Ecological Footprint of Waste Generation in Digos City, Davao Del Sur[1]

by
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Abstract

Waste is directly related to the consumption of food and dumping to the land. Ecological footprint describes a relationship between the amount of land required to dispose the generated waste. Like any other City, Digos City faces increasing urbanized waste but lacks waste dumping area. This study calculates the ecological footprint in order to assimilate the waste.

The waste generation in Digos City was 0.38kg/capita/day composed of the following: 6% paper, 19% plastic, 6% glass, 6% metal and food 60%. To assimilate these wastes (without recycling) requires 0.1 global hectare per capita consisting of 399.06 m^2/capita for paper, 180.53 m^2/capita for plastic,17.10 m^2/capita for glass, 68.41 m^2/capita for metal, and 342.05 m^2/capita for organic waste. By land category, 1,007 m^2/capita of energy land and 0.154 m^2/capita of built up land required for assimilating the total generated waste in Digos City respectively. Different scenarios related to recycling rate were formulated. The results could be used to develop environmentally friendly and sustainable waste management for Digos City.

1. Introduction

Ecological footprint is a measure of human demand on the earth's ecosystems. It compares human demand with the earth's ecological capacity to regenerate. It represents the amount of biologically productive land and sea needed to regenerate the

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resources a human population consumes and to absorb and render harmless the corresponding waste. The ecological footprints are the total land area required to support a given population with the resources they consume to absorb all the waste they produce. It provides a valuable insight into the carrying capacity of the earth and human appropriation of resources. Through the ecological footprint, it is possible to compare human demand and nature's supply. Using this assessment, it is possible to estimate how much of the Earth or how many planet Earths it would take to support humanity if everybody lived a given lifestyle (www.wikipedia.com).

Ecological footprint of waste generation means the measurement of biologically productive land (fossil energy land, forest land, pasture land, built up area etc) to assimilate the generated waste. Two key questions are highlighted by the waste footprint study; reducing the amount of waste that city's residents produce; and, deciding what to do with these generated wastes.

All human activities have impact on its surroundings unless nature's limits are respected. After originally being developed at the University of Columbia's School of Community and Regional planning in the early 1990's by Wackernagel and Rees (1996), the ecological footprints is increasingly being used as an indicator of sustainability. The ecological footprints have recently been calculated for 150 countries in the World Wildlife Fund's report Living Planet Report 2000. The ecological footprint confirms Ehrlich and Holdren's definition of human impact on the environment. All ecological footprints studies used I=PAT. Where I is impact, P is population, A is affluence, and T is technology (Ehrlich, 1971). In the Ehrlich-Holdren formulation the impact (I) corresponds to a population's ecological footprint, which is a function of population size and consumption (converted into land area).

In developing countries like the Philippines, ecological footprint changes in proportion to population size, average consumption per person, and the resource intensity of the technology being used. If population increases, then both resource consumption and waste generation will increase, consequently ecological footprint will also increase. The waste scenarios provide an insight into both efficiency and sufficiency measures to reduce the ecological footprint of waste. Efficiency measures include recycling and composting while “sufficiency measures” include the introduction of waste minimization schemes. Under the “business-as-usual” waste scenario (World wide assuming that an increase in the tonnage of domestic waste of 3% per year), by 2010 the ecological footprint for solid wastes will rise by 67,700 hectares. This is an increase from 1.1 hectare per person to 1.5 hectare per person (Harry et al., 2001). This demonstrates that current solid waste management policies will not be able to cope with the increase in waste generation.

Ecological footprint of waste generation mainly depends on the inorganic wastes (paper, plastic, glass, metal etc.) rather than the organic wastes (food, fruit peeling etc). Because of the high-energy intensity of inorganic wastes and energy required for their processing, the waste footprint of inorganic wastes is large. On the other hand, most of the organic wastes are food wastes and these foods are locally grown, consumed and are commonly found mostly in markets and some agricultural sector. So, a negligible energy is required for its processing. As a result, its energy intensity is low. Since organic waste is 80% of the total generated wastes and because of these large amounts of organic wastes, it requires more land to assimilate.

No study has been published related to the ecological footprint of an area in the Philippines. This study follows the simple methodology by Salequzzaman (2006) applied to a particular area in Bangladesh. This methodology used global carrying capacity standards. This study will find out if by using this methodology will have acceptable results, the information that can be generated will have large impact on sustainable environment

2. Objectives of the Study

The general objective of this study is to estimate the ecological footprint of waste generation of Digos City area by a specified mathematical tool. The specific objectives are:

1. To determine the composition and characterization of solid waste generation in Digos City;
2. To calculate the ecological footprint of waste generation in Digos City; and
3. To calculate the decrease in ecological footprints from recycling of the different solid wastes generated in Digos City.

3. Conceptual Framework

Figure 1 shows how to calculate ecological footprint as a sustainable tool using Salequzzaman (2006) framework. Accordingly, to calculate the total ecological footprint of waste generation, we must first identify the lands required for present and future, for different wastes, for land fill and the site or the location as required. The ecological footprint could be used to measure the impact of new developments from the extraction of resources and aggregates, processing, manufacture and transportation of materials and consumable goods and finally the environmental impact of the location.

Waste Generation
unsustainable phase

Footprint Calculation

Land required for present
and future use

Recycling in
relation to
reducing
footprint

sustainable
phase

Land required for different
wastes

Arbitrary land acquisition for
disposal

Land required for land fill

Suitable land acquisition for
disposal

Energy Recovery

Reduced land acquisition for disposal

Figure 1: Flow chart of ecological footprint calculation (Salequzzaman, 2006).

Generalized Procedure for Calculating the Ecological Footprint

1) For Digos City, its ecological footprint is the sum of the land requirements for the three individual land categories:
   - Energy land - the area of forest that would be required to absorb the CO2 emissions resulting from that individual's energy consumption.
   - Forest land – the area of forest required to produce the wood and paper.
   - Built up land - the area of land required to accommodate housing and infrastructure.

This represents the area's ecological footprint in per capita figures, by different types of waste (i.e. glass, plastic, paper, metal and organic waste).

2) Multiply the per capita data by the selected area's population to determine the total footprint of that area. This footprint will be the base for computing the land requirements for the different wastes determined for each district.
3) Compute the ecological footprint (EF), expressed in land "area units" (in hectares) where each area unit corresponds to one hectare of biologically productive space with the world-average productivity.
4) To calculate the ecological footprint of waste generation in hectares, we take the sum of the total lands requirement for the three land categories (land, forest and built up) for each type of waste per district.
5) These land requirements are directly related to the recycling rate of wastes and this could provide the bases of waste management for Digos City.

4. Underlying equations for calculation

The biologically productive land required for this waste generation are calculated by some equations, which are given below. This includes Energy land which is the area of forest that would be required to absorb the CO2 emissions resulting from that individual's energy consumption, the Forest land which is the area of forest required to produce the wood and paper, and the last one is Built up land which is the area of land required to accommodate housing and infrastructure. Summing all the biologically productive land required for waste generation is the total ecological footprint of Digos City.

The biologically productive land required for paper

Energy land = ab(c/d)(1-ef) **(1)**

where:

a = The energy yield (assumed to be average fossil fuel = liquid fossil fuel)

b = Energy intensity of paper

c = Amount of per capita paper per waste per year

d = Waste factor is the percentage of paper consumed.

e = Percentage recycling of paper.

f = Percentage of energy safe from recycling

Forest land = hi(c/d)(1-ef) **(2)**

where:

h = World average yield of round wood

i = Ratio of round wood needed per unit paper

c = Amount of per capita paper per waste per year

d = Waste factor is the percentage of paper consumed.

e = Percentage recycling of paper waste.

f = Percentage of energy safe from recycling of paper

Built up land = **(3)**

where:

j = Energy land required for paper waste obtained from equation 1.

k = Built up land footprint component of waste is $1100m^2$.

l = World average fossil fuel area of goods is 1324 hectare.

m = World average fossil fuel area of waste is 1196 hectare.

n = Primary biomass equivalence factor for built up area is 3.5

The biologically productive land required for plastic

Energy land = abc(1-ef) **(4)**

where:

a = The energy yield (assumed to be average fossil fuel = liquid fossil fuel).

b = Energy intensity of plastic.

c = Amount of per capita plastic per waste per year

e = Percentage recycling of plastic waste.

f = Percentage of energy safe from recycling of plastic

Built up land = **(5)**

where:

j = Energy land required for plastic waste obtained from equation 4.

k = Built up land footprint component of waste.

l = World average fossil fuel area of goods.

m = World average fossil fuel area of waste.

n = Primary biomass equivalence factor for built up area.

The biologically productive land required for glass

Energy land = abc(1-ef) **(6)**

Where:

a = The energy yield (assumed to be average fossil fuel = liquid fossil fuel).

b = Energy intensity of glass.

c = Amount of per capita glass per waste per year

e = Percentage recycling of glass waste.

f = Percentage of energy safe from recycling of glass

Built up land = **(7)**

where:

j = Energy land required for glass waste obtained from equation 6.

k = Built up land footprint component of waste.

l = World average fossil fuel area of goods.

m = World average fossil fuel area of waste.

n = Primary biomass equivalence factor for built up area.

The biologically productive land required for metal

Energy Land = abc(1-ef) **(8)**

where:

a = The energy yield (assumed to be average fossil fuel = liquid fossil fuel).

b = Energy intensity of metal.

c = Amount of per capita metal per waste per year.

e = Percentage recycling of metal waste.

f = Percentage of energy safe from recycling of metal.

Built up land = **(9)**

where:

j = Energy land required for metal waste obtained from equation 8.

k = Built up land footprint component of waste.

l = World average fossil fuel area of goods.

m = World average fossil fuel area of waste.

n = Primary biomass equivalence factor for built up area.

The biologically productive land required for food

Energy Land = abc(1-ef) **(10)**

Where:

a = The energy yield (assumed to be average fossil fuel = liquid fossil fuel).

b = Energy intensity of food.

c = Amount of per capita food per waste per year

e = Percentage recycling of food waste.

f = Percentage of energy safe from recycling of food.

Built up land = **(11)**

where:

j = Energy land required for organic waste obtained from equation 10.

k = Built up land footprint component of waste.

l = World average fossil fuel area of goods.

m = World average fossil fuel area of waste.

n = Primary biomass equivalence factor for built up area.

Data and Variable Used

Primary data on solid waste generation of Digos City was used to capture the total ecological footprint in Digos City. Data used were as follows: waste generation (kg/capita), by type (e.i Paper) and recycling (%). The data was obtained from the Land Use Plan and Solid Waste Management Plan of Digos City 2003-2010. The data obtained was used for the computation of land requirements such as energy land, forest land and built up land.

5. Results and Discussions

Composition of Solid Waste Generation and Characterization, Digos City

The solid waste generation, by source, in Digos City is reflected in Figure 3. The bulk of the wastes generated daily came from the market/commercial center at 45% followed by the low-end housing at 27%. The per capita generation is approximately 0.38 kg/day and the density is 445.8 kilograms per cubic meter. The waste generated is highly organic material.

Solid Waste Characterization

The general characteristic of the garbage of Digos City is shown in Figure 4. Total waste generated by Digos City includes food, plastic, glass, paper and metal. About 60% of the solid wastes are organic in nature consisting of 42% garden waste/food waste and 18% vegetable/fruit peeling. About 19% are plastic-based wastes; consisting of 9% plastic/styro which includes candy wrappers, plastic bottles, soft and hard plastics, and 10% cellophane. About 6% are glass, paper/cardboard, and metal. By source, hospital generated 19% garden waste/food waste, 32% plastic/styro, 14% glass/tin/aluminum, 14% paper/cardboard, and 21% cellophane. Medium-end residential establishments and the markets are the major generators of garden and food wastes while hospital is the primary source of plastic based wastes.

Ecological Footprint of Waste Generation of Digos City

Table 1 shows that the ecological footprint of waste generation for Digos City is 1,007.15 m^2 per capita or 0.1 hectare per capita, assuming no recycling of wastes generated. This means that 0.1 hectares/capita is required to assimilate wastes like paper, plastic, food, etc. Some 40% of the total ecological footprint comes from paper, followed by food waste (34%), plastic (18%), metal (7%) and glass waste (2%). By land category, energy land requires 1,007 m^2/capita, forest land 0.035 m^2/capita and built up land 0.154 m^2/capita respectively; Energy land is the area of forest needed required absorbing the CO_2 emissions resulting from that individual's energy consumption in Digos City. The 0.035 m^2/capita of forest land means that 0.035 m^2/capita is required to assimilate the paper waste generated in Digos City. This means that Digos City is generating small amount of paper wastes. For the built up land result, this means that 0.154 m^2/capita of the total built-up land is needed to assimilate the solid waste generated in Digos City.

Table 1: Ecological Footprint for Solid Waste Generation of Digos City, 2003.

Waste Component	Land Category	Sub-total (m^2/capita)	Total (ha/capita)	Percentage (%)		
	Energy Land (m^2/capita)	Forest Land (m^2/capita)	Built up Land (m^2/capita)			
Paper	399	0.035	0.061	399.06	0.040	40
Plastic	180.5	-	0.028	180.53	0.018	18
Glass	17.1	-	0.003	17.10	0.002	2
Metal	68.4	-	0.010	68.41	0.007	7
Food	342	-	0.052	342.05	0.034	34
Total	1007	0.035	0.154	1007.15	0.101	100

*Note: Calculation done based on methodology provided.

Compared to the Philippines, the ecological footprint is 1.0 global hectare per capita. The result of Digos City is well within the ecological footprint in the Philippines (Table 3). The per capita waste generation in Digos City was 0.38kg/capita/day composed of the following: paper is 6%, plastic is 19%, glass is 6%, metal is 6% and food 60% (refer to Figure 4). The ecological footprint for Digos City is comparable to that of KCC, Bangladesh at 0.088 gha/capita and lower when compared to that for Berlin at 4.06 of hectare/capita. The population of Digos City is 145,514. While the KCC area has a population of 1,435,422 with a per capita waste generation of 0.5 kg/capita/day or 455 tons/day, of which organic waste is 78%, paper 11.5%, plastic 5%, glass 4.7% and metal 2.8% (Salequzzaman, 2006). Berlin's footprint is as large as the eastern part of Germany, or 12.8 Mega-hectares, this because of the large area of Berlin and considerable population. As the population increases, the waste produces also increase that is why Berlin area really needs an area which is twice as UK mainland to supports its given population.

Ecological Footprint of Solid Waste Generation with Recycling

The estimated EF reflected in Table 3 was derived when no recycling is done of the wastes generated. Digos City however, practices recycling. Table 4 shows the recycling rate for the different types of wastes generated. It could be seen that the organic wastes are mostly recycled with 75% and only 25% will be disposed to the dumpsite. On the other hand, the inorganic wastes are recycled in a very small amount compared to its generation. As a result of this imbalance, it produces a large footprint and imposes a great impact on the environment.

Table 3: Recycling rate and ecological footprint for different types of waste in Digos City.

	Components	Characteristics of Waste (%)	Actual Recycling (%)	Waste Generation (kg/capita)	Ecological footprint (m^2/capita)
Inorganic Waste	Paper	6	5	83.2	390.1175
	Plastic	19	10	26.3	167.8696
	Glass	6	15	8.3	16.3325
	Metal	6	15	8.3	58.6555
Organic Waste	Food Waste	60	75	8.3	193.26
Total	-	-	-	-	826.23

It could be seen from the Table 4 that food contributes 60% of the total waste and it also contribute 25% of the ecological footprint. Paper on the other hand, contribute 6% of the total waste but contributes 45% of the ecological footprint. This emphasizes the need to recycle paper to reduce ecological footprint. Using the actual recycling rate for Digos City, the EF was computed at 0.08 hectare/capita this is equivalent to that of KCC, Bangladesh.

Figure 2 shows the graphical representation of the imbalance between the ecological footprint for different types of wastes and the recycling rate of wastes generated in Digos City. The graph allows us to know which of the wastes need to increase in terms of recycling initiatives to reduce in ecological footprint. The gap between ecological footprint and recycling rate is highest in paper, this means that a large amount of 390.12 m^2/capita is required to assimilate the 6% of paper waste generated in Digos City. This implies that there is a need to recycle more of paper in order to reduce ecological footprint of paper.

Figure 2: Comparison of ecological footprint and recycling (%) of solid waste in Digos City.

Table 4 shows the ecological footprints at various recycling initiatives. The “without recycling” describes the practice if Digos City does not recycle wastes it’s generated. This is the scenario observed when households and institutions indiscriminately dump their garbage on vacant lots along the road, and on waterways. This practice in not only unsanitary but also poses hazard to the health of community leading to a large ecological footprint of 1,007.15 m^2/capita. The “with recycling” on the other hand, describe the presence of Material Recovery Facility (MRF) and Transfer Stations. MRF is a specialized plant of Digos City, which separates, processes and stores recyclables, which are collected this will initially serve as depository station for recyclables like plastics, glass etc. With this condition 5% of paper is recycled along with 75% food waste and plastic 10%, glass 15% and metal 15% resulting to ecological footprint 826.23 m^2/capita or 0.08 hectare per capita. This emphasizes the importance of recycling to reduce ecological footprint. The “recycling target” presents the numeric waste reduction goals for 2013 with 30% recycling is the target for paper along with plastic 25%, glass 20%, metal 20% and food waste target is 80% resulting to a 748.95 m^2/capita which is need to assimilate the waste generated in Digos City. The “projected recycling” presents the condition when 60% of paper is recycled along with 90% for food waste and plastic 50%, glass 40% and metal 40% doubled their recycling efforts leading to the reduction in EF to 629.62 m^2/capita or 0.06hectare/capita.

Table 4: Estimated Ecological Footprint (m^2/capita) at various recycling levels, Digos City.

Waste Components	Without Recycling	With Recycling Or Actual recycling	Recycling Target	Projected Recycling	Ecological Footprint			
					Without	With	Target	Projected
Paper	0	5	30	60	399.06	390.08	345.19	291.31
Plastic	0	10	25	50	180.53	167.89	148.94	117.34
Glass	0	15	20	40	17.10	16.33	16.08	15.05
Metal	0	15	20	40	68.41	58.66	55.41	42.41
Food	0	75	80	90	342.05	193.26	183.34	163.50
Total	-	-	-	-	1,007.15	826.23	748.95	629.62

6. Conclusions and Recommendations

The results show that Digos City requires a sizeable area in order to provide it with all its present consumption needs and to absorb the resulting waste that is produced. This study highlights the role of ecological footprint as an excellent tool for demonstrating whether a city and its citizens are near to the objective of sustainability. The study concludes that ecological footprints of waste provide a robust measurement of Digos City's demand for nature. This is not, however, the only aspect of the sustainable development debate. It is also important to consider social sustainability issues, such as poverty, exclusion, health and education. Clearly, those charged with the management of Digos City have some important decision to make in relation to its ecological performance if they want their city achieve the goal of sustainability in the future. In this regard, the need to manage the wastes generated is imperative.

Recommendations

The scenarios within this study have shown that this can be done to good effect as we intend to increase recycling initiatives. In order to do that, the City must increase its budget for solid waste management. It must provide facilities to keep the waste to its minimum level. Aggressive information dissemination must be made in order to increase the level of awareness among the local residents to reduce wastes and also to change the attitude of the residents towards waste management. Second, more environmental legislation and policies/measures should be crafted to attain sustainability. The implementation of these laws and ordinances should be strictly observed.

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