GIS-BASED REGRESSION ANALYSIS OF THE RELATIONSHIP BETWEEN ECOLOGICAL FOOTPRINT AND ECONOMIC DEVELOPMENT OF SELECTED COUNTRIES

MUSARRAT ZAMAN

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ABSTRACT

Ecological footprint is an innovative concept to present the idea of consumption of natural resources and generation of waste by the human in terms of the Earth's biological carrying capacity. The aim of this research is to analyze the interactive relationship between economic development and ecological footprints of the selected nations. The GIS based spatial regression tool Ordinary Least Square (OLS) and Geographically Weighted Regression (GWR) are used for this purpose. In addition, the individual components which forms the aggregate ecological footprints are also analyzed with the per capita GDP of the nations in order to learn about their interrelationship. The analysis has found that, there is a significant relationship between ecological footprint and economic development and the OLS model can explain approximately 64% of the variation in the dependent variable with the explanatory variables. The OLSR model has also found that, there is a statistically significant heteroscedasticity or non-stationarity between the dependent and independent variables. Hence, the GWR analysis is applied for mapping the variation in spatial pattern of the regression model which shows the strong and weak predictors regions for the analysis. More to this, it is found that nation's economic development contributes much in increasing the carbon footprint as the Multiple R value is about 82%; R square and Adjusted R square value is around 67%. However, this study has not found any valid relationship with the other components like grazing, forest land, fishing ground and built-up land footprint with per capita GDP. The resulted outcome has enough significance for studying the spatial dimension of environment and economy. This can contribute to analyze the individual nation's economic growth and their impact on environmental degradation which can ultimately influence the sustainability of the Earth and its natural environment.

ABSTRAK

Jejak ekologi adalah satu konsep yang inovatif untuk membentangkan idea penggunaan sumber asli dan penghasilan sisa oleh manusia dari segi keupayaan membawa biologi Bumi. Tujuan kajian ini adalah untuk menganalisis hubungan interaktif antara pembangunan ekonomi dan jejak ekologi negara-negara yang dipilih. GIS berdasarkan alat regresi spatial Ordinary Least Square (OLS) dan Regresi geografi berwajaran (GWR) digunakan untuk tujuan ini. Di samping itu, komponen individu yang membentuk tapak kaki ekologi agregat juga dianalisis dengan KDNK per kapita negara-negara untuk belajar tentang hubungan sesama mereka. Analisis ini telah mendapati bahawa, terdapat hubungan yang signifikan di antara jejak ekologi dan pembangunan ekonomi dan model OLS yang dapat menjelaskan kira-kira 64% daripada variasi dalam pembolehubah bersandar dengan pembolehubah penerangan. Model OLSR juga telah mendapati bahawa, terdapat heteroskedastisiti statistik yang signifikan atau bukan kepegunan antara pembolehubah bersandar dan tak bersandar. Oleh itu, analisis GWR itu dipohon pemetaan perubahan dalam corak spatial model regresi yang menunjukkan peramal yang kuat dan lemah kawasan untuk analisis. Lebih kepada ini, didapati bahawa pembangunan ekonomi negara menyumbang banyak dalam meningkatkan kesan karbon sebagai nilai R Pelbagai adalah kira-kira 82%; R persegi dan nilai persegi R larasan adalah sekitar 67%. Walau bagaimanapun, kajian ini telah tidak menemui sebarang hubungan sah dengan komponen lain seperti ragut, tanah hutan, kawasan perikanan dan membina-up jejak tanah dengan KDNK per kapita. Hasil menyebabkan mempunyai maksud yang cukup untuk mengkaji dimensi spatial alam sekitar dan ekonomi. Ini boleh menyumbang kepada menganalisis pertumbuhan ekonomi negara individu dan kesannya terhadap kemusnahan alam sekitar yang akhirnya boleh mempengaruhi kelestarian bumi dan alam semula jadi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

There is always an integrated relationship between economic growth and environmental impact on the development of human civilization. Natural ecosystem is one of the major components of environment which has also an inevitable connection with the economic activities of human (Wang *et al.*, 2013). Human needs are supposed be met through the ecological sustainability without compromising the health of ecosystems (Callicott and Mumford, 1997). However, the over consumption of natural assets turn into the degradation of ecological system services in general (MEA, 2005 cited in Galli *et al.*, 2012) and leads towards the depletion that can hardly be restored. In this situation the sustainability of the environment cannot be ensured. In order to seek balance between these two factors, a considerable interest in analyzing this interrelationship has been geared up among the researchers over the past decades and the idea of ecological footprint is developed.

The ecological footprint is an important concept that estimates the Earth's biological carrying capacity required to support the resource use of human and produced waste of them in a standardized format (Venetoulis and Talberth, 2008). According to Wackernagel *et al.* (2005) ecological footprint accounts measures how much of the annual regenerative capacity of the biosphere is required to renew the resource input of a defined population in a given year (Wackernagel *et al.*, 2005 cited in Venetoulis and Talberth, 2008). The total productive land area is calculated on Global Hectare (GHA) unit that supplies the natural resources and processes the wastes of a particular entity. Ecological footprint is most commonly used to estimate the nation's consumption in National Footprint Accounts (NFAs) consisting the aggregate

result of six individual sectors such as cropland footprint, grazing footprint, carbon footprint, fish footprint and total built up land (GFN, 2016). The NFAs determines whether a particular country exceeds its ecological limits by consuming more renewable products than could be sustainably produced on the available land area of that country that is called "bio-capacity". According to Global Footprint Network (2016) bio-capacity refers to "the capacity of a given biologically productive area to generate an on-going supply of renewable resources and to absorb its spillover wastes" (GFN, 2016). In fact, the idea of ecological footprint of a country or a particular region is aggregately related with the demographic, economic and socio-economic context of that countries including the total population, Gross Domestic Product (GDP) as well as income inequality (Gini index) and Human Development Index (HDI) (Mattila, 2011). As the average per capita consumption of ecosystem goods and services has increased in the last 45 years, the human ecological footprint has continued to increase and bio-capacity to decrease (WWF, 2008). This leads towards ecological deficits for nations around the world and threat towards sustainability (Galli *et al.*, 2011). Although, the NFAs of the countries are measured every year to show total bio-capacity reserve and deficits, particular study is required to represent the specific statistical relationship between a country's economic growth along with particular socio-economic condition and the ecological footprint. It is also necessary to understand the spatial context and the geographical variation in between these factors through a cross country analysis. Geographic Information System (GIS) can efficiently exhibit both of the statistical and spatial interrelationship between these ecological variables with the economic components using regression analysis from which the idea of economic and environmental sustainability of the countries would become clearer. In addition, through the data visualization techniques the presentation of the result can become for interesting and better understanding. Thus this study seeks to analyze and visualize the relationship between ecological footprint and economic factors using the ArcGIS spatial analytics tools to understand the environmental sustainability of the countries.

1.2 Problem Statement

Ecological footprint of the nations are significantly spatially correlated at global level (Wang *et al.*, 2013). The world nations are exploiting their natural resources in a very rapid manner for the purpose of daily consumption and development need. As a result, ecological footprint is exceeding than the fixed bio-capacity of those territories. Most of the countries, including the lower income ones, have experienced successive economic growth in the recent decades (UNDP, 2006; 2007) and this positive aspect somehow has adverse impact on the environment as well as ecosystem (Behrens et al., 2007; Krausmann et al., 2009). As much as they use their resources without giving the time of proper retrieval as more it is directing towards environmental change such as global warming and climate change. So, the overall sustainability of the environment and ecosystem are under threat. It is suggested by the experts that, there should be balance between the existing measures of economic performance, such as Gross Domestic Product (GDP) and the measures of ecosystem services and biodiversity (Dasgupta, 2007 cited in Vackar, 2012). From the present situation, it can be inferred that, the capacity of natural ecosystems to provide the necessary life-support systems for humankind is decreasing rapidly and increasing scarcity of resources (Daly, 1990; MEA, 2005; WWF, 2006; Wackernagel and Galli, 2007; Pulselli *et al*., 2008 cited in Galli *et al*, 2012).

Though this phenomenon has a very well-known aspect of understanding, it is not very simple to determine the actual relationship among the various active factors. As mentioned before, researchers are studying continuously on these sectors to find out the interaction between the economic activities of human and impact on environment. But there is always a research gap that needs to be filled up. Previously, a curvilinear relationship was observed between the gross domestic product (GDP) per capita which is termed as affluence and some types of environmental impact such as air and water pollution. This relation indicated that environmental condition of a country or territory got improved with the highest levels of affluence (GDP) (Cavlovic *et al.* 2000). This curve is known as Environmental Kuznets Curve (EKC) whose nonlinearity occurs due to changes in many economic, institutional or financial arrangements such as economic structure, preferences, and patterns of consumption

etc. of the study areas (Dietz *et al.*, 2008). However, it was found from the study that, there is no inverse relationship between ecological footprint and the affluence (GDP), as indefinite economic growth within a clean environment could not be achieved simultaneously by the whole planet (Bagliani *et al.,* 2008 cited in Oshin and Ogundipe, 2015). So far analyses that have used EF as the dependent variable haven't produced results that suggest the existence of an EKC (Bagliani et al 2008; Caviglia-Harris *et al.*, 2009). That means EKC cannot clearly assesses the relationship between ecological footprint and economic growth factors. In fact, GDP is not only the underlying factor interacting with ecological footprint. There are also some demographic and socio-economic aspects such as total population, income inequality (Gini index) and Human Development Index (HDI) which have an intricate connection with it. The EKC does not relate all of these factors aggregately while explaining environmental change (Islam, 2015). Not only about the EKC analysis, there is also a noticeable research gap that determines how the economic and other relevant drivers have imposed impact on the ecological footprint and especially how they vary across the geographical boundaries. No significant study has been found which shows the spatial relationship among the interactive factors. This gap imposes significant hindrance to identify the potential and effective policies for reducing human impact on the environment and eco-system. It is also difficult to project the future impacts and reduce adverse effects on the environment and ensure overall sustainability without proper research connections and data analysis (Richy, 2014). Here, the Geographical Information System (GIS) can effectively fill up the gap by enabling the researchers to analyze both the interrelationship among the variables within a spatial platform. With these consequences GIS-based regression analysis can help to identify the correlation among the selected factors of economy as independent variables with ecological footprint as a dependent variable in the global context. In this case, Ordinary Least Square Regression (OLSR) and Geographically Weighted Regression (GWR) can act as effective tools for exploring spatial heterogeneity among the exploring variables in the whole global space. Specifically, this tool can successfully depict the regression model visually and graphically through the cartographic maps.

1.3 Research Questions

A research question is the core of a research which guides the development of research hypothesis and analysis. It is originated from the insightful and inquisitive mind of the researcher and by getting proper answer of the questions, the research outcome is acquired. This study is based on the following questions-

1. What is the pattern of spatial correlation between the dependent variable (EF) and the economic and socio-economic factors like GDP, HDI, income inequalities including population size of the selected nations?
2. How the variables differ with each other according to the variation in per capita GDP of the nations?

1.4 Objectives

The primary aim of this study is to understand the sustainability of the global nations by studying the relationship between ecological and economic development of some selected countries. The objectives of the study are-

i. To analyze the relationship between per capita Gross Domestic Product, Human Development Index, income inequality and total population with the ecological footprint of some selected countries using GIS based regression analysis.
ii. To measure the interrelationship of cropland, grazing land, forest land, carbon, fish ground and total built up land footprints with the per capita GDP of the selected countries.

1.5 Scope and Limitations

The scope of this study is to understand the variation in relationship of economic growth with the ecological footprints of the countries of the world. This study does not define any specific study area or territory rather describe the ecological footprint the selected countries all around the world from different regions. This selected number of the countries varies with the data availability. One of the major

scope of the study is understanding the geographical variation of the world nations that come along with the regression analysis and the spatial pattern of their relationship is expressed through visualization within the global boundary. In addition to this, finding out the correlation among the different components of ecological footprint with economic growth is also very effective to realize the best contributing factors on environmental degradation. Any study regarding ecological or environmental economics can relate the findings of the research without limiting geographical boundary. The study can also contribute to analyze the environmental sustainability of the nations by using the findings of this research.

However, there are some major limitations of the study that cannot be ignored. This study does not show any time series analysis in order to seek the relationship between dependent and explanatory variables of the countries due to data limitation. It also considers only four explanatory variables and consider per capita GDP as the major parameter of economic growth that is not always enough to demonstrate the resource consumption pattern of the nations. Analyzing the sustainability of the countries in terms of ecological footprint and bio-capacity deficit is also beyond the scope of this study. Due to time constraints and limited scope, the detail analysis according to regional variation cannot be accomplished. Hence, within the limited scope, this research has been conducted and found out the resulted outcome.

1.6 Organization of the Chapters

There are five individual chapters in this study. All these chapters bear their respective significance. The first chapter includes the background of the research which is the fundamental part of any study. The problem statement, research questions, aim and objective of the research are also stated with specific scope and limitation of the study. This chapter helps to get the overall introductory idea about the research.

Chapter 2 is formed with literature reviews and basic conceptual knowledge about the key terminologies of the research. The review and synopsis of previous studies are presented so that the readers can easily relate the ideas with the present context and the practical field.

Chapter 3 describes the methodology of the study, which is the backbone of any research. The data collection and data analysis methods are described thoroughly with specific equations and theoretical conceptions to make the readers understand the whole mechanism of the research.

Chapter 4 contains the data analysis which is the core part of this research. The relevant tables, charts, maps and figures are attached with the interpretation of the resulted outcome.

Finally the last chapter 5 concludes the topic with major findings and contribution of the research. It also leaves the benchmark for further analysis and scope for the readers to enhance their knowledge.

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