Australian Journal of Basic and Applied Sciences, 8(7) May 2014, Pages: 265-276

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Carbon Emission from Domestic Level Consumption: Ecological Footprint Account of Dhanmondi Residential Area, Dhaka, Bangladesh – *A Case Study*

[1]Shahadat Hossain Shakil, [2]Nabila Nur Kuhu, [3]Rifat Rahman, [4]Prof. Dr. Ishrat Islam

[1]*Department of Geography, University of Manchester, Manchester, UK*
[2]*Department of City/Urban, Community and Regional Planning, UT Arlington, Texas, USA*
[3,4]*Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh*

ARTICLE INFO

Article history:
Received 25 January 2014
Received in revised form
8 April 2014
Accepted 20 April 2014
Available online 10 May 2014

Keywords:
Ecological Footprint, Biocapacity, Component Method, Ecological Overshoot, Environmental Sustainability, Carbon Emission, Household Consumption, Dhanmondi Residential Area, Dhaka, Bangladesh.

ABSTRACT

Background: Ecological Footprint assessment helps to identify what activities are having the biggest impact on nature and opens up possibilities to reduce our impact and live within the means of 'one planet'. It provides measurement of collective consumption of the population whether they are exceeding the earth's ecological limits or not. The introduction of ecological footprint has been very necessary for the context of Bangladesh especially in Dhaka, where the unplanned consumption pattern of the population is producing a very unsustainable situation. **Objective**: This study intends to introduce this new concept through calculating the *Ecological Footprint Account* (usually 90% of it consists with Carbon Footprint/Emission Account) of the prestigious residential area Dhanmondi, which is one of the major resource consuming area of Dhaka city. **Method:** A blending of 'component' and 'direct' method has been used. Questionnaire survey (in 240 HH) has been conducted to gather information about the consumption pattern for different components (i.e. energy, food, service etc.) in the households for the year 2011. Biocapacity of Dhanmondi RA is also measured from the bioproductive lands available within the area. Following the generated results, sustainability analysis has been done. **Results:** An enormous gap between demand (1.19 global hectare/person) and supply (0.02 global hectare/person) of natural resources has been observed from the scrutiny. **Conclusion:** Natural gas consumption for domestic purpose has been found as the main motive behind the high footprint figure compared to the national average followed by Electricity, Food and Transportation. Biocapacity has been discovered as very petite amount because of unplanned urban agglomeration.

To Cite This Article: Shahadat Hossain Shakil, Nabila Nur Kuhu, Rifat Rahman, Prof. Dr. Ishrat Islam, Carbon Emission from Domestic Level Consumption: Ecological Footprint Account of Dhanmondi Residential Area, Dhaka, Bangladesh – *A Case Study*. ***Aust. J. Basic & Appl. Sci.****, 8(7): 265-276, 2014*

INTRODUCTION

The 21st century is going to introducing us to a more complicated scenario than ever to access the ecosystem service. The current trend of consumption, urbanization, industrialization is sending us closer to food shortages, biodiversity loss, depleted fisheries, soil erosion and freshwater stress. To manage both ecological reserve and demand in a better way, immediate strategies should be put forth and one of the major indicators for making these strategies is Ecological Footprint (Ewing *et al.*, 2010a). It is an evolving topic and modification of this tool is still going on. It was developed in 1990 by Mathis Wackernagel and William Rees as a means of making our ecological constraints clear and our sustainability strategies more effective and livable.

Bangladesh is a developing country of South-Asia where unplanned urbanization is taking place all over the country and agricultural land is turning into industrial land (Dewan and Yamaguchi, 2009). This trend is badly in need of a turning back in order to achieve a sustainable community. Thus calculation of ecological footprint is desirable in order to manage the demand pattern throughout the nation.

Capital Dhaka is the biggest sufferer of this rapid urbanization, along with its metropolitan area, had a population of over 15 million in 2010 (BBS, 2010), making it the largest city in Bangladesh. The rate of population growth continues to be high even now, at nearly 6% annually (Islam, 1998). To meet the endless demand of this population, natural resources from both inside and outside of the city are being used without keeping in mind their capacity to regenerate. Even though many of the rural areas of Bangladesh still have the decent and equitable living within the means of nature, the pattern of consumption and waste generation of

Corresponding Author: Shahadat Hossain Shakil, Graduate Student (MSc. Environmental Governance), Dept. of Geography, SEED, University of Manchester, UK.
E-mail: shshakil.buet@gmail.com Cell: +88-01717-189-153

Dhaka is unimaginable. So ecological footprint is a must to generate awareness to the magnitude of consumption of Dhaka city.

Some specific areas of Dhaka which provide residence to the upper class population (high income) have been found to be the areas with higher consumtion and waste generation. Gulshan, Banani, Dhanmondi, Uttara- these are planned areas and are residence of highest income population of the city. Dhanmondi is one of these happening areas. It is a planned area basically aimed of residential use but now with a large mixture of educational and commercial use. It is one of the first planned areas, developed in the early fifties to provide residential accommodation to high and higher middle income groups of population in Dhaka city (Hossain *et al*., 2009). It is located at the South-West part of Dhaka city. Its geographical position is within $23^{0}44^{/}30^{//}$N and $90^{0}23^{/}00^{//}$E.

Footprint calculation is a data intensive research work (MacManus and Haughton, 2006). An area should be selected where all kind of data should be available such as household expenditure, energy consumption, transport mode and expenditure etc. Moreover, there is homogeneity in the physical pattern of Dhanmondi residential area as well as in socio-economic condition of the inhabitants. Thus, Dhanmondi residential area has been selected to calculate the first ever ecological footprint of any area within Bangladesh.

Method:

Selection of Parameters and Calculation Method:

According to the "Calculation Methodology of National Footprint Accounts, 2010 Edition" (Ewing *et al*., 2010b) obtained from Global Footprint Network footprint account consists of six components. Among those six components (Table 1) *Cropland* and *Grazing Land* is absent within Dhanmondi residential area. *Fishing Ground* (Dhanmondi Lake) and *Forest Land* (trees) also cannot be included in the calculation index. Because Dhanmondi residential area does not get fish supply from that lake and trees or forest area exist within the area do not provide timber supply for fuel and other uses. So in this study the ecological footprint index of Dhanmondi residential area comprises of two components they are - *Built-Up Land* and *Carbon Uptake Land.* The following table (Table 1) describes the method selected to determine each of the components for Dhanmondi residential area.

Table 1: Method Selected for Determining Footprint Components.

Components of Footprint	Method Selected
Cropland Footprint	N/A
Grazing Land Footprint	N/A
Fishing Ground Footprint	N/A
Forest Land Footprint	N/A
Built-Up Land Footprint	Direct (derived from GIS land use map)
Carbon Uptake Land Footprint	Hybrid Method (following the Component approach but collection of data through Direct household survey)

Biocapacity of any area consist of the above mentioned land use type except the Carbon Uptake Land. Among those five components *Cropland* and *Grazing Land* is absent within Dhanmondi residential area. The rest three types of lands are present within Dhanmondi residential area. The following table (Table 2) shows the components of Biocapacity account which is applicable for Dhanmondi.

Table 2: Components of Biocapacity Account Present in Dhanmondi Residential Area

Components of Biocapacity	Existence
Cropland	Absent
Grazing Land	Absent
Fishing Ground	Present
Forest Land	Present (Very Negligible Amount)
Built-Up Land	Present

Data Collection:

Data regarding consumption pattern (food, goods, services, energy, waste, transportation etc.) of the inhabitants of Dhanmondi has been collected through questionnaire survey of the household (Appendix A). For this purpose, the total number of population in Dhanmondi residential area for 2011 has been forecasted 43,000 using exponential trend line method (BBS, 1981 and 2001). Finally total household number in 2011 has been determined 9,600 using average household size 4.72 person (BBS, 2010). From this household number sample size has been determined 369 household at 95% confidence level and 5% confidence interval (Creative Research System, 2010). Additionally, Ecological footprint is influenced by income status (Ewing *et al*., 2010a) and which is correlated with the household's floor space (Bertaud, 2007). Considering this factor, distribution pattern of the households in Dhanmondi according to floor space has been identified from the prior research (Nabi *et al*., 2004). The final survey has been done with the modified (subsequent to pilot survey) questionnaire on 220 households of Dhanmondi residential area for time constraints and difficulties in getting accessibility in those high class residential apartments for survey purpose. Therefore confidence interval has been changed to 6.53% at 95% confidence level for the final sample size 240 (sum of pilot survey and final survey) instead of previously determined 369.During the household survey housewives of each household who are mainly responsible for the daily/weekly/monthly grocery shopping has been interviewed. In some cases consultation has been also made with head of the family. The age range of the respondents was within 25-55 years. Respondent's educational qualification was ranged between secondary level up to post graduation.

Required standard and conversion factors (i.e. Sequestration factor; Equivalence factor; Yield Factor) have been collected from various international research agencies such as Stockholm Environment Institute (SEI), Berkeley Institute on the Environment (BIE), Intergovernmental Panel on Climate Change (IPCC), EPA, and Global Footprint Network etc.

Calculation:

1. Footprint Component:

1.1 Built-Up Land:

The number of land use categories exist in the GIS database has been sorted out under the four broad headings: Residential, Goods, Services and Transportation.

Table 3: Built-Up Land Footprint of Dhanmondi Residential Area.

Land Type	[1]Area (Hectare)		[2]Equivalency Factor (of Forest Land)		Area (Global Hectare - gha)
Residential	28.956	×	2.51	=	72.680
Goods	9.906	×		=	24.864
Services	84.848	×		=	212.968
Transportation	49.455	×		=	124.132
Total	173.166				434.644

Source: [1]DCC (2002); [2]Ewing et al., (2010a)

1.2 Carbon Uptake Land:

In this study, carbon emission from day to day consumption activity of Dhanmondi residential area's inhabitants has been studied following the Component Based Approach (Simmons *et al*., 2000).

1.2.1.1 Energy: Electricity Consumption:

Average monthly electricity bill has been inquired during the survey to the respondents, considering the variation during the summer and winter. After achieving the total amount of electricity bill in a year, it has been converted into unit of electricity consumption – MWh (Mega Watt-hour) with the help of unit price of electricity derived from DESCO (Dhaka Electric Supply Company Ltd.). Finally amount of carbon dioxide emission for each unit of MWh electricity use has been determined with the standard value derived from Greenhouse Gas Equivalencies Calculator - United States Environmental Protection Agency (EPA).

Table 4: Electricity Consumption Footprint.

		CO_2				Sequestration				Equivalency Factor
	=	*annual MWh*	×	*tons CO_2/MWh*	÷	*tons CO_2/acre/ year*	×	hectare	×	*gha/hectare*
Electricity Consumption	=	36,576.579[1]	×	0.69[2]	÷	1.6175[3]	×	0.4047[4]	×	1.26[5]
					=	*annual acres →*	=	*annual hectares →*	=	*annual global hectare*
					=	15,602.992	=	6,314.374	=	7,956.112

Source: [1]Household Survey (2011), DESCO (2012); [2] U. S. EPA (2011); [3]Ewing et al., (2010a); [4]U.S. Department of Energy and Information Administration (2011); [5]Xu and Martin (2010)

1.2.1.2 Energy: Natural Gas Consumption:

Respondents have been asked about the type and number of hours Gas Burner use per day on an average (approximate amount considering the variation during different seasons; still now there is no meter reading provision for gas usage in Bangladesh; so the total amount of gas usage per year may be leading to a minor imprecise result). After that, it has been converted to total amount of (cubic meter) gas usage in a year. During this conversion per hour gas consumption rate by a Double Burner (majority of the household uses double burner gas stove) Gas Stove has been used (The Engineering Toolbox, 2011). Then, it has been transformed into carbon emission amount utilizing standard value derived from Greenhouse Gas Equivalencies Calculator - United States Environmental Protection Agency.

Table 5: Natural GAS Consumption Footprint.

		CO_2				Sequestration				Equivalency Factor
Natural Gas Consumption	=	*annual cubic meter*	×	*tonsCO_2/ m^3 gas*	÷	*tons CO_2/acre/ year*	×	hectare	×	*gha/hectare*
	=	92,03,305.835[1]	×	0.00496[2]	÷	1.6175	×	0.4047	×	1.26
					=	*annual acres →*	=	*annual hectares →*	=	*Annual global hectare*
					=	28,221.575	=	11,420.989	=	14, 390.446

Source:[1]Household Survey (2011), The Engineering Toolbox (2011); [2]U. S. EPA (2011)

1.2.2 Water:

Water consumptions impact in GHG emission has not been mentioned in the Component Method of ecological footprint assessment (Simmons *et al*., 2000). However in case of some recent footprint studies (Chambers *et al*., 2005) it has been added as a component. Average monthly water consumption bill considering the seasonal variation has been collected from the households. Then the total amount (Million Liter) of water uses in a year has been computed using the unit price derived from Dhaka WASA (Water Supply and Sewerage Authority). After that total amount of carbon emission has been estimated using the standard value (Chambers et al., 2005).

Table 6: Water Consumption Footprint.

		CO_2				Sequestration				Equivalency Factor
Water Consumption	=	*annual million liter*	×	*tonsCO_2/ M liter water*	÷	*tons CO_2/acre/ year*	×	hectare	×	*gha/hectare*
	=	13,791.528[1]	×	0.1[2]	÷	1.6175	×	0.4047	×	1.26
					=	*annual acres →*	=	*annual hectares →*	=	*annual global hectare*
					=	852.645	=	345.057	=	434.772

Source:[1]Household Survey (2011), Dhaka WASA (2012); [2] Chambers et al., (2005)

1.2.3.1 Transportation: Fuel Consumption Impact:

To determine the total amount of fuel use of different types, respondents have been asked about the number and type of vehicle they have, and per month average fuel cost on each respective vehicle. Following the determination of total annual expenditure for each fuel type, annual quantity has been find out using the unit price of each fuel type. Carbon emissions have been calculated using the Mobile Transport-Fuel Combustion Standard for CNG, Diesel, Octane and Petrol, derived from Greenhouse Gas Inventory Protocol Core Module Guidance (Climete Leaders - EPA, USA, 2012).

Table 7: Fuel Consumption Footprint.

		CO_2					Sequestration				Equivalency Factor
Fuel Consumption	=	*CNG (annual cubic feet)*	×	*kg CO_2/ cubic feet*	=	*kg CO_2*					
	=	1,30,68,295[1]	×	0.053[2]	=	6,92,619.63					
	=	*Diesel (annual liter)*	×	*kg CO_2/ liter*	=	*kg CO_2*					
	=	4,09,950[1]	×	2.676[2]	=	10,97,160.28					
	=	*Octane (annual liter)*	×	*kg CO_2/ liter*	=	*kg CO_2*					
	=	18,09,886[1]	×	2.939[2]	=	53,19,098.39					
	=	*Petrol (annual liter)*	×	*kg CO_2/ liter*	=	*kg CO_2*					
	=	11,19,729[1]	×	2.272[2]	=	25,43,515.61					
					=	*Total kg CO_2*					
					=	96,52,393.92					
					=	*Total Tons CO_2*	÷	*tons CO_2/acre/ year*	×	hectare	× *gha/hectare*
					=	9,652.39	÷	1.6175	×	0.4047	× 1.26
							=	*annual acres →*	=	*annual hectares →*	= *annual gha*

Source: [1]Household Survey (2011), "X" Fuel Station in Dhanmondi (2012); [2] Climate Leader – EPA,USA (2012)

1.2.3.2 Transportation: Air Travel Impact:

Respondents have been asked about the number of air travel made by the household members and the number of persons traveled in each particular trip. Multiplying the number of trip by the number of person traveled in each the trip, total Person-Trip traveled in last one year has been determined. Then it has been multiplied by the Average Flight Length of Air Travel (DECC and Defra, 2011) to determine the Person Trip Travel Length. Uplift factor (10% of total) for running, landing, maneuvering has been added and total Person Trip Travel Length has been calculated. Finally total carbon emission has been assessed using standard emission value for per kilometer air travel.

Table 8: Air Travel Footprint.

		CO_2								Sequestration				Equivalency Factor
Air Flight	=	*annual no. of person-trip*	×	*average flight length (km)*	=	*annual person-trip travel length (km) [including 10% uplift factor]*	×	*tonsCO₂/ km air travel*	÷	*tons CO_2/acre/ year*	×	hectare	×	*gha/hectare*
	=	11107[1]	×	4775[2]	=	5,83,40,267.857	×	0.000103[2]	÷	1.6175	×	0.4047	×	1.26
									=	*annual acres →*	=	*annual hectares →*	=	*annual global hectare*
									=	3,720.43	=	1,505.62	=	1,897.08

Source: [1]Household Survey (2011); [2]DECC and Defra (2011)

1.2.3.3 Transportation: Asphalt Impact:

Asphalt impact has been considered from the amount of Asphalt used for the maintenance of road. Respective professionals of Dhaka City Corporation have been consulted about the frequency of carpeting. It has been evident that after two or three years interval carpeting is done. In this study this time interval has been assumed three years. That's why impact of Asphalt use will be one-third (1/3) in the total footprint account in a year. Total surface area of roads has been calculated from the GIS land use map. According to standard (RHD, GoB, 2001) on an average three centimeter (depth) Asphalt is used in case of traditional road maintenance in Bangladesh. Volume of Asphalt has been determined by multiplying the total road surface area with the depth of Asphalt used. Density of Asphalt and carbon emission for per unit mass (kg) use of Asphalt has been derived standard (Hammond and Jones, 2008).

Table 9: Asphalt Use Footprint.

		CO_2								Sequestration				Equivalency Factor
Asphalt Use	=	*total surface area of road (square meter)*	×	*average thickness of Asphalt layer (meter)*	×	*density of asphalt (kg/cubic meter)*	×	*tonsCO₂/kg Asphalt used for road construction*	*= CO₂ emitted in 1 year (tons)*	÷ *tons CO_2/acre/ year*	×	hectare	×	*gha /hectare*
	=	4,42,648.149[1]		0.0762[2]	=	2,100[3]	×	0.14[4]	= 9,917/3	÷ 1.6175	×	0.4047	×	1.26
										= *annual acres →*	=	*annual hectares →*	=	*annual global hectare*
									=	2,043.60	=	827.02	=	1,042.05

Source: [1]DCC (2002); [2]RHD, GoB (2001); [3,4] Hammond and Jones (2008)

1.2.4 Waste:

Determining the impact of waste production in GHG emission is a very complex procedure following the methodology of 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Eggleston *et al*., 2006). For this reason secondary data has been used. Per capita waste generation rate, total amount of waste generated in a year and the carbon dioxide emission from that amount annually, in Dhaka city has been derived from one of the technical documents of Waste Concern (Enayetullah *et al*., 2006). Dhanmondi residential area's annual waste generation amount has been determined. After that total carbon emission from that amount has been figured out.

Table 10: Waste Generation Footprint.

		CO_2				Sequestration				Equivalency Factor
Waste Generation	=	*annual waste generation (tons)*	×	*tonsCO₂/ tons of waste*	÷	*tons CO_2/acre/ year*	×	hectare	×	*gha/hectare*
	=	8,789.200[1]	×	0.449[2]	÷	1.6175	×	0.4047	×	1.26
					=	*annual acres →*	=	*annual hectares →*	=	*annual global hectare*
					=	2,441.299	=	987.969	=	1, 244.841

Source: [1]Forcasted Population for 2011 (43,000) of Dhanmondi Residential Area, Per Capita Waste Generation Rate (Enayetullah et al., 2006); [2]Enayetullah et al., (2006)

1.2.5 Food:

To assess the impact of food consumption, expenditure for food consumption has been collected following some predefined category and sub-category. This categorization has been determined on the basis of availability of standards for Economic Input-Output Life Cycle Assessment [EIO-LCA] (Green Design Institute, 2011). Maximum number of food consumption category has been tried to cover but for the absence of the standards and vast socio-cultural difference with abroad sub-categories finally fixed at a moderate number. Total consumption unit has been converted into annual consumption unit, and then using the unit price, yearly cost in taka has been calculated. Finally it has been transformed into yearly expenditure in Millions U.S. $ using a standard conversion rate (1 U.S. $=70 Taka). Using the GHG emission standards collected earlier, carbon dioxide emission from each consumption category of food has been calculated. Detail calculation procedure has been shown in Appendix-B

1.2.6 Goods:

In this research, goods consumption has been categorized under two broad headings. Equipment and Furnishing goods and goods used for Housekeeping activities. Subcategory of goods for day to day life use has been determined based on the availability of GHG emission standards (Green Design Institute, 2011). Moderate number of goods consumption category has been tried to include. Monthly or yearly expenditure has been collected for the specified categories. Then GHG emission resulted for per million dollar expenditure in each category has been calculated. Finally using the sequestration factor and equivalency factor footprint figure for goods consumption has been calculated (Appendix-C)

1.2.7 Services:

Expenditure in service activity has been found as a significant portion in most of the recent footprint studies (Xu and Martin, 2010; Cardiff Council, 2005; Stechbart and Jefry, 2010). In this research, service activity expenditure has been assessed under four broad categories. They are *Education*, *Health*, *Entertainment*, *Technical* and *Administrative*. Sub-categories have been determined based on the availability of carbon emission standard values (Green Design Institute, 2011) discussed earlier in the food and goods section. After collecting the monthly or yearly expenditure carbon footprint has been determined following the procedure discussed in the earlier two sections (Appendix-D)

2. Biocapacity Components:

2.1 Forest Land:

In the land use map of Dhanmondi (DCC, 2002) there is no layer or database for greenery exist within that area. So the area of Non Built-Up Land has been considered as the area of greenery or *Forest Land* in this research. This may be lead to slight inaccurate result but for the lack of data availability this procedure has been followed.

2.2 Fishing Ground and Built-Up Land:

Though there is no commercial fish cultivation in Dhanmondi Lake but in this study Yield factor has been assumed to be equal to the National Level, thus overestimating the actual biocapacity following the principles of footprint and biocapacity calculation (Ewing *et al*., 2010a). In case of *Built-Up Land*, its productivity or Yield factor has been assumed as equal to the *Cropland* of Bangladesh. Yield factors for all types of land uses for Bangladesh have been collected from Global Footprint Network directly through E-mail. Equivalency factors for all types of land uses have been derived from Ecological Footprint Atlas (Ewing *et al*., 2010a).

Table 14: Biocapacity Calculation.

Land Use	[1]Area (Hectare)		[2]Yield Factor		[3]Equivalency Factor (gha/hectare)		Biocapacity (gha)	[4]Biocapacity (gha/capita)
Cropland	0.000	×	1.852	×	2.510	=	0.000	0.0000
Grazing Land	0.000	×	1.898	×	0.460	=	0.000	0.0000
Forestland	45.848	×	0.351	×	1.260	=	20.277	0.0005
Fishing Ground	18.128	×	1.000	×	0.370		6.707	0.0002
Built-Up Land	173.167	×	1.852	×	2.510	=	804.970	0.0187
Total							831.954	0.0193

Source: [1]DCC (2002); [2]Yield Factors of Bangladesh, Global Footprint Network (2011); [3] Ewing et al., (2010a); [4]Forecasted Population for 2011 (43,000) of Dhanmondi Residential Area

Result:

Dhanmondi residential areas' total footprint through different components has been demonstrated in the following table

Table 15: Dhanmondi Residential Areas Total Footprint.

Footprint Components		Footprint (Hectare)	Footprint (Global Hectare)	Footprint (gha/capita)	Percentage Contribution in the Total Footprint
Carbon Footprint	Energy - Electricity	6314.375	7956.112	0.1850	15.516
	Energy - Natural Gas	11420.989	14390.446	0.3347	28.064
	Water	345.057	434.772	0.0101	0.848
	Transportation- Fuel	2414.978	3042.873	0.0708	5.934
	Transportation- Asphalt	827.024	1042.050	0.0242	2.032
	Transportation- Air Flight	1505.622	1897.083	0.0441	3.700
	Waste	987.969	1244.841	0.0289	2.428
	Food - Meat	1126.786	1419.751	0.0330	2.769
	Food - Dairy	897.756	1131.172	0.0263	2.206
	Food - Fruits and Vegetables	1117.078	1407.518	0.0327	2.745
	Food - Cereal	1671.209	2105.723	0.0490	4.106
	Food - Confectionary	848.475	1069.079	0.0249	2.085
	Food - Drinks	156.492	197.181	0.0046	0.385
	Food - Others	1553.502	1957.413	0.0455	3.817
	Goods - Furnishing and Equipment	1465.783	1846.886	0.0430	3.602
	Goods - Housekeeping	473.706	596.870	0.0139	1.164
	Goods - Others	1552.407	1956.033	0.0455	3.815
	Service - Education	2579.244	3249.847	0.0756	6.338
	Service - Health	173.575	218.705	0.0051	0.427
	Service - Entertainment	741.192	933.902	0.0217	1.821
	Service - Technical	937.304	1181.003	0.0275	2.303
	Service - Administrative	1413.047	1780.439	0.0414	3.472
Built-up Land Footprint	Land - Residential	28.956	72.680	0.0008	0.071
	Land - Goods	9.906	24.864	0.0003	0.024
	Land - Services	84.849	212.968	0.0025	0.208
	Land - Transportation	49.455	124.132	0.0014	0.122
Total Footprint		40,696.738	51,277.889	1.1925	

Discussion:

Comparison of Footprint and Biocapacity:

As calculated in this study Dhanmondi's ecological footprint amounts to 1.19 gha/capita (51,278 gha/43,000 person) for the year 2011. On the other hand biocapacity for the same year has been determined 0.02 gha/capita (832 gha/43,000 person). It means each inhabitant of Dhanmondi residential area needs 1.19 hectares of global average productive land in the year 2011 to support their various demand on nature. On the other hand only 0.02 hectare of global average productive land has been available for each person to meet the demand. So from the comparison Dhanmondi residential area's ecological demand (footprint) exceeds its ecological capacity (biocapacity) by sixty one (61) times. The actual extent of Dhanmondi residential area (about 174 hectare) has been compared with its footprint (40,697 hectare) and found that it needs about two hundred thirty four (234) "*Dhanmondi Residential Area"* to support the present one in terms of resource supply and waste absorption.

From the above observed result it can be inferred that Dhanmondi residential area is very unsustainable in terms of ecological resource consumption and waste production. Dhanmondi is termed as one of the ideally planned area within Dhaka. If this scenario prevails for the other areas Dhaka can be compared with the high carbon cities of Europe in the long run.

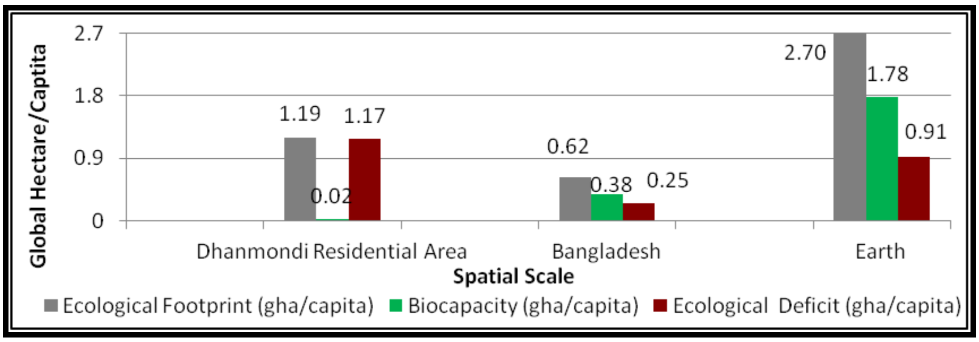

Fig. 1: Comparisons of Ecological Footprint, Biocapacity and Ecological Deficit among Different .
Spatial Scales:
Source: 2010 NFA Data Table (Global Footprint Network, 2010)

Contributing Sectors of Footprint and Biocapacity:

Dhanmondi residential area's ecological footprint by components percentage contribution has been illustrated in the following figure.

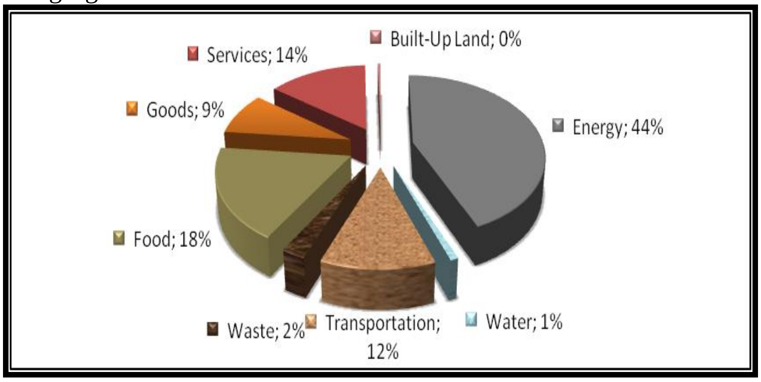

Fig. 2: Dhanmondi Residential Areas Ecological Footprint by Component Sector.

Conclusion:

Through this research Ecological Footprint concept has been introduced for the first time in Bangladesh for Dhanmondi Residential Area. Natural gas consumption for domestic purpose has been found as the main motive behind the high footprint figure compared to the national average. Biocapacity has been discovered as very petite amount because of unplanned urban agglomeration. Methodology and findings of this research can be used for further study and as the basis for future policy formulation. Because of initial research about this concept in Bangladesh there are some shortcomings of this research about data and standards availability. However this research has great scope in future if conducted on larger extent and can be used as an influential tool during urban policy formulation to enhance the environmental sustainability through utilizing our resources more sensibly.

ACKNOWLEDGEMENTS

Authors like to state their heartiest thank to Mr. Joydip Majumder, Transportation Planner, City of Lethbridge, Canada; Mr. Andalib Shams and Mr. Dip Bari, Undergraduate Student, Dept. of URP, BUET for enhancing their helping hand for conducting this research though primary and secondary data collection. Authors also like to express their gratitude to the three anonymous reviewers for their valuable comments in the earlier draft. Any remaining error is authors own responsibility. Finally for the supplementary materials (i.e. survey data, standards) and detailed calculation procedure corresponding author will be glad to be further contacted.

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Appendix-A: Co-Ordination Schema for Ecological Footprint Calculation of Dhanmondi Residential Area, Dhaka

Objective	Components	Parameter	Variable		Unit	Data Source	Data Collection Method
To calculate the ecological footprint of Dhanmondi residential area	Carbon Uptake Land	Energy	Electricity Consumption		Annual Mega Watt Hour	Household	Questionnaire Survey
			Natural Gas Consumption		Annual Cubic Meter	Household	
		Water	Consumption Amounts		Annual Mega Liter	Household	
		Waste	Production Amount		Annual Tones	Waste Concern	Secondary Source
		Cost of Living	Food	Meat	Annual Cost	Household	Questionnaire Survey
				Dairy			
				Fish			
				Egg			
				Oil			
				Fruit			
				Vegetable			
				Cereal			
				Confectionary			
				Other Food			
			Goods	Tobacco			
				Furnishing and Equipment's			
				Housekeeping			
				Clothing			
				Other			
			Services	Education			
				Healthcare			
				Entertainment			
				Technical			
				Administrative			
				Others			
		Transportation	Fuel Impact		Annual Fuel Use		
			Air Flight Impact		Annual No. of Person-Trip		
			Asphalt Impact		Area of Road	Land Use Map	Secondary Source
	Built-Up Land	Land Type	Housing	Residential	Area (Hectare)		
			Goods	Commercial			
			Services	Institutional			
			Transportation	Roads			
	Cropland	N/A					
	Grazing Land						
	Fishing Ground						
	Forest Land						

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Appendix-B: Food Consumption Footprint

		CO_2				Sequestration		Equivalency Factor
Food Category	Sub Category	[1]Annual Cost (Millions U.S. $)	[2]tons CO_2/ Million U.S. $	tons CO_2	tons CO_2	Annual Acres	Annual Hectare	Annual Global Hectare
1	2	3	4	5 = (3×4)	6 (Total)	7 = 6×(1.6175 tons CO_2 /acre/ year)	8 = (7×0.4047)	9 = 8×(1.26 gha/hectare)
Meat	Poultry	2.119	668.1	1415.949	4503.637	2784.320	1126.786	1419.751
	Beef	2.042	735.7	1502.930				
	Mutton	2.154	735.7	1584.758				
Dairy	Cheese	0.876	689.8	604.729	3568.228	2218.379	897.756	1131.172
	Milk Powder	1.987	608.4	1209.046				
	Condensed Milk	0.044	608.4	26.838				
	Fluid Milk	1.784	665.6	1187.743				
	Butter	0.735	665.6	489.454				
	Margarine	0.106	665.6	70.418				
Fruits & Vegetables	Fruits	3.114	722.2	2248.666	4464.832	2760.329	1117.078	1407.518
	Vegetables	3.069	722.2	2216.167				
Cereal	Rice	4.323	1092	4720.983	6679.631	4129.602	1671.209	2105.723
	Pulse	0.591	1092	645.128				
	Flour and Malt	0.616	1045.3	643.699				
	Bread	1.396	479.8	669.820				
Confectionary	Bakery	1.302	479.8	624.817	3391.260	2096.605	848.476	1069.079
	Snack	3.898	530	2065.929				
	Ice Cream and Frozen Desert	0.823	616	507.069				
	Noodles	0.365	530	193.445				
Drinks	Soft Drinks	0.296	543.6	160.695	625.483	386.697	156.492	197.181
	Coffee and Tea	0.436	678.2	295.501				
	Juice	0.544	311.2	169.286				
Others	Oil	1.630	1113.3	1814.208	6209.173	3838.747	1553.502	1957.413
	Egg	0.858	558.2	479.021				
	Others	7.015	558.2	3915.944				
Total					29,462.242	18,214.678	7,371.298	9,287.835

Source:[1]Household Survey (2011); [1]"X" Supershop Dhanmondi (2012);[2]Green Design Institute (2011)

Appendix-C: Goods Consumption Footprint

		CO_2				Sequestration		Equivalency Factor
Goods Category	Sub Category	[1]Annual Cost (Millions U.S. $)	[2]tons CO_2/ Million U.S. $	tons CO_2	tons CO_2	Annual Acres	Annual Hectare	Annual Global Hectare
1	2	3	4	5 = (3×4)	6 (Total)	7 = 6×(1.6175 tons CO_2 /acre/ year)	8 = (7×0.4047)	9 = 8×(1.26 gha/hectare)
Furnishing and Equipment	Paper and Printing	2.192	827.900	1814.706	5858.568	3621.989	1465.783	1846.886
	Paint and Adhesive	1.437	915.850	1315.833				
	Cleaning and Chemicals	2.325	451.850	1050.607				
	Furniture	2.881	401.350	1156.216				
	Medicine	1.965	265.300	521.206				
Housekeeping	Light	0.188	378.100	71.212	1893.349	1170.540	473.706	596.870
	Electric Spare Parts	0.293	416.700	121.970				
	Battery	0.263	376.500	99.044				
	Electric Equipment	3.095	517.300	1601.123				
Others	Tobacco	2.301	236.200	543.381	6204.796	3836.041	1552.407	1956.033
	Clothing	9.512	591.360	5625.161				
	Others	0.066	546.600	36.254				
				Total	13,956.713	8 ,628.570	3,491.896	4,399.789

Source: [1]Household Survey (2011); 2Green Design Institute (2011)

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Appendix-D: Service Activity Footprint

		CO_2				Sequestration		Equivalency Factor
Service Category	Sub Category	[1]Annual Cost (Millions U.S $)	[2]tons CO_2/ Million U.S. $	tons CO_2	tons CO_2	Annual Acres	Annual Hectare	Annual Global Hectare
1	2	3	4	5 = (3×4)	6 (Total)	7 = 6×(1.6175 tons CO_2 /acre/ year)	8 = (7×0.4047)	9 = 8×(1.26 gha/hectare)
Education	Education	21.421	481.245	10308.946	10308.946	6373.382	2579.244	3249.847
Health	Health	3.220	215.430	693.762	693.762	428.910	173.575	218.705
Entertainment	Art and Entertainment	2.325	392.135	911.534	2962.462	1831.507	741.192	933.902
	Hotels and Food	4.638	442.200	2050.928				
Technical	Professional Personnel Payment	28.335	104.320	2955.928	3746.299	2316.104	937.304	1181.003
	Technical	4.753	166.283	790.370				
Administrative	Management and Administrative	4.850	389.100	1886.976	5647.787	3491.677	1413.047	1780.439
	Waste Collection	0.183	327.300	59.876				
	Government Payment	8.046	460.000	3700.935				
				Total	23,359.255	14,441.579	5,844.363	7,363.897

Source: [1]Household Survey (2011); 2Green Design Institute (2011)