

Ecological Footprint of Different Nations

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Abstract—Today, dependency of human on ecosystem products and services is increasing. The concept of ecological footprint determines humanity's appropriation of ecosystems at the regional scales. The aim of this paper is to compare one person's ecological footprint in various countries by assuming equal consumption and wastage of resources. This paper compares ecological footprint in 13 countries in order to find logical relationship among ecological footprint, area size, and population. The Ecological footprint of selected countries has been calculated by aid of an appropriate formula and also an online questionnaire. Then statistical package for social science (SPSS) was used to investigate the association among these variables. The results indicate that there is no significant linear relationship between ecological footprint and the area size of studied countries. This study also resulted that the population does not influence on ecological footprint.

Index Terms—Area, ecological footprint, population.

I. INTRODUCTION

Human's demand on ecosystem services continues to increase, and there are indications that this demand may be outpacing the regenerative and absorptive capacity of the biosphere. Humanity depends on ecosystem products and services which involve resources, waste absorptive capacity, and space to host urban infrastructure. This reliance causes various changes in environment like deforestation, collapsing fisheries, and CO₂ accumulation in the atmosphere. As a consequence of these changes, the rate of attention to the Ecological Footprint (EF) has been increased as a potential indicator for sustainable development in recent years. The EF accounts human share of ecosystem products and services regarding with the amount of bio-productive space on the Earth and sea needed for provide these requirements [1].

The EF theory is based on the amount of biological productive area available in analyzed system – planet, country, local community, and individuals – to ensure its survival and development [2]. Moreover, EF is used for demonstrating the resource consumption and waste absorption transformed based on biological productive land which is needed by per capita [3]. The word EF means the effects of human consumption with regarding an observable footprint on natural functions; EF is applied to the long-term need of societies to nature continuing the need of traditional

societies on existing space [4]. The amount usage of land and water for the population of a nation is defined by footprint. Overall, the EF can be considered as a conceptual model or calculation method [4].

The objective of this paper is to compare an average ecological footprint of one person in various countries by assuming the equal amount of consumption and waste resources. In addition, this study intends to determine the relationship between ecological footprint and area, and also ecological footprint and the population of studied countries.

II. LITERATURE REVIEW

In the past two hundred years, the standard of living in industrialized nations has been significantly improved and also the health status has been developed by economic growth. On the other hand, simultaneously, noticeable increase in the consumption of natural resources, waste generation, and the pollution of the environment are determined as results of the combination of economic growth and population growth.

The EF analysis is more important concept in order to illustrate humanity's appropriation of ecosystems at the regional scales. The EF concept considers the need of a region/nation of the rest world [5]. The most widely application of the EF involve: crop land and pasture land, built-up land, forest, fish, and carbon assimilating capacity [4].

The word 'footprint' is used basically to indicate human impact on the planet. As frequently applied today, for instance, the expression 'carbon footprint' allude to the amount of carbon emitted by a person or activities or manufacture and transport of a product during a year. In EF the 'carbon Footprint' evaluates the quantity of bi-capacity, in global hectares, required by human emissions of fossil carbon dioxide [12].

EF demonstrates the dependence of human to ecosystem services regarding to land. EF analysis is able to determine whether per capita in various nations benefit from the equal ecosystem goods and services by mixing the concept of "fair earth-share" and "bio-capacity" [6]. The EF estimates the requirements of populations and activities put on the bio-sphere in a year, with the current knowledge and technology and resource management [1].

Human activities influence on the closed-loop ecosystem. Thus, the EF analysis calculates the amount of the biophysical output of the earth that is essential for the resource consumption and waste absorption for a given population [7]. Based on Ewing et.al.' research [1], (un)sustainability is evaluated by examining the existing and the required surfaces, presuming that if EF is larger than domestic land, this population are unsustainable [8].

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Consequential factors to determine the applicability of EF as a sustainable development indicator are, such as: (1) policy relevance and effectiveness for users, (2) analytical soundness, (3) measurability [15] and (4) communication to extensive public [16].

EF accounting is based on following fundamental assumptions [14]:

- Possibility of tracking the majority of the resources people consume and generated wastes.
- It is possible to calculate the huge amount of these resource and waste flows in regards of the biologically productive area necessary to keep flows.
- Diverse types of areas can be changed into the common unit of global hectares, hectares with world average bio-productivity, via weighting each area in proportion to its bio-productivity.
- Because these areas represent mutually limited uses, and each global hectare stands for the same amount of bio-productivity for a given year, they can be added up to obtain an aggregate human demand.
- Global hectares of biologically productive space can declared nature's supply of ecological services.
- Area demand can exceed area supply which is known as "ecological overshoot" (e.g., humans can temporarily demand more bio-capacity from forests, or fisheries, than those ecosystems have available).

There are two common calculation methods for EF analysis: the component-based calculation and the compound calculation [9]. Component-based calculation builds up the total EF through an item-by-item approach, but compound-based calculation starts from the overall consumption balance [10]. Meanwhile, there are some weaknesses for EF calculation methods such as, aggregation, the lack of common methodologies and definitions, productivity, and ecological deficits and surpluses [4].

The following factors make ecological footprint analysis valuable device for sustainability analyses [11]:

- It is accord to life cycle principle.
- The method focuses on consumption. Unsustainable consumption patterns are the main part of the environmental problems.
- The method can be used for consumption at any level, from an individual person up to a country or the global population.
- The technique incorporates the idea of equity and global justice.
- It is the best method for professionals and non-professionals in order to express the challenge between sustainable developments.

This paper has two principal objectives. The first is to compare the EFs of various countries for the similar usage and wastage of natural resources. The second objective is to contrast the EFs of developed and developing countries.

III. METHODOLOGY

The Ecological Footprint of a person is calculated by considering all of the biological materials consumed, and all of the biological wastes generated, by that person in a given year. These materials and wastes demand ecologically

productive areas, such as cropland to grow potatoes, or forest to sequester fossil carbon dioxide emissions. All of these materials and wastes are then individually translated into an equivalent number of global hectares [12].

Ewing B., et al. [1] represented a method for calculating EF. In this method, amount of materials consumed by a person (tons per year) is divided by the yield of the particular sea or land area (annual tons per hectare) from where its waste material was absorbed or which it was harvested. Then by using yield and equivalence factors, the result of this calculation (number of hectares) are changed to global hectares. The total amount of the global hectares required to provide the resources consumption and waste for a person is total EF for that person. For any land use type, the Ecological Footprint EF of a country, in global hectares, is calculated by (1):

$$EF = P / YN \times YF \times EQF \quad (1)$$

P: Amount of a Product Harvested or Waste Emitted, YN: National Average Yield for P, YF: Yield Factor, EQF: Equivalence Factor.

This paper calculated the ecological footprint of the various countries based on (1) by aid of an online questionnaire [12]. EF can be estimated for a person, or groups of people (like a nation). In this study, for making sense of comparison among some distinct countries, the input information is entered as same consumption and waste of natural resources for one assumed person in these countries.

The result of this questionnaire is calculated based on data from Global Footprint Network's National Footprint Accounts, and the result determines the EF and also the required plant Earth for supplying the enough resources for this assumed person.

IV. ANALYSIS AND RESULTS

To demonstrate the mechanics of the EF, 13 countries are compared in this study. This section explains the result of calculation of the EF related to America, Colombia, Ecuador, Peru, Argentina, Brazil, South Africa, Italy, Switzerland, Turkey, India, Japan, and China. Table I shows the area and the population of these countries.

TABLE I: AREA AND POPULATION OF COUNTRIES

Country		Area (km ²)	Population
Developed Country	America	9,826,675	309,826,000
	Japan	377,944	127,420,000
	Italy	301,338	60,231,214
	Switzerland	41,284	7,782,900
Developing Country	China	9,758,801	1,338,850,000
	India	3,287,240	1,183,880,000
	Brazil	8,514,877	192,272,890
	Turkey	783,562	72,561,312
	South Africa	1,221,037	49,320,000
	Colombia	1,141,748	45,393,050
	Argentina	2,766,890	40,134,425
	Peru	1,285,216	29,461,933
	Ecuador	283,561	14,573,101

Fig. 1 illustrates results of the EF's calculations and also the number of needed earth plants for the assumed person which has the similar consumption and waste resources in mentioned countries.

The graph demonstrates the rate of EF and required plant earth in order to provide the requirements of an assumed person. As the graph is shown, the EF and also the required plant earth for this person are the most in America by 7.6 GH and 4.2 required plants Earth. It is followed by Japan where the EF is 4.8 and the required plants Earth is 2.7. Colombia, Ecuador, Peru, Argentina, Brazil, South Africa, Turkey, India, and China are recorded as the similar rates around 1 to 1.5 required plants Earth and 1.7 to 2.5 GH for the EF. Italy and Switzerland illustrate the same rate for the required plant Earth (2). The rate of the EF in Switzerland is approximately 4 GH and for Italy is 3.5 GH. For this assumed person, the EF and the required plant Earth for supporting his/her needs are different in these countries, although, he/she has the same consumption and wastage of the resources.

Fig. 2 compares the rate of EF for this person in developed and developing countries (The red columns represent the rate of EF in developed countries and the blue columns portray the rate of EF in developing countries). As the graph is demonstrated, although he/she has a fix rate of consumption and wastage of the resources, the rate of EF for him/her is higher in developed countries compare to developing countries. The statistics in this graph depict that developing countries, such as India, China and Colombia, have the smallest EF. Beside, the most developed countries like America and Japan have the bigger EF. In consequence, the EF is firmly connected with per capita income.

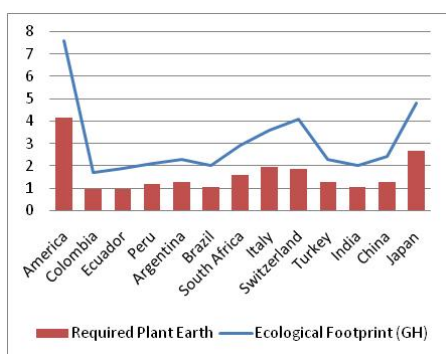


Fig. 1. Ecological footprint and required plant earth in different countries

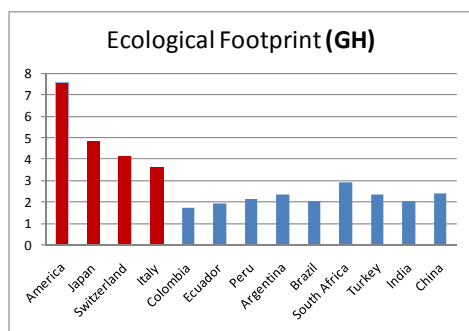


Fig. 2. Ecological footprint in developed and developing countries

A. Relationship between Footprint-population and Footprint-area

Statistical package for social science (SPSS) has been used to answer this question. All data from Table I and Fig. 1 were

imported to SPSS for analysis. The sample size for this study is small (N=13) and the normality of the sample is questionable and should be tested. The hypothesis of the normality test is as following.

H0: The distribution of the data is normal.

Ha: The distribution of the data is not normal.

If the normality is not rejected by the test, it is recommended that parametric tests can safely be used. Otherwise, non-parametric tests should be considered.

Table II reveals the result of Kolmogorov-Smirnov test. If the significant value (Sig.) of the test is more than 0.05 it means that the data are normally distributed. It is clear that all of the Sig. values are less than 0.05 and thus, the null hypothesis is rejected and the presented data are not normally distributed. Therefore, nonparametric tests should be considered.

TABLE II: TESTS OF NORMALITY

	Kolmogorov - Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Population	0.302	13	0.002	0.546	13	0.000
Footprint	0.241	13	0.038	0.779	13	0.004
Area	0.321	13	0.001	0.721	13	0.001

Is there any relationship between Footprint and population or Footprint and area of these countries?

For answering this question, correlation coefficient is used to investigate the linear association between the footprint, population and area.

A correlation coefficient (rho) close to +1 (or -1) reveals that there is a strong linear association between two variables. In contrary, by getting closer to 0 the association becomes weaker and weaker.

For this study, Spearman's correlation was used to examine the association between the area, population, footprint (Table III).

TABLE III: SPEARMAN CORRELATION TEST

Spearman's rho		Area	Population	Footprint
Developed Country	Correlation Coefficient	1.000	0.702	0.212
	Sig. (2-tailed)	0.0	0.007	0.486
	N	13	13	13
Developing Country	Correlation Coefficient	0.702	1.000	0.433
	Sig. (2-tailed)	0.007	0.0	0.139
	N	13	13	13
	Correlation Coefficient	0.212	0.433	1.000
	Sig. (2-tailed)	0.486	0.139	0.0
	N	13	13	13

As it was mentioned earlier, strong association would be proved with rho close to +1 or -1 while in this case it can be clearly seen that there is no linear association between footprint and area (rho = 0.21, p > 0.05), and also between footprint and population (rho = 0.44, p > 0.05). It can be concluded that these variables are independent of each other.

V. CONCLUSION

The EF prepares a criterion of requirements upon the biological productivity and assimilative capacity of nature which require by lifestyles [13]. The people are able to decrease the EF by reduce, reuse, recycle, such as reducing home energy consumption, using public transportation, ride a bike or walk, purchasing local foods.

In this study, one person with similar amount of consumption and wastage of resources is considered. The calculations of the ecological footprint show that the footprints and global hectares for providing the enough resources for him/her is different in these countries. The study found that there is no linear association between ecological footprint and the area size of considered countries. The study also indicated that population size does not influence on the ecological footprint. However, based on the statistics, the EF is firmly connected with per capita income.

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REFERENCES

- [1] B. A. R. Ewing, S. M. Rizk, A. Galli, M. Wackernagel, and J. Kitzes, "Calculation methodology for the national footprint accounts," Global Footprint Network, (ed. E.V. 1.1), 2008, Oakland.
- [2] S. Medved, "Present and future ecological footprint of Slovenia--The influence of energy demand scenarios," *Ecological Modelling*, 2006. vol. 192, no. 1-2, pp. 25-36.
- [3] G. R. Cranston and G. P. Hammond, "North and south: Regional footprints on the transition pathway towards a low carbon, global economy," *Applied Energy*, 2010. 87: p. 2945-2951.
- [4] D. P. Van Vuuren and E. M. W. Smeets, "Ecological footprints of benin, bhutan, costa rica and the netherlands," *Ecological Economics*, 2000. vol. 34, no. 1, pp. 115-130.
- [5] J.-J. Ferng, "Local sustainable yield and embodied resources in ecological footprint analysis--a case study on the required paddy field in Taiwan," *Ecological Economics*, 2005. vol. 53, no. 3, pp. 415-430.
- [6] M. Wackernagel and W. E. Rees, "Our ecological footprint: reducing human impact on the earth. New society publishers," *Gabriola Island*, 1996.
- [7] P. M. Vitousek, P. R. Ehrlich, A. H. Ehrlich, and P. A. Matson, "Human appropriation of the products of photosynthesis," *Bioscience*, 1986. vol. 36, no. 6, pp. 368-373.
- [8] M. Lenzen, S. Lundie, G. Bransgrove, L. Charet, and F. Sack, "Assessing the ecological footprint of a large metropolitan water supplier: lessons for water management and planning towards sustainability," *Journal of Environmental Planning and Management*, 2003. vol. 46, pp. 113-141.
- [9] C. Simmons, K. Lewis, and J. Barrett, "Two feet--two approaches: a component-based model of ecological footprinting," *Ecological Economics*, 2000. vol. 32, no. 3, pp. 375-380.
- [10] A. Y. Hoekstra, "Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis," *Ecological Economics*, 2009. vol. 68, no. 7, pp. 1963-1974.
- [11] E. Holden and K. G. Høyer, "The ecological footprints of fuels," *Transportation Research Part D: Transport and Environment*, 2005. vol. 10, no. 5, pp. 395-403.
- [12] Earthday Network. [Online]. Available: <http://earthday.net/footprint2/index.html> 2010.
- [13] S. Zhao, Z. Li, and W. Li, "A modified method of ecological footprint calculation and its application," *Ecological Modelling*, 2005. vol. 185, no. 1, pp. 65-75.
- [14] M. Wackernagel, B. Schulz, D. Deumling, A. Callejas Linares, M. Jenkins, V. Kapos, C. Monfreda, J. Loh, N. Myers, R. Norgaard, and J. Randers, "Tracking the ecological overshoot of the human economy," *Proc. Natl. Acad. Sci.* 2002. vol. 99, no. 14, pp. 9266-9271.
- [15] J. A. Bakkes, G. J. Van den Born, J. C. Helder, R. J. Swart, C. W. Hope, J. D. E. Parker, "An overview of environmental indicators: State of the art and perspectives," *UNEP*, Nairobi, Kenya. 1994.
- [16] D. P. Van Vuuren and E. M. W. Smeets, "Ecological footprints of benin, bhutan, costa rica and the netherlands," *Ecological Economics* vol. 34, no. 1, pp. 115-130, 2000.