ECOLOGICAL FOOTPRINT TO EVALUATE ENVIRONMENTAL SUSTAINABILITY OF APPAREL SECTOR BUILT ENVIRONMENTS: THE SRI LANKAN PERSPECTIVE

B.J. Ekanayake* and Y.G. Sandanayake

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Accelerated human pressure on earth has necessitated adopting environmental footprints to evaluate environmental sustainability. Ecological Footprint (EF), Carbon Footprint (CF) and Water Footprint (WF) are common environmental footprints used to evaluate environmental sustainability globally. Although there is a growing interest for calculating CF and WF, there is a lack of application of EF for environmental sustainability evaluation in Sri Lankan apparel sector. Therefore, this research investigates the applicability of EF to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. Research scope was limited to evaluate environmental impacts of energy consumption, water utilisation and waste generation in apparel sector built environments.

A qualitative research approach was followed to pursue the research aim. A comprehensive literature review was conducted to review the concept of EF and the relationship of EF with CF and WF. Subsequently, three apparel sector factories were investigated in detail to identify the nature of EF application in Sri Lanka and collected data was subjected to content analysis. Findings revealed that, even though EF is not currently fully calculated, it is partially evaluated through quantification of CF and Grey WF. It was also revealed that EF can be practiced to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. Difficulty to understand the underlying assumptions of EF of water utilisation and EF of waste generation was identified as the main barrier. Providing training and awareness on the application of EF, raising awareness on calculating EF of water utilisation and EF of waste generation are some of the strategies to overcome barriers.

Keywords: *Apparel Sector Built Environments; Carbon Footprint; Ecological Footprint; Environmental Sustainability; Water Footprint.*

1. INTRODUCTION

With the escalating world population growth, resource consumption has surpassed the regeneration capacity of earth (Toth and Szigeti, 2016). Environmental sustainability is conceptualised based on the notion of eco system services of resource consumption and waste absorption capacity (Moldan *et al*., 2012). Environmental footprints are indicators that used to evaluate environmental sustainability (Čuček *et al*., 2012). Čuček *et al*. (2015) identified EF, CF and WF as the most commonly used environmental footprints among other footprints such as Energy Footprint, Nitrogen Footprint, Phosphorous Footprint, Land Footprint, Bio diversity Footprint.

Wood and Lenzen (2003) argued that due to the diverse scope of EF, it can be considered as the main indicator, which addresses the broad spectrum of sustainability. According to Kitzes *et al*. (2007), the Global Footprint Network (GFN) takes the leadership in improving national footprint accounting and footprint standardisation. GFN (2017) defined EF as "a measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices". EF is a successful indicator for measuring environmental impacts, since it can be used with WF and CF (Galli *et al*., 2007).

*Corresponding Author: E-mail - biyankaje@gmail.com

Although the EF was initially developed to assess the environmental impacts of individuals and nations in the global context, it is being widely used as an environmental sustainability indicator at industrial, organisational and products levels (Weidmann and Barrett, 2010). Herva *et al*. (2008) suggested the application of EF to textile sector in order to evaluate the environmental impacts of manufacturing factories and production processes. Munasinghe *et al*. (2016) emphasised about growing interest in Sri Lankan apparel sector for applying CF to evaluate environmental sustainability. Herath (2015) stated that applying WF concept for Sri Lankan apparel sector helps in reducing water consumption, which in turn minimises environmental impacts. Although the application of CF and WF to evaluate environmental sustainability is trending, lack of an investigation in to the applicability of EF in apparel sector built environments in Sri Lanka is evident. Hence the aim of this research is to investigate the applicability of EF in apparel sector built environments in Sri Lanka.

This paper starts with a literature review on the concept of EF and the relationship of EF with CF and WF. The research methodology is presented in section 3 followed by data analysis and research findings. The paper finally presents conclusions of the study and provides the recommendations.

2. LITERATURE REVIEW

2.1. THE CONCEPT OF ECOLOGICAL FOOTPRINT

EF acts as an overall indicator, which measures environmental impacts (Van den Bergh and Grazi, 2013) and can be used as an indicator to quantify resource consumption and waste generation (Figge *et al*., 2016). Rees and Wackernagel (1996) defined EF as the total productive land and water area needed to generate resources consumed and absorb waste generated of a specific population or economy. It is generally measured in terms of global hectares (Galli *et al*., 2007). There are six categories of biologically productive lands namely, crop land, forest land, built up land, fishing ground, pasture land and carbon uptake land (Borucke *et al*., 2013). Table 1 explains about the biologically productive land categories, employed for EF accounting.

Table 1: Biologically Productive Land Categories

Land Types	Description
Crop Land	Provides plant based food and fibre products
Built-up Land	Provides built-up surface for shelter and infrastructure
Fishing Ground	Provides marine and inland area for fish products
Pasture Land	Provides animal products and grass
Forest Land	Provides timber and other forest based products
Carbon uptake Land	Sequestration of carbon dioxide by forests

(Adapted from: Borucke *et al*., 2013)

In EF accounting, with respect to the aforementioned biologically productive land categories, equivalence factors and yield factors are the two important coefficients to be informed of (Borucke *et al*., 2013). The equivalence factor converts a land type in to a universal unit of a biologically productive area and the yield factor measures the productivity of a land type in different countries (GFN, 2017).

2.2. RELATIONSHIP BETWEEN THE ECOLOGICAL FOOTPRINT WITH OTHER FOOTPRINTS

Galli *et al*. (2012) integrated EF, CF and WF in to a common set called footprint family, since they complement, overlap and interact each other. CF accounts for greenhouse gas (GHG) emissions and WF accounts for fresh water consumption (Galli *et al*., 2013). EF and CF are overlapping since EF quantifies the required biologically productive areas to absorb the GHG, carbon dioxide (Galli *et al*., 2012). The authors further explained that EF and WF are partially overlapping since the biological capacity of earth is influenced by water. Hoekstra (2009) highlighted the sub components of the WF as Blue WF, Green WF and Grey WF. Table 2 summarises the relationship of EF with CF and WF.

Table 2: Relationship between Ecological Footprint with Other Footprints

Indicators	Relationship
EF vs CF	Indicators are overlapping Carbon uptake land accommodates CF by accounting for sequestration of carbon dioxide emissions CF originated as a sub set of EF CF is a sub category under EF
EF vs WF	Indicators are partially overlapping A biologically productive land category is not assigned to quantify fresh water consumption WF originated as an analogue of EF WF is not a sub category under EF

(Sources: Borucke *et al*., 2013; GFN, 2017)

As tabulated above, EF has a strong relationship with CF, since it is a sub set of EF and moreover the relationship between the EF and WF is manifested due to partial overlapping between the two indicators.

2.3. *APPLICABILITY OF ECOLOGICAL FOOTPRINT IN APPAREL SECTOR*

Despite its major contribution to economic development, textile industry consumes a large amount of energy, water and it uses chemicals, which generate waste products (Jaganathan *et al*., 2014). Niinimäki and Hassi (2011) stated that textile industry provides basic materials and apparel industry converts these materials to meet the demand of consumers. Therefore, both industries are responsible for creating environmental impacts through energy consumption, water utilisation and waste generation. Since energy consumption, water utilisation and waste generation in apparel sector create adverse environmental impacts, determining the EF of these three impact categories is of paramount importance. Therefore, Butnariu and Avasilcai (2014) proposed EF as a tool to assess the environmental performance of apparel manufacturing factories and their manufacturing processes in order to optimise resource utilisation and minimise waste generation.

2.4. *ECOLOGICAL FOOTPRINT OF ENERGY CONSUMPTION, WATER UTILISATION AND WASTE GENERATION*

Butnari and Avasilcai (2014) explained that land category allocated to absorb carbon dioxide emissions from combustion of fossil fuels to generate energy is known as fossil land. According to the authors, since the energy consumed in apparel manufacturing processes comprises of electricity and fuels, EF of fuel usage and EF of electricity consumption is assigned to fossil land. Similarly, Herva *et al*. (2008) assigned fossil energy land to determine EF of fuel usage and EF of electricity consumption. Therefore, carbon uptake land is also known by the terms, fossil land and fossil energy land. It can be deduced that EF of energy consumption is assigned to carbon uptake land.

EF of water consumption is assigned to forest lands assuming forest as a water producer (González-Vallejo *et al*., 2015). However, Kitzes *et al*. (2007) stated that the National Footprint Accounts does not recognise assigning a land category for fresh water consumption. Therefore Martínez-Rocamora *et al*. (2016) suggested to quantify the impacts of water consumption, in terms of energy utilised in treating waste water generated. Accordingly, EF of water utilisation is assigned to carbon uptake land.

Tian *et al*. (2012) stated that biologically productive land category of waste generation is determined based on waste type and waste disposal process. Hence waste disposal and emissions have to be accounted and the share of energy recovered by recycling must be deducted (Herva *et al*., 2008).

According to literature findings, EF of apparel sector built environments is mainly quantified by EF of energy consumption, EF of water utilisation and EF of waste generation.

3. RESEARCH METHODOLOGY

The research design provides the plan to discover answers to the research problem through various research strategies (Saunders *et al*., 2009). This research was initiated with a literature survey to review the concept of EF and to identify the relationship between EF with other environmental footprints. The literature review was followed by a background study, which revealed that, EF is a new concept to Sri Lankan context and only few apparel sector factories are evaluating environmental footprints. Based on the comprehensive literature review and the background study, following research problems were developed.

- How EF is currently evaluating in apparel sector built environments in Sri Lanka?
- What are the barriers to apply EF in apparel sector built environments Sri Lanka?
- How to overcome barriers to apply EF in apparel sector built environments in Sri Lanka?

Yin (2011) explained that qualitative approach contributes to explore emerging concepts and is most suitable for researches which have small sample of respondents. Since EF is relatively new to Sri Lanka and only few apparel sector factories are currently evaluating environmental footprints, case studies were undertaken under qualitative approach to facilitate an in depth investigation. Accordingly, three apparel manufacturing factories which evaluate environmental footprints were selected as cases.

Employing un-structured interview method is preferred in qualitative approach since the respondents are given the opportunity to answer independently with a limited control imposed by the researcher (Dawson, 2002). Three respondents from each case, who involve in the current footprint evaluation process were interviewed. Moreover, observations and reviewing relevant documents were undertaken to capture data. Qualitative data analysing was conducted to analyse collected data using content analysis. Research findings were presented to an industry expert and an academic expert for validation and the final outcome of the research was refined accordingly. The profile of the case study factories and respondents is summarised in Table 3.

Table 3: The Profile of the Case Study Factories and Respondents

Case Name	Description of Case	Respondents	Description of Respondent
Factory A	• BOI approved apparel manufacturer and exporter, located outside Industrial Zone of Ekala • The factory manufactures loungewear and operates a fabric washing and colouring plant • The factory is a single storey building of 11400 m^3 and has 683 employees	A1	Group Facility Manager with 17 years of work experience, and responsible for evaluating footprints and formulating action plans
		A2	Senior Maintenance Executive with 10 years of work experience, and responsible for calculating footprints and monitoring data collection procedure
		A3	Senior Maintenance Technician with 11 years of work experience, and responsible for collecting and recording data for footprint calculations
Factory B	• BOI approved apparel manufacturer and exporter, located in EPZ of Katunayake • The factory manufactures sportswear • The factory is a single storey building of 9800 m^3 and has 550 employees	B1	Director of Compliance with 27 years of work experience, and responsible for analysing footprints for decision making
		B2	Engineering Executive with 08 years of work experience, and responsible for calculating and interpreting footprints
		B3	Maintenance Officer with 10 years of work experience, and responsible for collecting data for footprint calculations
Factory C	• BOI approved apparel manufacturer and exporter, located in Ratnapura • The factory manufactures lingerie • The factory is a single storey building of 9500 m^3 and has 472 employees	C1	Maintenance Manager with 21 years of work experience, and responsible for assessing footprints and formulating strategies
		C2	Factory Engineer with 15 years of work experience, and responsible for calculating and interpreting footprints
		C3	Maintenance Supervisor with 14 years of work experience, and responsible for collecting and recording data for footprint calculations

To capture data through unstructured interviews, one managerial level respondent, one executive level respondent and one non-executive level respondent were chosen as per the role they perform in the data collection for footprint calculations, calculation of footprints and evaluation of results for decision making through footprint calculations.

4. RESEARCH FINDINGS AND DISCUSSION

The following section presents the case study findings on

- Situational analysis on evaluating EF in apparel sector built environments in Sri Lanka
- Barriers in applying EF in apparel sector built environments in Sri Lanka
- Strategies to minimise barriers in applying EF in apparel sector built environments in Sri Lanka

4.1. SITUATIONAL ANALYSIS ON EVALUATING ECOLOGICAL FOOTPRINT IN APPAREL SECTOR BUILT ENVIRONMENTS IN SRI LANKA

All the respondents at factories A, B and C stated that other than the CF and WF, no other footprint calculation is done and thus these factories currently do not calculate EF. Respondents were requested to state currently calculated footprint indicators to evaluate the environmental impacts of energy consumption, water utilisation and waste generation.

CF is calculated to quantify the environmental impacts of energy consumption in respondent factories through fuel usage and electricity consumption. B1 commented, *"We already account for carbon emissions under CF. So, the EF of energy consumption is accounted using carbon emissions, but without converting to carbon uptake land"*. Accordingly, in order to calculate EF of energy consumption in respondent factories, data on CF of fuel usage and CF of electricity consumption should be computed. Furthermore, C3 emphasised, *"all necessary data is already available through CF calculation process to commence EF of energy consumption calculation"*. As per the respondents, partial practice of EF can be realised due to calculation of CF, which is a sub category of EF.

Respondents claimed that, current calculation of Grey WF, which is a sub category of WF, facilitates the quantification of waste water generated. Therefore, calculating Grey WF is an indication that waste water is treated at factory level and energy consumed in treating waste water can be quantified. B2 pointed out, *"EF methodology does not directly assign land categories to water consumption"*. According to A1, *"there is no land category assigned for water consumption related impacts, but there should be a way to compute those impacts under EF"*. Nevertheless, literature findings revealed that quantifying EF of water utilisation can be achieved by computing waste water treatment. Since all the respondent factories treat waste water using effluent treatment plants, which are operated from electricity, EF of energy consumption for treating waste water in a respondent factory should be deducted from total EF of electricity in that factory as explained under literature synthesis. Therefore, quantification of impacts of waste water generation through Grey WF calculations immensely facilitates potential to calculate EF of water utilisation.

Further it was revealed from the responses, environmental impacts due to waste generation are not quantified under currently practicing footprints. Since majority of waste products are processed by third parties, their impacts could not be quantified at factory level. B2 explained about assigning a land category to compute EF of waste generation in factory as, *"When it comes to waste types, impact of each and every waste should be considered to account under EF, for which the waste management strategy of each of them has to be known. But at our factory level, waste generation does not create adverse environmental impacts, since waste is handled by third parties"*. When waste products are processed by third parties, energy recovered from recycling and other processing methods cannot be quantified by the respondent factories to quantify EF of waste generation.

As expressed by majority of respondents, availability of necessary data on energy consumption, water utilisation and waste generation enables calculating EF. B3 emphasised, *"we already have energy, water and waste related data. If the calculation methodology is known properly, these data can be used to do EF calculation"*. Summary of the responses given by all the respondents is tabulated in Table 4.

Table 4: Footprints Evaluate in Case Studies Factories

Impact categories	Sub Categories	Footprint Indicator		
		Factory A	**Factory B**	**Factory C**
Energy Consumption	Direct emissions due to fuel usage in the factory	CF	CF	CF
	Indirect emissions due to electricity consumption in the factory	CF	CF	CF
Water Utilisation	Impacts due to waste water generation in the factory	Grey WF	Grey WF	Grey WF
Waste Generation	Impacts due to waste products generation in the factory	Not quantify	Not quantify	Not quantify

Moreover, through document reviewing and observations made at respondent factories, currently practicing strategies to minimise CF and WF in the respondent factories which contribute to reduce EF of energy consumption, EF of water utilisation and EF of waste generation were identified. The research findings revealed that, EF is not currently fully calculated in all three factories. All the respondents acknowledged that, they have the potential to calculate EF for evaluating environmental sustainability in their factory buildings. After computing the data captured from respondent factories and mapping them with literature findings, the related biologically productive land category to which the impact categories, energy consumption, water utilisation and waste generation are assigned should be determined as illustrated in Figure 1.

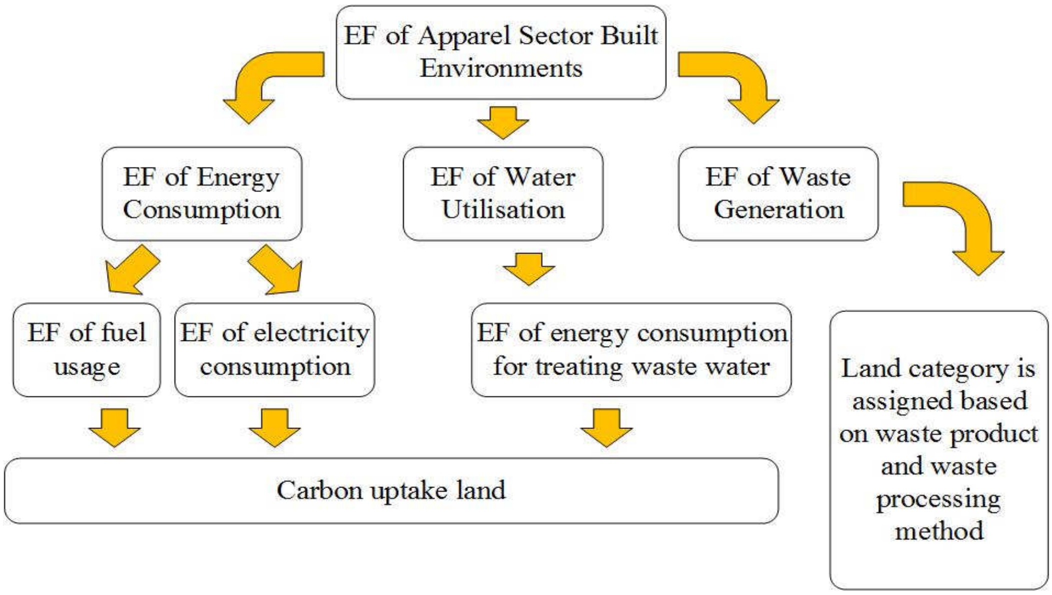

Figure 1: Assigning Land Categories to Impact Categories

As illustrated above, EF of energy consumption and EF of water utilisation are assigned to carbon uptake land and EF of waste generation is determined as per the waste product and waste processing method.

4.2. BARRIERS IN APPLYING ECOLOGICAL FOOTPRINT IN APPAREL SECTOR BUILT ENVIRONMENTS IN SRI LANKA

Barriers which constrain the successful applicability of EF were determined through the opinions of respondents. Accordingly, difficulty of understanding underlying assumptions of EF of water utilisation and EF of waste generation was identified as the major barrier to apply EF to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. A1 emphasised his opinion as *"Although the calculation of EF of energy consumption is straightforward, since it quantifies a part of EF through CF calculations, EF of water utilisation and EF of waste generation have controversial assumptions because of not allocating direct land categories by standard EF methodology, to measure their impacts"*. Some respondents highlighted difficulty to obtain conversion factors for EF calculations as a barrier. Expressing his views, B2 added, *"Yield factors and equivalence factors are not readily available in the local context and we have to download* *international reports like National Footprint Accounts to obtain this data. Without having conversion factors, EF calculations cannot be done in terms of global hectare units"*. Unavailability of waste water treatment in some factories is another barrier highlighted by some respondents. C2 emphasised *"Not all the factories treat waste water at their premises. So they cannot account for EF of water utilisation by quantifying energy consumed in waste water treatment"*. Therefore, unavailability of waste water treatment in some factories, is a barrier to calculate EF of water utilisation. Lack of data to calculate EF of waste generation in some factories, insufficient commitment of top management to calculate EF, lack of promotion of the EF concept by responsible authorities and reluctance of footprint calculating personnel to calculate many footprints are the other barriers highlighted by the respondents. These barriers are listed as follows:

- Difficulty of understanding underlying assumptions of EF of water utilisation and EF of waste generation
- Difficulty to obtain conversion factors for EF calculations
- Unavailability of waste water treatment in some factories
- Insufficient commitment of top management to calculate EF
- Lack of data to calculate EF of waste generation in some factories
- Lack of promotion of EF concept by responsible authorities
- Reluctance of footprint calculating personnel to calculate many footprints

4.3. STRATEGIES TO MINIMISE BARRIERS IN APPLYING ECOLOGICAL FOOTPRINT IN APPAREL SECTOR BUILT ENVIRONMENTS IN SRI LANKA

Strategies were proposed based on the opinions of respondents to minimise aforementioned barriers. Providing training and awareness on EF calculation at factory level, raising awareness on calculating EF of water utilisation and EF of waste generation are two of the strategies proposed by the respondents. Since calculation of EF of water utilisation and EF of waste generation contain certain assumptions, according to B3, *"Providing awareness about the EF concept throughout the apparel sector is the best way to address controversial assumptions"*. A3 commented on the importance of conducting training programmes as, *"These should specially focus non-executive employees who involve in current footprint calculation process, because they find it difficult to understand these concepts, without proper guidance"*. Many respondents pointed out that aforementioned two strategies can contribute to communicate the importance of EF calculations and encourage factories on treating waste water and managing waste. Some respondents suggested that implementing waste water treatment and waste management in factories should be mandated. Appointing a designated employee for footprint calculations at factory level is another strategy. C2 proposed, *"A job title for a Sustainability Officer should be created at factory level to calculate all these footprints and oversee the footprint calculation process"*. Convincing top management about the importance of EF calculation, maintaining records of conversion factors in a centralised database for apparel sector and implementing programmes to increase recognition for factories which calculate EF are the strategies which should be implemented as proposed by the respondents. These strategies are listed as follows:

- Providing training and awareness on applicability of EF
- Raising awareness on calculating EF of water utilisation and EF of waste generation
- Appointing a designated employee for footprint calculations at factory level
- Implementing waste water treatment and waste management in factories
- Convincing top management about the importance of EF calculation
- Maintaining records of conversion factors in a centralised database for apparel sector
- Implementing programmes to increase recognition for factories which calculate EF

5. CONCLUSIONS AND RECOMMENDATIONS

With the rising adverse impacts on environment, numerous indicators have been developed to evaluate environmental sustainability. Due to its wide scope, EF plays a major role in the context of environmental sustainability since it can be used as an indicator to quantify resource consumption and waste generation. Findings from the case studies proved that EF is partially practiced in apparel manufacturing factories which calculate CF and WF, although it is not quantified in terms of biologically productive land categories. It was deduced that EF is applicable to evaluate environmental sustainability in apparel sector in Sri Lanka. Barriers which constrain the successful applicability of EF were determined by the opinions of respondents. Accordingly, difficulty of understanding underlying assumptions of EF of water utilisation and EF of waste generation was identified as the major barrier to apply EF to evaluate environmental sustainability in apparel sector built environments in Sri Lanka. Strategies were proposed by the respondents to overcome these barriers. Providing training and awareness on EF calculation at factory level, raising awareness on calculating EF of water utilisation and EF of waste generation, appointing a designated employee for footprint calculations at factory level are some of the strategies. Outcomes of this research will be beneficial for the industry practitioners of apparel industry, for improving the environmental performance of Sri Lankan apparel sector built environments.

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