Zurich, June 15-17 2016
Sustainable Built Environment (SBE) Regional Conference

Expanding Boundaries:
Systems Thinking for the Built Environment

ECOLOGICAL FOOTPRINT ANALYSIS OF CANADIAN HOUSEHOLD CONSUMPTION BY BUILDING TYPE AND MODE OF OCCUPATION

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Abstract
This paper expands the system boundaries of the residential built environment to the Ecological Footprint (EF) in Canada. The proposed methodology is applied in two steps. First, we compare the household expenditures according to building type. These differences account for the varying resource requirements of households residing in different types of building. Second, the EF of the household consumption is calculated with a multiregional input-output model based on the Global Trade Analysis Project. The study is based on data from Statistics Canada, from the annual survey of household expenditures and according to four different building types (single detached house, single attached house, apartment and others) and different modes of occupation (owner with mortgage, owner without mortgage and renters). The resource requirements are derived from household expenditures and reclassified according to the Classification of Individual Consumption According to Purpose category of the United Nations Statistics Division (COICOP) and according to the Consumer Land Use Matrix, which displays resource requirements from final household demand by consumption categories (food, housing, transport, goods and services). The paper provides insights on how to drive the consumption in order to have a reduced EF not only in terms of daily needs, but also on how the housing type and the mode of occupation have an impact on resource requirements. The methodology can be used to analyse and to compare the design of residential buildings in order to generate economic policies in various countries and to encourage citizens to take responsibility for their choice of residence.

Keywords:
Ecological Footprint; Top-down analysis; Residential building; Household expenditures; Mode of ownership; COICOP

1 INTRODUCTION

Reducing environmental impacts through sustainable use of natural wealth is an important challenge for governments and decisions makers around the globe (Kitzes and Wackernagel, 2009) [1]. According to the most recent studies, the resources of 1.7 Earth equivalent are necessary to support our current consumption (Global Footprint Network (GFN), 2015) [2]. This situation, referred to as overshoot (Wackernagel and Rees, 1996) [3], means that our consumption is currently so intensive that the ability of the ecosphere to regenerate is altered (Galli, 2015) [4]. Since the early 1960's and the industrial era, consumption in developed countries has exploded and cities have become the nerve centres of our society (Moore and al., 2013) [5]. Managing resources in urban areas is a big challenge, but it would provide natural wealth for future generations and represents a source of economic, social and, of course, environmental influence (Mackenzie and al., 2008) [6]. Accumulation of human pressure on ecosystems is fundamental to many environmental problems and world leaders face the challenge of selecting appropriate measures and policies to prevent

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DOI 10.3218/3774-6_88, ISBN 978-3-7281-3774-6, http://vdf.ch/expanding-boundaries.html

further ecological disasters (Wackernagel and al., 2006 ; Sutton and al., 2012) [7] [8].

According to several studies in different parts of the world, household consumption holds a large place in the global ecological impact of a nation (Holden, 2012; Gressot and al., 2015) [8] [9]. The world population has increased faster for decades and is foreseen to achieve 9 billion by 2050 with 67% of which is expected to live in urban areas (FAO, 2009) [10]. In order to reduce climate changes, pollution and to preserve the biosphere, it is necessary to monitor and to regulate such demand of natural capital (Borucke and al., 2013) [11].

Despite some criticisms (Kitzes and al., 2009) [12], a concrete indicator is necessary to quantify and qualify the use of natural resources and the Ecological Footprint (EF) is one of the most common. Using standardized measurements, the Ecological Footprint was introduced by William Rees and Mathis Wackernagel in the 1990s (Rees, 1992 ; Wackernagel, 1994) [13] [14]. It measures the area of biologically productive land and water required to support the demands of a population or its production capacity. Such areas compound the six components of the EF: cropland, grazing land, forest land, fishing grounds, built-up land and carbon zone. Based on the fundamental assumptions that most of the consumed resources and waste production can be tracked (Wiedmann and al., 2007) [15], this demand can be compared to biocapacity (Butchart and al., 2010) [16], the amount of biologically productive land and water available for human use. The measurement units are global hectares, gha, corresponding to one hectare of biologically productive space with world average productivity for the given year (Galli and al, 2007) [17].

Different approaches have been performed in order to head toward a sustainable world and surveys highlight several factors influencing the human pressure in cities such as design, size, or the localization of the residential areas (Jin, Xu and Yang, 2009 ; Holden, 2004) [18] [19]. Based on a single top-down approach to consistently track the EF inside a high-density area, E. Holden presented studies in Norway analysing the structure of a sustainable town, comparing a city located in an urban area to one in a rural environment (Holden, 2012) [20]. This approach is applied in this article for the first time in Canada, for 4 different building types, including the mode of occupation. The aims of this study are to compare EFs from different types of building and from different modes of occupation in order to involve population in consuming more responsibly and to encourage a more energy-efficient design of the residential areas.

2 DATA AND METHOD

2.1 Data

Raw data has been acquired from Statistics Canada for the 2010 to 2013 period from the Survey of Household Spending (Statistics Canada, 2015) [21]. Detailed average household expenditures from everyday life have been classified in 16 principal categories (food, shelter, household operations, household furnishings and equipment, clothing and accessories, transportation, health care, personal care, recreation, education, reading materials and other printed matter, tobacco products and alcoholic beverages, games of chance, gifts, financial services). These categories are inspired from those created by the United Nations Statistics Division, the COICOP classification (United Nations Statistics Division, 2015) [22]. All expenditures are in $CA.

Expenditures have been extracted according to the building type and the mode of occupation. The four building types studied are single detached houses (building usually occupied by a single household and consists in a single dwelling unit), single attached houses (home sharing a common party wall), apartments and, other types of location (hotel, rooming, lodging house, construction camp or mobile home for example). The three modes of occupation studied are owner with mortgage, owner without mortgage and renter. Household spending on income taxes is not integrated in the study.

2.2 Consumption Land Use Matrices

Evaluation of EF requires tables provided by the Global Footprint Institute, the Consumption Land Use Matrices (CLUMs). The CLUM-GTAP8 indicates the EF associated with purchases from the major consumption categories. It is unique to the economic system of a country, and can often highlight surprising findings that reveal important underlying features of a nation's consumption and its impact on ecological systems (GFN, 2015) [2]. Within the CLUM, there are two broad classifications:

- Areas that are under direct influence of households, such as direct consumption under the broad categories of food, shelter, transportation, goods, and services.
- Areas that are under indirect influence of households, such as gross fixed capital formation and government expenditure.

In GTAP, the Gross Fixed Capital Formation does not have a link with citizen expenditures. As Canada is a democratic country, government's EF is the same for each citizen. Results do not include the GCFC and EF from the government.

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3 METHODOLOGY

The classification from Statistics Canada differs from those used in the CLUM. Indeed, food, shelter and transportation are the same for both categorizations but goods and services in CLUMs differ slightly from Canadian expenditures. A database and different comparison tables have been created to link the most detailed level of Canadian categories to the five major groups of the GFN. Surveys using this linkage have been previously done (Calgary and Global Footprint Network, 2007) [23] in Calgary.

In order to monitor our results according to the type of building (Fb) and the mode of occupation (Fo) several factors have been calculated. EFs per capita have been obtained by dividing the total expenditures for each category by the size of the household. Each factor is calculated as:

$$Fb = \frac{Households\ expenditures\ (type\ of\ building)}{Total\ expenditures\ (all\ dwelling)} \quad (1)$$

$$Fo = \frac{Households\ expenditures\ (mode\ of\ occupation)}{Total\ expenditures\ (all\ dwelling)} \quad (2)$$

Calculations using the Canada given CLUM and the ranged expenditures can be made (Galli, Kitzes and Wermer, 2007) [24] and allow to give us the Ecological Footprint for each category of the classification. At the final stage of our expenditures classification, we will get CLUMs with footprints organised by COICOP consumption categories sectors of expenditures for each type of building and mode of occupation.

4 RESULTS

Survey results have been obtained by Statistic Canada from the Survey of Household Spending for the 2010-2013 periods. Size of households varies from 1.8 in apartments to 3.1 residents per household in single detached houses. In 2010, 11,746 persons were in the sample and this represents a weighted estimate of 13,514,008 households with an average size of 2.48 persons per household.

4.1 Expenditures and EF analyses depending the type of building

Figure 1 presents household expenditures (in $CA) according to the type of building from 2010 to 2013 and to the five categories of consumption. Households living in single detached houses spend more money than the others, and in average, household they spend 83,600 $CA per year, households in single attached houses spend in average 70,375 $CA, followed by those living in apartments (50,455 $CA) and in other types of building (47,890 $CA). The main expenses for Canadian households are in housing (35% for apartments to 44% of the total expenditures for SD houses) and services (22% for SD houses to 27% for apartments). Transportation, goods and food (respectively 11% to 15%, 12% to 15% and 09% to 11%) are minor parts of the expenditures.

As we can notice, expenditures have increased every year, especially for single detached houses and apartments. Over these four years, Canada has been impacted by inflation. All household fees increased during this period.

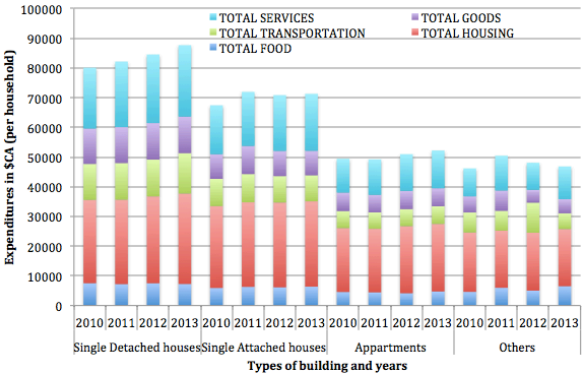

Fig. 1: Households expenditures according to the type of building from 2010 to 2013.

Figure 2 shows us the Ecological Footprint per capita for the different types of building studied. Consumption from single detached houses households generates the highest EF with an average footprint of 6.3 gha per capita for the years 2010-2013. Inhabitants from single attached houses have an average EF of 4,9 gha per capita and occupants from other types of building have an average EF of 3.7 gha per capita. Finally, dwellings living in apartments generate the lowest EF (3.2 gha per capita).

Despite to the variation in expenditures, most of the expenses are spent in housing and services sectors. Transportation and food are the main drivers for the EF of Canadian households. They are respectively part of 36% and 22% of the total EF whereas, goods, housing and services represent 17%, 14% and 10% of the total EF.

Transportation is the main driver of the Canadian households for all types of building. Purchase and maintenance of vehicle are responsible for more than 80% of the transportation EF. SD houses occupants have the greatest impact, followed by inhabitants of SA houses, other types of building, and dwellings living in apartments. Food is the second sector with the highest EF for Canadian households' consumption, regardless to the types of building. This sector represents between 20% and 24% of the total EF and is driven by the meat and the animal-origin food, and this for all the different types of building.

Bigger buildings consume more energy (electricity, gas and other fuels for heating for example) and gather more people in one household. The housing EF rises with the size and the type of building.

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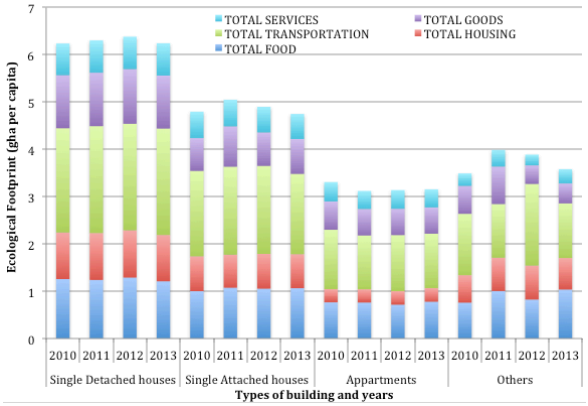

Fig. 2: Ecological Footprint according to the type of building from 2010 to 2013.

4.2 Expenditures and EF analyses depending on the mode of occupation

In average, owners with a mortgage spend 99,600 $CA per year, owners who do not have one spend 62,100 $CA (in average 82,500 $CA for owners, that is more than 1,5 times more than the renters (49,800 $CA) (Fig. 3). Main expenses for Canadian households still concern housing and services sectors.

Owners who have a mortgage have more fees to pay than those without a mortgage, especially in the services and housing category. These fees mainly correspond to the financial services and taxes related to household management. Renters pay less for these, but are responsible for their energy consumption, major part of their expenses in the housing sector. Only 62% of renters are car owners. Expenditures allowed for transportation are far less than owners and are 22% of their total consumption whereas it represents 28% of the total for the owners.

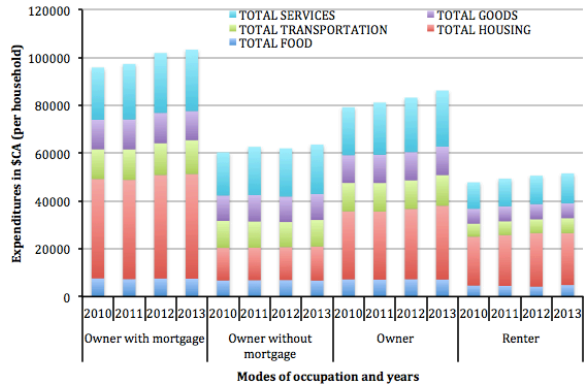

Fig. 3: Household expenditures according to the modes of occupation from 2010 to 2013.

Owners without mortgage have the highest EF (average value of 6.5 gha per capita). Owners with mortgage have a reduced one (5.6 gha per capita in average) compared to those with mortgage, but the part of the owners is really more important than the renters one. The EF from the owners' consumption is 1.8 times the one of the renters (respectively 6.1 and 3.3 gha per capita). Transportation and food have the greatest impact on EF, even depending to the mode of occupation (Fig. 4).

In the transportation field, the EF generated is mainly due to the rate of car ownership. Whereas only 62% of the renters have a car, the rate of owners of a dwelling having a car exceeds the 95%. The EF associated for the owners is almost twice the one of the renters, and reducing it becomes the main goal. According to the figures, the expenditures and the EF embedded to the housing sector are much higher for owners than the ones for renters. Even if their footprint in the sector of housing is over three times below the owners' ones, it is important that they should be aware of their impact.

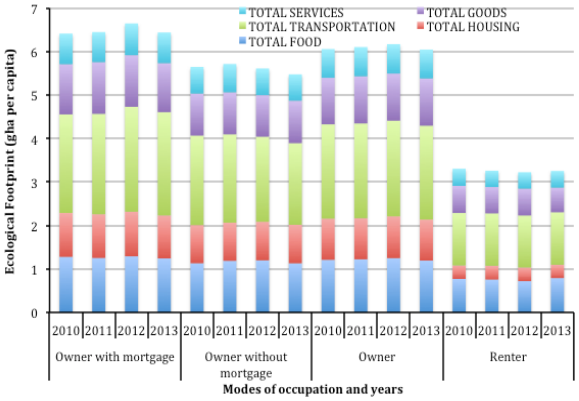

Fig. 4: Ecological Footprint according to the modes of occupation from 2010 to 2013.

4.3 Ecological Footprint in term of land use

The largest part of the EF is due to personal transportation on a personal scale (Figure 5). Food and goods follow this trend and so does housing. Carbon Footprint for personal transportation is the single most important driver of the total footprint, followed by the cropland footprint for food consumption and the carbon footprint for housing. The carbon footprint or "energy land" represents between 52% and 55% of the total footprint.

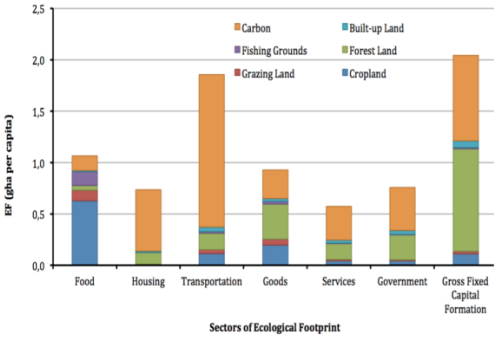

Fig. 5: Consumption Land Use Matrix (CLUM) breakdown for Canada in 2010, indicating ecosystem types mostly demanded by Canadian households.

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5 DISCUSSION AND CONCLUSION

The top-down (MRIO-based) Ecological Footprint approach presented in this paper allowed for the first time to study the link between the income, the type of building and the mode of occupation. In Canada, the Ecological Footprint of people living in single detached houses is twice as high as the EF of people living in apartments. Those living in a property with a mortgage have an EF twice of those renting. Overall, we found that the main drivers of the EF were transportation, then food regardless of the types of building and the modes of occupation of the Canadian households. However, the income, the size of the household, and the location of the dwelling are the main factors that influence the EF (Rees and Walker, 1997) [25]. Centralization of the activities to avoid transportation impacts and high-density cities could lead to smaller Ecological Footprints of Canadian households (Biesiot and Klaas, 1999) [26].

In Canada, even if households spend more money on housing and services; the main share of EF is due to transportation and food. Canada is a large country and modes of transportation have not changed in decades. Most inhabitants have their own car (Transport Canada, 2013) [27], and especially for those living in single detached houses, usually located outside of the cities. Living in apartments and renting have a lowest impact when it comes to transportation and other categories. Food is not the main category for expenditures, but has a large impact on total EF. Canada import a large quantity of food supply, so local consumption requires more resources than if produced locally.

Housing and especially energy is largely due to the size of habitation. When we compare the footprint allocated to the housing category, EF for single attached houses is more than twice the apartment ones. Heating and maintenance of the dwelling generate more impact; more money is also spent in these sectors for single attached and single detached households, whereas rentals for housing expenditures are higher for whom living in apartments. It is also largely taken over by the owners. So does work the heating: renters are not necessary allowed to regulate the heating and not even responsible for the energy fees. In order to involve the renters into environmental and more sustainable practices, sharing of the energetic fees between owners and tenants could have a positive effect and make the renters reduce their consumption.

With a novel approach, this ecological indicator is used for different types of building linked to the type of the households. This combination allows a more accurate analysis of the households' consumption according to residential building type and mode of occupation, and its correlation on ecosystem impacts. Transportation has the larger impact and is mainly responsible for the carbon footprint of the Canadian households. Public transport has to be developed near the main centres of activities, and prices for fuel have to be risen in order to promote low-carbon emission energies (Rees and Wackernagel, 1996) [28]. Promoting low-protein food, reducing the amount of meat and dairy products and diminishing food waste are important to succeed in the reduction of the EF associated to the production, the consumption and the waste generated by the food. Housing footprint could also be reduced by planning ecological construction (LEED certification), by constructing high-density areas that concentrates transportation, commercial areas and population.

Households' consumption awareness is critical. This paper highlights that living in single detached houses with a mortgage is the biggest resource driver, as compared with the lower impact of renting an apartment. Public policies must encourage citizens to take responsibility for their choice of residence and their allocation of expenditures toward sustainable goals.

6 ACKNOWLEDGEMENT

The CLUM-GTAP8 was kindly provided by the Global Footprint Network.

The author would like to thank a reviewer from Statistics Canada.

Mathis Wackernagel and Jon Martindill are thanked for the discussion on EF methodology.

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