J. Environ. Sci. & Natural Resources, 11(1&2):143-149, 2019 ISSN 1999-7361

Analyses of Ecological Footprint at Bangladesh Agricultural Research Institute (BARI) Residential Area

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Abstract
Ecological Footprint (EF) 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. The introduction of EF has been very necessary for the context of Bangladesh especially in the industrial areas such Gazipur as the endless demand and the unplanned consumption pattern of the population here have been producing a very unsustainable situation. Thus this study intends to initiate it by calculating the Ecological Footprint of Bangladesh Agricultural Research Institute (BARI), one of the important residential area of Gazipur and major consuming areas of that city as a sustainability indicator. Basic equation for assessing EF has been done according to Nunes *et al.* (2013). EF has been calculated for these components: energy, food, waste and building material consumption. Questionnaire survey has been conducted to gather information about consumption pattern for different components in the households of BARI residential area. The study also identified consumption of natural gas for household purpose as the most contributing factor in the footprint of BARI residential area followed by waste, building materials and electricity consumption.

Key words: BARI, Ecological footprint, Energy, Food, Natural gas

Introduction

Addressing sustainable development in the process of urbanization becomes one of the most concerned issues to keep environment safe and to meet global ecosystem goals. With the increase of population, the consumption of environmental resources is also increasing. According to (Michel, 2017), "Humanity's ecological footprint has exceeded the Earth's capacity and has risen to the point where 1.6 planets would be needed to provide resources sustainably". EF is an ecological stability indicator. The theory and method of measuring sustainable development with the ecological footprint was developed during the past decade (Chambers *et al.*, 2000) (Wackernagel *et al*., 1996).

Urban areas are causing environmental change, drastically by altering land use and using natural resources for production and human consumption, affecting biogeochemical cycles and climate through urban waste discharge. To face this challenge, the concept of eco-cities has been evolved. Gazipur is one of the most densely populated urban areas in the Bangladesh and is expanding fast to accommodate its ever-increasing population. Many of the surrounding districts and Gazipur itself are also facing the urbanization pressure and turning them into complex hybrid morphology. The selected study site, BARI residential area is situated in the Gazipur city. These study site is one of the most important residential area in the Gazipur city corporation. By the analysis of EF of the residential area will help to understand the natural resources depletion in Gazipur City Corporation.

Methodology

Study area description

Bangladesh Agricultural Research Institute (BARI) is the largest multi-crop research institute in Bangladesh. The Institute was established in 1976 to carry out research on agricultural crops. The main center of BARI is located at Joydebpur in Gazipur, Bangladesh .The research compound of the central station is spread over 176 hectares of land of which 126 hectares are experimental fields.

Methodological approach

Basic equation for calculating EF is:
EF= Annual consumption in tons (P) *Equivalence factor (Nunes *et al.,* 2013)

Factors for EF calculation

Factors for EF was followed by Moore *et al.* (2013). To assess the EF the factors are:
Energy (Electricity consumption, cooking fuel consumption), food consumption, waste generation and building materials consumption.

Data collection

Primary data

The primary data was collected by household survey in BARI residential area. For household survey, 50 families has been surveyed in BARI residential area. Primary data was collected for monthly electricity bill, monthly food consumption, daily probable amount of water use and daily waste generation for a family.

Secondary data

Secondary data was collected from BARI office for collecting information about those areas and for collecting data about consumption of building materials. Data about daily use of natural gas for cooking in those residential areas was collected from Titas gas company, Gazipur.

Carbon emission calculation

For estimating the amount of CO_2 emission from the energy, food, water, waste and building material consumption the given formula was used according to

Department for Environment, Food and Rural Affairs of UK (DEFRA), 2009:
CO_2 emission (kg CO_2 eq $Year^{-1}$) = Σ Total consumption per year × Emission factor
In this study, published value was used for emission factor.

EF computational approach
Energy consumption (Electricity and cooking fuel)
EF of electricity generation = ECF × (EF/ (1000×1000)) ×CF (Nunes *et al.,* 2013)
Here, ECF = Energy contribution of fuel to produce electricity
EF = Equivalence factor (shown in Table 2)
CF = Conversion factor
For calculating the Ecological Footprint of Electricity consumption it is necessary to determine the Electricity mix of relevant country. (Solis-Guzman *et al.*, 2013)

Table 1. Percentage of electricity components

Fuel Type	Percentage
Coal	1.60
Natural gas	62.61
HFO+HSD	29.56
Hydro	1.44
Imported Portion (Natural gas based)	4.79
Total	100.00

Source: Bangladesh Power Development Board (2017)

Table 2. CO_2 emission factor for electricity production from various fuel sources

Electricity Production fuel type	CO_2 emission factor (kg e/kWh)
Coal	0.9*
Natural gas	0.5**
Oil (Heavy Fuel Oil, High Speed Diesel)	0.65**
Hydro	0.01**

Source: Mittal et al. (2012)*
***Parliamentary Office of Science and Technology, UK parliament (2006)*

Cooking fuel
Ecological Footprint of cooking fuel = Q×CO_2 equivalent× Heating value × CF (Vreuls, 2004)
Here, Q = the annual tonnage (t) of fuel
CO_2 equivalent for natural gas is 56.5 ton / GJ and heating value is 31.65 Mj/ ton (Vreuls, 2004)

Food
Ecological Footprint of food (x) = C/YW×EQF (CHEN *et al*., 2010)
Here, C= the annual tonnage (t) of consumed agricultural and food commodity.
YW= the annual average global yield (t/ha) (shown in Table 3)
EQF= Equivalent factor (shown in Table 3)

Table 3. Factors used in EF calculation for food

Variables	Embodied CO_2 tons CO_2-e/ton	Annual average ton/ha	Equivalence Factor (Global hectares/hectare)
Rice	2.7	4.32	2.51
Beef	27	1693.75	0.46
Fish	3.8	1747.4	0.37
Oil	2	2.41	2.51
Potato	1.51	18.2	2.51
Sugar	0.241	69.82	2.51
Chicken	6.9	2073.24	0.2
Milk	1.9	16236.60	0.5
Pulse	0.9	0.90	2.51
Vegetables	2	18.33	2.51

Source: Embodied CO_2, Annual average yield: Our world in data, 2018. Equivalence factor source: FAOSTAT Database (2010)

Consumables and wastes
Ecological Footprint of consumables and wastes = (Q×CMF) × CO_2eq×CF (Nunes *et al.*, 2013)
Here, Q = the annual tonnage (t) of waste

Table 4. Typical municipal waste characteristics in Dhaka and its adjacent areas

Waste type	Weight (%)
Food / Organic	84.37
Paper and packaging	5.68
Plastic	1.74
Textile	1.83
Glass	6.38

Source: Islam (2016)

Table 5. Factors used in EF calculation for waste disposal

Component	CO_2 eq.
Food / Organic	1.9
Paper and packaging	3.0
Plastic	2.7
Textile	3.0
Glass	.9

Source: Salequzzaman et al. (2005)

Building materials
Ecological Footprint of building materials = Q× Embodied CO_2×K (Nunes *et al.*, 2013)
Here, Q = the annual tonnage (t) of building materials used
K = Conversion factor (2.7) used to convert tons to global hectares (Wackernagel and Rees, 1996)

Table 6. Factors used in EF for building materials

variables	Embodied CO_2
Iron	.466
Sand	.01
Cement	.89
Brick	.132

Source: Hammond and Jones (2008)

Result and Discussion

Assessment of EF from energy consumption

EF of energy was calculated for two aspects. One is for electricity generation and another is for cooking fuel consumption.

Electricity

Yearly electricity consumption of BARI

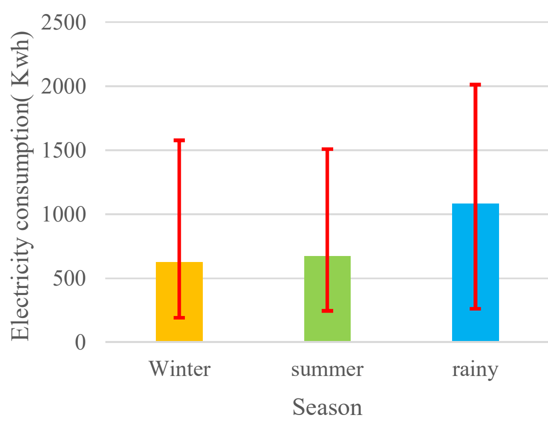

Fig 1. Total consumption of electricity in BARI

To assess the EF of electricity consumption, firstly, total electricity consumption for a year was determined. Electricity consumption of two study sites have been determined by dividing the whole year into three seasons namely (winter, summer and rainy). Among three seasons, consumption of electricity is highest for both study sites in rainy season because its duration is long than other seasons.

CO_2 emission from the sub-components of electricity

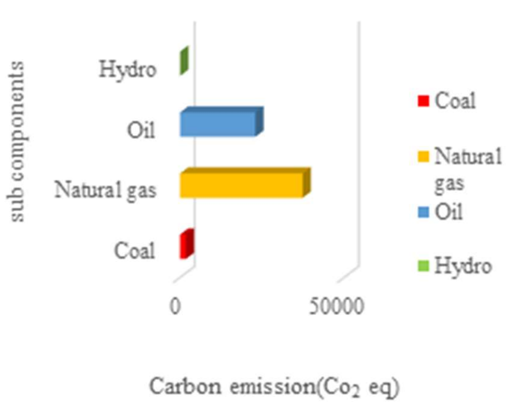

Fig 2. Carbon emission from the sub-components of electricity consumption in BARI residential area

Among all sub-components of electricity natural gas emits highest amount of CO_2. Hydro has negligible contribution for carbon emission.

EF from electricity consumption

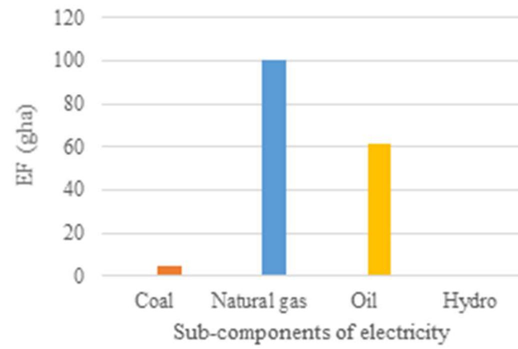

Fig 3. EF of electricity consumption in BARI residential area

Figure 3 shows EF of Electricity consumption in BARI residential area. BARI residential area needs total 167.17 global hectare of biologically productive area to absorb CO_2 produced from the electricity consumption.

Cooking fuel

Table 7. Consumption of cooking fuel, C emission and EF the two study sites

Yearly consumption of natural gas	7966.69 ton
Carbon emission of natural gas	121890.357 ton CO_2eq
EF of Natural gas	10416140.46 gha

According to Titas Gas Limited, Gazipur; 21 cft natural gas is supplied per hour and in BARI residential area. In addition, according to Titas gas Ltd. 1800 people of BARI use cooking fuel gas averagely 8 hours in a day. According to the information, yearly consumption of natural gas in BARI residential area is 7966.69 ton. For this consumption, on an average 121890.357 ton $CO_{2\ eq}$ is emitted annually. Ecological footprint for natural gas as cooking fuel is 10416140.46 global hectare.

Assessment of EF from food consumption

Yearly food consumption

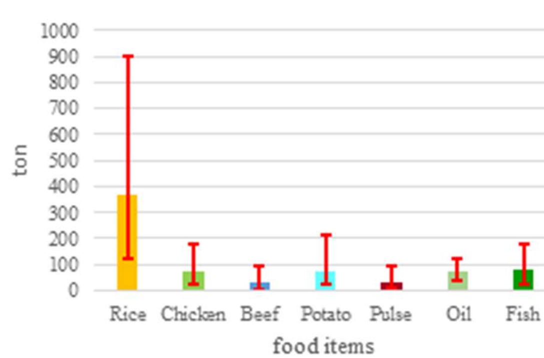

Fig 4. Yearly food consumption of BARI area

In BARI people consume rice more than any other food and consumption amount is much higher than others. The second highest consumable food item is fish. Potato is in the 3rd position based on consumption and beef consumption is the lowest.

Carbon emission from food consumption

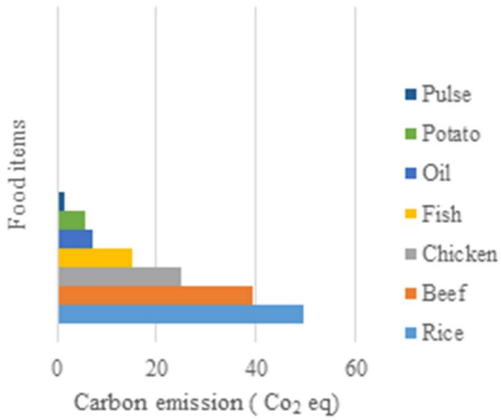

Fig 5. Carbon emission from consumed food items from BARI residential area

As rice was the most consumed food that of other food items in BARI residential area the CO_2 emission is the highest for it. It is followed by beef, chicken, fish, oil, potato and pulse.

EF from food consumption

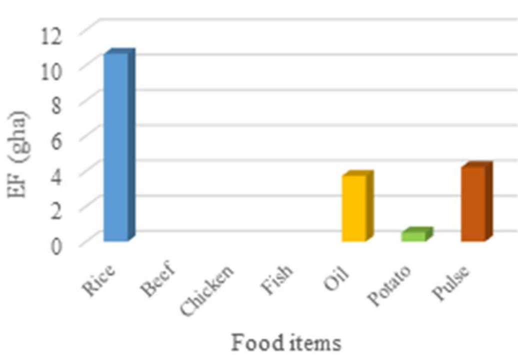

Fig 6. EF from food consumption in BARI residential area

Here, EF of rice is highest of all food. Then pulse and oil have highest EF. In BARI residential area should have 19.11 gha biologically productive area to absorb CO_2 that produce from food consumption.

EF of waste generation of BARI

Total generation of waste

Fig 7. Total consumption of waste generation in BARI residential area

It has seen from figure no.4.8 that the kitchen waste is the most generated waste than the other waste types in BARI residential area. It is followed by glass and paper but yet has a huge difference.

CO_2 emission from generated waste

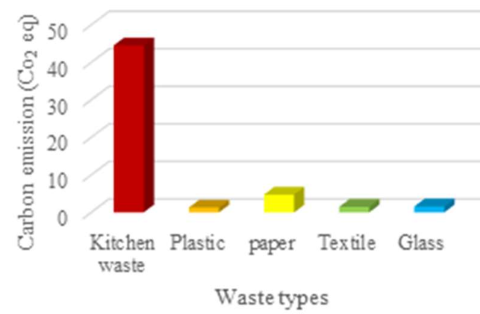

Fig 8. Carbon emission of waste generation in BARI residential area

In BARI, Carbon emission was the highest for kitchen wastes, which is, mostly degradable, and releases 44.5 ton CO_2 eq annually in the atmosphere. Wastes like plastic or glass which do not rot and assumed not to have any outputs in terms of CO_2 emission.

EF of waste generation

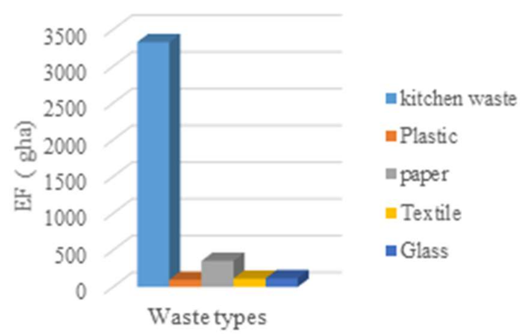

Fig 9. EF of waste generation in BARI residential area

The figure showed that most of the EF comes from kitchen wastes. In BARI residential area total EF from waste generation is 4013.675 gha.

EF of building materials

EF of building materials was calculated for residential and official areas both in BARI.

Total consumption of building materials

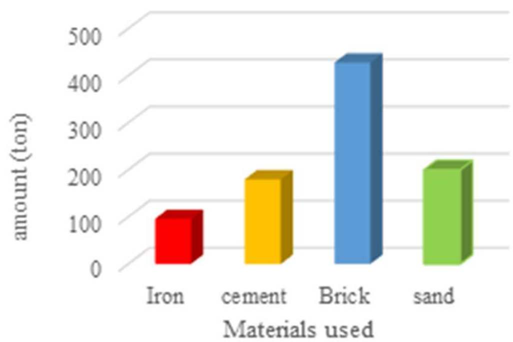

Fig. 10. Total consumption of building materials of residential area in BARI

CO_2 emission from building materials

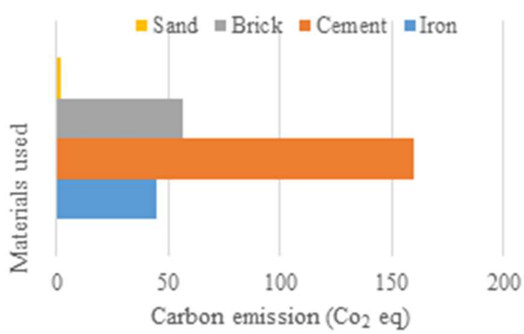

Fig. 11. Carbon emission from building materials of residential area in BARI

If we look for the CO_2 emission then we found that most of the CO_2 is released from cement (around 160.2 CO_2 eq), then brick (56.47 ton CO2 eq). Besides iron and sand also emits some amount of CO_2 in the time of 2011-2012 and 2019-2020 in BARI residential area.

EF of building materials

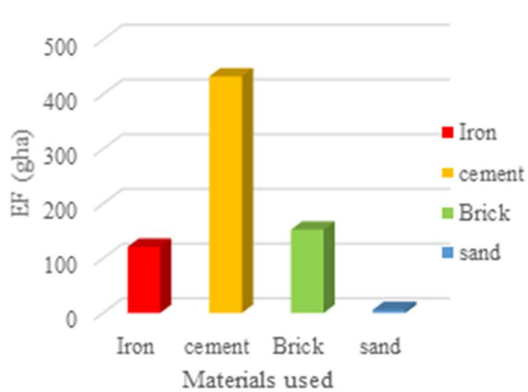

Fig. 12. EF of building materials of residential area in BARI

EF found mostly in cement and that was 432.54 ton in global hectares and then brick which has 152.47 global hectares EF in BARI residential area. In BARI residential area should have 711.2 gha biologically productive area to absorb CO_2 that produce from building materials in the year of 2011-2012 and 2019-2020.

Total consumption of building materials from official areas

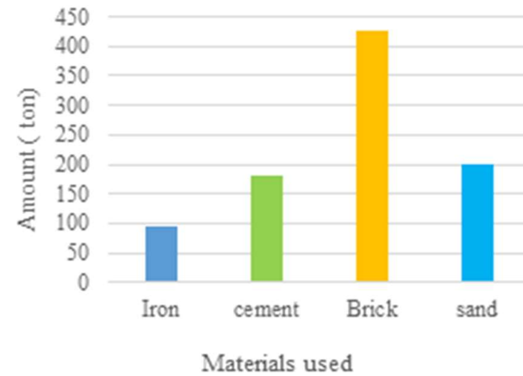

Fig 13. Total consumption of building materials of official area in BARI

From figure 13, it has been seen that among all the building materials brick is mostly used. Its amount is around 1587 ton per year. Then sand is used in comparable amount (around 705 ton) followed by cement (around 363.5 ton in the year of 2007-08 and 2012-2013.

CO_2 emission from building materials from official areas

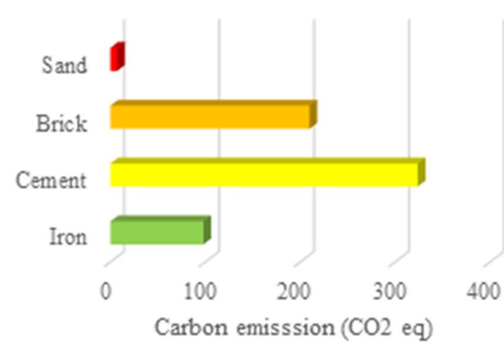

Fig. 14. Carbon emission of building materials of official area in BARI

If we look for the CO_2 emission then we found that most of the CO_2 is released from cement (around 323.52 ton CO_2), then brick (209.57 ton CO_2 eq). Besides iron and sand also emits some amount of CO_2 in the time of 2007-08 and 2012-13.

EF of building materials from official areas

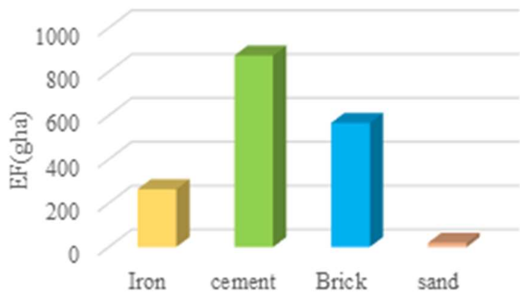

Fig. 15. EF of building materials of residential area in BARI

EF that found mostly in Cement that is 873.5 ton in global hectares and then brick which has 565.84 global hectares EF. In BARI residential area needs 1722.6 gha biologically productive area to absorb CO_2 that produce from building materials in the year of 2011-2012 and 2019-2020. Fig.15 shows the comparative footprint of various building materials.

Table 8. Total EF of BARI (in gha)

EF factors	EF (gha)
Food Consumption	19.12
Waste consumption	4013.675
Building materials consumption	2433.8
Energy consumption (electricity + household fuel gas	1008843985
Total EF	1008850452

Here in the tables total EF is of BARI residential area has been shown. Total EF of BARI residential area is 1008850452 gha. Almost amount of EF generated from energy consumption because cooking fuel is consumed in highest amount. EF of electricity consumption is much lower than fuel gas consumption. Fuel gas consumption contribute most of the footprint account because all people in that residential area is dependent on supplied natural gas for their cooking and it release a large amount of CO_2annually in the residential areas. After that waste and building materials consumption has contribution to EF.

Conclusions

As the world urbanizes, cities must assume an ever-greater role in determining sustainability outcomes. EF analyses helps to make an eco-society which society cares for air, water, land and other blessings and restrains the mass consumption of resources and energy and generation of waste. In BARI, among all material and resource consumption, natural gas consumption is higher. 1800 people of BARI are fully dependent on supplied natural gas for their cooking purpose and each family in study site use double burner gas stove which create more consumption of natural gas. After energy, waste share the highest amount of EF. Waste is directly related to the consumption of food and dumping to the land. Kitchen waste is highest generated waste which is mostly degradable and releases Co_2 in the atmosphere. However, Food consumption has less contribution to EF analysis.

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