight percent and footprint percent basis is shown in Fig. 2. This shows that a diet of foods that are higher up on the food chain (beef, fish) require more (land) resources to support them than the lower ones (fruit, vegetables, grains).

An EFA encompasses more components that a GHG inventory. This sustainability metric captures environmental impacts beyond those of climate change. By evaluating actual food consumption data and materials recycled versus disposed, an EFA also represents components that are more behavior or personal-choice related than a GHG inventory. Dietary choices, participation in recycling programs, and transit choices are all primarily driven by personal behavior choices.

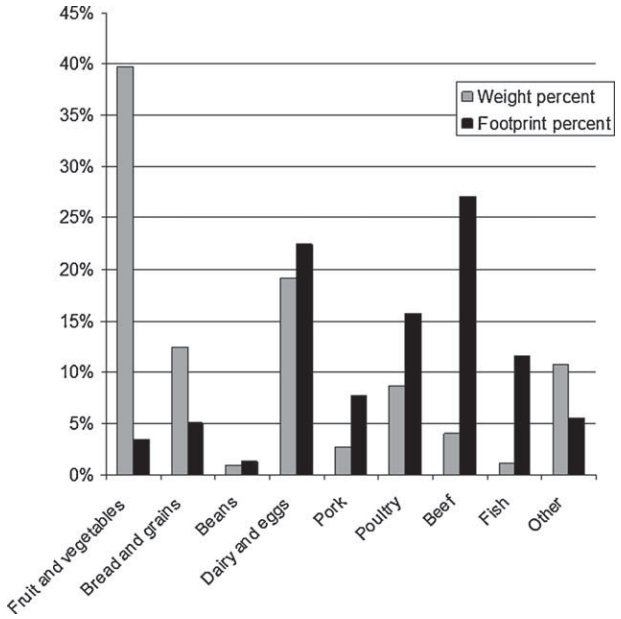

Fig. 2. Distribution of food categories to total food consumption (by weight) compared to total footprint of food for UIC.

The energy footprint could be reduced through energy efficiency and conservation programs. UIC's Climate Action Plan proposes a 40% reduction in GHG emissions by 2030 primarily through these actions which would also reduce the ecological footprint by 33% (about 33,000 gha). Use of more renewable energy sources such as wind and solar, either through on-site generation or power purchase agreements would reduce the ecological footprint further.

We compared EFAs among nine college campuses (Table 1). UIC's overall footprint is the second largest after Ohio State University which has the largest population. UIC's per capita footprint of 2.66 ha/per person is similar to Colorado College (2.24) but materials and waste or paper are not included in their analysis. The ratio of ecological footprint to land area is very high for a highly urban university (UIC – 1005) as compared to a very rural university (Holme Lacey College – 1.23). This shows that an urban university with a small land footprint cannot provide or assimilate within its own construct much of what its population and function require, similar to the large ratios that are found for cities (Rees and Wackernagal, 1996). This is because people and economic activities are located in places primarily due to the availability of resources and natural infrastructure and an EFA does not account for optimal location patterns (Van Den Bergh and Grazi, 2010).

At UIC, Northeastern University, the University of Toronto at Mississauga, and Colorado College building energy makes up the largest portion of the footprint. Colorado College has low contribution from commuting/transportation (1.4%), since 80% of students live on campus and some housing is available to faculty and staff (Colorado College, 2009). Northeastern University had a very low portion of its emissions from transportation (0.08%). Li et al. (2008) suggest that this is due to the lower standard of living in China and that in the future the contribution from commuting could increase as more cars are brought to campus. UIC had the next lowest portion of its emissions from transportation, most likely due to its proximity to urban public transit.

Many assumptions were made for the sensitivity analysis based on the scenario that no changes were made operationally in response to changing climactic factors. Increased temperatures would mean that less heating would be needed, thereby decreasing the natural gas consumption. However, cooling needs would increase the electricity demand. Depending on the source of elec-

tricity, renewable, nuclear, gas or coal, the impact of that increase on the footprint would vary. It is difficult to predict what the effect of weather patterns would have on the overall interplay of purchased versus on-site power. However, there is an indication from the analysis that UIC's footprint would change slightly simply due to climate change itself.

The national footprint in the United States is 9.5 gha/person. With a global biocapacity of 2.1 per person and if everyone on the planet lived like the U.S., we would need 4.5 earths to support our lifestyle (World Wildlife Federation, 2008). UIC's footprint of 2.7 per person, represents only a small portion of each person's footprint.

An ecological footprint is a site-specific analysis that depends on factors related to the type of location (rural, suburban, urban), the scope (university, city, region, nation), and the normative behavior of the specific population. Therefore, the comparative sustainability of an institution must be evaluated in the larger context of the location and its influence on the surrounding environment. However, an EFA can be used as a measure of sustainability that captures a broad range of impacts to look at progress over time within the defined boundaries.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ecolind.2010.11.002.

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