MODELING THE PER CAPITA ECOLOGICAL FOOTPRINT FOR DALLAS COUNTY, TEXAS: EXAMINING DEMOGRAPHIC, ENVIRONMENTAL VALUE, LAND-USE, AND SPATIAL INFLUENCES

A Dissertation

by

HYUNG CHEAL RYU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2005

Major Subject: Urban and Regional Science

MODELING THE PER CAPITA ECOLOGICAL FOOTPRINT FOR DALLAS COUNTY, TEXAS: EXAMINING DEMOGRAPHIC, ENVIRONMENTAL VALUE, LAND-USE, AND SPATIAL INFLUENCES

A Dissertation

by

HYUNG CHEAL RYU

Submitted to Texas A&M University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Approved as to style and content by:

Samuel D. Brody
(Chair of Committee)

Christopher D. Ellis
(Member)

Ming Zhang
(Member)

Hongxing Liu
(Member)

Sharada R. Vadali
(Member)

Forster Ndubisi
(Head of Department)

May 2005

Major Subject: Urban and Regional Science

ABSTRACT

Modeling the Per Capita Ecological Footprint for Dallas County, Texas: Examining Demographic, Environmental Value, Land-Use, and Spatial Influences. (May 2005)

Hyung Cheal Ryu, B.A., University of Seoul, Korea;

M.A., University of Seoul, Korea;

M.A., University of Southern California

Chair of Advisory Committee: Dr. Samuel D. Brody

This study addresses factors driving the variation in the per capita Ecological Footprint (EF) in Dallas County, Texas. A main hypothesis was that scientifically estimated demography, environmental values, spatial attributes, and land-use patterns surrounding an individual are significant factors in the size of per capita EF. This study was based on the survey method and GIS routines. Additionally, a multiple regression method was employed to address the study question. The survey measured respondents' EF using an 'Ecological Footprint Quiz' consisting of sixteen questions regarding individual food, mobility, housing, and goods/services consumption. GIS technologies were used to objectively measure spatial attributes. The environmental values were measured by selected questions regarding ecological crises.

This study found from the descriptive analysis that Dallas County's average personal EF was 26.4 acres: food (5.1), mobility (3.3), shelter (8.3), and goods and

services (9.8). The study indicates that the residents need ecologically productive land more than 105 times the area of the county.

Based on the explanatory analysis, the following summary points can be made about the factors driving of the variance, not only in the per capita composite footprint but also in each of the personal footprint components:

First, a highly educated, non-married, older male living in a high income household located in a low population density area is more likely to have a larger personal composite footprint. *Second*, a person with a weak environmental awareness living where the ratio of employment opportunities (places to work) is worse, and living far from freeways and major lakes but close to major malls, is more likely to have a larger personal food footprint. *Third*, a younger person living in a high income household located close to major malls but far from Dallas/Fort Worth Airport is more likely to have a larger mobility footprint. *Fourth*, a highly educated non-married older male living in a highly developed area is more likely to have a larger shelter footprint. *Fifth*, a highly educated non-married older male living in a high income household located in a low population density area is more likely to have a larger goods and services footprint.

DEDICATION

To my family, Hyun-Hee, Ha-Rim, and Kang-Mun

ACKNOWLEDGEMENTS

This study was supported in part by U.S. National Science Foundation Grant No. CMS-0346673 and the Texas Transportation Institute. First of all, I would like to thank Dr. Samuel D. Brody, the chair of my dissertation committee, for his support during this project. He not only provided financial assistance for my study, but was the person who understood the power of warm encouragement. I hope to emulate him in my work with future generations. I was also fortunate to have an advisory committee that covered every aspect of research. Volumes of gratitude go to Dr. Christopher D. Ellis for research methodology, Dr. Ming Zhang for sustainable transportation planning, Dr. Hongxing Liu for GIS/remote sensing, and Dr. Sharada R. Vadali for statistics. Special thanks to Dr. Vadali at the Texas Transportation Institute for providing financial support during my doctorate. My special thanks to Carleen Cook for editing my manuscript. She always took time to make thoughtful suggestions which made this dissertation much better. I wish to acknowledge the many wonderful persons who shared time with me in the Environmental Planning and Sustainability Research Unit and the Department of Landscape Architecture and Urban Planning. Finally, I'm indebted to the love of my family: Hyun-Hee, Ha-Rim, and Kang-Mun. Truly, my success was also deeply rooted in the endless love from my parents (Jung-Hwa Ryu in heaven and Jae-Sim, Kim), my two sisters (Hyang-Ran and Hyang-Hee Ryu), my two brothers (Jeom-Seok and Cheol Ryu), my parents-in-law (Eung-Soon Ahn and Keum-Rae Jung), and my brother-in-law and his wife (Byung-Min Ahn and Sook-Ki Kim).

TABLE OF CONTENTS

CHAPTER Page

LIST OF FIGURES

FIGURE Page

FIGURE Page

LIST OF TABLES

CHAPTER I

INTRODUCTION

1.1. Background of the Study

Since the publication of the Brundtland Report (WCED, 1987) carried the sustainability discussion into governments and businesses worldwide, much effort has gone into clarifying the meaning of the sustainability concept (Wackernagel and Yount, 2000). Fifteen years after the report, however, humanity is farther away from sustainability. We live in an even more hazardous world with more consumption, more waste, more people and poverty, but with less biodiversity, forest area, available fresh water, soil and stratospheric ozone layer (Brown et al., 1997a,b; UNDP, 1994; WRI, 1996). In this context, Rees and Wackernagel (1996) simply defined sustainability as living peacefully in material comfort and with each other within the means of nature. To make sustainability a reality, they developed an Ecological Footprint Analysis (EFA) as a measurement tool to determine whether humanity's demands remain within the capabilities of the globe's natural capital stocks (Wackernagel et al., 1999b). With documented declines in the biophysical state of the planet, the EFA has been promoted as a policy guide and planning tool for sustainability (Wackernagel et al., 1997).

The EF is an indicator of sustainability that converts consumption and waste production into units of equivalent land area (Flint, 2001). Since people use resources

---

This dissertation follows the style of and format of *Journal of the American Planning Association*.

from all over the world, and affect faraway places, the footprint is the sum of these areas wherever they are on the planet (Wackernagel et al., 2002). If the total area required for supporting the final consumption of a given human population exceeds what is available locally, it would imply that the population satisfies its demands by appropriating the environmental carrying capacity of other regions (Ferng, 2001). Wackernagel et al. (2002) report that the world average EF is 2.3 hectares, but there is only an average of 1.9 hectares of biologically productive land and sea area available for each person, not including the space needed by other species.

The EFA has typically been applied at the global/national (e.g., Wackernagel et al., 2002), municipal/institutional (e.g., Barrett and Scott, 2003; Flint, 2001), and individual level (Crompton et al., 2002). Most previous studies have mainly focused on measuring the size of our ecological impact. These studies suggest that humans are liquidating natural capital to support current resource use, thereby reducing the Earth's capacity to support future life. What is missing in the literature is empirical research that identifies the factors driving the size of a footprint and provides guidance on reducing the scale of human impacts. Thus, an important next step is to examine which factors affect the EF account.

1.2. Research Purpose and Objectives

The purpose of this study is to investigate driving forces causing variation in the per capita Ecological Footprint Account in 2004 within Dallas County by using multiple regression analysis and GIS/Remote sensing routines. The study objectives are:

1) To examine the effects of socioeconomic/demographic attributes on per capita EF.

2) To investigate whether or not environmental awareness influences per capita EF.

3) To address the effects of land-use patterns on per capita EF.

4) To assess the relative impact of different spatial attributes on per capita EF.

1.3. Research Justification

The results of this study will provide meaningful information so local governments and decision makers can effectively manage natural resources to reduce their municipalities' environmental impact resulting from economic activities. By understanding which factors influence biologically productive natural resource consumption, local and regional planners can set appropriate policy programs, e.g., land-use planning, to reduce the ecological burden on the planet.

The study is theoretically meaningful for the following reasons. First, the Ecological Footprint Account can show the bottomline sustainability of natural resource consumption of residents in Dallas County. The EFA is useful because it aggregates and converts typically complex resource use patterns to a single number (Costanza, 2000). Second, this study will contribute to understanding ecological and social dimensions of the environment accepted as essential for sustainability (Flint, 2001), and also incorporate a spatial dimension. Despite the wealth of empirical and conceptual investigations, few studies have been conducted to address the relationship between spatial attributes and biophysically productive natural resources. This research will provide appropriate policy implications for sustainability planning emphasizing the role of land-use planning and will attempt to understand their integrated influences on sustainability. Third, this study is the first attempt to measure per capita EF using a survey method based on a case in North Central Texas.

Practically, this dissertation will benefit governments, environmentalists, and the sustainability research community. Specifically, this study will benefit local governments targeting sustainability as a municipal priority in support of a Local Agenda 21 in co-operation with citizens, local organizations and enterprises. Additionally, it will provide environmental activists with information on the ecological bottom line of sustainability. Putting sustainability in simple and concrete terms helps to build common understanding and set a framework for action (Wackernagel, 1994). Thus, this study can show how to achieve sustainability in Dallas County by understanding the main drivers of per capita EF.

Dallas County is an ideal study site to investigate EFA for the following reasons: 1) During the last decade, the county has grown in typically sprawling patterns. Between 1990 and 2000, the selected growth indicators of Dallas County clearly demonstrated the spatial patterns. This sprawling growth is particularly, conspicuous in terms of demographics (e.g., density, ethnicity, growth, and income), housing (owner occupied, housing age, and apartment dwellers), and transportation (public transportation accessibility) (ERSystem.com). 2) Dallas County has ample socioeconomic and GIS/Remote sensing data covering entire communities. I obtained high-quality digital geographic data from the North Central Texas GIS Data Clearinghouse that is open to the public through the North Central Texas Council of Governments (NCTCOG) Web site. Socioeconomic data is available for areas from the Texas State Data Center and Office of the State Demographer. Furthermore, satellite imagery data for the areas are available through Texas Natural Resources Information Systems.

Finally, I have already conducted a pilot study to examine the basic statistical relationship between the per capita ecological footprint and some of the selected factors using relatively small sample size and different geographical context. These results were promising and justified a more extensive study as proposed by my dissertation.

1.4. Dissertation Structure

This dissertation consists of seven chapters. Chapter II reviews the literature related to the topics of this dissertation to form an understanding of the concept of ecological footprint. The first and second sections of this chapter look into the definition and methodology of ecological footprint analysis. The third section discusses previous research findings from three scales of approach – global and national scale, municipal and institutional scale, and household and individual scale.

Chapter III builds a conceptual framework for ecological footprint modeling. This section identifies the variables in the conceptual model and develops research hypotheses based on the literature review. Seventeen hypotheses to be tested are formally stated with their expected outcomes. Particularly, it discusses four groups of independent variable which are considered as main drivers of the personal ecological footprint: socioeconomic and demographic, environmental awareness, land-use patterns, and spatial attributes surrounding a particular person.

Chapter IV describes study design, data collection, sampling method and empirical study flow. It also explains the process of concept measurement for the dependent and independent variables and the types of analyses used to interpret the data. This chapter finishes with the description of validity threats to the dependent and independent variables.

Chapters V and VI contain results of the descriptive and explanatory analyses on the survey data. Chapter V describes characteristics of respondents, the study site, and the individual consumption behavior of Dallas County. In addition to evaluating the average personal composite ecological footprint score of the County, this chapter also details the four footprint components including food, mobility, shelter, and goods and services. Chapter VI presents the regression analysis results seeking to explain what factors impact the variance in the personal footprint score by testing the study hypotheses. Following the four independent variable groups identified in the conceptual framework, there is an examination of six separate regression models, one for each component and a composite footprint score to draw conclusions about the impact of independent variables on the per capita ecological footprint.

Chapter VII summarizes the key findings and conclusions of this dissertation, describes the study limitations, and makes recommendations for future study. Furthermore, it suggests policy implications and recommendations to eliminate the ecological footprint deficit of Dallas County and other local municipalities.

CHAPTER II

LITERATURE REVIEW

This chapter, with four subsections, reviews the literature related to the topics of this dissertation to form an understanding of the concept of the ecological footprint. The first section of this chapter organizes the literature review. The second section gives a brief history of recent attempts to measure humanity's ecological impacts on the planet and covers the conceptual, theoretical, and methodological issues of ecological footprint analysis. The third section discusses previous research findings from three scales of study including global and national scale, municipal and institutional scale, and household and individual scale. The last section summarizes the key findings from the existing research and addresses shortcomings or gaps. It then sets an agenda for the direction of this dissertation.

2.1. The Concept and Methodology of Ecological Footprint

2.1.1. Humanity's Ecological Impacts and the Concept of Ecological Footprint (EF)

Recent attempts to measure the human load on the planet build on earlier studies that estimated the dependence of human life on nature (Cohen, 1995; Martínez-Alier, 1987). To quote Wackernagel et al. (1999a), "the EF also builds on a series of other tools and assessment approaches." In the 1960s and 1970s, the intellectual groundwork for the EF included Borgström's analysis of "ghost acreage", William Catton's "phantom planets", Odum's energy analysis examining systems through energy flows, Forrester's advancements in modeling world resource dynamics (as presented by the Club of Rome), Holdren and Ehrlich's IPAT formula, or, in the spirit of the International Biological Programme, Whittaker's calculation of net primary production of the world's ecosystem. The last 10 to 15 years have witnessed exciting new developments: e.g. life-cycle assessments; energy-based lifestyle appraisals; environmental space calculations going back to the ideas of Opshoor and further developed by the Friends of the Earth; human appropriation of net primary production; documentation of regional and industrial metabolisms; systemic energy assessments; mass intensity measures such as Mass Intensity per Unit of Service (MIPS); indicators of human processes such as the Sustainable Process Index (SPI); systematic socio-ecological indicators; evaluation of ecosystem services; resource accounting input-output models; computer-based spatial models analyzing land-use developments and ecological potentials; computer-based scenario models such as "PoleStar"; or spatial indicators such as the ecological footprint assessment, etc (Wackernagel et al., 1999a). In spite of the variety of their applications and representations, their goal was to quantify human use of nature to motivate and implement a reduction of human impact.

Ecological footprint (EF) is one method which offers a quantitative measure of sustainability that can be systematically tracked and compared across individuals, households, institutions, and geographic areas. The concept of sustainability can be broadly defined as maintaining human consumption and development within the limits of existing natural resources (Rees and Wackernagel, 1996).

Rees and Wackernagel first introduced the Ecological Footprint concept in an effort to convert these broad principles into a measurable indicator of whether population demands remain within the confines of the earth's natural capital stocks (Wackernagel et al., 1999b). An EF is measured as the total area of productive land and water required to continuously produce all resources consumed and to assimilate all wastes produced by a defined population in a specific location (Rees and Wackernagel, 1996).

2.1.2. Methodology

The ecological footprint is useful because it aggregates and converts typically complex resource use patterns into a single number (Costanza, 2000). EF calculations are based on two basic assumptions: first, most of human consumption and much of the waste generated can be accounted for; and second, the biologically productive areas appropriated for these consumption patterns and the assimilation of waste can be calculated (Wackernagel et al., 1999a).

Wackernagel and Rees (1993; 1996) developed a template for calculating an EF through a consumption-land use matrix consisting of five major consumption categories and six major land use categories. Consumption categories include: food, housing, transportation, consumer goods, services, and wastes. Land use categories used to support the human economy include: cropland and pasture land (for production of food and goods), built-up land (to support infrastructure), forest (for the production of wood products), fish (food production), and carbon assimilating capacity (for carbon dioxide emissions from fossil fuels). Using this matrix, an EF can be measured for individuals, communities, regions, or countries.

The method proposed by Wackernagel to calculate footprints involves the use of spreadsheet software (Figure 2.1). The spreadsheet is composed of three main sections: the first section consists of a consumption analysis of over 20 main resources.

The rows represent resources of product types. The columns specify the productivity, production, import, export, and consumption of these resources or product types. Consumption is calculated by adding imports to production and subtracting exports. The consumption quantities are divided by their corresponding (world average) biotic productivity, giving the land and sea area necessary to sustain this consumption.

The second section of the table provides an energy balance of the traded goods. This analysis is required to adjust the energy consumed in the country by the amount of energy that was previously consumed in producing the exported and imported goods. This traded energy is calculated by multiplying, for each trade category, the amount of net import by the typical embodied energy in net imports which can be a significant portion of the consumed energy.

In the third section the results are summarized. All the footprint components are added to obtain the total footprint. Ecological foot printing thus shows the global impact of local consumption (Kumar et al., 2001).

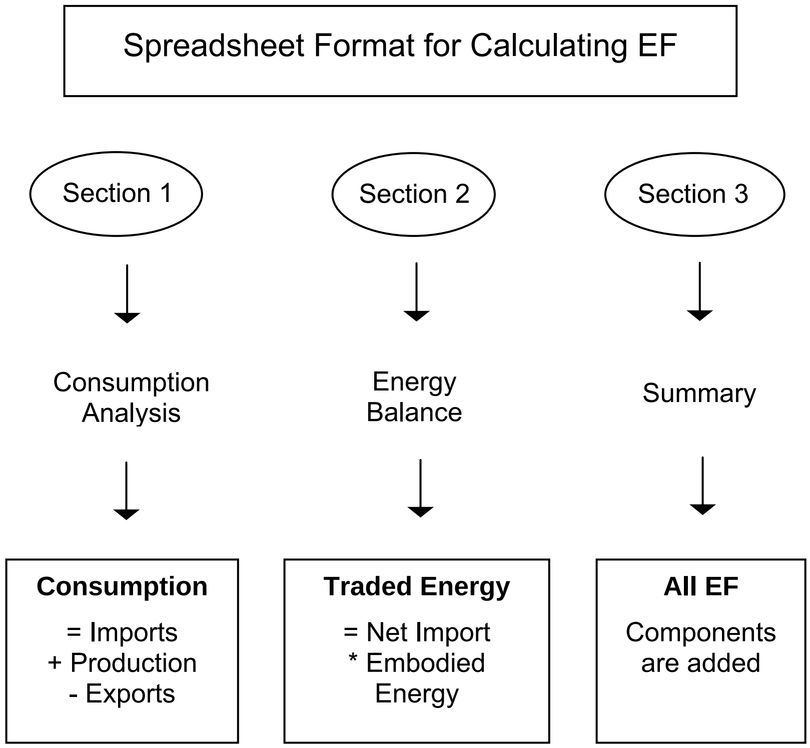


Figure 2.1. Wackernagel Method for Calculating Ecological Footprint (Kumar et al., 2001)

Table 2.1 provides an example of the consumption-land use matrix developed for Sonoma County, California. Acreages for consumption categories for each land use are tabulated and summed to calculate a total county footprint of approximately 22 acres.

Table 2.1. Ecological Footprint in Sonoma County, California

	Energy Land	Crop Land	Pasture	Forest	Built Area	Sea	Total
Food	1.7	2.2	0.8	0.0	0.0	0.7	5.4 (24%)
Housing	2.7	0.0	0.0	1.5	0.2	0.0	4.4 (20%)
Transportation	3.7	0.0	0.0	0.0	0.3	0.0	4.0 (18%)
Goods	3.8	0.4	0.1	1.2	0.1	0.0	5.5 (25%)
Services	2.1	0.0	0.0	0.9	0.1	0.0	3.0 (13%)
Total	13.9 (62%)	2.6 (12%)	0.8 (4%)	3.6 (16%)	0.6 (3%)	0.7 (3%)	22.4 (100 %)

Cite: (Sustainable Sonoma County with Redefining Progress, 2002). Figures are for 1999 in acres.

An EF is usually expressed in global acres (or hectares). Each global acre corresponds to one acre of biologically productive area based on the earth's average productivity. Because people use natural resources from all over the world and affect faraway places with their activities, the footprint is usually conceptualized as the sum of these areas wherever they are located (Wackernagel et al., 2002). In this sense, if the total area required for supporting the total consumption of a given human population exceeds what is available locally, it would imply that the population satisfies its demands by appropriating the environmental carrying capacity of other regions, i.e. running an 'ecological deficit' (Ferng, 2001). According to the most recent assessment, the average EF for the planet is 2.3 hectares (approximately 5.6 acres). However, there is only an average of 1.9 hectares (approximately 4.5 acres) of biologically productive land and sea area available for each person (not including the space needed by other species) (Wackernagel et al., 2002).

2.1.3. Theoretical and Methodological Issues on the EF Analysis

Ecological Footprint analysis is still an emerging methodology (Simmons et al., 1998) as a guideline to achieving sustainability (Costanza, 2000). There have been two complementary approaches to calculating EF: Compound and Component-based calculation (Chambers et al., 2000).

Like most EF calculations published thus far, compound calculation, devised by Wackernagel and Rees (1996), converts trade flows and energy data to area (hectares) using global yields of the respective year (Haberl, Erb and Krausmann, 2001). The calculation is composed of three main parts. The first part consists of a consumption analysis of over 50 biotic resources including meat, dairy produce, fruit, vegetables, seeds, grains, tobacco, coffee, wood products, etc. Consumption is calculated by adding imports to production and subtracting exports. Where necessary, further adjustments are made to avoid double counting across categories. The second part of the calculation determines the energy balance considering both locally generated energy and that embodied in over 100 categories of traded goods. The final part of the calculation summarizes the EF in six ecological categories and presents the total as per capita figures. In this step, 'equivalent factors' are used to scale the land categories in proportion to their productivities and the actual land area is adjusted by a 'yield factor' to equate local productivity of each land category to the global average (Chambers et al., 2000).

In the component-based model, the EF values for certain activities are pre-calculated using data appropriate to the region under consideration. The land categories originally proposed by Wackernagel and Rees (1996) are essentially retained: energy land, build land, bio-productive land, sea and biodiversity land. The aim is to account for most consumption with a series of component analyses. This is easier to communicate and is more instructive than the compound model because the breakdown of impacts by activity has a definite appeal to those involved in policy-making or education. However, the component-based method has problems with data variability and reliability, which make national and international comparisons problematic (Chambers et al., 2000).

In Table 2.2, the global/national level studies usually employ compound methodology, whereas municipal, household, and individual level studies are commonly conducted by a component-based approach. In addition, most of the studies calculated EF by aggregating all consumption-related direct and indirect ecological impacts in terms of land use (van den Bergh et al., 1999). However, this aggregation approach has been widely criticized (e.g., van den Bergh, 1999; Costanza, 2000; van Vuuren, 2000). The drawbacks of the aggregation indicator are that, if one is not careful and informed, one can be ignorant of where the numbers came from, how they were aggregated, the uncertainties, weights, and assumptions involved (Costanza, 2000).

In this sense, a disaggregation type of approach is needed (van den Bergh et al., 1999). Van Vuuren et al. (2000) focused on individual components of the EF such as land and carbon dioxide emissions and local yields instead of global averages. Venetoulis (2001) also focused only on the carbonprints when he examined the EF for the cities in Los Angeles County, California.

Wackernagel and Rees' methodology (1996) has faced the challenge of distinguishing the commodities used as intermediate input from those used as final consumption (Ferng, 2001). In spite of recent efforts by Wackernagel et al. (1999a), it is not an easy job to calculate the raw materials used directly in traded manufactured products because indirect input requirements are also involved.

In this context, Bicknell et al. (1998), first suggested using the monetary values of products in order to alleviate the difficulty based on the adopted input-output analysis. In their calculation for the EF of New Zealand, they used land multipliers to obtain the production land areas required to produce the outputs for domestic final consumption directly and indirectly and presented the estimates in three land categories: agricultural land, forest land, and degraded land (Ferng, 2001). They claimed that the input-output approach [1] explicitly link the level of economic activity in a country and its corresponding impact on the environment (Bicknell et al., 1998).

Recently, this method was pursued and upgraded by Ferng (2001) who used the composition of land multipliers instead of land multipliers in estimating the production land footprint so that the calculated areas can be expressed by land category. In 1991, the revised calculation was then applied to Taiwan to estimate two footprint components, production land and energy land (Ferng, 2001; Ferng, 2002).

[1] Input-output analysis, developed in the 1930s and 1940s by Wassily Leontief, is a well known economic tool that can be used to study how various sectors of a regional or national economy are related (Bicknell et al., 1998).

2.2. Major Literature Associated with Ecological Footprint Analysis

Various applied research projects have already been completed – from the global down to the local scale (Wackernagel and Yount, 2000). Understanding human impact on the natural ecosystem at the cities' scale was the focus of the earliest studies (Fricker, 1998). Then, the studies expanded their arena to the global and national, municipal and institutional, and household and individual scale.

The most popular EFA approach is the aggregation method that converts complex resource use patterns to a single number (Costanza, 2000). As mentioned above, a typical tool is the consumption-land use matrix with five major consumption categories and six major land use categories (Wackernagel and Rees, 1993; 1996). The disaggregation method is another approach that, instead of summing up all consumption, distinguishes between the consumption categories (Van den Bergh and Verbruggen, 1999). Recently, Bicknell et al. (1998) proposed a modified form of input-output analysis that accounts for the complex interdependencies between economic activities and corresponding impacts on the environment. Table 2.2 shows the various approaches of current EF studies.

Table 2.2. Current EF Studies and Their Approaches

		Object(s) of Analysis		
		Globe/Nation	Municipality/Institution	HH/Individual
Approach	Aggregation	Rees and Wackernagel (1996) Wackernagel, et al. (1997) Fricker (1998) Parker (1998) Wackernagel, Lewan and Hansson (1999a) Wackernagel, et al. (1999b) Haberl, Erb and Krausmann (2001) Wackernagel et al. (2002) WWF (2002)	Rees and Wackernagel (1996) Onisto et al. (1998) Wackernagel and Yount (1998) Best Foot Forward (1999) Simmons and Lewis (2000) Flint (2001) Wilson (2001) Lewan and Simmons (2001) Venetoulis (2001) Cole (2002) Simmons (2002) Barret and Scott (2003)	Simmons and Chambers (1998) Christensen (1998) Best Foot Forward (2002) Crompton, Roy and Caird (2002) Williams (2002)
	Dis. Aggre.	Van Vuuren & Smeets (2000)	Třebický (2000) Venetoulis (2001)	
	I/O Anal.	Bicknell et al. (1998) Lenzen & Murray (2001) Ferng (2001) Ferng (2002)		

2.2.1. Global and National Scale EF Studies

These studies have compared the countries' overall consumption to their eco-capacities. According to the aggregation method, Rees and Wackernagel (1996) initially estimated the EF of the 13 industrialized countries using World Resources data. Wackernagel et al. (1997) expanded the study by including 52 large nations in the "Footprints of Nations" report. Using published statistics from the United Nations (1993), they calculated the biologically productive areas of our planet. According to the report, only 1.7 ha per capita is available for human use when we reserve 12 percent of the ecological capacity for biodiversity protection. Meanwhile, the data reveals that humanity's average EF measures 2.3 ha, which means that the average EF is more than 35 percent larger than the available space. Wackernagel, Monfreda and Deumling (2002) updated the report including 146 nations and concluded that humanity exceeds the Earth's biological capacity by 20 percent as of 1999. Another study at the global level is the Living Planet Report 2002 by the World Wildlife Fund (WWF, 2002) which showed the biophysical state of the planet by region and income group.

At the national level, Parker (1998) assessed the aggregate environmental consequence of Japanese economic activity from 1961-1995. The research found that the Japanese economy quadrupled in size while the associated EF nearly doubled to over 6 ha of productive habitat per person by the mid 1990s. Fricker (1998) employed the EFA to discuss sustainable New Zealand. Wackernagel, Lewan and Hansson (1999a) conducted EFA for regions and even catchment areas in Sweden. This study shows that Sweden has 8.2 ha ecocapacities per person; meanwhile, their EF is 7.2 ha. Wackernagel et al. (1999b) measured Italy's EF and found that the average citizen occupies 4.2 ha of biologically productive space while there is 1.3 ha available. Some methodological improvements in this study lead to larger EFs than the account calculated by previous studies (Wackernagel and Rees, 1996).

Several studies were conducted based on the disaggregation approach. For instance, van Vuuren and Smeets (2000) applied the EF concept to Benin, Bhutan, Costa Rica and the Netherlands in 1980, 1987 and 1994. They focused on individual components of the EF such as land and CO_2 emissions. Haberl, Erb and Krausmann

(2001) calculated and interpreted the EF for Austria 1926-1995. A fossil-energy footprint was evaluated on the basis of constant carbon sequestation rates published by Wackernagel. They concluded that although EF is useful for the comparison of EF and biocapacity of different nations, it is difficult to interpret in a time-series analysis.

Initially, Bicknell et al. (1998) proposed the input-output approach for the EF with an application to the New Zealand economy. The study found approximately 3.49 ha of ecologically productive land per year was required to sustain the average New Zealander's current level of consumption (Bicknell et al., 1998). This approach was also employed by Lenzen and Murray (2001) to calculate Australia's EF. In this study, they took a regional, disturbance-based approach including actual Australian land use and emissions data. The study found that per capita EF shows a correlation with household expenditure and decreases noticeably with household size. Ferng (2001, 2002) revised the Bicknell et al. study (1998) in estimating the production land footprint so that the calculated area can be expressed by land category. In 1991, the revised calculation was applied to Taiwan for estimating two footprint components, production land and energy land.

2.2.2. Municipal and Institutional Scale EF Studies

At the municipal scale, local footprints are measured against the national average, and sustainability strategies are evaluated with the EF tool (Wackernagel and Yount, 2000). Since the initial EF study by Rees and Wackernagel (1996) for the Vancouver and Fraser Basin in Canada, a great many aggregation approaches have been conducted at the municipal level. Onisto et al. (1998) estimated the EF of Toronto and the results suggested that the city impacts an area over 280 times its size, which accounts for more than 7 ha of productive ecosystem per capita. The 29 largest cities of Baltic Europe were examined (Folke et al., 1997) and were found to require more than 200 times the spatial area of the cities themselves. At the county level in the UK, Best Foot Forward (1999) examined the EF of Oxfordshire County in collaboration with Oxfordshire County Council. The County requires about 12 times the actual size of Oxfordshire and its EF is 5.69 ha, nearly 20 percent higher than the UK average (4.6 ha). In a county level study for the U.S., Sustainable Sonoma County with Redefining Progress (2002) calculated the EF for Sonoma County in California and determined that it is 8.9 ha per resident. Similar studies have been carried out for Canada's Alberta (Wilson, 2001), Scotland's five cities including Aberdeen, Dundee, Edinburgh, Glasgow and Inverness (Simmons, 2002) and London (Best Foot Forward, 2002), all of which show a reliance on huge appropriations of ecosystem productivity. At the institutional context, Venetoulis (2001) calculated the EF of the University of Redlands in the U.S. and Flint (2001) applied the EFA at the University of Newcastle, Australia.

Using the disaggregation approach, Venetoulis (2001) examined the carbon prints in Los Angeles County, California. He conducted a series of comparative case study analyses using cities in the county to find the relationship between EF and per capita income, environmental values and land use density. The results show that higher per capita income tends to correspond with larger EF but the environmental values seem to offset the income effect on the EF. A similar effect is also apparent in cities that are more compact with a better ratio of employment opportunities. Třebický (2000) studied the transportation EF for Prague Conurbation, Czech Republic. The authors used the EF concept to link the amount of carbon emission with the amount of fossil energy used and land developed. They compared the overall EF of cars, buses and bicycles in Prague and found that cars put 4 times more pressure on the environment than public transport and 9 times more than cyclists.

2.2.3. Household and Individual Scale EF Studies

On the household scale, the individual impact is assessed through direct accounting or simplified questionnaires (Wackernagel and Yount, 2000). Simmons and Chambers (1998) devised an EF tool for households called 'EcoCal', an easy-to-use computer-based questionnaire comprised of 45 questions. The authors used the tool to measure the EF of 42 households in UK and found that the average household EF is almost 5 ha or 1.7 ha per occupant. The EF ranged from less than 0.5 hectares per household to several hundred. The high EF comes from large families with energy-inefficient homes taking long holidays abroad coupled with 'high impact' purchases. Transport ranks as the highest impact closely followed by direct energy use (Simmons and Chambers, 1998).

Christensen (1998) employed a 'life cycle assessment' to examine multiple identities, differences in lifestyles and how they affect the ecological footprint. The study chose to postulate five lifestyles in Denmark with quite different consumer behaviors in housing, transportation, heating and electricity, as well as provisions and leisure. The results demonstrated that the five family lifestyles influenced the environment very differently; therefore, the author claimed, lifestyle should be more thoroughly analyzed so that discussions of lifestyle and consumption patterns could be incorporated (Christensen, 1998). Crompton et al. (2002) introduced the EF concept into an undergraduate course at the Open University, UK. Using the 'EcoCal', the students were required to calculate their EF and then consider and model the effects of changes to their lifestyles. The average EF from 692-student samples was 3.34 ha per household, or 1.33 hectare per person. Households without children (under 16 years) had a higher EF per person than households with children, and rural households had a higher average transport EF than urbanites. On average, transport and energy accounted for nearly three-quarters of the total household EF per person. The results reinforce the conclusions of many other studies (e.g., Simmons et al., 1998; Brower and Leon, 1999; Venetoulis, 2001) that transportation and energy are the key issues for reducing human impact on the natural environment.

2.3. Summary

2.3.1. Findings from Existing Research

The key finding of current EF studies shows that, passing the 1980s, humanity's consumption and waste production today exceed the Earth's capacity to create new resources and absorb waste (Wackernagel et al., 2002). Specifically, the global EF was 2.3 global hectares per person in 1999; however, in the same year, the productive quarter of the biosphere was to an average 1.9 global hectares per person. Therefore, human consumption of natural resources that year overshot the Earth's biological capacity by 20 percent (WWF, 2002).

As of 1999, it has been reported that about 56 nations out of 145 nations exceed the global EF account, 2.3 hectares. Among the high EF nations, the EF of the United Arab Emirates, USA, Canada, New Zealand, and Finland is over 8.0 global hectares per person (Wackernagel et al., 2002). So far, using different methodologies, the EF studies have been widely conducted at various levels including global, national, municipal, institutional, and individual. Despite some differences among the studies, they reached an identical conclusion – humanity is liquidating natural capital to support current resource use, thereby reducing the Earth's capacity to support future life.

2.3.2. Limitations and Future Study Direction

Current EF studies have mainly provided a better understanding about the size of our ecological impact. They suggest that failing to keep a reliable and comprehensive accounting of our ecological expenditures will lead to an inevitable result – ecological bankruptcy (Wackernagel et al., 2002). Thus, the next step should be focused on ways to reduce the EF from a variety of perspectives. To do so, the first step is to understand what factors affect the EF account then develop appropriate policy options. The current EF analyses have indicated the level of ecological deficit reduction that is needed, but have not determined what action to take. In other words, the researches have neglected to suggest solutions.

The literature review found gaps in the current EF studies. Despite the wealth of empirical and conceptual investigations that have been carried out since these early studies, few studies have been conducted to look for specific driving factors which influence the variations of ecological footprints of specific entities. Particularly, no studies have attempted to research this issue from the perspective of urban planning.

In order to fill the aforementioned gaps, this study looks for the potential driving forces of the per capita EF account from household members through further literature reviews on broad urban studies focused on socioeconomic/demographic, environmental value, land use patterns, and spatial factors. Then, a multivariate regression analysis will be used to identify which variable most influences the per capita EF. Based on the results, the dissertation will suggest several policy implications and recommendations using a planning perspective to reduce the individual EF account, not only for Dallas County but also for other locales.

CHAPTER III

CONCEPTUAL FRAMEWORK FOR ECOLOGICAL FOOTPRINT MODELING

This chapter constructs a conceptual framework to further understand the theoretical components of and influences on the personal ecological footprint. It identifies the variables in the conceptual model and develops research hypotheses based on the literature review. Specifically, the first section of this chapter builds a conceptual framework. The second section illustrates the conceptual model of the per capita ecological footprint as a dependent variable separated into four components. The third section formally states the seventeen research hypotheses to be tested with their expected outcomes. Finally, the last section provides a statement of predicted outcomes.

3.1. Conceptual Framework

In order to develop a conceptual framework, the study has drawn upon four potential driving forces based on a literature review of previous urban studies. These drivers include socioeconomic/demographic, environmental value, land-use patterns, and spatial factors. Specifically, mixed-use and development density are the two major land-use patterns driving the individual Ecological Footprint account. This framework will provide the theoretical foundation of the multiple regression analysis for the study of the relationship between the per capita footprint and its potential driving forces. Figure 3.1 is intended to simplify the complex relationship by modeling the relationship between individual resource consumption and its drivers.

It illustrates how each factor discussed in this section is conceptually related. The remainder of this section describes the rationale and constructs research hypotheses for each factor.

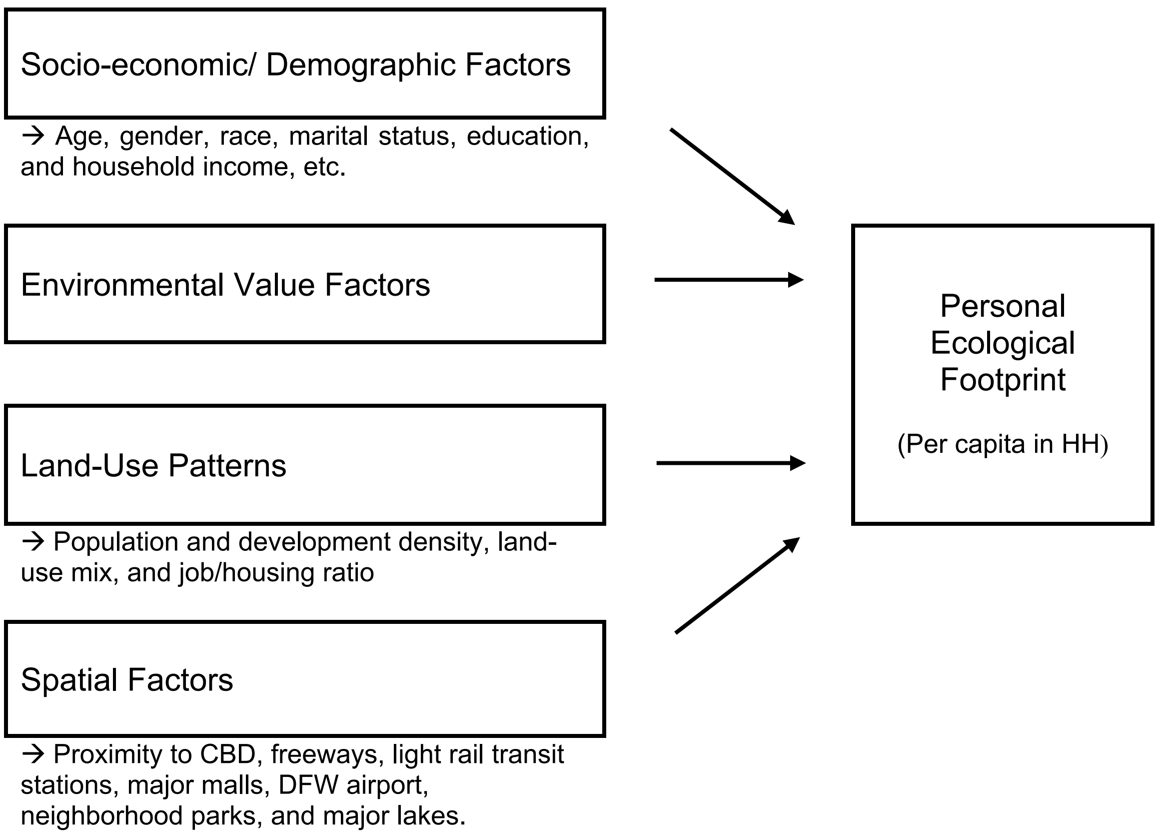


Figure 3.1. Conceptual Framework

3.2. Dependent Variable: Per Capita Ecological Footprint Account

The dependent variable of the conceptual framework which consists of the food, mobility, shelter, and goods/services footprint, is the per capita Ecological Footprint Account of Dallas County. As explained in Chapter IV, the EF is the total area of productive land and water required to continuously produce all the resources consumed and to assimilate all the waste produced by a defined population wherever that land is located (Rees and Wackernagel, 1996). The EF is expressed in 'global acres (or hectares)' that correspond to one acre of biologically productive space world average productivity. The calculations are based on two simple facts: first, most of human consumption and much of the waste generated can be accounted for; and second, the biologically productive areas appropriated for production of this consumption and for assimilation of the waste can be calculated (Wackernagel et al., 1999a). Wackernagel and Rees (1993, 1996) constructed a consumption-land use matrix with five major consumption categories and six major land use categories. Consumption categories included food, housing, transportation, consumer goods, services, and waste. Land use categories used to support the human economy included cropland and pasture land, built-up land, forest, fish and carbon assimilating capacity.

In this study, the per capita EF will be measured by sixteen questions using the Ecological Footprint Quiz[2] that was created by Redefining Progress (2002). To calculate *food footprint*, the quiz sums up arable land, pasture, sea space, and land areas to sequester CO_2 from the energy expended to grow, process and transport the items. The

[2] www.myfootprint.org

mobility footprint includes many of the impacts that result from walking, cycling, taking trains, driving cars, and flying. Included in this estimate are areas needed for roads, manufacturing vehicles, motor vehicle departments, police, insurance, and forests needed to absorb CO_2. The *housing footprint* includes yard area, energy and materials for constructing the building, and energy to operate it. Finally, the *goods and services footprints* are determined based on the size of food, shelter, and mobility footprints. This result considers average lifestyles, and estimates use of appliances, clothing, electronics, sports equipment, toys, computers, communications equipment, household furnishings, and cleaning products. The quiz includes *services* such as water, sewage, garbage, telecommunications, education, healthcare, financial services, entertainment, recreation, tourism, military, and other governmental services (Merkel, 2003). Figure 3.2 illustrates the per capita EF conceptual model.

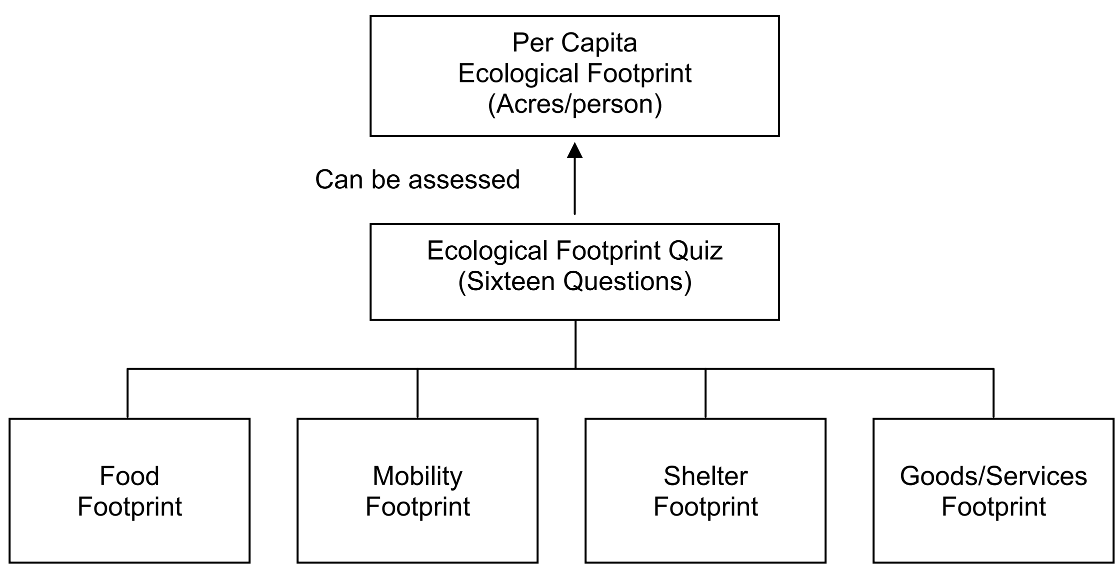


Figure 3.2. Per Capita EF Conceptual Model

3.3. Independent Variables: Socioeconomic/Demographic, Environmental Awareness, Land-Use Patterns, and Spatial Influence

3.3.1. Socio-Economic/Demographic Factors: The Socioeconomic/Demographic Factors May Affect the per Capita Ecological Footprint

It is widely known that significant differences exist in social behavior among generations (e.g., Mears and Ellison, 2000). Naturally, the consumption pattern will vary depending on age. For example, the young usually have a different preference for housing choice and show a different travel pattern compared to older adults – particularly, shopping behaviors.

Hypothesis 1: Younger respondents will have a higher per capita EF than older respondents.

Since the 1970s, women have entered the workforce in record numbers. A number of studies have shown that women have shorter commutes, in both distance and time, than men (Ross and Dunning, 1997). Gender differences should contribute to a variation in transportation's EF. For example, Mauch and Taylor (1997) reported that gender is a robust predictor of shopping trips.

Hypothesis 2: Males will have a higher per capita EF than females.

Lifestyle varies according to ethnicity or race. According to Census 1990 and 2000, throughout Dallas County, the spatial distribution of residents is clear depending on ethnicity. The black population is clustered at the core of the county, while the white residential area is far from the center. Meanwhile, Hispanics are clustered northwest of the center. Therefore, it is supposed that each group will consume goods, shelter and transportation differently. Mauch and Taylor (1997) reported that travel patterns vary somewhat according to ethnicity.

Hypothesis 3: White respondents will have a higher per capita EF than non-white respondents.

It is thought that married individuals increase the possibility of sharing resources in comparison with non-married individuals whose marital status is never married (single), divorced, and widowed. Therefore, the average per capita consumption of goods, shelter and transportation in households of the married may be less than that of households of the non-married.

Hypothesis 4: A married individual will have a lower per capita EF than a non-married individual.

It has been a widely accepted assertion that "ignorance" and "poverty" are the main causes of much of the world's ecological degradation (a position supported even by the Brundtland Commission [World Commission on Environment and Development 1987]). Reality, however, appears to deny this. As suggested by Orr in a 1994 essay, the "ignorant and uneducated" are not primarily to blame for the environmental crisis; instead, the solution to ecological challenges would require reconsideration of the "substance, process, and purpose of education at all levels" (Wolfe, 2001). So far, a variety of studies have contended that the major environmental problems are the result of production and consumption processes traceable mainly to the highly urbanized, well-educated, high-income population of developed countries (Rees, 2003). Snyder (1990) even maintained that the universities and colleges are an important source of unsustainable attitudes and behavior. Therefore, the level of education will influence the individual consumption variation.

Hypothesis 5: A more educated person will have a higher per capita EF than a less educated person.

Lenzen and Murray (2001) observed that with an income increase of 10 percent, the EF increases by only 3.8 percent. Venetoulis (2001) reported that there are mixed findings on the relationship between levels of income and anthropogenic emissions of sulfur dioxide, nitrogen oxide, and carbon dioxide gases. However, at the individual level, Williams (2002) reported that those with greater personal income consume more energy, space and goods. Recently, Ryu and Brody (2005) also found that graduate students living in a high income household showed a significantly higher per capita ecological footprint than students living in a relatively low income household, particularly for mobility, shelter, and goods and services. At the international level in 1999, WWF (2002) reported that the footprint per person of high income countries was on average over six times that of low income countries, and over three times greater than the Earth's biological capacity. Therefore, I expect that household income will influence personal consumption behavior.

Hypothesis 6: A person in a high income household will have a higher per capita EF than a person in a lower income household.

3.3.2. Environmental Value Factors: The Degree of Environmental Awareness May Affect the per Capita Ecological Footprint

There has been considerable discussion on the possibility that the stronger proenvironmental values are more likely to be observable in action associated with consumption patterns (Inglehart, 1990; Kempton, 1996; Inglehart, 1997). However, few studies have investigated this issue using ecological footprint methodology.

Venetoulis (2001) conducted a series of comparative case study analyses and cross-county statistical tests to address the value hypothesis using data from fifty-one cities in the county of Los Angeles. Environmental values in this study were measured from the average percentage of total votes in a city that were *for* two environmental measures, Proposition 116 (Rail Transportation Bond Act) and 117 (California Wildlife Protection Act). The evidence revealed that where environmental values are stronger, ecologically intensive consumption is lower on a per capita basis as compared to where these values are not as strong, controlling for other independent variables.

Most recently, Ryu and Brody (2005) conducted an ecological footprint analysis in an interdisciplinary graduate level course on sustainable development using multivariate regression analysis to identify the major factors driving students' consumption behavior. They found that a student with a strong environmental awareness was more likely to have a smaller per capita ecological footprint than a student with a weak environmental awareness. However, the direction was statistically not significant.

It is thought that a person who has a high environmental awareness or attitude is more likely to seek a more environmentally friendly lifestyle. Thus, the degree of environmental awareness will influence individual consumption behavior.

Hypothesis 7: A person with strong environmental awareness will have a lower per capita EF than a person with weak environmental awareness.

3.3.3. Land-Use Patterns: Scientifically Measured Land-Use Patterns Surrounding a Particular Household May Affect the per Capita Ecological Footprint

The environmental impacts of urban sprawl have been widely identified. It is thought that households in more compactly developed areas have a lower footprint than those in less compactly developed areas. The literature on urban sprawl has been documented in several recent articles (Burchell, 1998). The following brief review attempts to organize the literature in terms of resource consumption. Urban sprawl can be defined in a variety ways. Ottensmann (1977) defines it as the scattering of new development on isolated tracts, separated from other areas by vacant land. Gordon and Richardson (1997) refer to it as leapfrog development. According to The Sierra Club (1999), sprawl is "low density development beyond the edge of service and employment, which separates where people live from where they shop, work, recreate and educate – thus requiring cars to move between zones." Ewing (1997) defines sprawl as the combination of three characteristics: (1) leapfrog or scattered development; (2) commercial strip development; and (3) large expanses of low-density or single-use developments. Richmond (1995) adds the following indicators of sprawl: decentralized land ownership and fragmentation of governmental land-use authority, and disparities in the fiscal capacities of local governments. Downs (1998) adds two more characteristics of sprawl: widespread commercial strip development, and no low-income housing outside central cores.

Urban sprawl has been criticized for the inefficient use of land resources and energy and large-scale encroachment on agricultural land (Yeh and Li, 2001). The most concrete costs are various environmental problems that are exacerbated by this pattern of development (Squires, 2002). Johnson (2001) summarized the environmental impacts of urban sprawl identified by many researchers as follows:

- loss of environmentally fragile lands, reduced regional open space, greater air pollution, higher energy consumption, and decreased aesthetic appeal of landscape,
- loss of farmland, reduced diversity of species, increased runoff of stormwater, and increased risk of flooding,
- excessive removal of native vegetation, monotonous residential visual environment, absence of mountain views, and presence of ecologically wasteful golf courses,
- ecosystem fragmentation.

Consumption patterns of sprawl stimulate greater use of energy, despoil forests, damage the stratospheric ozone layer, and possibly contribute to global warming. Sprawl creates a car-intensive culture: lots of new roads, long-distance commutes, and the need to get in the car for just about everything (Gallagher, 2001). Farm and forestland itself is consumed and residential and commercial development proceeds outward (Goldsmith, 1999). Empirically, Real Estate Research Corporation (RERC, 1974) analyzed the various costs of sprawl and revealed that high density planned communities consume *fewer* resources such as land, energy, and water than low density sprawled communities.

Discussions of sprawl and associated costs often focus on transportation and land use (Squires, 2002). Sprawl often leads to inefficient land use practices requiring large infrastructure investments for roads, sewer systems, schools, and other public services. Traffic congestion causes more people to spend more time in their automobiles (Downs, 1998; Duany et al., 2000; Sierra Club, 2000).

However, Hayward (1988) and O'Toole (1999) point out that increases in automobile usage are not synonymous with increases in commuting times, and neither of these is necessarily synonymous with low-density development. Particularly, Gordon and Richardson (1997) claim that suburbanization has been the dominant and successful mechanism for reducing congestion. Based on several empirical reports, they argue that it has shifted road and highway demand to less congested routes and away from core areas and thus contained metropolitan area commuting times (Gordon and Richardson, 1994). Burchell et al. (1998) also conclude from their research on the impacts of sprawl that the three conditions that define the *negative* impacts of sprawl – leapfrog development and low-density and unlimited outward expansion – are the same as those that define the positive aspects of sprawl.

Urban and suburban sprawl do provide benefits for at least some residents. Such development provides a low-density lifestyle with ease of commuting and access to shopping for those who live and work in selected suburban areas. It provides greater separation from the problems of poverty, racial conflict, and other issues generally associated with city life. Clearly, many families prefer single-family homes on large lots in communities that are distant from urban centers (Danielsen et al., 1999; Downs, 1998; Gordon and Richardson, 2000).

Recently, Kahn (2001) found that sprawl caused the black/white housing consumption gap to become smaller in more sprawled areas. Using 1997 American Housing Survey data, he measured housing consumption for blacks and whites in metropolitan areas characterized by more and less sprawl. In sprawled areas, black households consume larger units and are more likely to own their homes than black households living in less sprawled areas. Thus, further sprawl is advocated as a key to creating opportunities for racial minorities and immigrants who are just starting to enjoy the American dream and to encourage economic growth generally (Easterbrook, 1999) (Squires, 2002).

An Ecological footprint (EF) reflects human consumption behaviors in terms of food, housing, transportation, consumer goods, services, and wastes. From the definition of ecological footprint, the variation of per capita footprint for household member is highly likely to be sensitive to land development patterns. First, the highly sprawled urban development patterns will increase housing consumption. In theory, households are assumed to maximize their consumption of housing, transportation, and other goods in choosing a residential location. Thus, they trade off transportation cost and housing unit. Clearly, if the benefits of moving toward the suburbs exceed the costs, a household will do so. In the reverse case, it will move toward the city center. Only when the costs and benefits of a move are equal will the household achieve location equilibrium (Mills and Hamilton, 1994). This implies that the household residing in the suburbs tends to consume more housing units than those in the city center.

In practice, studies demonstrate that households in highly sprawled areas consume more housing than those in less sprawled areas – not only white head households but also black head households in terms of number of rooms, unit size, and unit year built (Kahn, 2001). Especially, black households in the sprawled metropolitan area consume more rooms and more housing space and are more likely to own and live in the suburbs than the same black household living in a nonsprawled metropolitan area (ibid). Thus, it is supposed that households in highly sprawled areas have a higher shelter footprint than those in less sprawled areas. Second, urban sprawl will increase the mobility footprint per capita household member. Sprawl coexists with high volumes of personal travel by automobile due to more dispersed destinations that may increase (Helling, 2002) total VMT (Vehicle Miles Traveled).

Numerous investigations show that sprawling land use patterns in the United States require more driving (e.g., Downs, 1998; Duany et al., 2000; Sierra Club, 2000; Squires, 2002). This phenomenon is consistent with in European context, such as Italy. In the recent study, Camagni et al. (2002) demonstrated in an empirical study on Milan that a low urban density generates a higher environmental impact due to the mobility generated.

These sprawl lifestyles consume a variety of ecologically productive land areas such as: cropland and pasture land for production of goods; built-up land to support infrastructures including roads, sewer systems, schools, and other public services; forest land for the production of wood products needed for soaring housing demand; carbon assimilating capacity land for carbon dioxide emissions from fossil fuels. Particularly, sprawl diminishes the Earth's carbon assimilating capacity. Deforestation associated with sprawl exacerbates global warming by destroying the natural carbon sink. Trees absorb carbon dioxide and lock it up in their biomass, therefore when trees are cut for development, they no longer serve as carbon sink, and carbon from vehicles and other fossil fuel combustion eventually is released back into the atmosphere. Also, sprawl increases energy consumption and resulting CO_2 emissions from energy generation.

Recent research shows that deforested, paved areas become "urban heat islands" where temperatures may increase 10 to 15 degrees above normal. Higher temperatures lead to increased utility use and higher power demand, which in turn leads to more fuel combustion, more CO_2 emission, and ultimately, to accelerated global warming (Gallagher, 2001). Sprawl also results in increased water consumption. The sprawl lifestyle, which often includes large lawns, car washes, and swimming pools, contributes to overdraft of water resources across the United States (ibid). Empirically, Speir and Stephenson (2002) demonstrate that the more spread out housing patterns are, the more costly it is to supply public water and sewer services.

In this context, it is thought that population density is significant for individual consumption patterns. Higher population density will increase the possibility of sharing public infrastructure. Particularly, it provides a chance to construct public transportation which decreases automobile dependence. Therefore, high density will decrease the per capita transportation EF. Newman and Kenworthy (1989) reported that high-density cities consume less gasoline than low-density cities.

Hypothesis 8: A person in a high population density area will have a lower per capita EF than a person in a low population density area.

Dallas County, Texas is a well-known area where urban sprawl is rapidly proceeding. According to the most recent report, Measuring Sprawl and Its Impact (Ewing et al., 2003), the Dallas Primary Metropolitan Statistical Area (PMSA) was ranked 13th most sprawling among 83 metro areas nationwide. Between 1990 and 2000, the spatial pattern exhibited by population change for the Dallas PMSA region typically displays that negative (or low) population change is concentrated within the major urban center, whereas higher positive change tends to increase with greater distance from the urban centers (The University of Texas, Dallas, 2003). Many people may be leaving the urban cores to pursue potential benefits from low density suburban development including access to employment, access to open space amenities, lower crime rates, lower housing costs, better air quality, more flexible transportation by auto, and preferred separation of residences from commercial and industrial activities (Gordon and Richardson, 1997; Peiser, 1989). Therefore, it is supposed that a person living in less developed areas far from the urban centers, i.e. suburban areas, will have a bigger footprint, particularly in the mobility and housing consumption.

Hypothesis 9: A person living in a low development density area will have a higher per capita EF than a person in a high development density area.

It is thought that a person living in a highly mixed land-use location will show a smaller personal footprint than a person living in a homogeneous land use pattern location. Theoretically speaking, there exist high possibilities that mixed use is likely to reduce per capita EF in household members. First, it can reduce the individual transport footprint because mixed use attempts to integrate segregated urban land functions such as office, retail, hotel, leisure, and residential uses in a pedestrian-oriented environment. This effort has the potential to make travel distance shrink as the physical distance between origin and destination becomes shorter. The integrated land use pattern will provide an opportunity for travelers to change their travel behaviors. It will decrease not only travel frequency but also vehicle miles traveled (VMT), particularly for automobile travel. As the automobile-dependent VMT decreases, the overall transportation-oriented energy use will also decrease suggesting that the mobility footprint will become lighter since this decrease will enhance the carbon-assimilating capacity for carbon dioxide emissions from fossil fuels.

Second, mixed-use development promotes “Transit-Oriented Development (TOD)” that concentrates development in nodes associated with transit stations (Bernick & Cervero, 1997; Calthorpe, 1993). Commercial, office, entertainment, and high-density residential uses collocate near the station, thus TOD creates an urban region structure with clusters of uses aligned in a density gradient from a transit station. This will increase the balanced modal split among automobile, public transit, and environmentally friend transports such as bicycling and walking, etc. The balanced modal split is an important conditionfor reducing the personal EF account. For example, Třebický (2000) studied the transportation EF for Prague Conurbation, Czech Republic. The authors used the EF concept to link the amount of vehicle emissions (carbon emission) with the amount of fossil energy used and land developed. They compared the overall EF of cars, buses and bicycles in Prague and found that car drivers put 4 times more pressure on the environment than public transport users and 9 times more than cyclists. Other empirical studies demonstrate that transport and energy are the key issues for reducing the environmental impacts of humanity on the planet (e.g., Simmons et al., 1998; Brower and Leon, 1999; Venetoulis, 2001).

However, Crane (1996) has suggested it is possible that the compactly integrated land use patterns may increase rather than reduce automobile use, depending on case-by-case empirical considerations, because shorter origin-destination distances reduce the average cost per trip. Cheaper trips mean more vehicle trips, and it is conceivable that total VMT may increase.

Reducing the mobility footprint is by no means the only significant potential for mixed-use development. It also presents other significant issues such as shelter footprint. Within a given residential land use, planners may enhance the range of choices available to encourage a mix of forms and tenures in housing consumption. Mixing housing types could increase affordability and equity by reducing the premium that exclusive, segregated areas enjoy. However, unlike the case of sprawling suburbs, increased affordability may not mean an increase in housing volume itself such as rooms, unit size, and unit year built. It means that per capita shelter footprint may not be increased with enhanced housing affordability. Additionally, the inherent nature of mixed-use development does not include large lawns, car washes, and swimming pools in housing supply. Thus, it will also contribute to saving water resources.

Hypothesis 10: A person in a high mixed-use area pattern will have a lower per capita EF than a person in a low mixed-use area pattern.

So far, many studies have calculated a jobs-housing ratio in order to explain the individual's commuting travel patterns throughout local municipalities (Cevero1989, 1996). If a specific location has more jobs than houses, the location is likely to import workers, decreasing the possibility of local residents commuting to other locations.

Otherwise, the location is likely to export workers increasing the possibility of local residents commuting to other locations. Therefore, it is thought that a person living in a community with more suitable places for local residents to work will have a consumption behavior different from a person living in a community where there are fewer suitable places to work for local residents. Particularly, it is supposed that the former will have a smaller mobility footprint than the latter; additionally, this will result in different consumption behavior in terms of shelter and goods and services.

Hypothesis 11: A person living in a location with a high job/housing ratio will have a lower per capita EF than a person living in a location with a low job/housing ratio.

3.3.4. Proximity to Spatial Factors: Scientifically Measured Proximity to Spatial Factors Surrounding a Particular Household May Affect the per Capita Ecological Footprint

The standard model of urban form explains urban structure using transportation costs and land use in the monocentric city. In the model, households are assumed to maximize their consumption of housing, transportation, and other goods in choosing a residential location. They trade off transportation costs and housing units until they reach location equilibrium (Mills and Hamilton, 1994). Therefore, it is thought that proximity to a Central Business District (CBD) is an important factor influencing households' EF.

Hypothesis 12: A person close to a CBD will have a lower per capita EF than a person far from a CBD.

Location relative to freeways has been widely studied in terms of housing price (e.g., Vadali, 2001). Vadali (2001) claimed that different proximity specifications should be studied in any housing evaluation study. Thus, it is thought that proximity to major roads impacts housing consumption. Additionally, it also influences travel patterns due to the road's dual externalities (positive and negative effects) like airport facilities (Wilhelmsson, 2000).

Hypothesis 13: A person close to major freeways will have a lower per capita EF than a person far away.

It is intuitively thought that a person living close to public transit stations has a relatively higher possibility of using public transportation compared to a person living farther away. Therefore, a person who is located close to Dallas County's light rail transit station is supposed to have a smaller mobility footprint than a person living farther away. Additionally, since the light rail transit stations are located at the center of Dallas County, this will also influence personal housing consumption.

Hypothesis 14: A person close to light rail transit stations will have a lower per capita EF than a person farther away.

Major commercial malls are places where households' consumption occurs. Proximity to malls is also considered to be an important factor influencing households' travel patterns. Thus, it is thought that proximity to major malls will impact a per capita household member's EF for both transportation and goods.

Hypothesis 15: A person close to major commercial malls will have a higher per capita EF than a person far away.

Airport transportation is one of the major factors contributing to an individual's EF. However, it is widely known that proximity to an airport produces two externalities. On one hand, it enhances accessibility. On the other hand, it produces noise pollution that has a substantial negative effect on housing values (Wilhelmsson, 2000). Thus, it is thought that proximity to an airport will influence households' housing consumption as well as transportation patterns.

Hypothesis 16: A person close to an airport will have a lower per capita EF than a person farther away.

Neighborhood parks and lakes are the major recreation areas which provide the public with natural resources. It is thought that households near these public open spaces will show a different consumption pattern from those who are located far from the facilities. Particularly, residents can easily access public open spaces with fewer vehicle traveled miles and additionally, open spaces could be utilized as land to produce locally grown food.

Hypothesis 17: A person close to parks and lakes will have a lower per capita EF than a person far from them.

3.4. Statement of Predicted Outcomes

According to the literature review of broad urban studies and conceptual framework for each of the variables described above, this study will test the following main hypothesis: *Personal socioeconomic and demographic factors, environmental awareness, land-use patterns, and spatial characteristics surrounding a person are related to the average personal ecological footprint of Dallas County, Texas.*

CHAPTER IV

RESEARCH DESIGN AND METHOD

This chapter discusses the research design and methods employed to measure, analyze, and interpret the survey data collected from Dallas County. First, general study design, population, sampling method, and outline of study flow are discussed. Second, the processes of concept measurement for the dependent and independent variables are explained. Next, this chapter describes the plan of statistical analysis and develops a predictive model to address the combined influence of the independent variables on the personal ecological footprint. The chapter concludes with a description of validity threats associated with the variable measurement.

4.1. General Study Design

This study is based on 1) a survey that measures the respondents' consumption behaviors associated with food, goods, shelter and mobility and their environmental values and attitudes. 2) A GIS inventory that objectively measures surrounding land-use patterns and spatial attributes of respondents. This study is a cross-sectional, current study because data on dependent variables (Ecological Footprint Account) and independent variables (socioeconomic and demographic factors, environmental value factors, land-use attributes, and spatial factors) are all taken at one point in time (Wooldridge, 2000).

The design of this study can be justified for the following reasons. First, to measure the per capita Ecological Footprint Account, the survey questionnaire is based on the *Ecological Footprint Quiz* created by Wackernagel who is one of the developers of the Ecological Footprint concept. Second, the use of satellite images provides a useful objective tool for measuring surrounding land-use patterns and spatial attributes of respondents. Third, the cross-sectional dataset for the dependent and independent variables is ideal for testing research hypotheses and evaluating their statistical relationships (Wooldridge, 2000).

4.2. Sampling Method and Study Flow

4.2.1. Study Area

Dallas County, in north central Texas, as shown in Figure 4.1, is bordered by Kaufman and Rockwall counties to the east, Tarrant County to the west, Denton and Collin counties to the north, and Ellis County to the south. Dallas is the county seat and largest city. The county is drained by the Trinity River and its tributaries.

Dallas County has 879.6 square miles of land area and a population density of 2,596.7 per square mile. The population increased rapidly from 1950 to the 1990s. By 1950, 89.8 percent of Dallas County was considered urban. In 1950 the whole county was officially classified as the Dallas Metropolitan Statistical Area by the census bureau. The population tripled between 1950 and 1990, from 614,799 to 1,852,810. While both the black and white population increased, the percentage of blacks in the population grew from 13 percent in 1950 to 20 percent in 1990. In 1980 the Hispanic population made up 9 percent of the population, but by 1990 it was 17 percent (The Handbook of

Texas Online: Dallas County). On the 2000 Census form, 97.3 percent of the population reported only one race, with 20.3 percent of these reporting African-American. The population of this county is 29.9 percent Hispanic (of any race). The average household size is 2.71 persons compared to an average family size of 3.34 persons (STATS Indiana - USA Counties IN Profile, 2005).

4.2.2. Study Population and Sampling

The study population was the 2,219,000 households distributed throughout Dallas County in Texas reported in the U.S. 2000 Census of Population and Housing. The target population was 800 respondents consisting of men and women over 18 years of age in order to decrease the variance caused by age. The unit of analysis in this study was the single and multifamily housing unit within Dallas County. This county was selected because most of its communities are growing rapidly with clearly sprawling land-use patterns. To randomly sample the required number of residents, the Dallas Central Appraisal District residential records were purchased from ITCdata, Inc. This data had the following information: Parcel ID, address, owner name, land-use code, appraised value, and other physical attributes such as number of baths / fireplaces / stories, year built, and building area.

Based on the residential records, this study utilized a stratified random sampling in which the required number of households and their residents was randomly selected. The survey sampling procedures were designed to generate 800 households in the county. Dallas County consists of approximately 86 zip codes that were identified as subpopulation groups, called strata in this study. For the 800-target population, an appropriated sample size for each stratum was determined according to the percentage population of each zip code within the county so that samples were evenly distributed throughout the entire county. For example, twenty-six samples were assigned to the 75217 zip code because its population accounts for approximately 3.0 percent of the total population; fourteen samples in 75081 with about 1.0 percent population, etc. According to this procedure, no samples were assigned to certain zip codes (e.g., 75202, 75247, 75251, and 75261) (See Appendix 4: The sample distribution by zip code). Then, the simple random sampling method was applied to choose the specified household within each stratum.

Dallas County residents received packets containing a cover letter, questionnaire, and return envelope. The cover letter described the research, its risks for the respondents and its benefits for the respondents. The respondents were asked to fill out the questionnaire by reporting their consumption behaviors associated with food, goods, shelter and mobility, and their environmental values/attitudes. Following Dillman's Total Design Method (1978), non-respondents received a reminder post card, and as many as three follow-up questionnaires. Respondents' confidentiality was preserved by identifying questionnaires only through the use of arbitrary identification numbers.

The overall response rate was 27.1 percent, which generated a sample of 217 for analysis. These samples were geocoded (placed in their true location on earth using X and Y coordinates) by tying their reported addresses to a 2000 U.S. Census Bureau TIGER line file. Once each respondent was placed in space, the study could effectively utilize geographic factors to examine the Ecological Footprint account within the study area. Figure 4.1 illustrates the 217 respondent locations throughout Dallas County.

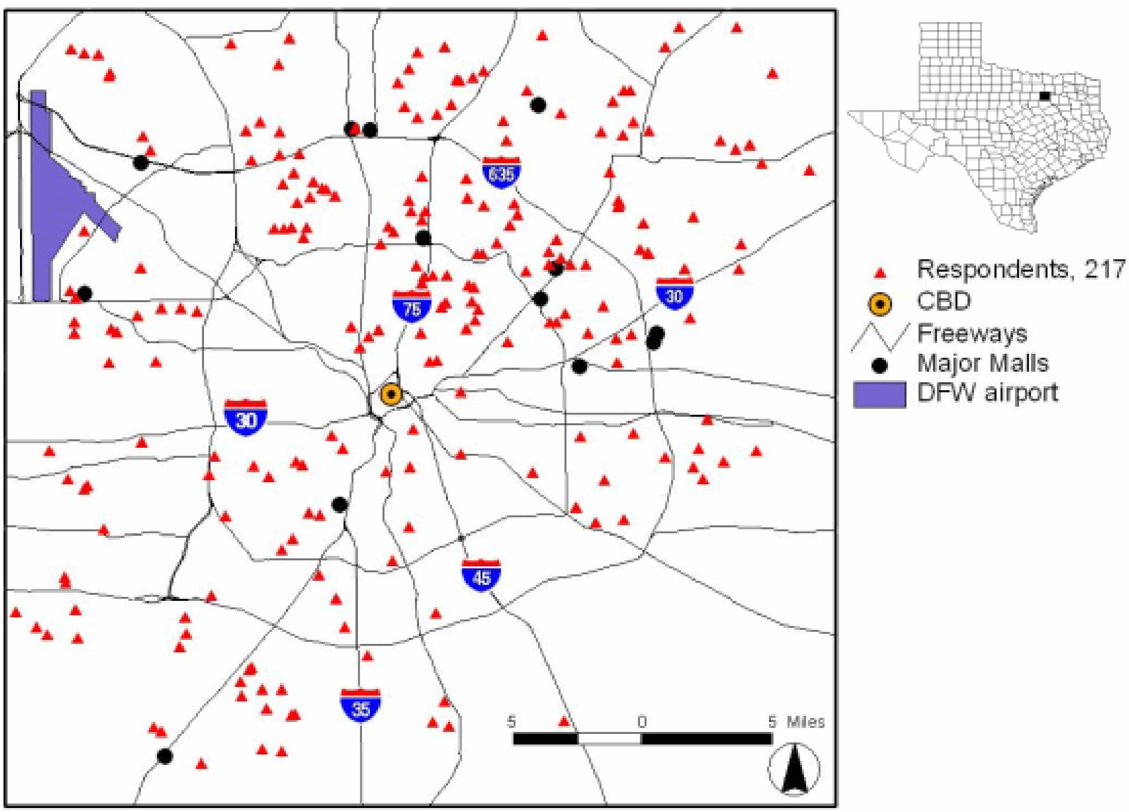


Figure 4.1. Respondent Locations

4.2.3. Outline of Study

As illustrated in Figure 4.2, the empirical process of this dissertation proceeded in three phases: 1) Survey, 2) GIS and remote sensing analysis, and 3) Ordinary least squares (OLS) multiple regression analysis.

First, through the survey, background information, environmental awareness, and personal ecological footprint score were measured. Assuming that a person with strong environmental values will have a lower per capita footprint, the environmental awareness was measured by seven questions regarding the degree to which humans are impacting the environment. Respondents' footprints were measured using the 'Ecological Footprint Quiz' that consisted of sixteen questions regarding individual food, goods/services, mobility, and housing consumption. Second, GIS and remote sensing routines were employed to calculate land-use patterns and geographic spatial attributes surrounding a particular person. Shannon's Evenness Index was used to calculate land-use mixedness. To measure development density, Landsat 7 ETM+ NLAPS images with 30×30 meters resolution were classified into three land covers: built-up, non built-up, and water-bodies with unsupervised classification in ER Mapper image processing software. Census TIGER data were used to measure the distance from respondent to spatial features by the Nearest Feature software. Third, the study used sequential multiple regression to examine five separate regression models, one for each component (food, mobility, shelter, and goods and services) and a composite footprint score to reach a conclusion about the impact of independent variables on the per capita ecological footprint.

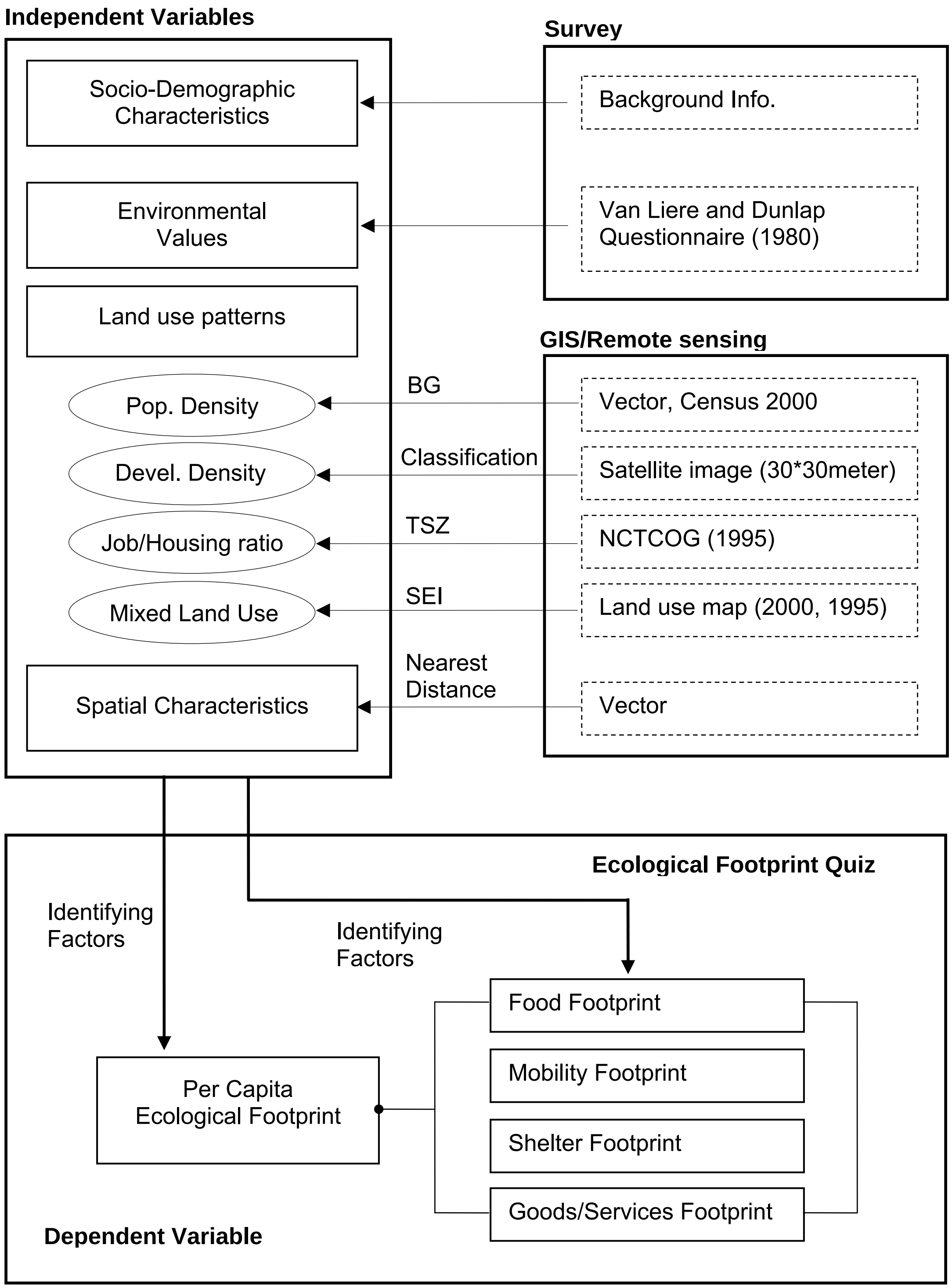


Figure 4.2. Process of the Empirical Study Using Survey, GIS and Remote Sensing

4.3. Concept Measurement

4.3.1. Dependent Variable

The dependent variable is the per capita Ecological Footprint Account in 2004 within Dallas County. This study calculated each respondent's footprint by administering the Ecological Footprint Quiz (EF Quiz) originally designed by a nongovernmental organization called Redefining Progress.

Consumption activities for each survey question were weighted by a "footprint factor" calculated by the amount of energy and land needed to support the given activity. Footprint factors were pre-calculated by Redefining Progress according to national levels of productivity. Multiplying each respondent's level of activity by its corresponding footprint factor yielded an equivalent impact in terms of acres of land/sea that could be compared across all nations[3]. A composite EF score was calculated by aggregating four separate components: food, mobility, housing, and goods and services.[4]

The survey questions for food included the types of food respondents regularly eat and where this food was produced; for mobility their mobility habits included the mode, distance, and relative energy efficiency of their daily travel or commute; for shelter the size and type of shelter, and the number of inhabitants; for goods and services information about utility use including water, sewer, and trash disposal services.

---

[3] For more detail on individual footprint calculation, refer to Merkel (2003).

[4] Four footprint components were combined into a single variable. The reliability of a scale has good internal consistency, with a Cronbach alpha coefficient reported of 0.7.

4.3.2. Independent Variables

Based on the literature review in Chapter II, four independent variable groups were identified as elements driving the per capita ecological footprint score including socioeconomic and demographic factors, environmental values, land-use patterns, and geographic spatial features surrounding a particular household.

Socioeconomic and Demographics Variables

This set of variables included age, gender, race/ethnicity, education year, and household income: questions from 24 to 36. Age and household income, as reported by survey respondents, were measured as continuous variables. Gender was a dichotomous variable where 1 was male and 0 was a female respondent. Race/ethnicity was also a dichotomous variable where 1 was white and 0 was non-white respondent. Education was measured as a continuous variable based on the years of formal schooling completed.

Environmental Values: Respondents' Awareness on Sustainability Crisis

This variable was measured by selected questions from the questions initially used by Van Liere and Dunlap (1980). Respondents were asked to indicate whether they strongly agree, agree, disagree, strongly disagree, or have no opinion on each of the questions: questions from 17 to 23. Responses were summed and ranged from 1 (strongly agree that humans are abusing the natural environment) to 28 (strongly disagree that humans are abusing the environment). Seven separate questions regarding the degree to which humans are impacting the environment on a scale from 1 to 4 are combined into a single variable.[5] It is a reverse index in which the high scores indicate

[5] Seven separate questions regarding the degree to which humans are impacting the environment on a scale

low awareness.

Land-Use Patterns Variables: Density and Mixed-Land Use

In measuring population density, the traditional analyses for demographics have been conducted based on census boundaries such as census tract, block group, block, and ZIP code, etc. However, these methods have some drawbacks in measuring the population and housing density characteristics surrounding each of the respondents because these areal units do not necessarily guarantee homogeneity and functional integrity. It is particularly critical for this study to attempt to measure the neighboring demographic characteristics of individual respondents.

For example, census tracts tend to increase in areal size with distance from the regional core. This creates the possibility for underestimating the population and housing density in outer areal units. However, in order to enhance the traditional method in measuring population and housing density, the study employed a "customized" unit of analysis as illustrated in Figure 4.3.

---

from 1 to 4 were combined into a single variable. Cronbach's alpha for the final scale is 0.86.

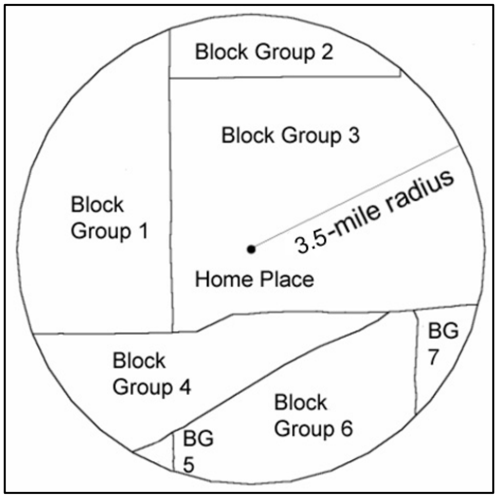


Figure 4.3. The 3.5-mile Customized Unit for Population Density Measurement

The 3.5-mile radius was identified through an average one-direction distance from the respondents' home place to seven-selected key locations that were anticipated to create most daily trips. In the survey, question 35 was asking about the approximate one-direction distance in miles from home to most frequently used facilities such as grocery market, shopping mall, elementary school, bank, post office, hospital, and nearest park, etc.

As illustrated in Figure 4.4, the process of measuring population density within the 3.5 mile customized zone proceeded in three main phases. The census block group (BG) was used as a unit of analysis assuming that population is evenly distributed over the census units.

The first phases computed the number of residents per cell of census grid file. To do this, the census BG vector file was converted into 30×30 meter grid file and the 2000 census population table was joined to the grid file. The second phase was geo-referencing the respondents and creating 3.5-mile buffers surrounding each of the respondents. The 217 respondents were placed in their true locations on earth using X and Y coordinates by tying their reported addresses to a 2000 U.S. Census Bureau TIGER line file. Then, 3.5-mile buffers were created surrounding each of the respondents. The third phase overlaid the customized buffers onto the population grid file and conducted "tabulation" function in ArcView 32 to calculate the population density within each of the 217 customized buffer zones.

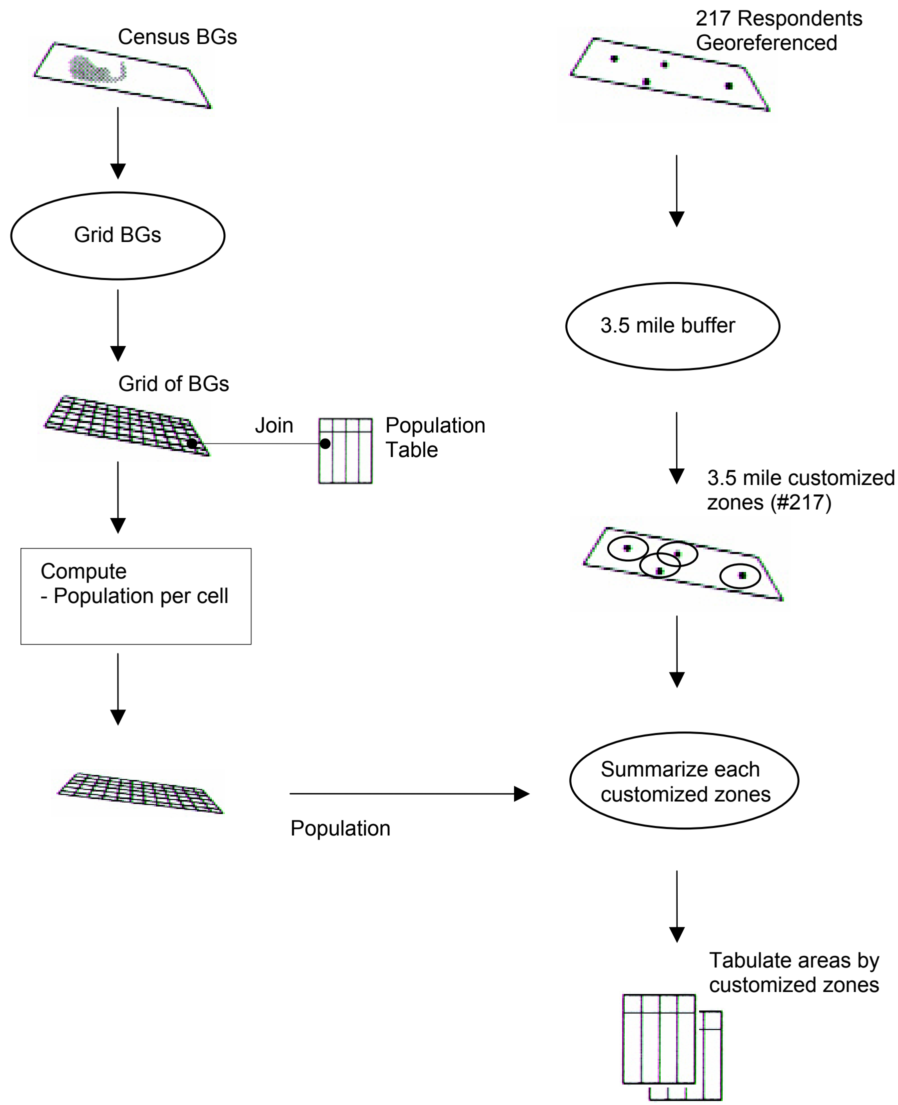


Figure 4.4. The Data Processing Flow: Population Density

The process of calculating development density within the 3.5-mile buffered areas from respondents was charted in Figure 4.5. Landsat 7 Enhanced Thematic Mapper Plus (ETM+) NLAPS image taken in 16 April 2001 was used to measure the degree of development. Appendix 1 illustrates the spectral range (microns) and ground resolution (meter) for the eight bands. A customized histogram stretch has been applied to the source data for optimum display. ETM+ NLAPS data for Texas are precision terrain corrected and registered to the UTM coordinate system and the WGS 84 datum.

For mapping urban features, all of the bands except for band 6 were composite and classified using an iterative self-organizing clustering algorithm (ISOCLASS) (ER Mapper Unsupervised Classification). This classified the pixels of each landscape into 30 spectral classes. Once the images were classified, these spectral classes were then amalgamated into five categories: water-body, natural vegetation, grass/parks, urban residential, roads and transportation. During the posteriori re-labeling process, the study merged all of the clusters classified as urban features, such as urban residential, roads, and transportation, into one thematic class representing built-up areas. And water-body, natural vegetation, and grass/parks were labeled as non built-up areas. This classified image was converted into a grid to be used in measuring the development density.

Finally, the 3.5-mile buffers were overlaid on top of the converted grid. Then, the “tabulation” function was employed to summarize how much area within each of the 217 customized buffer zones was already developed into a built-up area. In this research, the development density was measured as a ratio of the developed area to the customized 3.5-mile buffer area.

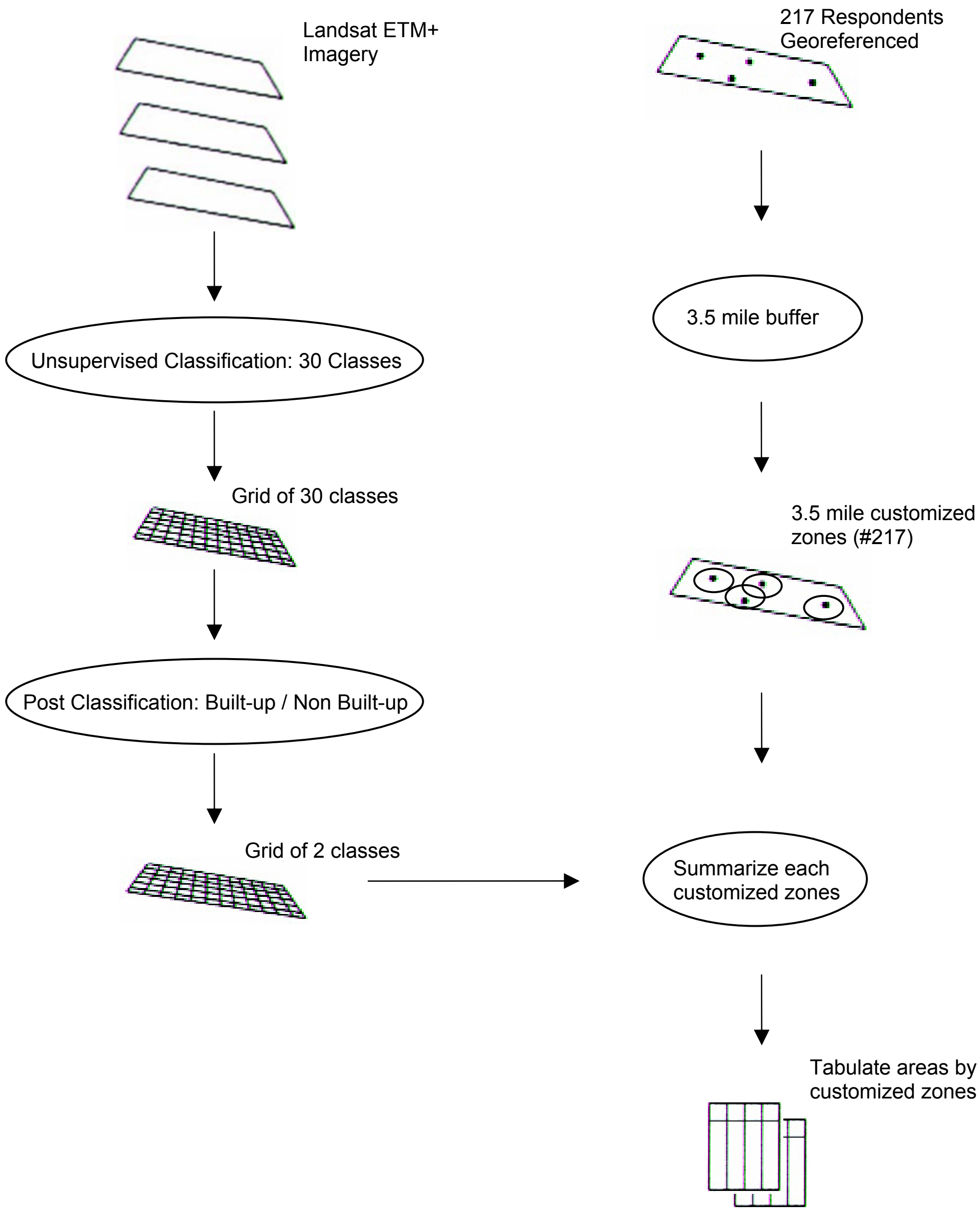


Figure 4.5. The Data Processing Flow: Development Density

The ratio of jobs to housing was computed by counting jobs and housing units within a given distance from each respondent. If a community has more jobs than houses, the residents in the community are less likely to make longer commutes. However, if a community has fewer jobs than houses, the residents are more likely to have longer commutes. This study utilized the traffic survey zones (TSZs) as a unity of analysis (Figure 4.6). As illustrated in Figure 4.7, first, the TSZs vector file was joined with 1995 employment estimates data from NCTCOG. This phase computed the number of employment sources and housing in each TSZ. Second, the customized zone was expanded to 5-mile buffer area which was adjusted by the self-reported average commute distance by the respondents. Third, the 5-mile customized buffer zone was overlaid onto the TSZs vector file. Then, the study selected the TSZ in the computation if its centroid point was within the customized buffer zone boundary.

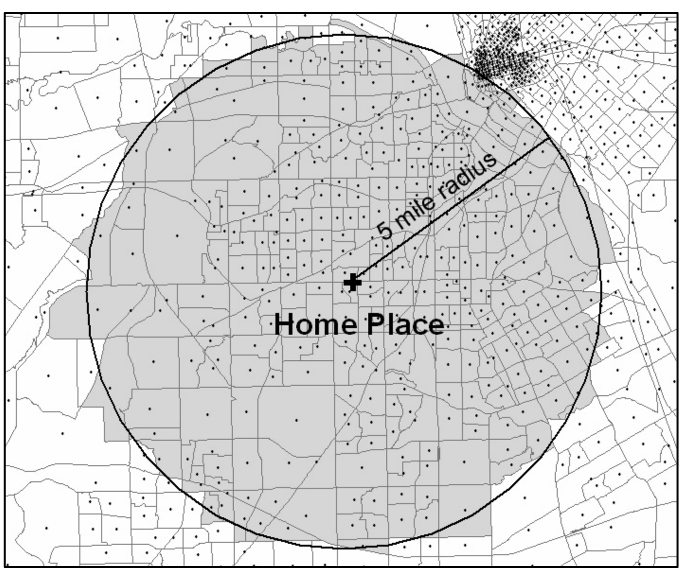


Figure 4.6. Illustration of Measuring Job/Housing Ratio

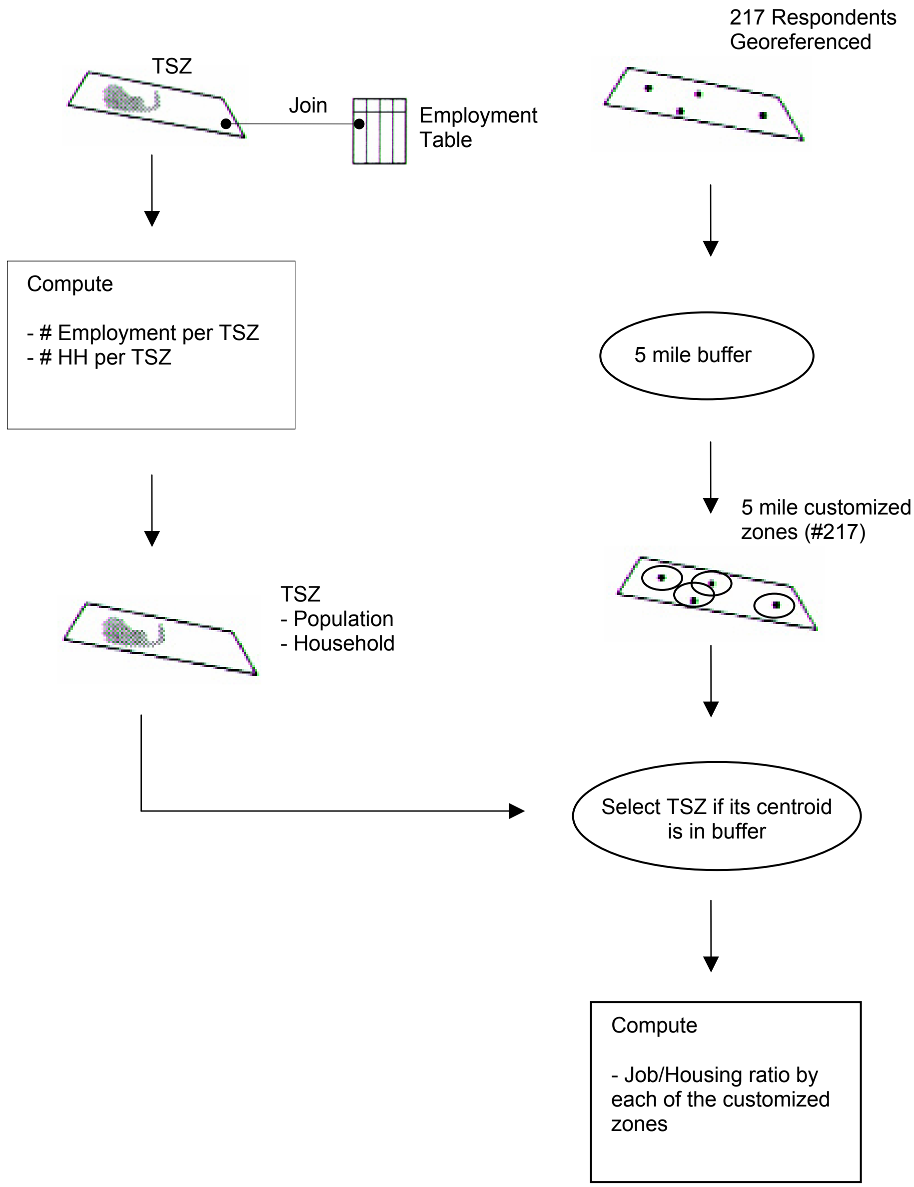


Figure 4.7. The Data Processing Flow: Job/Housing Ratio

The measurement of land-use mix is illustrated in Figure 4.8. First, the overlay of the 2000 land-use map (1995 for Ellis, Kaufman, and Rockwall Counties) onto the point theme made by address geocoding identifies the land use distribution neighboring the respondents. Second, the buffer function of ArcView 3.1 created a 3.5-mile buffer from each respondent's home place. Third, the overlaid land use map was clipped based on the buffer. This operation used the buffer as a clip theme like a cookie cutter on the 2000 land-use map. Shannon's Evenness Index (SEI) was utilized to measure this land use pattern as follows:

$$SEI = \sum_{i=1}^{n} [p_i \log(1/p_i)] / \log(n)$$

where, "p_i" indicates the proportion of the land use occupied by land use type "*i*," and "*n*" is the number of land uses. The measure represents the evenness of distribution of square footage of development across four types of land uses within a 0.25-mile distance from each participant's household. The four land uses used to calculate this measure were residential, commercial, office, and institutional.

The SEI ranges from 0 to 1. It is equal to zero when there is only one land use type in the buffered area and increases as the number of land use types or proportional distribution of land use types increases (McGaril and Marks, 1994). Therefore, one (= 1) indicates a perfectly even distribution of square footage across all four land uses. Figure 4.9 presents four examples of land-use patterns illustrated by the SEI index.

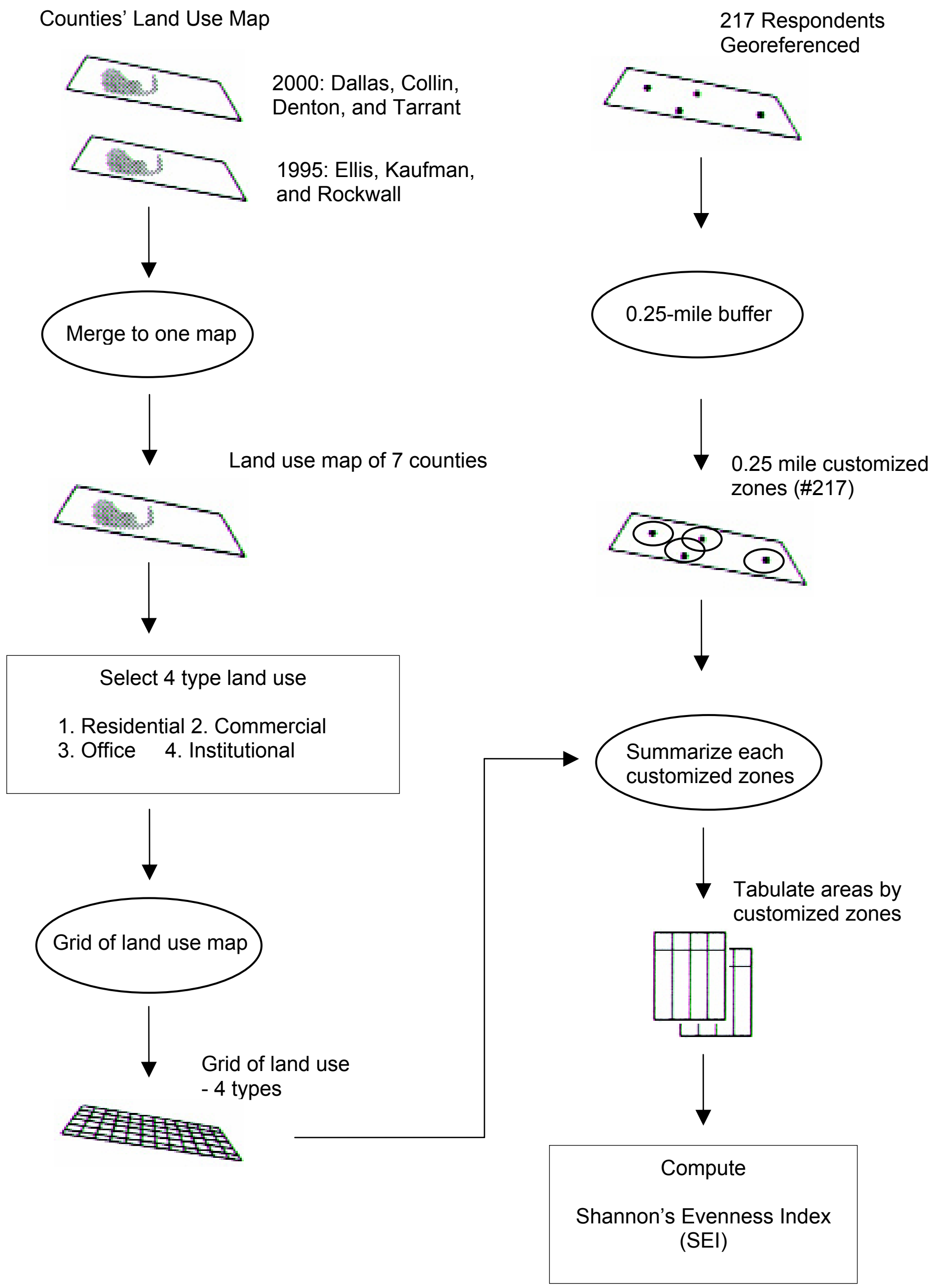


Figure 4.8. The Data Processing Flow: Land-Use Mix

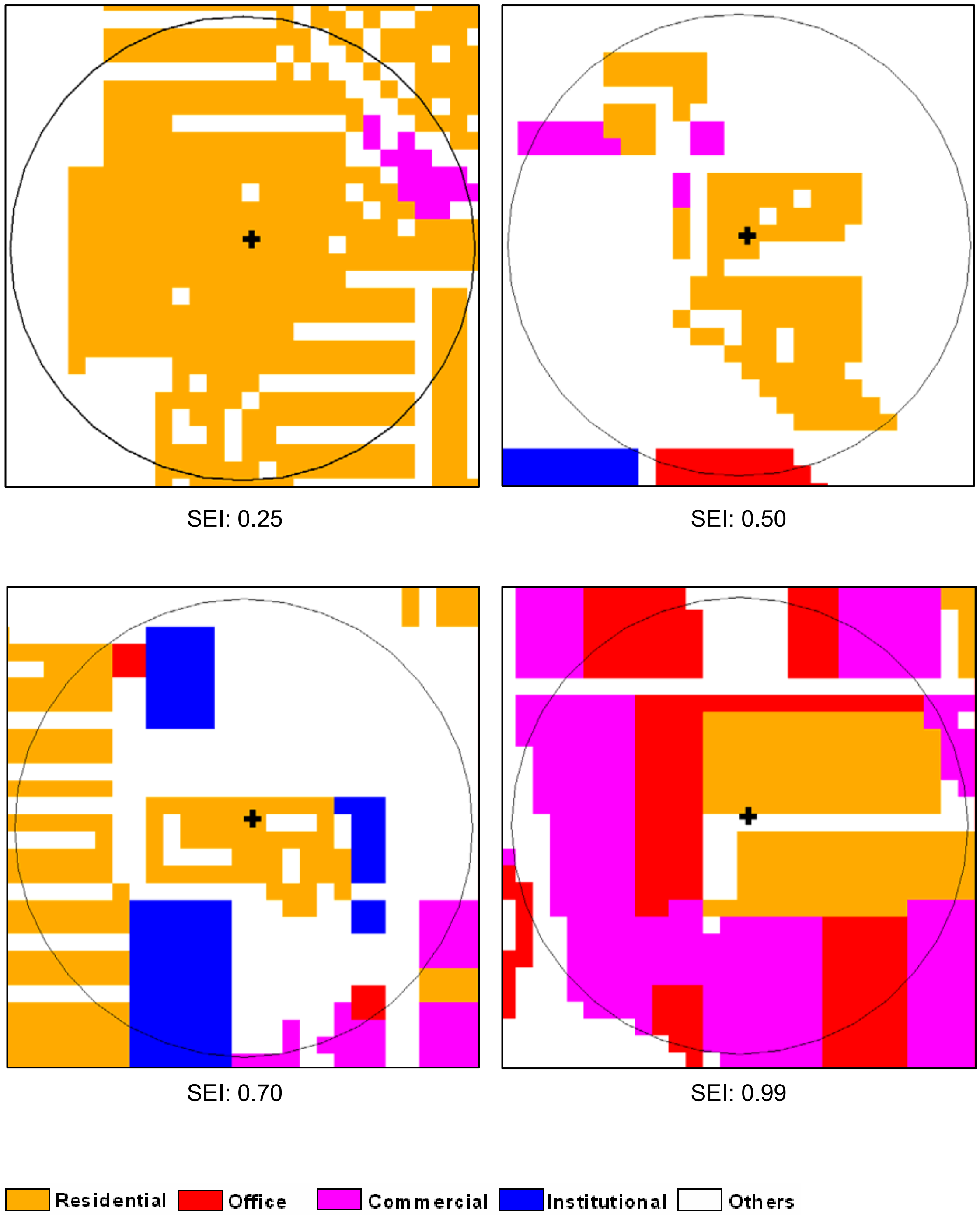


Figure 4.9. Land Use Patterns within a 0.25-mile Radius from the Respondents

Spatial Attributes

The geographic spatial attributes included Central Business District (CBD), freeways, light rail transit stations, major malls, Dallas/Fort Worth airport, parks, and major lakes. The Nearest Feature software, an extension of ArcView 3.1, was utilized to measure the nearest distance from a particular resident's home place to the spatial entities mentioned above. Figure 4.10 illustrates an example measuring the distance from home to the nearest parks.

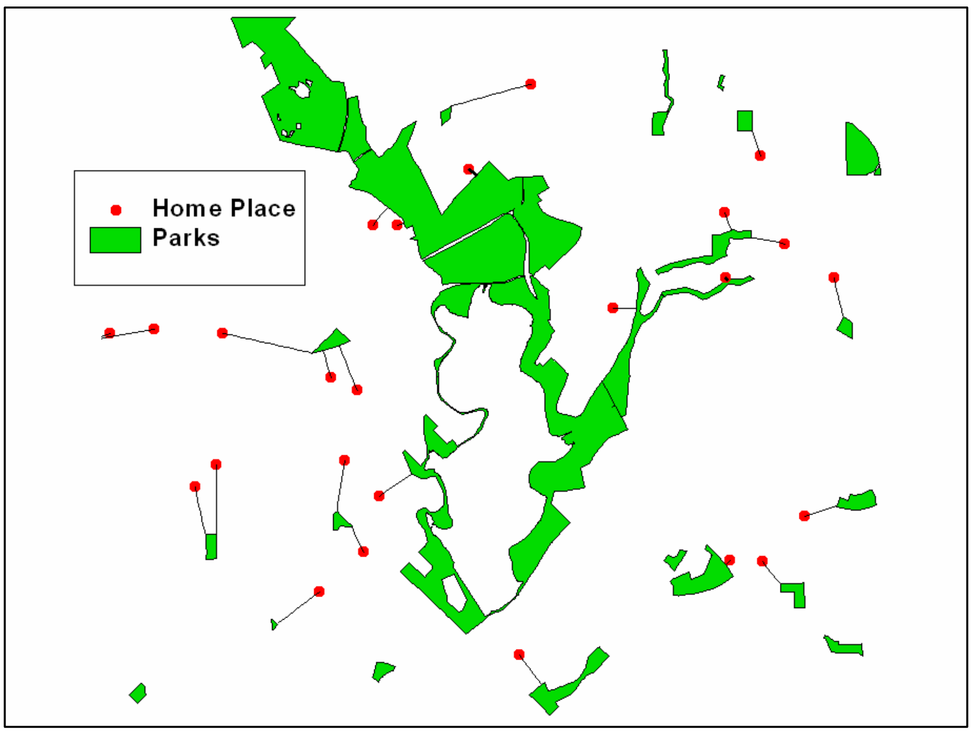


Figure 4.10. Illustration of Measuring Distance from Home to the Nearest Parks

In short, variables to be used in this study are tabulated in Table 4.1 that shows the concepts, variables, operational measures, and their sources.

Table 4.1. Concept, Variables, Operational Measures, and Their Sources

Concept	Variable, Type, and Direction	Operational Measures	Data Name & Sources
Person's Ecological Impact	EF per Household Member: **Y**	**Ratio:** EF account measured by EF Quiz	Survey
Socioeconomic and Demographic Characteristics	Age: **X (+)**	**Ratio:** Age of respondents	Survey
	Gender: **X (+)**	**Nominal:** Male=1, Female=0	Survey
	Race: **X (+)**	**Nominal:** White=1, Non-white=0	Survey
	Marital Status: **(+)**	**Nominal:** Married=1, Non-married=0	Survey
	Education: **X (+)**	**Ratio:** Years of respondents' education	Survey
	HH Income: **X (+)**	**Ratio:** yearly household income before tax	Survey
Awareness of Environmental Crisis	Environmental Value: **X (-)**	**Ratio:** measuring individual's environmental awareness	Survey
Land-Use Patterns	Population Density: **X (-)**	**Ratio:** ratio of # of people to Area of the 3.5 mile customized zone	2000 Census Data: Bureau of Census
	Development Density: **X (-)**	**Ratio:** ratio of # of developed land to the area of the 3.5 mile customized zone	2000 Census Data: Bureau of Census
	Land Use Mix: **X (-)**	**Ratio:** degree of diversity in surrounding land-use patterns of residents measured by Shannon's Evenness Index.	2000 (1995) Land Use Data: North Central Texas Geodata Warehouse (NCTGW)
	Job/Housing Ratio: **X (-)**	**Ratio:** ratio of jobs to houses within 5-mile radius from respondents	1995 Employment Estimates data from NCTCOG

Table 4.1. (Continued)

Proximity to Spatial Attributes	Proximity to CBD: **X (+)**	**Ratio:** nearest distance to CBD	Census TIGER Data: NCTGW
	Proximity to Freeway: **X (+)**	**Ratio:** distance to the nearest Freeways	Census TIGER Data: NCTGW
	Proximity to Transit: **X (+)**	**Ratio:** distance to the nearest Light Rail Transit station	Census TIGER Data: NCTGW
	Proximity to major malls: **X (-)**	**Ratio:** distance to the nearest major malls	Census TIGER Data: NCTGW
	Proximity to DFW Airport: **X (+)**	**Ratio:** nearest distance to Dallas/Fort Worth International airport	Census TIGER Data: NCTGW
	Proximity to Parks: **X (+)**	**Ratio:** distance to the nearest neighborhood parks	Census TIGER Data: NCTGW
	Proximity to Major Lakes: **X (+)**	**Ratio:** distance to nearest major lakes	Census TIGER Data: NCTGW

4.4. Multiple Regression Model and Data Analysis

4.4.1. Multiple Regression Model

To address the combined influence of the independent variables on per capita EF score, a predictive model was developed. The model hypothesized that the variance in the per capita EF will be influenced by four major factors: socioeconomic and demographics, environmental value, land-use patterns, and spatial attributes. Specifically, this study employed the multivariate regression method to find the driving forces of EF per household member. Following the four independent variable groups, it examined six separate regression models, one for each component, e.g. food, mobility (and car), shelter, and goods and services; and a composite footprint score. Specifically, the study used the four-steps sequential regression for each of the six models to examine the unique impact of each independent variable group on the variance in the personal footprint score after other independent variable groups were controlled for. The four independent variable groups were entered by steps into the equation in the order of socioeconomic and demographic, environmental value, land-use patterns, and spatial attribute variable.

In this research, the original scales of per capita ecological footprint scores were systematically converted to a new scale of measurement to get a normal distribution of each footprint's data. This involved mathematically modifying the EF scores using SPSS until the distribution looked more normal. This made estimates less sensitive to outlying (or extreme) observations of the dependent variable to meet the parametric statistics test assumption (Pallant, 2001). For example, the composite footprint, mobility component, goods and service component scores were converted to natural log formation; food footprint component to squared formation; car and shelter footprint components to square root formation. The model equations tested in this dissertation are described as follows:

Composite EF Variable

$$LnEF = \alpha + \beta_1 X_1 + e$$
$$LnEF = \alpha + \beta_1 X_1 + \beta_2 X_2 + e$$
$$LnEF = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e$$
$$LnEF = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e$$

Food Footprint Component Variable

$$FOOD^2 = \alpha + \beta_1 X_1 + e$$
$$FOOD^2 = \alpha + \beta_1 X_1 + \beta_2 X_2 + e$$
$$FOOD^2 = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e$$
$$FOOD^2 = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e$$

Mobility Footprint Component Variable

$$LnMOBILITY = \alpha + \beta_1 X_1 + e$$
$$LnMOBILITY = \alpha + \beta_1 X_1 + \beta_2 X_2 + e$$
$$LnMOBILITY = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e$$
$$LnMOBILITY = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e$$

Car Footprint Component Variable

$$\sqrt{CAR} = \alpha + \beta_1 X_1 + e$$
$$\sqrt{CAR} = \alpha + \beta_1 X_1 + \beta_2 X_2 + e$$
$$\sqrt{CAR} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e$$
$$\sqrt{CAR} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e$$

Shelter Footprint Component Variable

$$\sqrt{SHELTER} = \alpha + \beta_1 X_1 + e$$
$$\sqrt{SHELTER} = \alpha + \beta_1 X_1 + \beta_2 X_2 + e$$
$$\sqrt{SHELTER} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e$$
$$\sqrt{SHELTER} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e$$

Goods and Services Footprint Component Variable

$$LnGOODS = \alpha + \beta_1 X_1 + e$$
$$LnGOODS = \alpha + \beta_1 X_1 + \beta_2 X_2 + e$$
$$LnGOODS = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e$$
$$LnGOODS = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e$$

where, *LnEF* = Natural log of Ecological Footprints per person
$FOOD^2$ = Squared Food Footprint Component per person
LnMOBILITY = Natural log of Mobility Footprint Component per person
$\sqrt{CAR}$ = Square Root of Car Footprint Component per person
$\sqrt{SHELTER}$ = Square Root of Shelter Footprint Component per person
LnGOODS = Natural log of Goods and Services Footprint Component per person
α = Regression intercept
X1 = Socio-economic and Demographic attributes
X2 = Environmental Value attributes
X3 = Land-Use Patterns attributes
X4 = Spatial attributes
E = Error term

4.4.2. Data Analysis

The study conducted two major steps of data analysis. First, descriptive statistics were evaluated in Chapter V to correctly describe the amount of per capita EF of Dallas County's residents. Particularly, this step made sense of the County's EF of four consumption components such as food, mobility, shelter, and goods and services footprint. Then, the results were compared to the average EF, both worldwide and American, in order to understand their overall environmental impacts. It also characterized the degree of average personal environmental awareness and described their consumption behaviors. Then, these consumption patterns were converted into an ecological footprint score using 'Ecological Footprint Quiz.'

The second step of analysis sought to explain the driving elements influencing the variance in the per capita ecological footprint using ordinary least squares (OLS) regression analysis in Chapter VI. As mentioned above, six regression models were tested to check the research hypotheses described in Chapter III. Each of the six models proceeded through sequential regression by steps according to the four independent variable groups identified in the conceptual model. Therefore, in total, twenty four regression models were tested in this dissertation. Each model was analyzed in the following order. First, a correlation matrix was constructed among the dependent variable and the independent variables to preliminarily check the degree of association among the variables. Second, an F-statistics was analyzed to determine if each of the models was statistically significant. Finally, regression analysis was conducted to seek which variable impacted the personal ecological footprint scores and tested them at the .1 and .05 levels. If no statistical significance was found in any particular variables, they still remained in the model to analyze the direction of their regression coefficients.

Several statistical tests for reliability were conducted to ensure the OLS estimators are Best Linear Unbiased Estimates (BLUE). First, the study checked the multicollinearity among the independent variables. This research included many spatial attributes as the explanatory variables. The empirical studies (e.g., Shin, 2002) have reported a variety of relationships among the spatial variables. Therefore, it is believed that the models may violate the assumption for no perfect collinearity among the independent variables. For example, population density is likely to be positively correlated with development density. The collinearity was checked in various ways including correlation matrix, scatterplot matrix, analysis of residual, VIF (variance inflation factor), and tolerance. No multicollinearity was found. Second, to check outliers, the study drew scatterplot, probability plot, and residual plot of dependent variables versus each of the independent variables. No seriously influential data points were found. Third, to check lack of fit of the model, residual plot was used to evaluate the inadequacy. Additionally, a plot of residuals against each independent variable is used to check nonlinearity. No models violated the nonlinearity assumption. Fourth, the study tested for the property of constant variance, heteroskedasticity, by plotting the residuals versus the predicted per capita footprint scores. The White’s test and Breusch-Pagan test were used to check the problem. Finally, autocorrelation was also tested based on the Durbin-Watson statistic as well as by plotting the residuals. No heteroskedasticity or autocorrelation were found.

4.5. Validity Threats

4.5.1. Dependent Variable

The validity of the EF comes from the conceptual accuracy. The EF approach is conservative. It underestimates the amount of nature that is required to sustain a given lifestyle with prevailing technology. The EF does not focus primarily on precise estimates, but on conceptual accuracy measured with sufficient precision. In the first place, the concept should help us to think about and conceptualize the implications of human impact rather than provide us a technical tool to manage these impacts (Wackernagel, 1994). Also, the EF's internal validity will be increased by the stratified random sampling method in the survey that enhances the representativeness of population (Scheaffer et al., 1996).

The reliability of the EF is sustained by at least two factors, including the preliminary test of the questionnaire. Preliminary testing of the questionnaire is expected to reduce use of obscure terms, which is also expected to enhance the internal (content) validity of the EF measurement. The EF methodology suggested by Wackernagel has been widely accepted in the measurement of the appropriated carrying capacity for individuals, municipalities, nations, and at the global level. For example, according to Simmons and Chambers (1998), the EF, although clearly still an emerging methodology, has matured sufficiently to form the basis of a household environmental impact calculator. The "Ecological Footprint Quiz" used in the study was developed by the EF creator and has been used as a stable measuring instrument for individuals' EF in the global context.

4.5.2. Independent Variables

The socioeconomic and demographic variables can sustain their reliability and validity from the data collecting process. They were directly measured by the questionnaire; thus, they were not aggregated but disaggregated data. Preliminary testing of the questionnaire also enhanced the internal (content) validity of these variables. In terms of spatial attribute factors, using GIS to analyze the data enabled the study to derive more accurate measurements of geographic factors than rough approximations of distance or general land use settings (Brody et al., 2003). Particularly, the Nearest Feature software, an extension of ArcView 3.1, provided a reliable measurement for the nearest distance from a particular resident's home to various spatial entities such as lakes, roads, airports, and shopping malls, etc. The reliability of the measurement of the environmental values was demonstrated with high Cronbach's alpha in 0.96 (Brody et al. 2003).

However, there are several limitations in securing internal validity for variables among the land-use pattern factors. In measuring the degree of development density, this study used Landsat ETM+ imagery with 30-meter resolution. It is anticipated that the resolution will commit some measurement errors that affect the internal validity of the variable. In terms of the population density variable, the scale problem due to the aggregation of data should also be noted as a limitation that will affect securing internal validity. Data availability is another important factor threatening internal validity of land-use mixedness and the job/housing ratio. In measuring the degree of mixedness, this dissertation utilized the 1995 land use map for the County's bordering areas, e.g.

Ellis, Kaufman, and Rockwall counties. Additionally, this study measured the job-housing ratio using 1995 employment estimates data from NCTCOG. As mentioned in Chapter I, Dallas County metropolitan areas are experiencing rapid changes associated with population, economy, and spatial structure. Therefore, the data might affect securing internal validity of these variables.

This research relied on a self-reported approximate one-direction distance from respondent's place to the most frequently used neighborhood facilities, and averaged the distances to obtain a 3.5-mile radius as a unit of analysis for land-use patterns. Therefore, there is a potential that the customized 3.5-mile buffer might not be an appropriate boundary within which most daily trips of the County's residents are supposed to occur.

Finally, the issue of external validity should be mentioned. Since this study used a cross-sectional research design, there is a limit to the extent to which the findings can be generalized.

CHAPTER V

CHARACTERIZING CONSUMPTION BEHAVIOR AND THE AVERAGE PERSONAL ECOLOGICAL FOOTPRINT ACCOUNT

This chapter presents the results of descriptive analysis on the survey data. First, it describes the respondents' socioeconomic and demographic characteristics and evaluates the degree of environmental awareness of Dallas County's residents by examining the participants' answers for seven selected statements on the ecological crisis. Additionally, it briefly sketches characteristics of the land-use patterns and geographic spatial features surrounding a respondent. Second, the characteristics of the respondents' consumption behaviors are evaluated in terms of food, housing, mobility, and goods and services. The third section of this chapter presents the average personal ecological footprint account along with its four footprint component scores calculated by the EF Quiz. This section also provides a footprint comparison between Dallas County and the U.S.A. Additionally, the County's footprints are compared to the actual area of the County itself. The chapter concludes with a summary of the findings.

5.1. Characteristics of Respondents and the Study Site

5.1.1. Respondents

The socioeconomic and demographic characteristics of the respondents are summarized in Table 5.1. About twenty-seven percent (217) of the eight-hundred households completed and returned the questionnaire. Seventy-one percent (569) did not respond to the survey. Fourteen samples were returned with no answers. As shown in Table 5.1 below, the results of descriptive analysis indicated that over fifty-six percent (122) of the respondents were male and about forty-two percent (92) were female. The average age of the respondents was 53.2 years. The youngest (oldest) respondents was 23 (89) years old. The largest age group was 40s (31 percent) followed by 50s (18 percent).

In terms of ethnic/racial identity, the Caucasian group was the dominant ethnic group with seventy-five percent while other groups which included African Americans (10 percent), Hispanics (10 percent), and Asian (4 percent) were very small. The average household size was about three persons (2.8) and almost seventy percent had no children (less than or equal to 16). The distribution of the highest education the respondents acquired was less than high school (4.6 percent), high school/GED (15.7 percent), some college (25.8 percent), college graduate (31.3 percent), and graduate degree (22.1 percent). The most frequent marital status was 'Married' (68.7 percent) whereas the other categories which included Single, Divorced, and Widowed accounted for about ten percent, respectively. The average number of years the respondents had lived at the current residence was 18.1 years. About thirty-three percent of the respondents had lived at the current location for more than twenty years and thirty percent for less than five years. For total annual household income, the participants were divided into seven groups. Over twenty-five percent (55 samples) earned more than $100,000 while about thirteen percent (29 samples) had income of less than $24,000, and approximately five percent (10 samples) of the respondents did not indicate their annual household income.

Table 5.1. Socioeconomic and Demographic Characteristics of the Respondents

Variables	Freq.	percent	Variables	Freq.	percent
Gender			**Education**		
Male	122	56.2	Less than high school	10	4.6
Female	92	42.4	High school/GED	34	15.7
Missing	3	1.4	Some college	56	25.8
			College graduate	68	31.3
Age			Graduate degree	48	22.1
20s-30s	35	16.1	Missing	1	0.5
40s	68	31.3			
50s	39	18.0	**Marital status**		
60s	34	15.7	Married	149	68.7
over 70s	36	16.6	Single	22	10.1
Missing	5	2.3	Divorced	22	10.1
			Widowed	23	10.6
Ethnic/racial identity			Missing	1	0.5
African American	22	10.1			
Caucasian	162	74.7	**Tenure**		
Hispanic	21	9.7	1-4yrs	65	30.0
Asian/Pacific Islander	9	4.1	5-9yrs	35	16.1
Other	3	1.4	10-14yrs	23	10.6
			15-19yrs	20	9.2
Household size			over 20 yrs	72	33.2
1	30	13.8	Missing	2	0.9
2	87	40.1			
3	32	14.7	**Household income**		
4	39	18.0	Less than $14,000	16	7.4
5	18	8.3	$14,000-$23,999	13	6.0
over 6	11	5.1	$24,000-$34,999	26	12.0
			$35,000-$49,999	27	12.4
Number of Children			$50,000-$69,999	39	18.0
0	147	67.7	$70,000-$100,000	31	14.3
1	31	14.3	over $100,000	55	25.3
2	25	11.5	Missing	10	4.6
3	8	3.7			
4	6	2.8			

5.1.2. Measured Environmental Awareness

As stated in Chapter VI, the respondents' environmental awareness on the ecological crisis was measured by selected questions from the questions initially used by Van Liere and Dunlap (1980). The seven questions selected were about 'limit of population,' 'balance of nature,' 'interference with nature,' 'earth as a spaceship.' 'limit to growth,' 'abusing the environment,' and 'steady-state economy.' Respondents were asked to indicate whether they strongly agree (= 1), agree (= 2), disagree (= 3), strongly disagree (= 4), or have no opinion on each of the questions. Responses were summed and ranged from 1 (strongly agreeing that humans are abusing the natural environment) to 28 (strongly disagreeing that humans are abusing the environment).

Seven separate questions scaled from 1 to 4 were combined into a single variable called 'eco-value.' The measured respondent's eco-value was summarized with mean values and standard deviation in Table 5.2. The survey results indicated that the residents in Dallas County, on average, showed a high environmental awareness with around 2.0 of four scales. Specifically, the residents in the county were keenly aware that mankind is severely abusing the environment (Mean= 1.8) while they expressed relatively less awareness on the statement that we are approaching the limit of the number of people that the Earth can support (Mean= 2.3) and there are limits on growth beyond which our industrialized society cannot expand (Mean= 2.1). The detailed information of respondents' attitudes toward the seven questions is graphically illustrated in Figures 5.1-5.7 where a majority of the respondents in the County expressed a keen awareness of environmental crises throughout the statements.

Table 5.2. Measured Environmental Awareness

Variable	N	Mean	Std. Deviation
Limit of population	178	2.3	0.9
Balance of nature	193	2.0	0.8
Interference with nature	193	1.9	0.7
Earth as a spaceship	194	2.0	0.8
Limit to growth	186	2.1	0.8
Abusing the environment	200	1.8	0.7
Steady-state economy	187	2.0	0.8

Figure 5.1 shows the responses to the statement that we are approaching the limit of the number of people that the Earth can support. Approximately 50 percent of the respondents strongly agreed (36) or agreed (72) to the statement, while 33 percent of them disagreed (54) or strongly disagreed (16) to the statement. Meanwhile, many of the respondents did not express their attitudes to this question (39).

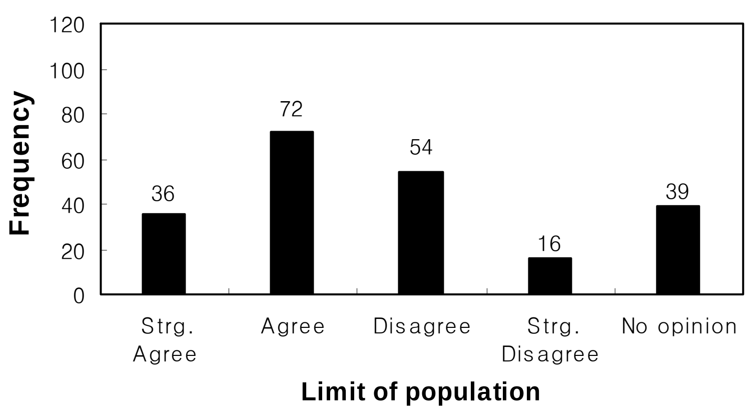


Figure 5.1. Respondents' Environmental Attitudes on the Limit of Population (N= 178)

Figure 5.2 shows the responses to the statement that the balance of nature is very delicate and easily upset. A dominant number of respondents agreed (108) or strongly agreed (48) to the statement, while less than twenty percent of the residents disagreed (28) or strongly disagreed (9) with the statement. Meanwhile, about eleven percent of the respondents (24) did not have any opinion on this question.

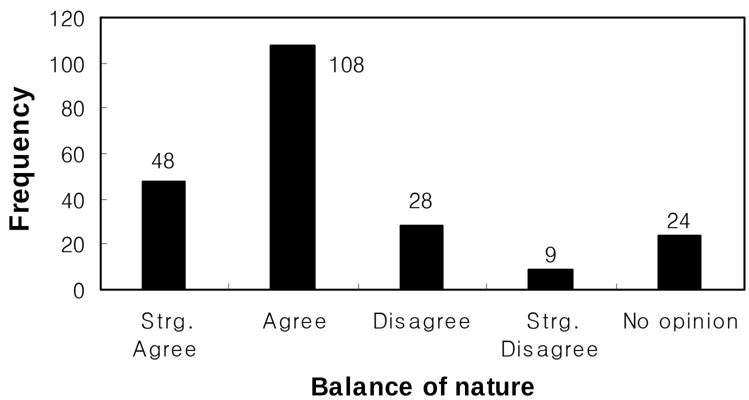


Figure 5.2. Respondents' Environmental Attitudes toward the Balance of Nature (N= 193)

Figure 5.3 shows the residents' environmental attitudes toward humanity's interference with nature. Almost of the respondents (158) were concerned about our interference with nature; more than 28 percent of the respondents strongly agreed or agreed (44 percent) that when humans interfere with nature, it often produces disastrous consequences. Meanwhile, only sixteen percent of the respondents disagreed (31) or strongly disagreed (4) with the statement. About eleven percent of them (24) did not indicate their opinion.

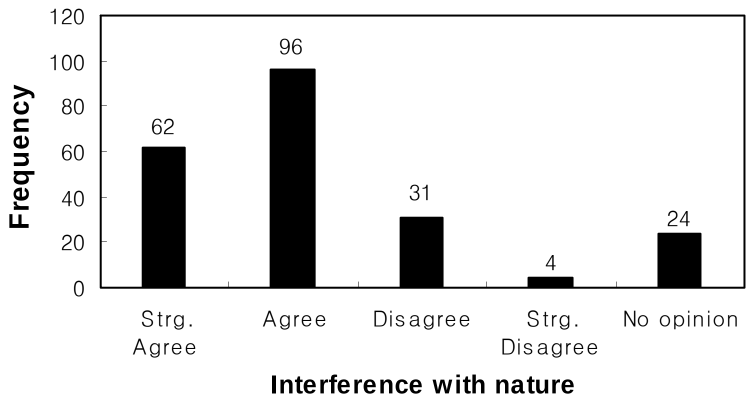


Figure 5.3. Respondents' Environmental Attitudes toward Interference with Nature (N= 193)

Figure 5.4 illustrates respondents' opinions about the statement that the Earth is like a spaceship with only limited room and resources. Approximately 70 percent of the respondents (152) regarded the Earth as a closed-system like a spaceship. Twenty-four percent of the residents (53) strongly agreed and 46 percent (99) of them agreed to the statement. Less than 16 percent of the respondents (34) disagreed and approximately 4 percent of them (8) strongly disagreed to the statement. Twenty three of 217 respondents had no opinion on this question.

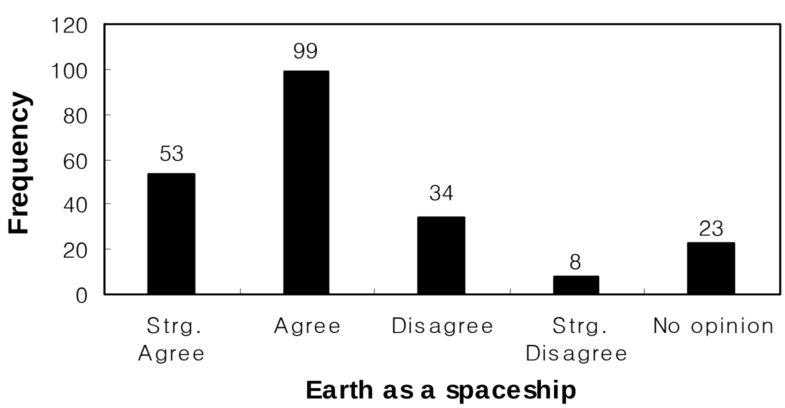


Figure 5.4. Respondents' Environmental Attitudes on Earth as a Spaceship (N= 194)

Figure 5.5 shows the responses to the statement that there are limits on growth beyond which our industrialized society cannot expand. Comparing the other statements, slightly fewer respondents agreed to the statement (64 percent). In other words, a relatively large number of people in the county thought that our industrialized society does not have a limit to growth (more than 22 percent). However, a good many of the respondents did not show their opinions about the limits to growth.

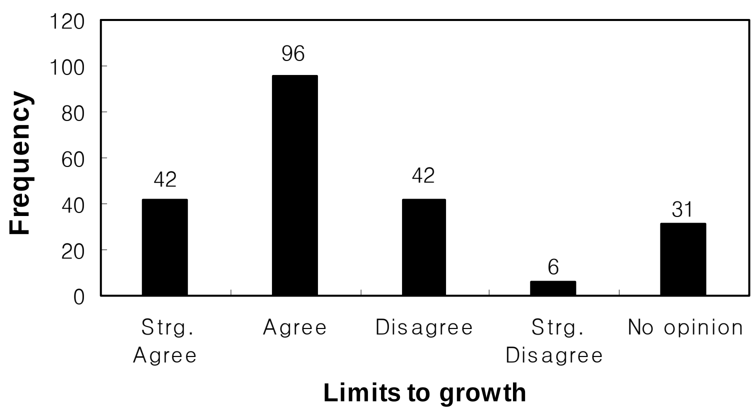


Figure 5.5. Respondents' Environmental Attitudes toward the Limits of Growth (N= 186)

Figure 5.6 indicates the respondents' opinions about the statement that mankind is severely abusing the environment. Among the seven questions, the largest number of the residents strongly agreed with the statement. Almost 36 percent of the participants (78) expressed a strong agreement and more than 40 percent (88) also agreed. Meanwhile, only 1 percent of the respondents (2) indicated strong disagreement and less than 15 percent (32) disagreed with the statement. A relatively small number of respondents (17) did not answer the question.

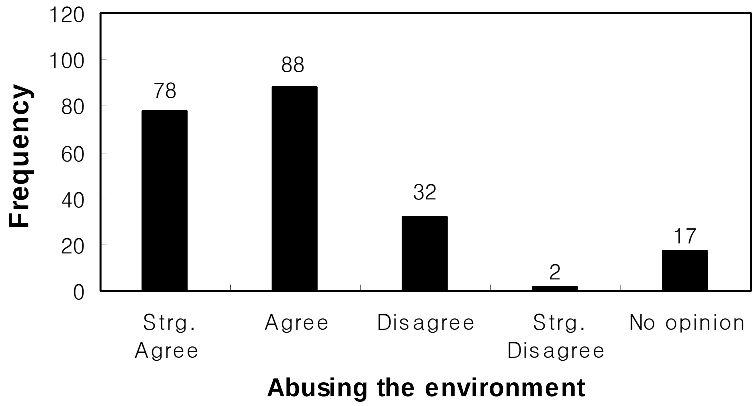


Figure 5.6. Respondents' Environmental Attitudes toward Abusing the Environment (N=200)

Finally, Figure 5.7 illustrates the residents' attitudes toward the economy. Approximately 40 percent of the participants (86) agreed that we have to develop a steady-state economy where industrial growth is controlled to maintain a healthy environment. Additionally, more than 22 percent (48) strongly agreed with the statement. Meanwhile, 23 percent of the respondents disagreed and less than two percent strongly disagreed with the steady-state economy. About 14 percent (30) did not answer the question.

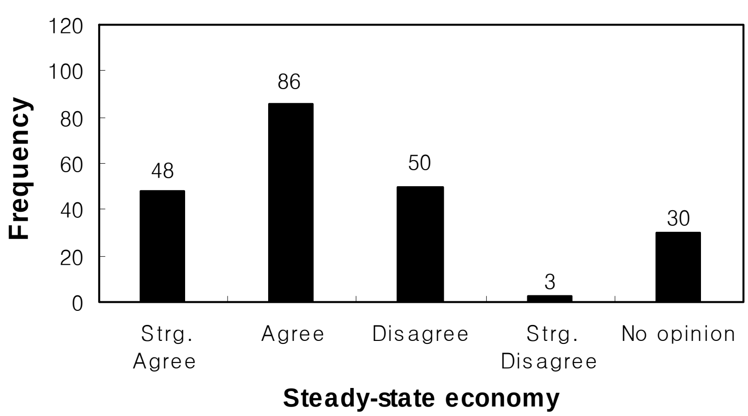


Figure 5.7. Respondents' Environmental Attitudes toward Steady-State Economy (N=187)

Figure 5.8 is a chart of the environmental value index which provides a summary of the respondents' environmental attitudes toward each of the statements on ecological crisis. Overall, the results indicate that the respondents showed a high environmental awareness with around 2 on a scale of 4. Particularly, the respondents strongly agreed that mankind is severely abusing the environment (1.8) and human interference with nature often produces disastrous consequences (1.9).

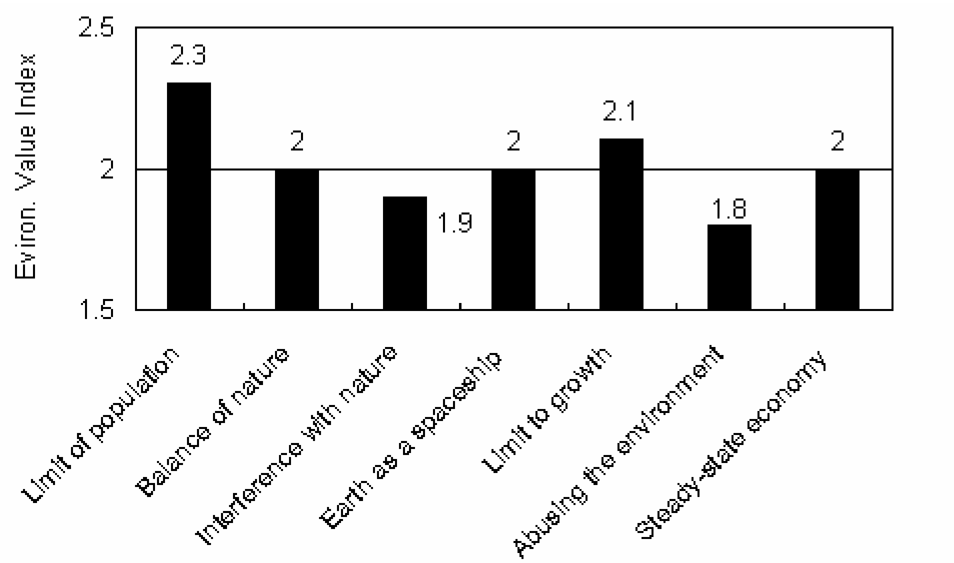


Figure 5.8. Summary of the Environmental Value Index

5.1.3. Land Use Patterns Surrounding the Respondents

This section examines the land use patterns surrounding each respondent's home place. Three land use concepts were analyzed to measure the land use patterns including density, mixedness, and job/housing ratio. Specifically, the study utilized the population density and the development density within 3.5 mile buffers from the respondents to measure the density concept. Shannon's Evenness Index (SEI) was employed to measure the mixed-use pattern of four types of land use within a quarter-mile buffer from the respondent's place. Finally, the job/housing ratio was calculated based on the Traffic Survey Zones (TSZ) within a five-mile buffer from the residents.

In Table 5.3 below, the four descriptive statistics are summarized. For example, concerning the population density, the study received information from 217 respondents. The range of population density within a 3.5-mile buffer from the residents was from 471.1 to 17,375.4 people per square mile, with a mean of 9,757.9 and standard deviation of 3,872.2.

Table 5.3. Measured Land Use Patterns at Each Customized Scale

Variable	Minimum	Maximum	Mean	Std. Deviation
Pop. Density (person/sq. mile)	471.2	17,375.4	9,757.9	3,872.2
Develop. Density	0.06	0.70	0.44	0.13
Mixedness	0.00	1.00	0.34	0.27
Job/housing Ratio	0.50	6.10	2.16	1.23

N= 217

5.1.4. Spatial Attributes Surrounding the Respondents

Using the Nearest Feature software, an extension of ArcView 3.1, the study measured the nearest distance from a particular resident's home place to various spatial entities including CDB, freeways, Light Rail Transit stations, Dallas/Fort Worth Airport, major malls, parks, and major lakes. The extension identified which comparison features were nearest to the respondents' home place and measured the nearest distance between them. For instance, the distance between the resident's home place and the nearest Light Rail Transit station throughout Dallas County ranged from 0.1 to 12.6 miles with a mean of 4.1 and standard deviation of 3.1. Table 5.4 below summarizes the nearest distance in miles from the respondents to the seven spatial features.

Table 5.4. The Nearest Distance in Miles to the Spatial Features

Variable	Minimum	Maximum	Mean	Std. Deviation
CBD	1.53	19.42	10.14	3.98
Freeway	0.09	4.82	1.47	0.94
Light Rail Transit	0.10	12.60	4.12	3.13
Dallas/Fort Worth Airport	1.34	28.28	15.98	6.15
Major Malls	0.13	11.96	3.61	2.08
Parks	0.00	1.43	0.36	0.26
Major Lakes	0.04	15.08	4.33	2.65

N= 217

5.2. Characterizing Individual Consumption Behavior

This section describes the characteristics of individual consumption behaviors in Dallas County in terms of food, housing, mobility, and goods and services. The study calculated each respondent's EF by administering the Ecological Footprint Quiz (EF Quiz) originally designed by a nongovernmental organization called Redefining Progress. The survey consisted of sixteen questions. Consumption activities for each survey question were weighted by a "footprint factor" calculated by the amount of energy and land needed to support the given activity. Footprint factors were pre-calculated by Redefining Progress according to national levels of productivity. Multiplying each respondent's level of activity by its corresponding footprint factor yielded an equivalent impact in terms of acres of land/sea that can be compared across all nations (Merkel, 2003).

5.2.1. Food Consumption Patterns

Characterizing individual food consumption, the EF Quiz questions included the types of food respondents regularly eat and where this food was produced. A plant-based diet generally requires less land, energy, and other resources. The size of the food footprint largely depends on where it's grown because a significant portion of the energy involved in the food system is spent on transporting food from harvest to market, and for processing, packaging and storage (Merkel, 2003).

Regarding the frequency of eating animal based products as shown in Figure 5.9, more than 44 percent of the respondents (96 out of 217) answered 'Very Often,' approximately 30 percent answered 'Almost Always,' and 24 percent answered 'Often.' Meanwhile, only one respondent answered 'Never.' Overall, the survey results indicate that the average person in Dallas County regularly eats food which increases the need to expend more land, energy, and other resources in production.

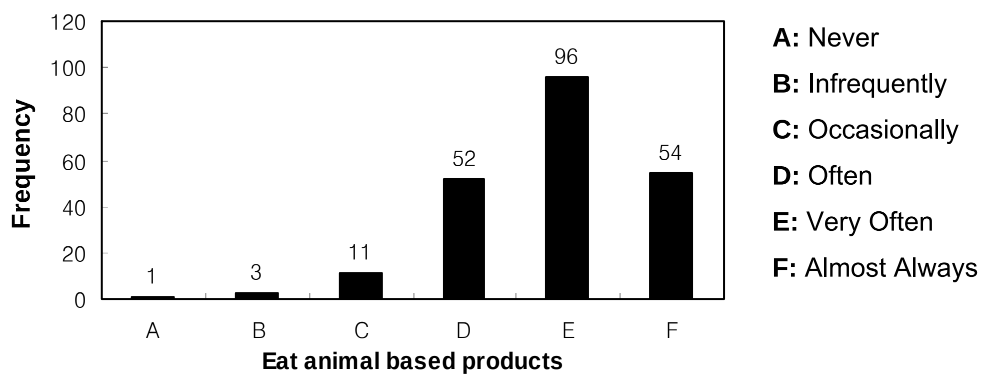


Figure 5.9. How Often Do You Eat Animal Based Products? (N= 217)

Figure 5.10 shows how regularly eaten food is produced. Most of the residents in the county answered that at least half of the food they eat is processed, packaged and not locally grown (from more than 200 mile away). Meanwhile, twenty-seven people (slightly above 12 percent) responded that three quarters of the food they eat is locally grown and not processed or packaged. Six percent of the respondents (13) answered that 'Very Little' of the food they eat is processed, packaged and not locally grown. Again, the results suggest that the Dallas County's residents largely consume food requiring high levels of transportation from farm to market.

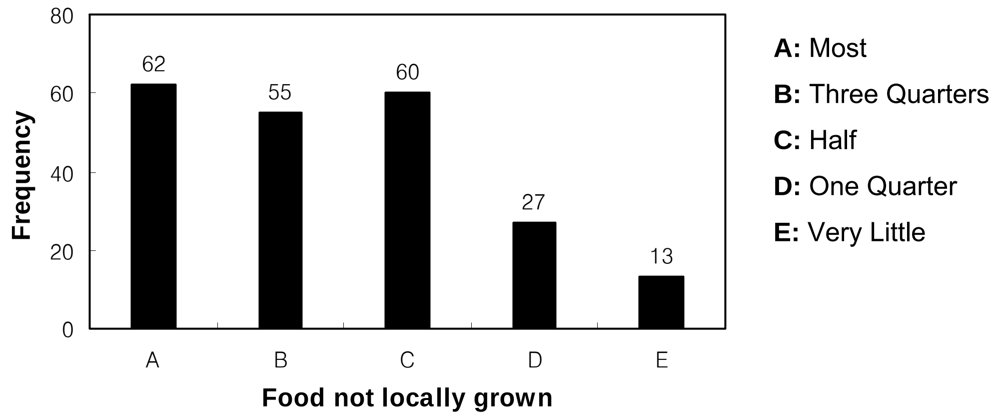


Figure 5.10. How Much of the Food That You Eat Is Processed and Not Locally Grown? (N= 217)

5.2.2 Housing Consumption Patterns

The specific questions for housing consumption included the number of inhabitants, the size, the type of shelter, and the use of energy conservation and efficiency measures throughout the home. Figure 5.11 illustrates the number of inhabitants reported by the respondents.

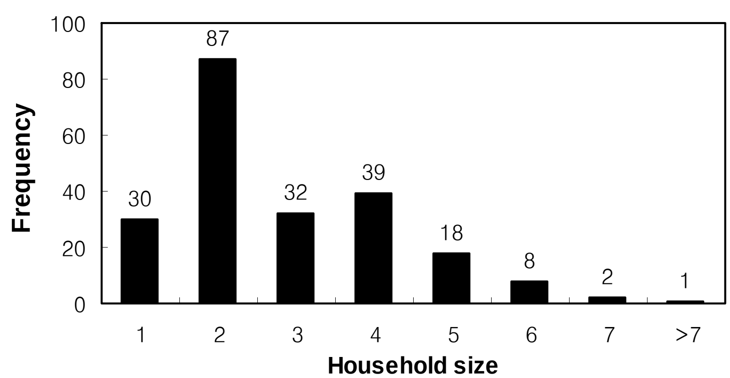


Figure 5.11. How Many People Currently Live in Your Household? (N= 217)

The survey results showed that more than 40 percent of the respondents' households are shared by two members, approximately 15 percent by three members, about 18 percent by four members, and 13 percent by more than five members. Whereas results showed that approximately 14 percent of respondents' housing was occupied by only one person. In terms of home size as shown in Figure 5.12, approximately 25 percent of the respondents are living in a house with 2,500 square feet or more, 29 percent have 1,900-2,500 square feet, 21 percent have 1,500-1,900 square feet, and approximately 19 percent have 1,000-1,500 square feet. Meanwhile, only 6 percent of the respondents live in houses with 500-1,000 square feet and no respondents are living in 500 square feet less.

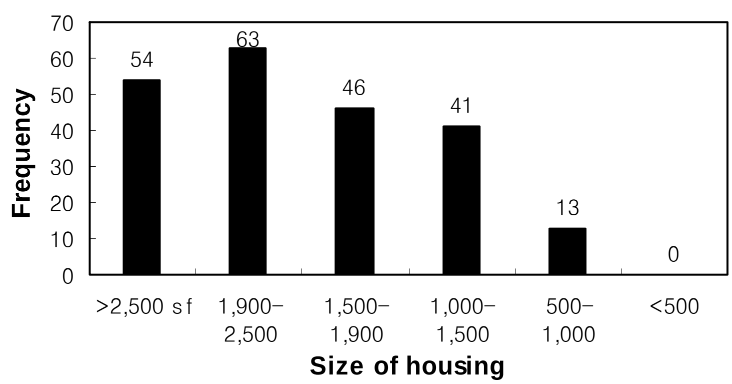


Figure 5.12. What is the Size of Your Home? (N= 217)

Figures 5.13 and 5.14 report the respondents' housing type and their usage of energy conservation and efficiency measures. As shown in Figure 5.13, the survey results showed that almost all of the respondents (approximately 89 percent) are living in a free standing house with running water. While less than 2 percent of the respondents are living in a free standing house without running water, about 3 percent live in multi-story apartment buildings, and approximately 4 percent in a row house or building with 2-4 housing units. Six respondents out of 217 answered that they live in a green-design residence. In regard to electricity as shown in Figure 5.14, more than 83 percent of the respondents reported that they have electricity in their home; however, one respondent answered ‘No.’ Noticeably, more than 16 percent of the respondents (35) reported that they have equipped their houses with energy conservation and efficiency measures.

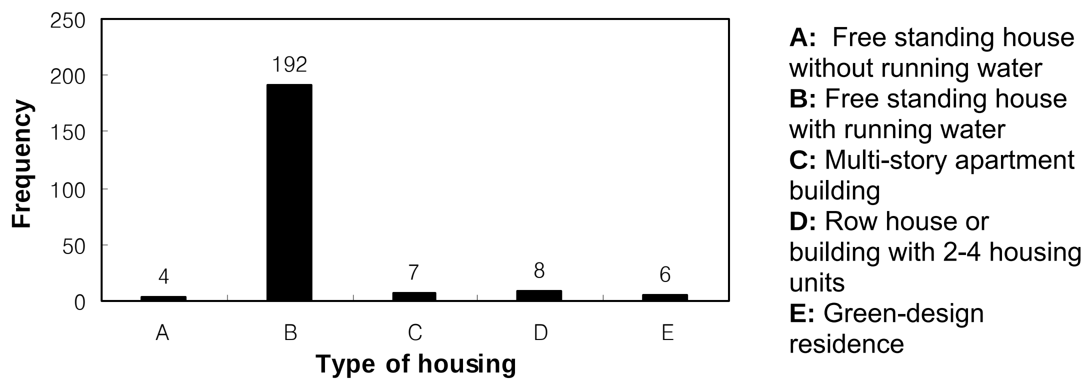


Figure 5.13. Which Housing Type Best Describes Your Home? (N= 217)

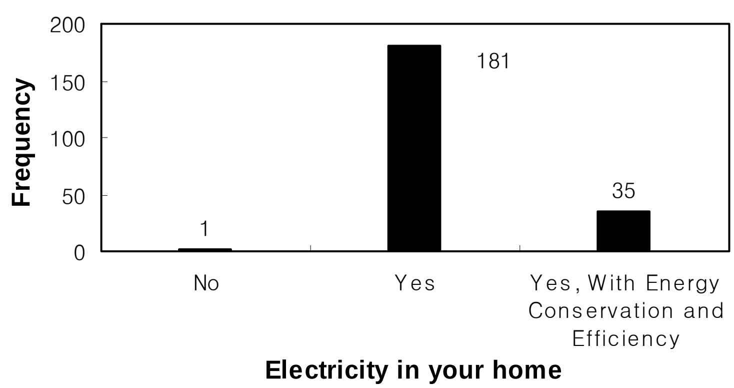


Figure 5.14. Do You Have Electricity in Your Home? (N= 217)

5.2.3. Mobility Consumption Patterns

Respondents were asked to provide information on their mobility habits including the mode, distance, and relative energy efficiency of their daily travel or commute. Figure 5.15 illustrates the residents' travel mileage on public transportation each week. Almost 91 percent of the respondents answered that they average zero miles per week on public transportation. Meanwhile, less than 5 percent of the average Dallas County's residents travel 1-25 miles, about 2 percent travel 25-75 miles, and approximately another 2 percent travel 75-200 miles. Only one respondent reported 200 miles or more.

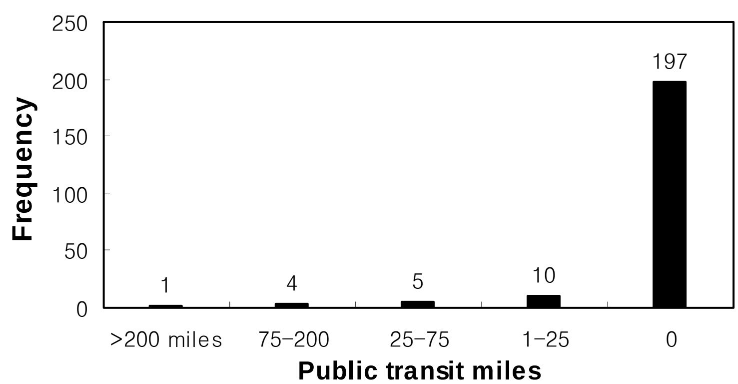


Figure 5.15. On Average, How Far Do You Travel on Public Transportation Each Week? (N= 217)

In terms of travel on motorbike, the survey results showed that few residents use this mode. As shown in Figure 5.16, more than 97 percent of the respondents reported '0 miles.' Whereas, one respondent averaged 1-25 miles, two respondents 25-75 miles, and three people 75-200 miles. However, none of the respondents travel 200 miles or more by motorbike.

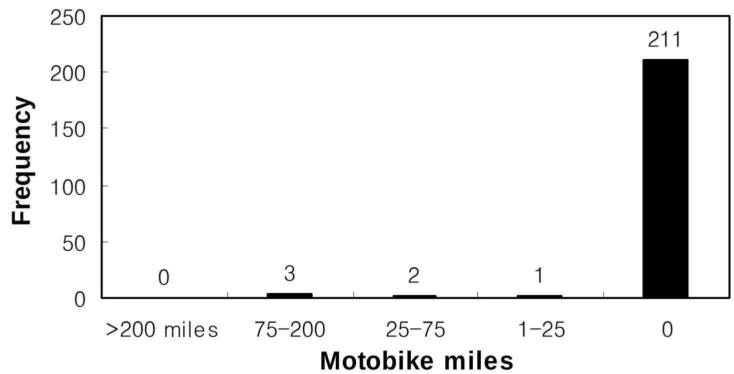


Figure 5.16. On Average, How Far Do You Go by Motorbike Each Week? (N= 217)

Figure 5.17 illustrates, on average, how far the respondents travel by car as a driver or passenger. Considering that the average car-driving American travels about 14,000 vehicle miles per year, or 270 miles per week (Merkel, 2003), the survey results indicated that a majority of the respondents are below the national average. More than 58 percent of the respondents (126) reported that they travel less than 200 miles each week by car and three respondents answered that they travel less than 10 miles per week by car. Meanwhile, approximately 19 percent of the respondents answered that they travel by car more than the national average. Five percent of respondents travel 400 miles or more each week by car. The survey results showed that 23 percent of the respondents travel at around the national vehicle mileage (200-300 miles). Generally speaking, the results demonstrated that Dallas County has a deeply auto-oriented transportation system.

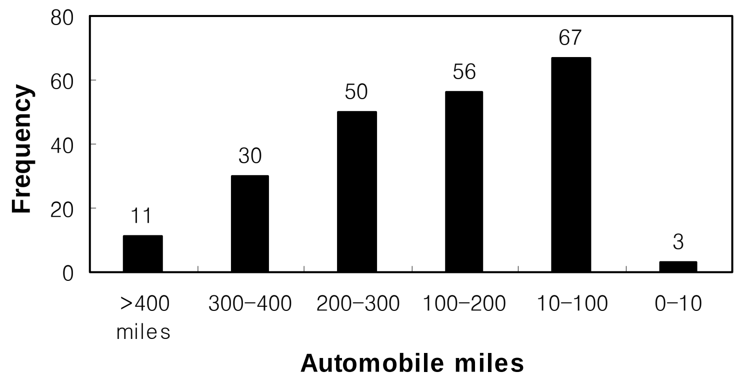


Figure 5.17. On Average, How Far Do You Go by Car Each Week? (N= 217)

Figure 5.18 shows the respondents' non-motorized travel patterns including cycling, walking, or using animal power. The survey results revealed that almost 70 percent of the respondents answered 'Seldom.' However, a considerable number of the respondents (more than 28 percent) answered that they depend on non-motorized transportation. Furthermore, about 2 percent of the respondents reported that they bicycle or walk 'Most of time' in their daily trips.

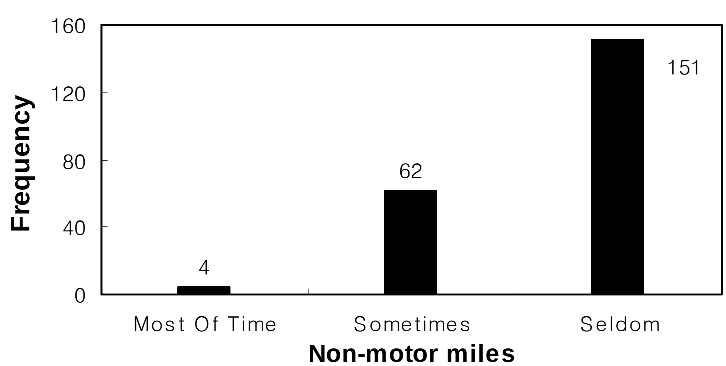


Figure 5.18. Do You Bicycle, Walk, or Use Animal Power to Get Around? (N= 217)

The approximated respondents' average air travel hours per year are illustrated in Figure 5.19. Every year Americans fly an average of 4.7 hours per person on commercial airlines. This is roughly equivalent to one round trip flight between Washington, DC and Chicago each year (Merkel, 2003). Although more than 33 percent of the respondents reported that they 'Never fly,' it appeared that a great many respondents spend more hours flying each year than the national average. Almost 51 percent of the respondents reported that on average, they spend at least 10 hours flying (approximately one coast-to-coast U.S. roundtrip per year). More than 8 percent fly 100 hours or more (approximately one coast-to-coast US roundtrips each month), over 19 percent spend 25 hours (approximately 2-3 coast-to-coast US roundtrip each year), and about 23 percent spend 10 hours (approximately one coast-to-coast US roundtrip per year).

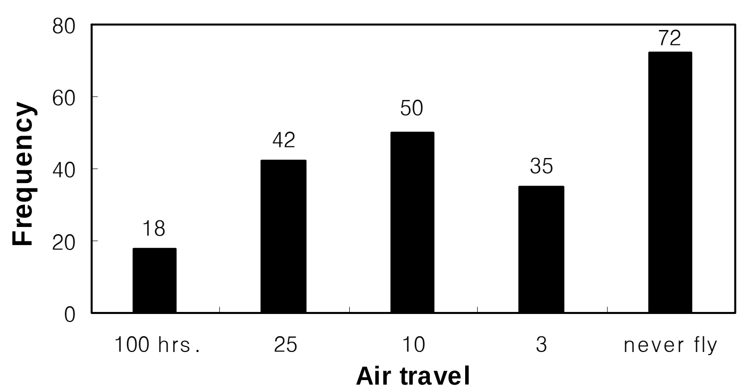


Figure 5.19. Approximately How Many Hours Do You Spend Flying Each Year? (N= 217)

Figures 5.20 and 5.21 show the relative fuel efficiency of the respondents' cars and motorbikes in average miles per gallon (MPG). More than 67 percent of the respondents estimated that their cars get 15-25 MPG which is equivalent to the U.S.

average. More than 26 percent of the respondents reported that their cars' fuel efficiency is higher than the national average. Over 23 percent estimated 25-35 MPG, approximately 2 percent 35-50 MPG, and one respondent reported more than 50 MPG. On the other hand, approximately 7 percent of the respondents estimated that their cars' fuel efficiency is below the national average (less than 15 MPG). In terms of motorbike fuel efficiency, only 12 people reported their MPG as shown in Figure 5.21.

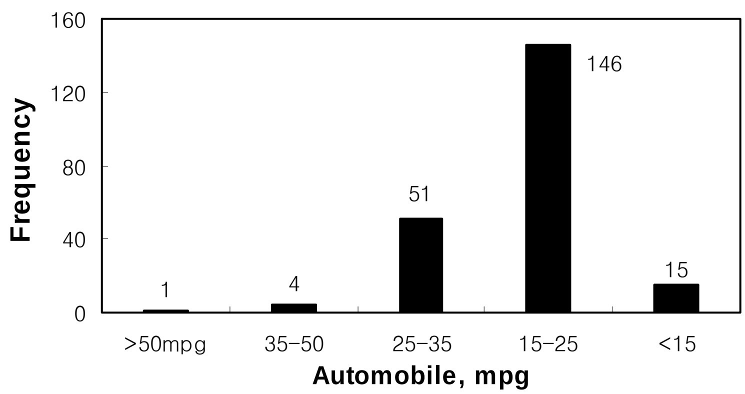


Figure 5.20. How Many Miles per Gallon Does Your Car Get? (N= 217)

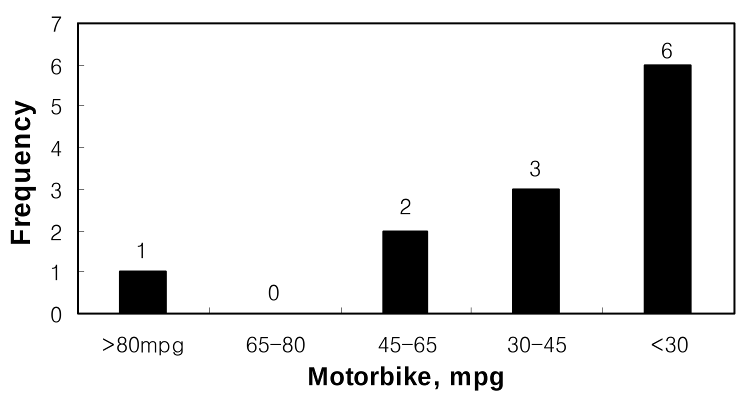


Figure 5.21. How Many Miles per Gallon Does Your Motorbike Get? (N= 12)

Figures 5.22 and 5.23 illustrate how often the respondents drive a car (or motorbike) with someone else rather than alone. In terms of carpooling, approximately 40 percent of the respondents answered *'Occasionally'*, almost 21 percent *'Often,'* and 13 percent *'Very often.'* Furthermore, approximately 12 percent of the respondents reported that they *'Almost always'* drive with someone else. Meanwhile, the survey results showed that more than 15 percent of the respondents *'Almost never'* drive with others.

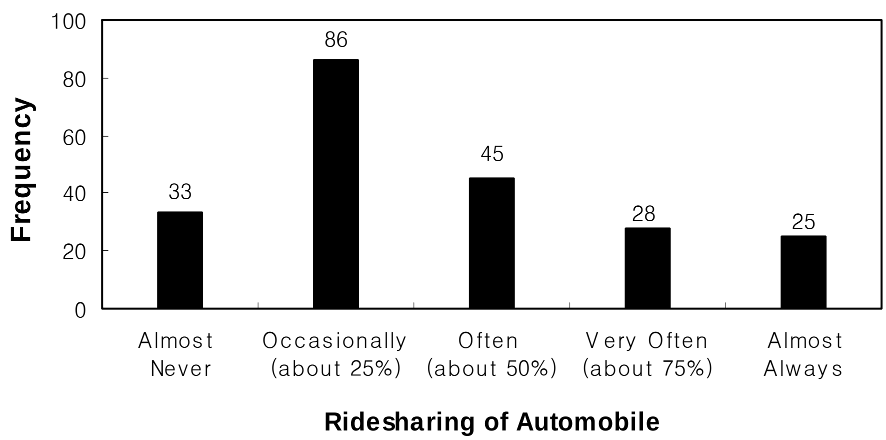


Figure 5.22. How Often Do You Drive in a Car with Someone Else, Rather Than Alone? (N= 217)

As shown in Figure 5.23, only 13 respondents reported motorbike ridesharing. Almost all of the motorbike users (10 people) of the thirteen respondents answered that they *'Almost never'* drive their motorbike with someone else. Only two respondents reported that they *'Occasionally'* drive with others and just one respondent answered *'Very often.'*

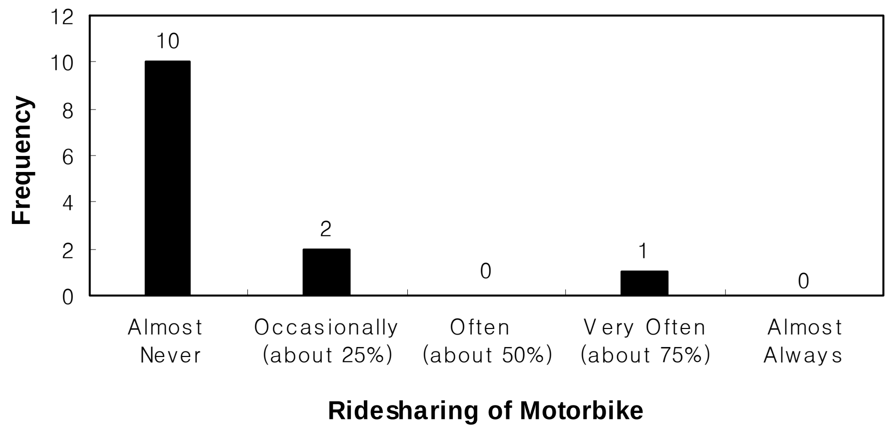


Figure 5.23. How Often Do You Ride Your Motorbike with Someone Else, Rather Than Alone? (N= 13)

5.2.4. Goods and Services Consumption Patterns

Goods and services consumption are determined based upon the size of food, shelter, and mobility consumption. This result considered average lifestyles, and estimated the use of appliances, clothing, electronics, sports equipment, toys, computers, communications equipment, household furnishings, and cleaning products (Merkel, 2003). Figure 5.24 shows how much waste the respondents generate in comparison to their neighbors; this was considered a goods factor in calculating the goods and services footprint.

The survey results indicated that almost 62 percent of the respondents answered that they generate *'About the same'* waste as their neighbors which is equivalent to the national average. Approximately 31 percent of the respondents reported that they generate *'Much less'* waste; however about 7 percent of the respondents answered that they produce *'Much more'* waste than their neighbors.

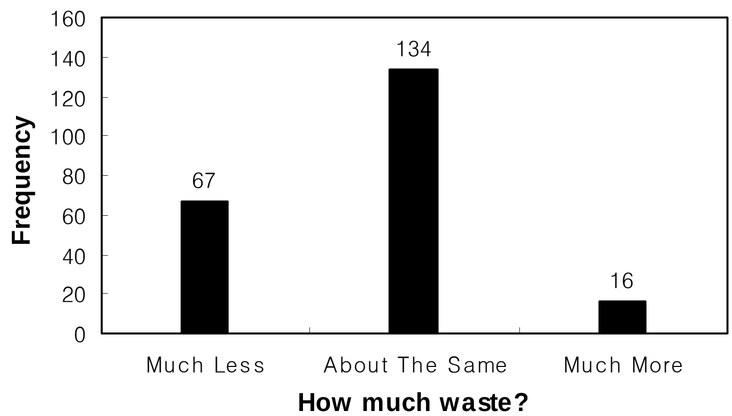


Figure 5.24. Compared to People in Your Neighborhood, How Much Waste Do You Generate? (N= 217)

5.3. Evaluating the per Capita Ecological Footprint in Dallas County

The consumption behaviors of Dallas County's residents described in the previous section were converted into an ecological footprint score using the EF Quiz. As shown in Table 5.5, the survey results revealed that the average per capita composite Ecological Footprint account of Dallas County was approximately 26.4 acres. This indicates that the average person in the County requires more than 26 acres of ecologically productive land to support their current life style. The range of footprint value was surprisingly large, from 7.9 acres to 78.2 acres. From a statistical analysis of the data, the contributions to the per capita footprint for the entire Dallas County sample are in rank order from goods and services (9.8 acres), shelter (8.2 acres), food (5.1 acres), and mobility (3.3 acres). The goods and services footprint, the most important component, accounted for approximately 37 percent of the total per capita footprint in the County. The shelter footprint accounted for more than 31 percent, food footprint more than 19 percent and mobility almost 12 percent.

These figures were compared to the average personal footprint of the United States in Table 5.5, where 37 percent (8.6 acres) of the composite footprint was from the goods and services component, 23 percent (5.5 acres) from food, 22 percent (5.1 acres) from shelter, and 18 percent (4.3 acres) from mobility. In comparison to the nation, the average person in Dallas County has a larger footprint in both shelter and goods and services components. Meanwhile, the County's residents have a smaller footprint in food and mobility components.

Table 5.5. Average per Capita Ecological Footprint for Dallas County and the U.S.A.

EF Component	**Dallas County**	**U.S.A.***
Food	5.1 (19.2 %)	5.5 (23.4 %)
Shelter	8.3 (31.3 %)	5.1 (21.7 %)
Mobility	3.3 (12.5 %)	4.3 (18.3 %)
(Car)	*2.32* *(70.3 %)*	*4.0* *(93.0 %)*
(Public Transit)	*0.02* *(0.6 %)*	*0.1* *(2.3 %)*
(Air Travel)	*0.96* *(29.1%)*	*0.3* *(6.9 %)*
Goods and Services	9.8 (37.0 %)	8.6 (36.6 %)
Composite Footprint Account	**26.4** **100** %	**23.5** **100** %

Note: Numbers above represent global acres per person, and may not add up due to rounding.
(U.S.A. Data Source from Jim Merkel, 2003: p. 93)*

In Table 5.5, the mobility component was collapsed into three elements including car footprint, public transit footprint, and air travel footprint. Of the national average per capita mobility footprint, 93 percent came from the car footprint, approximately 7 percent from air travel footprint, and slightly more than 2 percent from public transit. The element breakdown for Dallas County's mobility footprint was similar to the nation; however, the substantially larger (more than 29 percent) mobility footprint stemmed from air travel. This characterized Dallas County's personal average mobility footprint in that the air travel footprint was three times larger than the national average and a much smaller mobility footprint came from the car footprint (approximately 70 percent) unlike the national average (93 percent). In other words, the average person in the County has a per capita car footprint 42 percent lower than the national average. However, the County's air travel footprint was 69 percent higher than the national average.

Figure 5.25 graphically illustrates the ecological footprint figures for Dallas County measured by the Ecological Footprint Quiz. The county's composite footprint figure represents that the 2,287,288 residents within Dallas County as of January 1, 2004 (estimated by Texas State Data Center) need an area approximately 105 times larger than the area of the County itself from forest, agriculture and marine ecosystems for their consumption of food, transportation, housing, and goods and services. The total area of the County is 575,458 acres; meanwhile, the total amount of ecosystem area (the whole county's ecological footprint) appropriated by the County residents was calculated to be 60,384,403.2 acres (= 26.4 acres * 2,287,288 people).

Specifically, the amount of biologically productive land required to support the mobility consumption was estimated to be 13 times larger (red square in Figure 5.25), food consumption to be 20 times larger (green square), shelter consumption to be 33 times larger (blue square), and goods and services consumption to be 39 times larger (purple square) than the total area of the County. It means that the huge amount of appropriated biologically productive land for the County's population comes from outside the County.

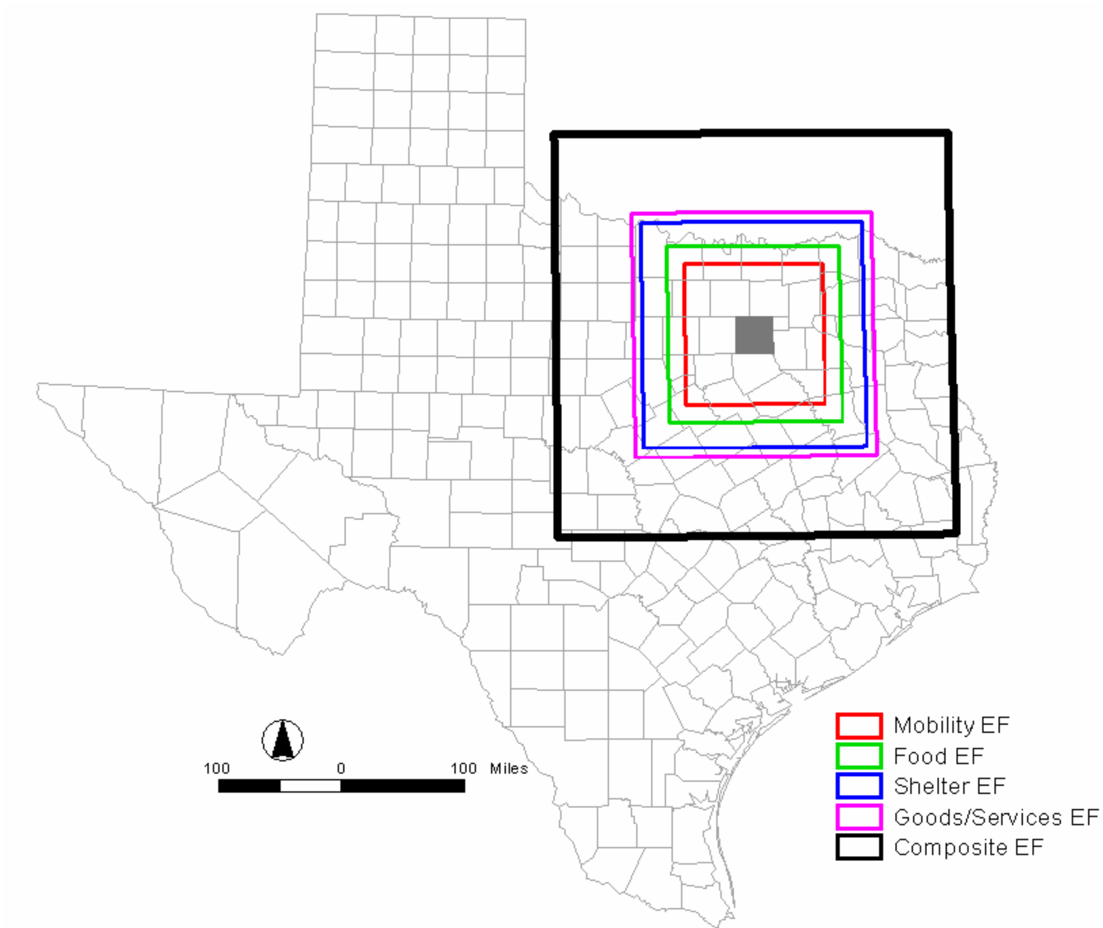


Figure 5.25. Dallas County Ecological Footprint Map

The ecological footprint figure of 26.4 acres per person derived from the EF Quiz for Dallas County can be compared to other regions that have had their footprints estimated by Redefining Progress (2004). Compared to the average footprint in Sarasota County (22.8 acres) in Florida, San Francisco Bay Area (20.9 acres) and Santa Monica (20.9 acres), Dallas County's footprint was larger. However, Dallas County's per capita footprint was smaller than the average of Marin County (27.4 acres) located in the San

Francisco Bay Area. Furthermore, the composite footprint figure for Dallas County was above the national per capita footprint (approximately 24 acres) and far above the global footprint (approximately 5.6 acres). As shown in Figure 5.26, the figure was almost six times larger than the world average for personal carrying capacity. According to the Redefining Progress, worldwide, there exist approximately 4.5 biologically productive acres per person. Therefore, if everyone lived like the average resident of Dallas County, we would need 5.9 planets.

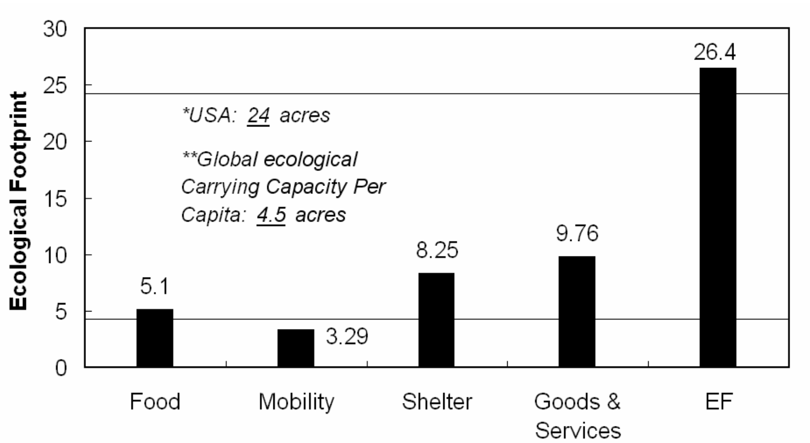


Figure 5.26. The EF Comparison by Component between Dallas County, U.S., & Global

5.4. Summary

Overall, the majority of the respondents had a strong environmental awareness; however, they were consuming a huge amount of natural resource to support their economic activities. Most respondents were well aware of the limit to natural resources of the Earth and concerned about the disastrous consequences of humanity's interference with nature. They agreed that humanity is severely abusing the environment and supported the idea that we have to develop a steady-state economy where industrial growth is controlled.

Although the County's residents had a strong environmental awareness, the data suggested that their natural resource consumption pattern was a matter of grave concern. The respondents were eating more animal-based and less locally grown products which require more land, energy, and other resources to produce. They were living in large free standing houses with a small number of inhabitants and with less usage of energy conservation and efficiency measures. They did more traveling by private cars with low fuel efficiency and less traveling with someone else. They were also spending more hours flying than the national average. Finally, they were consuming more service-oriented or luxury items.

Therefore, these lifestyles produced a personal footprint of 26.4 acres of which the food component accounted for 5.1 acres, mobility for 3.3 acres, shelter for 8.3 acres, and goods and services for 9.8 acres. The County's composite footprint score was 11 percent higher than the national average (about 23.5 acres per person) and the range of footprint scores for the County was from 7.9 acres to 78.2 acres. Comparing the globally sustainable ecological footprint of 4.5 acres per person, the average Dallas County resident should reduce the footprint by about 83 percent to achieve sustainability.

CHAPTER VI

EXAMINING FACTORS INFLUENCING THE PER CAPITA ECOLOGICAL FOOTPRINT

This chapter presents the regression analysis results explaining the variance in personal footprint score by testing the study hypotheses. Following the four independent variable groups identified in the conceptual framework (Chapter III), I examine six separate regression models, one for each component and a composite footprint score to draw conclusions about the impact of independent variables on per capita ecological footprint.

The study used sequential multiple regression to examine the unique impact of each independent variable group on the variance in the personal footprint score after other independent variable groups were controlled for. The four independent variable groups were entered by steps into the equation in the order of socioeconomic and demographic, environmental value, land-use patterns, and spatial attribute variable. The research paid close attention to the standardized coefficients (Beta) to compare the explanatory power among different variables and seek the best predictor of personal footprint score.

Several statistical tests for reliability were conducted to ensure that OLS estimators were Best Linear Unbiased Estimates (BLUE). Tests for normality, multicollinearity, autocorrelation, and heteroskedasticity revealed no violation of regression assumptions.

6.1. Composite Ecological Footprint Account

Table 6.1 presents the results of four regression models which are separated by independent factor groups against the composite ecological footprint score. Socio/demographic variables tested in Model 1 explained 29 percent of the variance in the composite footprint score. Among the variables, “household income” variable was the most powerful predictor of the average personal ecological footprint in Dallas County, which is positively significant at the .01 level. The results support ***Hypothesis 6*** that a person in a high income household will have a higher per capita EF than a person in a low income household. The “education years” was another strong predictor of the per capita footprint, which was also positively significant at the .01 level. The more years of education, the larger the ecological footprint (based on the amount of formal schooling completed). This was an expected result which supports ***Hypothesis 5*** that a more educated person will have a higher per capita EF than a less educated person. This finding is highly relevant to public policy decision makers who have tried to incorporate sustainability into higher education. To the extent that higher education just meant years of education attained, their efforts aimed at enhancing public education may unconsciously lead to an unsustainable society promoting more natural resource consumption.

“Marital status” indicating whether married or not was the next important predictor which had a negative influence on the personal footprint score at the .01 level. As hypothesized, married individuals were more likely to have a lower ecological impact than non-married individuals whose marital status was never married (single), divorced, and widowed (***Hypothesis 4***). In terms of gender effects, the study found that a male was significantly more likely to have a bigger ecological impact than a female, which was an expected result (***Hypothesis 2***) with a strong significance at the .01 level. Additionally, the analysis of model 1 found that age also had a significantly positive influence on the composite personal footprint score at the 0.1 level. The result showed that older residents were more likely to have a bigger personal footprint score than younger residents. This result contradicts ***Hypothesis 1***, which expects that younger respondents will have a higher per capita EF than older respondents, particularly associated with mobility and the goods/services footprint. This result suggests that to better understand the driving forces of the per capita footprint variation, a more detailed examination needs to be conducted at each level of the footprint components. Race has no significant statistical bearing on the average personal footprint of Dallas County (***Hypothesis 3***). As the coefficient beta of "race" variable shows, "white" appeared to have a bigger footprint than non-white which included African American, Hispanics, Asian/Pacific Islander, and other. However, it was not statistically significant at the 0.1 level.

Model 2 added "environmental value" variable into the independent variable group to explain the average personal composite footprint score. The environmental value score is an inverse index indicating that the higher value represents an individual's weak environmental awareness of the ecological crises which are stated in the survey questionnaire. Analysis of the model 2 did not statistically support ***Hypothesis 7*** that a person with strong environmental awareness will have a lower per capita ecological footprint than a person with weak environmental awareness. Controlling the socio/demographic variables, the “Ecovalue” score was positively related to the per capita composite footprint. The result indicated that the individual who reported higher “Ecovalue” was more likely to have a bigger footprint. In other words, a person with strong environmental awareness had a lower per capita ecological footprint than a person with weak environmental awareness. However, the t-value (0.35) was so minimal that the direction was statistically not significant (p=0.727).

To test the effect of land use pattern on average personal composite footprint of Dallas County, model 3 incorporated four variables including population density, development density, mixedness, and job/housing ratio controlling socio/demographic and environmental value factor groups. Despite a strong theoretical justification in Chapter III, the land-use pattern variable group did not play a significant role in explaining additional variation in the average personal footprint of Dallas County. The adjusted R squared decreased (.283 to .280) and none of the variables in the group showed any statistical significance at the .1 level. However, it is worth noting that most land use pattern variables reported the same sign of influence on individual composite footprint score except for the “development density” variable as hypothesized in Chapter III. First, the “population density” was negatively related to the personal composite footprint score, which indicated that a person in a high population density area was more likely to have a lower per capita footprint than a person in a low population density area (***Hypothesis 8***). Second, the degree of land-use mixedness was also negatively related to the per capita composite footprint score. In other words, as the degree of land-use mixedness surrounding a certain household increased in terms of residential, commercial, office, and institutional, a person was more likely to have a lower composite footprint than a person in a low mixed-use area pattern (***Hypothesis 10***). Third, as expected in ***Hypothesis 11***, the "job/housing ratio" was also negatively related to the average personal composite footprint score. The analysis result indicated that a person in a higher job/housing ratio area was more likely to have a smaller ecological influence on the Earth than a person in a lower job/housing ratio place (***Hypothesis 11***). This result was consistent with a city level study of Los Angeles County conducted by Venetoulis (2001). Examining the factors influencing carbonprint at the city level, he found that cities where the ratio of employment opportunities and residents' employment requirements are better are more like to have less carbonprint, as compared to a lower percentage of jobs for local residents. Finally, however, the "development density" was positively related to the average personal composite footprint score (***Hypothesis 9***). As the built-up area surrounding a particular person increased the average personal composite footprint score was more likely to become bigger.

Model 4 is a fully specified model incorporating spatial attributes variables including the proximity to CBD, freeways, light rail transit stations, major malls, Dallas/Fort Worth airport, parks, and major lakes. The spatial attribute variable group also did not play a significant role in explaining additional variation in the average personal footprint of Dallas County. The adjusted R squared decreased (.280 to .267) and none of the variables in the group showed any statistically significant contribution at the .1 level. Variables associated with the personal socioeconomic/demographic factor still remained powerful predictors of the average per capita composite footprint in the fully specified model. However, after inclusion of the spatial attribute variable group in the model, there was a noticeable change in the "population density" variable which had no significant statistical bearing on the per capita footprint score in model 3. First, the regression result showed that the "population density" had a negative relation to the dependent variable. In other words, as expected in ***Hypothesis 8***, a person living in a high density area was more likely to have a smaller footprint. Second, there was a noticeable increase in the standardized beta of the population density variable compared to model 3 (-.108 to -.318). Surprisingly, the variable became the strongest predictor to explaining the dependent variable when the variance explained by all other variables in the model was controlled for. This increase in the standardized beta might be associated with the inclusion of the spatial attribute variable group in the model. Once the geographic effects were controlled by the seven spatial attribute variables, the population density variable's influence on the personal ecological footprint became clear. The addition of the spatial factor group thus was critical in explaining how the land-use patterns impact the personal footprint variation.

Additionally, it is important to note that most spatial attribute variables showed unexpected influence on the personal composite footprint score although their t-values were so minimal (from .174 to -1.003) that the directions were statistically insignificant (from .317 to .862). Another possible explanation for the discrepancies might be that the dependent variable consisted of four components which were supposed to be very sensitive to geographic spatial attributes. This could also be another justification in conducting the supplementary regression analysis in the remainder of this section.

Overall, as shown at the bottom of Table 6.1, all of the models tested (model 1-4) were significant at the .01 level. In terms of model fit, however, it is important to note that although adjusted R-squared values were consistent over the four models (the adjusted R-squared values for model 1 to 4 are .285, .283, .280 and .267, respectively), there was still a large amount of unexplained variance that needs to be addressed in future studies.

Table 6.1. Explaining the "Per Capita Composite EF" of Dallas County

Dependent **LOG (EF)**	Model 1	Model 2	Model 3	Model 4
	(Beta)	(Beta)	(Beta)	(Beta)
Socio/Demo				
Age	0.131*	0.131*	0.125*	0.128*
Gender	0.193***	0.186***	0.177***	0.170**
Race	0.107	0.107	0.103	0.116
Marital Status	-0.252***	-0.250***	-0.267***	-0.260***
Edu. Years	0.276***	0.275***	0.290***	0.301***
HH Income	0.292***	0.289***	0.282***	0.293***
Environ. Value				
Ecovalue		0.023	0.035	0.022
Land Use Pattern				
Pop. Density			-0.108	-0.318*
Dev. Density			0.110	0.181
Mixedness			-0.085	-0.074
Job/Housing			-0.010	-0.012
Spatial Attribute				
CBD				-0.103
Freeway				0.012
Light Rail				-0.086
Major Mall				-0.043
DFW Airport				0.075
Parks				-0.035
Major Lakes				-0.069
(***Constant***: coeff.)	2.167***	2.141***	2.125***	2.360***
	N=196	N=196	N=196	N=196
	F(6,189)=14.062	F(7,188)=12.015	F(11,184)=7.911	F(18,177)=4.941
	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000
	Adj.R^2 =.287	Adj.R^2=.283	Adj.R^2=.280	Adj.R^2=.267

* < 0.1 level, ** < 0.05 level, and *** < 0.01 level

Variable Definition:

Dependent Variable: Log of Composite Ecological Footprint

Independent Variables: 1. Age; 2. Gender (1=male, 0=female); 3. Race (1=white, 0=non-white); 4. Marital Status (1=married, 0=non-married); 5. Education Years (=educational attainment); 6. Household Income (= 1,000 dollars); 7. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 8. Population Density (= within 3.5 mile buffer); 9. Development Density (= within 3.5 mile buffer. built-up/non built-up); 10. Mixedness (= within 0.25 mile buffer. 4 land-use types); 11. Job/Housing Ratio (= within 5.0 mile buffer); 12. CBD (=nearest distance to CBD); 13. Freeway (=nearest distance to freeways); 14. Light Rail Transit (= nearest distance to LRT); 15. Dallas/Fort Worth Airport (= nearest distance to DFW); 16. Major Malls (= nearest distance to major malls); 17. Parks (= nearest distance to parks); and 18. Major Lakes (= nearest distance to major lakes)

6.2. Component Food Footprint Account

Table 6.2 shows the regression results against average personal food footprint. In model 1, regression analysis suggested that the socioeconomic/demographic variables might not play a significant role in explaining the variation in the per capita food footprint. Age, gender, race, marital status, education years, and household income by themselves explained only 0.9 percent of the variance of the dependent variable, indicating an extremely weak fit of the data.

In model 2, as the "environmental value" variable was entered into the model, "marital status" turned out to have a positive relation with the dependent variable. This meant that a married person was less likely to eat animal based products such as beef, pork, chicken, fish, eggs, and dairy products than a non-married person. It also meant that a married person was less likely to eat food that was processed, packaged and not locally grown from more than 200 miles away. The regression analysis suggested that "environmental awareness" also made a unique contribution to explain the average personal food footprint. This supported ***Hypothesis 7*** that a person having a strong environmental awareness on the ecological crises is more likely to have a smaller personal food footprint. In other words, a person being keenly aware of the ecological crises was not only less likely to eat animal based food but also more likely to eat locally grown food although the regression model was not significant [$F(7, 188) = 1.577$, $p = .145$].

The inclusion of the land-use pattern variable group in the model decreased the model fit (.020 to .010) and also washed out the marital status' unique contribution.

Table 6.2. Explaining the "Per Capita Food Footprint Component" of Dallas County

Dependent **Square (Food)**	Model 1	Model 2	Model 3	Model 4
	(Beta)	(Beta)	(Beta)	(Beta)
Socio/Demo				
Age	-0.078	-0.075	-0.078	-0.078
Gender	0.071	0.029	0.030	0.058
Race	0.116	0.117	0.108	0.135
Marital Status	0.121	0.132*	0.121	0.110
Edu. Years	-0.082	-0.087	-0.077	-0.105
HH Income	-0.091	-0.107	-0.108	-0.071
Environ. Value				
Ecovalue		0.135*	0.129*	0.157**
Land Use Pattern				
Pop. Density			-0.044	-0.031
Dev. Density			0.125	0.050
Mixedness			0.013	-0.001
Job/Housing			-0.098	-0.300**
Spatial Attribute				
CBD				-0.033
Freeway				0.164**
Light Rail Transit				-0.106
Major Mall				0.023
DFW Airport				-0.204*
Parks				-0.115
Major Lakes				0.205***
(***Constant***: coeff.)	31.974***	28.015***	26.293***	34.645***
	N=196	N=196	N=196	N=196
	F(6,189)=1.286	F(7,188)=1.577	F(11,184)=1.186	F(18,177)=1.682
	Prob.>F=.265	Prob.>F=.145	Prob.>F=.300	Prob.>F=.046
	Adj.R^2=.009	Adj.R^2=.020	Adj.R^2=.010	Adj.R^2=.059

* < 0.1 level, ** < 0.05 level, and *** < 0.01 level

Variable Definition:

Dependent Variable: Squared Food Footprint

Independent Variables: 1. Age; 2. Gender (1=male, 0=female); 3. Race (1=white, 0=non-white); 4. Marital Status (1=married, 0=non-married); 5. Education Years (=educational attainment); 6. Household Income (= 1,000 dollars); 7. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 8. Population Density (= within 3.5 mile buffer); 9. Development Density (= within 3.5 mile buffer. built-up/non built-up); 10. Mixedness (= within 0.25 mile buffer. 4 land-use types); 11. Job/Housing Ratio (= within 5.0 mile buffer); 12. CBD (=nearest distance to CBD); 13. Freeway (=nearest distance to freeways); 14. Light Rail Transit (= nearest distance to LRT); 15. Dallas/Fort Worth Airport (= nearest distance to DFW); 16. Major Malls (= nearest distance to major malls); 17. Parks (= nearest distance to parks); and 18. Major Lakes (= nearest distance to major lakes)

None of the added variables made a significant unique contribution to the prediction of the dependent variable at the .1 level. However, the environmental value variable remained a positive predictor of the per capita food footprint component score with a slight decrease in its significance value (.074 to .093) although model 3 was not still significant [F (11, 184) = 1.186, p = .300].

In model 4, the model fit was enhanced almost six times as much as in model 3 and the model as a whole was significant [F(18, 177) = 1.168, p = .046]; however, it still explained a very small amount of the variance in the dependent variable which was approximately 6 percent. The inclusion of the spatial attribute factors to the model increased the significance value of the environmental awareness variable (.093 to .042). Additionally, there was a surprising increase in the standardized beta value (-.300) of the "job/housing ratio" variable which became the strongest unique contribution to predict the dependent variable which did not have any significant statistical bearing in model 3. The regression analysis suggested that a person living in a community where there are more suitable places to work for local residents is less likely to eat the animal based products and more likely to eat locally grown food. This was the consistent result with the regression result conducted against the average personal composite footprint score. In terms of the spatial attribute variable group's influence on the dependent variable, the analysis results showed that proximity to freeway, Dallas/Fort Worth Airport and major lakes was statistically significant from the .1 to the .01 level. Proximity to CBD, light rail transit stations, major malls, and parks continued to not have any statistical bearing on the dependent variable. Model 4 suggested that a person living close to major freeways was *less* likely to eat animal based products and/or *more* likely to eat locally grown food. A similar effect was also apparent for a person living close to major lakes with a strong significance at .01. The closer the major lakes, the smaller the average personal food footprint. There may be two explanations for this result. One possibility is that people who are environmentally oriented tend to locate close to the major lakes. Therefore, they try to consume food grown by themselves or purchase locally grown food. However, the correlation analysis suggested that there was no correlation between environmental awareness and proximity to the major parks (Appendix 12). The other explanation may be that a person living close to the major lakes usually shops at farmers' markets or buys directly from farmers; additionally, there may be a possibility that open spaces may be utilized as kitchen gardens for neighborhood residents.

Generally, regression analyses suggested that the models tested did not play a significant role in predicting the average personal food footprint component score with an extremely low value of the adjusted R square. Therefore, more work is needed in the future to improve model fit and adequately predict the dependent variable. The environmental value variable showed a consistent positive unique contribution to the dependent variable although models were not significant. Furthermore, the geographic spatial attributes surrounding a particular person were significant to explain the personal food footprint component.

6.3. Component Mobility Footprint Account

Like the ecological footprint account, the mobility footprint score is also a composite index which consists of the car, air travel, and public transportation footprint component. Therefore, two regression analyses were conducted: the personal composite mobility footprint which included all mobility components and the personal "car" footprint component which factored out the airplane and public transportation footprint components. With this separation, the impacts of the four groups of independent variables on the dependent variable become better understood.

Tables 6.3 and 6.4 show the results of regression analysis to explain the impacts of the independent variable groups on the composite mobility footprint and the car footprint, respectively. The socioeconomic/demographic variables explained 25.6 percent of the variance in the composite mobility footprint (Table 6.3); meanwhile, they explained just 7.3 percent of the variance in the car footprint (Table 6.4). Together, "education years" and "marital status," which were two very powerful predictors to explain the composite EF in the initial analysis, did not show any unique contribution to predicting the composite mobility footprint and car footprint component. Instead, regression analysis showed that "household income" made the strongest positive contribution to explain both of the dependent variables. As expected, males were more likely to have a bigger mobility and car footprint than females. Interestingly enough, however, regression results showed that "age" made a significant *negative* contribution to the prediction of the mobility and car footprint. Unlike the initial result on the composite EF, this result supported ***Hypothesis 1*** that younger respondents have a higher mobility (and car) footprint than older respondents, which remained continuously throughout the four models tested (p<.1).

Model 2 slightly increased model-fit, not only for mobility but also for the car footprint, by including the environmental value variable in the model. While "Ecovalue" remained positively related to the mobility and car footprint in model 2, there was a increase in its p-values (from .727 to .058 against mobility footprint, from .727 to .009 against car footprint). The regression analyses suggested that the degree of individuals' awareness of environmental crisis issues would play an important role in reducing personal mobility, particularly the car footprint. The stronger environmental awareness reported, the smaller the mobility and car footprint.

Incorporating the land-use pattern variables, model 3 explained 26.0 percent of the variance in the mobility footprint and 12.5 percent of the variance in the car footprint. None of the land-use pattern factors made a significant unique contribution to predict the composite mobility footprint at the .1 level; however, regression analysis showed that both population density and development density made a significant contribution to explain the personal car footprint. Population density was negatively related to the car footprint at the .01 level; whereas, the development density was positively associated with the car footprint at the .1 level. In terms of the car footprint, regression analysis confirmed the initial analysis on the personal composite EF with a statistical significance that a person living in a high land-use mixed location is more likely to have a smaller car footprint than a person living in a less land-use mixed location. Surprisingly, the results also confirmed that development density made a positive contribution to predict the personal car footprint which was an unexpected outcome against ***Hypothesis 9***. In other words, a person living in a highly developed location was more likely to have a bigger car footprint than a person living in a less developed location. This was an opposite outcome considering that the Dallas County PMSA is one of the typical regions experiencing rapidly sprawling growth far from the urban core. However, the development density's unique contribution to explaining the personal car footprint disappeared once the geographic spatial influences surrounding a respondent were controlled by the inclusion of spatial attribute variables as shown in model 4. While the sign of "development density" remained in the same direction, there was a noticeable decrease in its p-value compared to the regression analysis in model 3 (p-value from .081 to .533). A possible explanation for this discrepancy might be Dallas County's socioeconomic and demographic spatial structure. As shown in Appendices 6-11, the highly developed urban areas throughout Dallas County were mostly occupied by high income households and white people; meanwhile, the less developed locations were predominantly populated by low income households and minorities. Numerically speaking, the correlation analysis also reported a positive association between development density and the white population ($r=.19$, $p<.05$) (Appendix 12). Therefore, it is thought that the socioeconomic/demographic influence outpaced the development density influence on the personal footprint score which produced an opposite outcome to the study hypothesis.

A fully specified model 4 in Table 6.3 and Table 6.4 explained 28.1 percent of the variance in the mobility footprint and 15.6 percent of the variance in the car footprint, respectively. Regression analysis suggested that the geographic features' proximity variables were important predictors of the mobility and car footprint. Proximity to the major malls was the second most significant predictor to explain the mobility footprint and the third strongest predictor to explain the car footprint. These results confirmed the initial analysis on the personal composite EF bearing a statistical significance and supported ***Hypothesis 15*** that a person close to major commercial malls will have a higher per capita EF than a person far away. It is thought that people living close to the major malls shop more frequently and drive their private automobile than a person living far away. In terms of proximity to Dallas/Fort Worth Airport, as expected in ***Hypothesis 16***, the regression result reported a positive association with the mobility footprint ($p<.1$) and the car footprint. Surprisingly, proximity to light rail transit stations had a negative influence on the mobility and car footprint. In other words, regression analysis suggested that a person living close to the light rail stations was more likely to have a bigger mobility footprint (not significant at the .1 level) and car footprint (significant at the .05 level) than a person living far away. While this result was an unexpected outcome against ***Hypothesis 14***, the discrepancy could be explained when we consider Dallas County respondents' consumption behavior on public transportation and the location of light rail transit stations.

Table 6.3. Explaining the "Per Capita Composite Mobility Footprint" of Dallas County

Dependent **LOG (Mobility)**	Model 1	Model 2	Model 3	Model 4
	(Beta)	(Beta)	(Beta)	(Beta)
Socio/Demo				
Age	-0.185***	-0.185***	-0.193***	-0.183**
Gender	0.162**	0.123*	0.115	0.095
Race	0.000	0.000	-0.011	-0.008
Marital Status	-0.099	-0.088	-0.098	-0.081
Edu. Years	0.082	0.079	0.100	0.107
HH Income	0.375***	0.358***	0.359***	0.342***
Environ. Value				
Ecovalue		0.125*	0.129*	0.087
Land Use Pattern				
Pop. Density			-0.122	-0.238
Dev. Density			0.135	0.047
Mixedness			0.006	0.016
Job/Housing			-0.022	0.174
Spatial Attribute				
CBD				0.118
Freeway				-0.016
Light Rail Transit				-0.108
Major Mall				-0.252***
DFW Airport				0.188*
Parks				0.024
Major Lakes				-0.091
(***Constant***: coeff.)	0.259	-0.113	-0.327	-0.058
	N=194	N= 94	N=194	N=194
	F(6,189)=12.796	F(7,186)=11.024	F(11,182)=7.151	F(18,175)=5.197
	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000
	Adj.R^2=.256	Adj.R^2=.267	Adj.R^2=.260	Adj.R^2=.281

* < 0.1 level, ** < 0.05 level, and *** < 0.01 level

Variable Definition:

Dependent Variable: Log of Mobility Footprint

Independent Variables: 1. Age; 2. Gender (1=male, 0=female); 3. Race (1=white, 0=non-white); 4. Marital Status (1=married, 0=non-married); 5. Education Years (=educational attainment); 6. Household Income (= 1,000 dollars); 7. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 8. Population Density (= within 3.5 mile buffer); 9. Development Density (= within 3.5 mile buffer. built-up/non built-up); 10. Mixedness (= within 0.25 mile buffer. 4 land-use types); 11. Job/Housing Ratio (= within 5.0 mile buffer); 12. CBD (=nearest distance to CBD); 13. Freeway (=nearest distance to freeways); 14. Light Rail Transit (= nearest distance to LRT); 15. Dallas/Fort Worth Airport (= nearest distance to DFW); 16. Major Malls (= nearest distance to major malls); 17. Parks (= nearest distance to parks); and 18. Major Lakes (= nearest distance to major lakes)

Table 6.4. Explaining the "Per Capita Car Footprint Component" of Dallas County

Dependent **SQRT (Car)**	Model 1	Model 2	Model 3	Model 4
	(Beta)	(Beta)	(Beta)	(Beta)
Socio/Demo				
Age	-0.146*	-0.143*	-0.134*	-0.139*
Gender	0.147**	0.088	0.067	0.046
Race	0.068	0.070	0.063	0.064
Marital Status	-0.036	-0.020	-0.041	-0.027
Edu. Years	-0.073	-0.080	-0.026	-0.012
HH Income	0.220**	0.196**	0.212**	0.211**
Environ. Value				
Ecovalue		0.190***	0.202***	0.162**
Land Use Pattern				
Pop. Density			-0.291***	-0.478**
Dev. Density			0.186*	0.089
Mixedness			0.028	0.038
Job/Housing			-0.049	0.091
Spatial Attribute				
CBD				0.132
Freeway				0.023
Light Rail Transit				-0.256**
Major Mall				-0.231**
DFW Airport				0.147
Parks				-0.024
Major Lakes				-0.060
(***Constant***: coeff.)	1.610***	1.216***	1.054**	1.577**
	N=195	N=195	N=195	N=195
	F(6,190)=3.542	F(7,187)=4.125	F(11,183)=3.524	F(18,176)=2.989
	Prob.>F=.002	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000
	Adj.R^2=.073	Adj.R^2=.101	Adj.R^2=.125	Adj.R^2=.156

* < 0.1 level, ** < 0.05 level, and *** < 0.01 level

Variable Definition:

Dependent Variable: Squared Root of Car Footprint

Independent Variables: 1. Age; 2. Gender (1=male, 0=female); 3. Race (1=white, 0=non-white); 4. Marital Status (1=married, 0=non-married); 5. Education Years (=educational attainment); 6. Household Income (= 1,000 dollars); 7. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 8. Population Density (= within 3.5 mile buffer); 9. Development Density (= within 3.5 mile buffer. built-up/non built-up); 10. Mixedness (= within 0.25 mile buffer. 4 land-use types); 11. Job/Housing Ratio (= within 5.0 mile buffer); 12. CBD (=nearest distance to CBD); 13. Freeway (=nearest distance to freeways); 14. Light Rail Transit (= nearest distance to LRT); 15. Dallas/Fort Worth Airport (= nearest distance to DFW); 16. Major Malls (= nearest distance to major malls); 17. Parks (= nearest distance to parks); and 18. Major Lakes (= nearest distance to major lakes)

As described in Chapter V, almost 91 percent of the respondents answered that they average zero miles per week on public transportation. The light rail transit stations are located along Dallas County's economic corridor. Although the proximity effect of CBD was controlled in model 4, it might not entirely control the locational effect of the economic corridor. Simply speaking, the location of light rail transit stations was coincident with the main economic corridor of Dallas County. Therefore, a person living close to the light rail transit stations was more likely to have a bigger car footprint than a person living far away. Another interesting point was that "population density" became the strongest predictor to explain personal car footprint with the inclusion of the spatial attribute variable group in the model 4.

Overall, regression analysis suggested that the four independent variable groups tested were important predictors of the per capita mobility and car footprint. However, there was still a large amount of unexplained variance that needs to be addressed in future studies. Particularly, more studies need to be conducted to explain the variance in the personal car footprint.

6.4. Component Shelter Footprint Account

As illustrated in Table 6.5, the socioeconomic/demographic variable group was a significant factor in explaining the average personal shelter footprint of Dallas County. Regression analysis suggested that education years, marital status, age, and gender factors made a unique contribution to predicting the dependent variable, while race and household income did not make a significant contribution. The education years factor was the most significant predictor ($p<0.01$). A more educated person was significantly more likely to have a higher shelter footprint than a less educated person. The second most important predictor of the shelter footprint was the respondent's marital status ($p<.01$). A married person was more likely to have a lower shelter footprint than a non-married person. This is a reasonable outcome because a married person is more likely to share housing space than a non-married person. Age and gender factors again were significant predictors of the shelter footprint. Particularly, the statistical significance of the age variable was much more prominent in predicting the shelter footprint compared to the composite footprint account (from .056 to .000). Unlike the mobility and car footprint, an older person was more likely to have a bigger personal shelter footprint than a younger person. In terms of gender, there was an expected outcome which confirmed the regression analysis result on the per capita composite EF that a male was more likely to have a bigger shelter footprint. Surprisingly, the household income factor did not play any significant role in predicting the shelter footprint whose prediction power for the shelter footprint remarkably decreased compared to the initial analysis of the composite EF account (p-value from .000 to .191).

Table 6.5. Explaining the "Per Capita Shelter Footprint" of Dallas County

Dependent **SQRT (Shelter)**	Model 1	Model 2	Model 3	Model 4
	(Beta)	(Beta)	(Beta)	(Beta)
Socio/Demo				
Age	0.270***	0.268***	0.266***	0.265***
Gender	0.110*	0.134*	0.128*	0.124*
Race	0.099	0.098	0.098	0.109
Marital Status	-0.301***	-0.307***	-0.324***	-0.321***
Edu. Years	0.368***	0.371***	0.382***	0.391***
HH Income	0.102	0.111	0.104	0.123
Environ. Value				
Ecovalue		-0.075	-0.064	-0.067
Land Use Pattern				
Pop. Density			-0.071	-0.287
Dev. Density			0.069	0.222*
Mixedness			-0.089	-0.077
Job/Housing			-0.020	-0.093
Spatial Attribute				
CBD				-0.191
Freeway				-0.023
Light Rail Transit				-0.040
Major Mall				0.080
DFW Airport				0.023
Parks				-0.026
Major Lakes				-0.087
(***Constant***: coeff.)	0.385	0.552	0.581	1.024
	N=196	N=196	N=196	N=196
	F(6,189)=13.558	F(7,188)=11.837	F(11,184)=7.723	F(18,177)=5.010
	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000
	Adj.R^2=.279	Adj.R^2=.280	Adj.R^2=.275	Adj.R^2=.270

* < 0.1 level, ** < 0.05 level, and *** < 0.01 level

Variable Definition:

Dependent Variable: Squared Root of Shelter Footprint

Independent Variables: 1. Age; 2. Gender (1=male, 0=female); 3. Race (1=white, 0=non-white); 4. Marital Status (1=married, 0=non-married); 5. Education Years (=educational attainment); 6. Household Income (= 1,000 dollars); 7. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 8. Population Density (= within 3.5 mile buffer); 9. Development Density (= within 3.5 mile buffer. built-up/non built-up); 10. Mixedness (= within 0.25 mile buffer. 4 land-use types); 11. Job/Housing Ratio (= within 5.0 mile buffer); 12. CBD (=nearest distance to CBD); 13. Freeway (=nearest distance to freeways); 14. Light Rail Transit (= nearest distance to LRT); 15. Dallas/Fort Worth Airport (= nearest distance to DFW); 16. Major Malls (= nearest distance to major malls); 17. Parks (= nearest distance to parks); and 18. Major Lakes (= nearest distance to major lakes)

Generally, model 1 explained 27.9 percent of the variance in the personal shelter footprint and these socioeconomic/demographic variable effects on the dependent variable continued over other models.

As shown in model 2, the environmental awareness variable did not make a significant contribution to predicting the shelter footprint at the .1 level. Surprisingly, however, it showed an unexpected association with the dependent variable. Although it did not have any statistical bearing, it would indicate that a person with strong environmental awareness is more likely to have a bigger per capita shelter footprint than a person with weak environmental awareness. The negative association remained over the other models even though the land-use patterns and the spatial attribute variable influences were controlled for.

Land-use pattern effects did not make a significant contribution to explaining the variance in the dependent variable. Nonetheless, all of the signs confirmed the initial analysis results conducted on the personal composite EF. Regression analysis suggested that a person living in a higher population density location, higher land-use mix area with a higher percentage of jobs for local residents was more likely to have a smaller personal shelter footprint; whereas, a person living in a location with highly developed built-up land was more likely to have a bigger shelter footprint than a person living in a less developed location. In the shelter footprint calculation of the EF Quiz, the size of household directly impacted the per capita shelter footprint. A correlation analysis indicated that there was a weak negative association ($r=-.140$, $p<.05$) between development density and household size throughout Dallas County. This means that the average number of persons living in a particular household in a highly developed area was smaller than that of a household in a less developed area. Therefore, it was thought that the per capita shelter footprint score was highly related to a person living in a highly developed location.

Results regarding distance to spatial attributes were, for the most part, identical to the results for the composite EF account, with the exception that distance to freeway was negatively associated with the shelter footprint and distance to major malls was positively related to the shelter footprint. In other words, a person living close to a freeway was more likely to have a bigger shelter footprint than a person living far away; whereas, a person living close to major malls was more likely to have a lower shelter footprint than a person living far away. However, these outcomes had no significant statistical bearing on the dependent variable at the .1 level.

Overall, regression analyses suggested that the socioeconomic/demographic variables were powerful predictors to explain the personal shelter footprint in the rank order of education years, marital status, age, and gender; but, the household income variable did not make a significant contribution to predicting the dependent variable. Additionally, the other independent variable group did not play a significant role in explaining the personal shelter footprint of Dallas County.

6.5. Component Goods and Services Footprint Account

As mentioned in Chapter V, the goods and services footprint component accounted for approximately 37 percent of the per capita composite EF of Dallas County. Regression analysis to test the effects of independent variable groups on the personal goods and services footprint confirmed all of the initial results of the personal composite EF as shown in Table 6.6. In model 1, socioeconomic/demographic variables explained 29.8 percent of the variance in the per capita goods and services footprint. Analysis results suggested that most of the variables made a strongly significant contribution to predict the dependent variable except for the "race" variable. The variables of age, gender (male), education years, and household income were positively associated with the personal goods and services footprint; whereas, the marital status variable was negatively related to the dependent variable. Again, household income was the strongest predictor to explain the personal goods and services footprint followed by education years, marital status, gender, and age. Regression analysis suggested that an old, non-married, highly educated, male in a high income household was more likely to have a bigger goods and services footprint than a young, married, less educated, female in a low income household.

In model 2, regression analysis suggested that the degree of environmental awareness did not make a unique contribution to predict the personal goods and services footprint. It appeared that a person with a strong environmental awareness was more likely to have a smaller per capita goods and services footprint. However, the "Ecovalue" had no significant statistical bearing on the dependent variable which remained consistent throughout the other models.

The land-use patterns variable groups in model 3 also could not provide additional power to explain the per capita goods and services footprint with a marginal decrease in adjusted R-squared value (from .294 to .292). Nonetheless, all of the signs of the variables remained the same direction as the initial findings when the per capita composite EF was regressed against the land-use patterns variables. Regression analysis suggested that population density, land-use mix, and job/housing ration were negatively associated with the personal goods and services footprint but development density was positively related to the dependent variable.

Regression analysis results in model 4 produced an outcome identical to the results of the fully specified model for the per capita composite EF score. The inclusion of seven geographic spatial attribute variables did not make any unique contribution to explain the variance in the dependent variable and, on the contrary, it somewhat decreased the adjusted R-squared value from .292 to .277. However, the fully specified model 4 markedly increased the standardized beta coefficient in the “population density” variable from -.114 to -.332. Similar to results for the per capita composite EF, regression analysis suggested that the population density variable was the strongest powerful predictor of the per capita goods and service footprint once we successfully controlled for geographic spatial attribute influences.

Overall, analysis results found that the powerful predictors explaining the personal goods and services footprint were in the rank order of population density, education years, household income, marital status, gender, and age.

Table 6.6. Explaining the "Per Capita Goods and Services Footprint" of Dallas County

Dependent **LOG (Goods)**	Model 1	Model 2	Model 3	Model 4
	(Beta)	(Beta)	(Beta)	(Beta)
Socio/Demo				
Age	0.127*	0.127*	0.120*	0.123*
Gender	0.187***	0.185***	0.176**	0.171**
Race	0.104	0.104	0.099	0.117
Marital Status	-0.212***	-0.212***	-0.230***	-0.223***
Edu. Years	0.289***	0.289***	0.304***	0.314***
HH Income	0.305***	0.305***	0.297***	0.306***
Environ. Value				
Ecovalue		0.006	0.019	0.010
Land Use Pattern				
Pop. Density			-0.114	-0.332*
Dev. Density			0.117	0.211
Mixedness			-0.088	-0.076
Job/Housing			-0.007	-0.036
Spatial Attribute				
CBD				-0.138
Freeway				0.020
Light Rail Transit				-0.070
Major Mall				-0.021
DFW Airport				0.056
Parks				-0.017
Major Lakes				-0.068
(***Constant:*** coeff.)	0.697***	0.688**	0.660**	0.982*
	N=196	N=196	N=196	N=196
	F(6,189)=14.768	F(7,188)=12.593	F(11,184)=8.321	F(18,177)=5.160
	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000	Prob.>F=.000
	Adj.R^2=.298	Adj.R^2=.294	Adj.R^2=.292	Adj.R^2=.277

* < 0.1 level, ** < 0.05 level, and *** < 0.01 level

Variable Definition:

Dependent Variable: Log of Goods and Services Footprint

Independent Variables: 1. Age; 2. Gender (1=male, 0=female); 3. Race (1=white, 0=non-white); 4. Marital Status (1=married, 0=non-married); 5. Education Years (=educational attainment); 6. Household Income (= 1,000 dollars); 7. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 8. Population Density (= within 3.5 mile buffer); 9. Development Density (= within 3.5 mile buffer. built-up/non built-up); 10. Mixedness (= within 0.25 mile buffer. 4 land-use types); 11. Job/Housing Ratio (= within 5.0 mile buffer); 12. CBD (=nearest distance to CBD); 13. Freeway (=nearest distance to freeways); 14. Light Rail Transit (= nearest distance to LRT); 15. Dallas/Fort Worth Airport (= nearest distance to DFW); 16. Major Malls (= nearest distance to major malls); 17. Parks (= nearest distance to parks); and 18. Major Lakes (= nearest distance to major lakes)

6.6. Summary

This chapter presented the regression analysis results identifying the factors and their impact on the variance in the per capital ecological footprint based on the study hypotheses and objectives. To better understand the effects of the four independent variable groups on the dependent variable, the per capita composite footprint score was broken down into four component scores and then the data was analyzed in two phases.

First, the four independent variable groups, including socioeconomic and demographic, environmental value, land-use patterns, and spatial attribute, were examined against the per capita composite footprint score using four multiple regression models according to the variable groups. Second, the same independent variable groups were analyzed for each of the footprint component scores including the food, mobility, shelter and goods and services footprint. In terms of the mobility footprint, I conducted another regression analysis for the car footprint which factored out the air travel and public transit footprint scores which were supposed to respond differently from the car footprint against each of the independent variable groups.

Based on the regression analyses above, I produced the following summary Table 6.7 using the independent variables that had shown a significant relationship to the dependent variable in each of the models tested. The rank in the table was yielded based on the standardized coefficient (Beta) of each explanatory variable.

Table 6.7. Summary of Regression Results

Per Capita Composite EF			Food Footprint			Mobility Footprint		
Rank	Sign	Variables	Rank	Sign	Variables	Rank	Sign	Variables
1	-	* Population Density	1	-	** Job/Housing Ratio	1	+	*** Household income
2	+	*** Education Years	2	+	*** Major Lakes	2	-	*** Major Malls
3	+	*** Household Income	3	-	* Major Malls	3	+	* DFW Airport
4	-	*** Marital Status (= Married)	4	-	** Environ. Awareness	4	-	** Age
5	+	** Gender (= Male)	5	+	** Freeways			
6	+	* Age						
Car Footprint			Shelter Footprint			Goods and Services Footprint		
Rank	Sign	Variables	Rank	Sign	Variables	Rank	Sign	Variables
1	-	** Population Density	1	+	*** Education Years	1	-	* Population Density
2	-	** Light Rail Transit	2	-	*** Marital Status (= Married)	2	+	*** Education Years
3	-	** Major Malls	3	+	*** Age	3	+	*** Household Income
4	+	** Household Income	4	+	* Development Density	4	-	*** Marital Status (= Married)
5	-	** Environ. Awareness	5	+	* Gender (= Male)	5	+	** Gender (= Male)
6	-	* Age				6	+	* Age

* < 0.1 level, ** < 0.05 level, and *** < 0.01 level

CHAPTER VII

CONCLUSIONS

For a sustainable society, humanity's consumption of renewable natural resources must stay within the limits of the earth's biological capacity over the long term. But there is growing consensus that humanity is immersed in problems beyond its control (Meadows et al., 2004). For example, this concern was echoed in "World Scientists' Warning to Humanity" signed by more than 1,600 scientists from 70 countries, including 102 Nobel laureates:

> Human beings and the natural world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and on critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it will be unable to sustain the life in the manner that we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about (Union of Concerned Scientists, 1992).

While the studies on the size of our ecological impact are well developed, the problem of how to reduce our Ecological Footprint remains largely unresolved. This study addresses this issue by modeling socioeconomic/demographic, environmental value, land use pattern, and spatial effects in the case of Dallas County.

7.1. Summary of Key Findings and Conclusions

This study used Ecological Footprint Account as an indicator of sustainability and provided guidance on how to reduce humanity's ecological burden on the Earth. Specifically, the study addressed the drivers causing the variance in the per capita ecological footprint in Dallas County, Texas. A main hypothesis was that scientifically estimated demography, environmental values, spatial attributes, and land-use patterns surrounding an individual are significant factors in the size of the per capita EF. This study combined a survey methods and GIS routines with multiple regression analysis to address the study primary question: *Which factors affect the per capita Ecological Footprint Account?*

Based on the descriptive analysis of the survey data in Chapter V, this study found mixed results regarding the characteristics of Dallas County's residents. On the positive side, a majority of residents in Dallas County showed a keen awareness of the environmental crises. On the negative, the average person in Dallas County reported an alarming pattern of natural resource consumption that had a much larger environmental impact on the Earth than the average American.

The survey results indicated that the majority of the respondents agreed or strongly agreed that humanity is approaching the limit of population that the Earth can support. More than 70 percent of the respondents agreed or strongly agreed that the balance of nature is very delicate and easily upset. Therefore, they were concerned about humanity's interference with nature because it often produces disastrous consequences. Furthermore, the data revealed that most respondents considered the Earth to be like a spaceship with only limited room and resources. Thus, they believed that there are limits on growth beyond which our industrialized society cannot expand. Particularly, almost 80 percent of the respondents were seriously concerning that humanity is severely abusing the environment. To maintain a healthy environment, more than 60 percent of the respondents supported the idea that we have to develop a steady-state economy where industrial growth is controlled.

Although Dallas County's residents had a strong environmental awareness, the data suggested that their natural resource consumption pattern was a matter of grave concern. For instance, most of the Dallas County populations regularly eat products which require more land, energy, and other resources from harvest to market for processing, packaging and storage. Regarding housing consumption, it was characterized by the descriptive analysis that most of the respondents were living in large free standing houses with a small number of inhabitants (usually one or two people) and with little usage of energy conservation and efficiency measures. In terms of travel behavior, a remarkable number of respondents (more than 90 percent) averaged zero miles per week on public transportation; whereas, a greater part of the respondent used private cars more than the national average vehicle mile traveled (VMT) and spent less driving with someone else. Furthermore, each year a great many of the respondents were spending more hours flying than the national average which is roughly equivalent to one round trip flight between Washington, DC and Chicago. Subsequent to the size of food, shelter and mobility consumption, the descriptive results indicate that the average person in Dallas County shows much higher goods and services consumption than the average person in the United States.

Another important descriptive finding of the study showed that the high consumption lifestyle of Dallas County's residents produced a very large per capita ecological footprint of 26.4 acres as compared to the U.S. and world averages. Of the per capita composite footprint score, 19 percent came from the food component (5.1 acres), 13 percent from mobility (3.3 acres), 31 percent from shelter (8.3 acres), and 37 percent from goods and services (9.8 acres). These figures indicate that the 2,287,288 residents of Dallas County as of 2004 need land approximately 105 times more ecologically productive than the area of the County itself to support their consumption. Specifically, the appropriated biocapacity area by mobility consumption was estimated to be 13 times larger, by food consumption 20 times larger, by shelter consumption 33 times larger, and by goods and services consumption 39 times larger than the total area of Dallas County.

Furthermore, the descriptive analysis revealed that the average personal composite footprint within Dallas County (26.4 acres) was 11 percent higher than that of the average American (about 23.5 acres per person). The range of the footprint score for the County was from 7.9 acres to 78.2 acres. Recently, Redefining Progress (2004) estimated that a globally sustainable ecological footprint is about 4.5 acres per person which is equivalent to the global average of biological capacity per person. If we accept these estimates, all of the residents in Dallas County could be regarded as "unsustainable" in the sense of having a footprint per person greater than the average biological capacity per capita of the Earth. An average Dallas County resident would have to reduce its footprint by 43-94 percent (about 83 percent as whole) to achieve sustainability.

A key finding of the explanatory phase of analysis in Chapter VI was that population density, and more generally the land use pattern surrounding a particular person, was the most powerful factor explaining an individual's ecological impact on the Earth. Based on the regression analysis of the data, this study concluded that a person living a high density area is more likely to have a smaller ecological impact on the Earth than a person living in a low density area. This finding statistically supports what many urban researchers and public policy makers have known for decades: higher population density increases the possibility of sharing public infrastructures and particularly, it provides an opportunity to construct public transportation which decreases automobile dependence. Excitingly enough, the regression analysis results revealed that population density was the strongest factor for predicting not only the personal car footprint but also the goods and services footprint. The higher the population density, the smaller the personal car footprint and goods and services footprint.

Another major finding from the explanatory phase of analysis was that personal socioeconomic and demographic characteristics were significantly powerful in explaining how much an individual depends on nature resources. The amount of formal schooling completed and annual household income had a marked unique influence on the personal ecological impact on the Earth. Interestingly, the multiple regression analysis showed that higher levels of household income and education years correspond with larger ecological impacts. This result confirmed the argument that those with greater personal income consume more energy, space and goods (Williams, 2002). It was also consistent with the results of a carbonprint (and water) study conducted at the city level in Los Angeles County by Venetoulis (2001) who reported that in high-income areas, income tends to be associated with larger ecological impacts as compared to areas with lower levels of economic development. So far, plenty of studies in this arena have demonstrated that people (specifically, women) with high levels of income and education are the most likely to consider environmental protection a priority and demonstrate greater recognition of and concern for environmental problems (Van Liere and Dunlap, 1980; Buttell, 1987; Jones and Dunlap, 1992; Scott and Willets, 1994; Guagano and Markee, 1995; Howell and Laska, 1992; Raudsepp, 2001; Brody et al., 2004). However, no studies have demonstrated whether the level of income and education prompt an individual to embrace an environmentally sustainable life style. Based on the regression analysis results, this study concluded that high household income and more years of formal schooling drive larger personal ecological impacts on the Earth.

Furthermore, results found that the degree of environmental awareness does not play a significant role in explaining the per capita composite footprint score. However, it has made a strongly unique contribution to predicting the component footprint, particularly the individual food and car footprint. This study concluded that a person with a high level of environmental awareness in regard to ecological crises tends to have a more environmentally sensitive lifestyle with less impact on the Earth. When we come to understand that the population of Dallas County has a mobility footprint 13 times larger and a food footprint 20 times larger than the total area of the county, it is vital for local policy makers to realize that the level of environmental awareness is a powerful factor driving personal ecological impacts.

This study also concluded that the per capita footprint significantly varies according to the geographic attribute factors surrounding an individual. For instance, the distance to the major malls appeared to have a negative association with the personal food and mobility footprint (particularly in the car footprint component). In other words, a person living close to the major malls is more likely to have a larger food and mobility footprint than a person living far away. Meanwhile, the distance to the major lakes and freeways had a positive association with the personal food footprint, and the distance to the Dallas/Fort Worth Airport also had a positive association with the personal mobility footprint. In short, the results of this study found that a person living close to major lakes and freeways is more likely to eat foods which are less animal-oriented and more locally grown requiring less energy to produce.

Based on the explanatory phase of the analysis above, the following summary points can be made about the drivers of the variance, not only in the per capita composite footprint but also in each of the personal footprint components:

First, a highly educated, non-married, older male living in a high income household located in a low population density area is more likely to have a larger personal "***composite ecological footprint***" than a less educated, married, young female living in a low income household located in the high population density area.

Second, a person with a weak environmental awareness living where the ratio of employment opportunities (places to work) is worse, and living far from freeways and major lakes but close to major malls, is more likely to have a larger personal "***food footprint***" than a person with a strong environmental awareness located where the ratio of employment opportunities is better, living close to freeways and major lakes but far from major malls.

Third, a younger person living in a high income household located close to major malls but far from Dallas/Fort Worth Airport is more likely to have a larger "***mobility footprint***" than an older age person living in a low income household located close to Dallas/Fort Worth Airport but far from major malls.

Fourth, a younger person with weak environmental awareness living in a high income household located in a low population density area and close to Light Rail Transit stations and major malls is more likely to have a larger "***car footprint***" than an older person with strong environmental awareness living in a low income household located in a high population density area and far from Light Rail Transit stations and major malls.

Fifth, a highly educated non-married older male living in a highly developed area is more likely to have a larger "***shelter footprint***" than a less educated married young female living in a less developed area.

Sixth, a highly educated non-married older male living in a high income household located in a low population density area is more likely to have a larger "goods and services footprint" than a less educated married young female living in a low income household located in a high population density area.

7.2. Policy Implications

7.2.1. General Implications for a Sustainable Dallas County

By modeling the per capita ecological footprint for Dallas County and examining the four sets of independent variables (socioeconomic and demographic, environmental awareness, land-use patterns, and geographic spatial attribute influences,) this study provides key insights into how to effectively reduce the ecological footprint of residents in Dallas County and other areas across the United States. The study could help direct local planning and policy decisions in Dallas County that affect resource use such as sprawl, community vitality, zoning, transportation, environmental regulations, and open space preservation. This dissertation makes significant suggestions for alleviating Dallas County's ecological burden on the Earth as follows:

First, this study could help Dallas County define its sustainability goals in specific and measurable terms. As described in Chapter V, the average per capita footprint of Dallas County is approximately 26.4 global acres which is almost six times larger than the global average of biocapacity per person. To achieve sustainability, an average person would have to reduce his/her footprint about 80 percent. These figures provide local governments and NGOs with a standard for the tangible realization of their sustainability goals. The footprint can help to build consensus to focus on sustainability and provide a meaningful context for decision making.

Second, this research can help Dallas County see where it could make the most effective movement toward sustainability. Of the county's footprint score, 37 percent comes from the goods and services component, 31 percent from shelter, 19 percent from food, and 13 percent from mobility. These figures show not only the major components in producing that footprint, but can enable the County to examine the costs of reducing these factors. Such an examination will help the County determine a direction for reducing its footprint and therefore its overall shadow on the planet.

Third, by creating a footprint map for the County, the study can help Dallas County visually assess its ecological impacts and compare them to the County's actual area. As illustrated in Figure 5.25, Dallas County's footprint was approximately 105 times larger than the area of the County itself. Specifically, the goods and services footprint was 39 times larger, shelter footprint 33 times larger, food footprint 20 times larger, and mobility footprint 13 times larger than the physical area of the County. These figures provide a simple framework for understanding the ecological bottom-line of sustainability. The graphics and figures communicate clearly and offer a useful educational tool for furthering public debate on sustainability and encouraging appropriate action. This study can lead to a greater public understanding of sustainability and also raise awareness of Local Agenda 21 Initiatives for the County.

Fourth, understanding the key drivers of the variance in the personal footprint not only tests important theoretical assumptions about sustainable behaviors, but also encourages more systemic approaches at the community level. The study can help Dallas County create a platform for municipal planning around housing, energy infrastructure, and transportation by encouraging policies that guide private and public decision making toward sustainable choices. For instance, increasing population density could be strategic in reducing the County's environmental impacts knowing that a person living in a high population density area is more likely to have a smaller footprint than a person living in a low population density area once the other socioeconomic and demographic, environmental awareness, and spatial attribute influences are controlled for.

7.2.2. Approaches to Eliminate the Ecological Footprint Deficit

The footprint deficit refers to the amount by which the ecological footprint of a population (e.g., county or region) exceeds the biological capacity of the space available for that population (WWF, 2002). The footprint deficit in Dallas County is huge as mentioned above. A sustainable society requires that humanity's consumption of renewable natural resources must stay within the limits of the Earth's biological capacity over the long term. Based on the understanding of the factors driving the size of the per capita ecological footprint, the local governments in Dallas County can reduce their ecological deficit by addressing at least two issues as follows. Figure 7.1 shows the approaches for eliminating the footprint deficit.

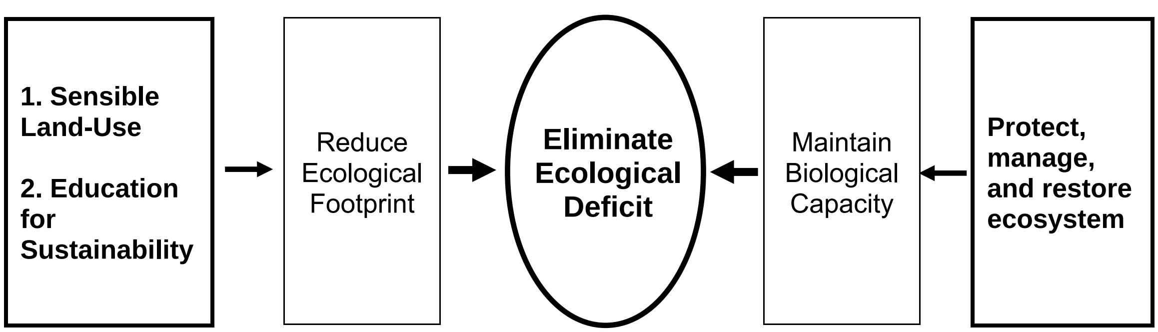


Figure 7.1. Approaches to Eliminate the Ecological Footprint Deficit (Adapted from WWF, 2002)

The remainder of this section sets forth a series of policy recommendations which are based directly on the findings of this research. Overall, two factors were drawn from the data analyses for the sustainability planning initiatives: sensible land-use and education for sustainability. In addition, the Earth's biological capacity can be determined by the health of its ecosystems which can be improved and maintained through good management and conservation (WWF, 2002). However, this research did not involve protecting, managing, and restoring ecosystems, which remain an arena for other sustainable planning research through different approaches.

Ecological Footprint vs. Sensible Land-Use

The most significant finding of this study was that the degree of population density surrounding a particular person is the strongest predictor of the size of the per capita footprint. Regression analysis shows that higher population density is significantly associated with a smaller personal footprint. Other land-use pattern variables, mixedness and job/housing ratio, also act in the predicted direction but with less force, and are not statistically significant. In other words, it appears that a person living in a highly mixed area and a neighborhood with a high ratio of jobs to resident employment is more likely to have a smaller ecological impact than his counterpart. These relationships hold up even when individual socioeconomic and demographic, environmental awareness, and geographic spatial attribute influences are controlled. Therefore, the crucial issue for the local government in Dallas County becomes how to implement a sensible land-use plan to reduce the residents' ecological impacts on the Earth.

A key recommendation derived from the explanatory analysis suggests that planners should target locally efficient land-use planning. For example, sensible land use would make many trips unnecessary by clustering the main places where people want to be within walking distance. This would reduce the personal car footprint and subsequently shrink the individual goods and services footprint. This might be done by encouraging denser population and housing, and more jobs where infrastructure – roads, schools, and commercial facilities – already exists (Venetoulis, 2001). Empirical evidence provided in this dissertation reveals that a person living close to the Light Rail Transit stations and major malls is more likely to have a bigger footprint, particularly in mobility and the goods and services. Therefore, it is also highly recommended that local land-use planners in Dallas County should target those areas as their policy priority. However, many researchers have pointed out that the linkage between land use (urban design) and individual travel behavior (e.g., Crane, 1996; Boarnet and Sarmiento, 1998) is still not well enough understood. It has been suggested that comprehensive market-based incentives need to be provided to change personal behavior.

One leading example of incentives is a Location Efficient Mortgage (LEM) which resulted from a three-year long research program led by three non-profit organizations: the Center for Neighborhood Technology, the Natural Resources Defense Council, and the Surface Transportation Policy Project. The LEM promotes location efficient communities which are neighborhoods where residents can walk from their homes to stores, schools, recreation, and public transportation. Residents of location efficient neighborhoods have less need to drive than people living in less convenient locations, thereby saving money on transportation costs.

The LEM is a mortgage that recognizes the savings available to people who live in location efficient communities. LEM lenders count this available savings as additional income for people buying homes in location-efficient communities. People who might not otherwise qualify for a mortgage can become homeowners with an LEM, and qualified homebuyers can secure larger mortgages than would otherwise be available to them. Aside from increasing a homeowner's buying power, this new mortgage would increase home purchases in a variety of location-efficient communities; boost public transit ridership; support neighborhood consumer services and cultural amenities; reduce energy consumption; and improve local and regional air quality (Location Efficient Mortgage®).

Fannie Mae, the nation's largest source of home mortgage funds, launched a billion-dollar experiment in 1995 to test this scheme; currently it's being expanded nationwide (Hawken et al., 1999) and is available in the metropolitan areas of Chicago, Los Angeles County, San Francisco Bay, and the city of Seattle.[6] Ultimately, it might reduce driving dramatically because studies in three cities have shown that, compared with sprawl, higher urban density reduces driving by up to two-fifths, and proximity to transit by one-fifth (Holtzclaw et al., 2002).

---

[6] For more information see The LEM® webpage at http://www.locationefficiency.com/

Ecological Footprint vs. Education for Sustainability

It has been thought that education is one of the most profound ways to achieve a sustainable society and widely accepted that "ignorance" is the main cause of much of the world's ecological degradation. This position is supported by the Bruntland Commission. In reality, however, it appears to be untrue to the extent that higher education just indicates the years of education attained. According to the results of this dissertation, years of education completed have a strongly positive association with the personal ecological footprint once the other independent variable groups were controlled for. Regression analysis results revealed that the more educated person is more likely to have a bigger footprint than the less educated person, particularly in the shelter and goods and services footprint component. Meanwhile, the results demonstrated that the degree of environmental awareness makes a unique contribution to reducing the personal footprint, e.g. the food and the car footprint component.

The evidence of this dissertation statistically supports the claim that the "ignorant and uneducated" are not primarily to blame for the environmental crisis and instead, the solution to ecological challenges would require reconsideration of the "substance, process, and purpose of education at all levels (Orr, 1994)."

As the first step, the approach to sustainability education should be changed in higher education. Over the last 30 years, the discussion on critical dimensions of sustainability in higher education has continued through the signing of multiple international declarations, the implementation of national programs, and specific initiatives within universities (Clungston and Calder, 1999; Wright, 2003). However, they have mainly focused on developing curriculum, teaching, and training students on the principles of sustainability. While there is no consensus on how best to actually teach sustainability at the university level, one approach called problem-based learning (PBL) has received recent attention (Jucker, 2002; Steinmann, 2003; Warburton, 2003). PBL emerged as a response to criticism that the traditional classroom environment does not provide essential contextual features to enable students to understand and apply information (Schmidt, 1993). In these contexts, student frequently are not active agents in the learning process but are instead passive receptors of knowledge provided by an imposed educational structure. In contrast, PBL is grounded in the notion that learning occurs when students are given problems and situations that represent genuine complexity (Brown et al., 1989). Since authentic tasks mirror reality, they are thought to help students become aware of the relevance of what they are learning. As a result, PBL prepares students to solve real world, interdisciplinary problems associated with sustainability once they leave the classroom environment and become working professionals. Directing students to work through actual sustainable development scenarios (e.g. green building, site and community designs, simulated negotiation, etc.) builds their capacity to address the complex interaction of human decisions and the biophysical environment (Brody and Ryu, 2005).

Most recently, Brody and Ryu (2005) conducted an ecological footprint analysis in an interdisciplinary graduate level course on sustainable development to determine how education can facilitate learning and transform the perceptions and behaviors of class participants. The design and content of the sustainability course was based on the

PBL approach. This course covered a broad range of topics related to sustainable planning and development. Readings and discussions were organized by geographic scales as opposed to media (air, water, waste, etc.) or subject matter (ecology, economics, social equity, etc.). Substantive class sessions were grouped into the following seven spatial study units: global/biosphere, national, institutional/organizations, community, site, building, and household/individual. Findings supported the effectiveness of PBL techniques in teaching the principles of sustainable development and the ability of a single course to change student consumptive patterns in a period of only three months. Specifically, the study found that a PBL-based sustainability class at the graduate level significantly reduced a student's ecological footprint. In terms of which study units in the course on sustainable development may have contributed most to increased learning and behavioral changes, respondents indicated materials on smaller spatial scales (community level and below) were most helpful. Additionally, individual or household scales were ranked the highest for learning about sustainability and altering consumption patterns (Brody and Ryu, 2005).

At the community level, another important issue for the local government of Dallas County becomes how to educate residents to help them become aware of the environmental crises. Local agents could increase the residents' environmental awareness through public participation. *In this context, it is highly recommended that local authorities of Dallas County construct a local Agenda 21 through collaborative work with their residents and adopt the ecological footprint as one of the indicators of local municipalities' sustainability.*

Local Agenda 21, agreed upon during the United Nations Conference Environment and Development (UNCED) in Rio de Janeiro in June 1992, outlined a process for developing local policies and principles for sustainable development and building partnerships between local authorities and communities. Chapter 28 of the Agenda 21 emphasizes local authorities' initiatives in support of Agenda 21 and the adoption of a Local Agenda 21 program in co-operation with citizens, local organizations and enterprises. Local actions are essential since sustainability depends on local priorities and circumstances. Sharing and dissemination of information and expertise is also a vital component of local initiatives (Local Agenda 21 in Helsinki).

The ecological footprint concept provides a simple framework for understanding the ecological bottom-line of sustainability. Putting sustainability in simple and concrete terms helps to build common understanding and set a framework for action (Wackernagel, 1994). Thus, the EF could help communicate the advantages of sustainable development to a community. It could assist understanding of public perceptions of sustainability and raise awareness of Local Agenda 21 Initiatives. It also empowers the people and explains what sustainable development is all about (Barrett, Bestfootforward.com). Worldwide, a growing number of local authorities have conducted an ecological footprint for their local authority area. Examples are Berlin, Germany; Liverpool, UK; London, UK; Manali, India; Santiago, Chile; Sonoma County, USA; Tokyo, Japan; Toronto, Canada; and York, UK.[7] Particularly, the City of Helsinki, Finland, adopted the ecological footprint as one of the indicators in establishing their

[7] For more information see Urban Footprints at http://www.gdrc.org/uem/footprints/index.html

Local Agenda 21. However, so far, no efforts have been reported by local municipalities within Dallas County neither on developing Local agenda 21 or an ecological footprint analysis. It is probable that this exercise, which is a type of learning through involvement, would help Dallas County communities understand the relevance of sustainable development to their individual lifestyle choices.

Another important finding of this dissertation which would affect local policy is that marital status is one of the most significant factors in predicting the per capita footprint. Compared to married people, non-married individuals (e.g., never married (single), divorced and widowed) were significantly more likely to cause serious ecological impacts on the Earth. The effect held over each of the footprint components except the food footprint. Therefore, reducing the divorce rate could be an important sustainability-planning tool for public sector planners to alleviate their residents' ecological impacts. Particularly, it could an essential factor for the city of Dallas to reduce its ecological impacts on the earth because the divorce rate in the region is 50 percent higher than the national average (Professional Researcher's Encyclopaedia, 2004).

In addition to the recommendations listed above, the following policy options are suggested to alleviate Dallas County's ecological impacts on the Earth beyond the descriptive and explanatory results reported in Chapter V and VI. So far, many footprint studies have demonstrated that the single largest component of any ecological footprint on the basis of land area is "energy land" (e.g., Flint, 2001; Crompton et al., 2002). Therefore, one of the most effective policies would be to reduce local reliance on non-renewable energy sources (Redefining Progress, 2004). Local government agencies could:

Mandate developers to build green buildings using recycled materials which are more reliant on renewable energy such as wind and solar. Such buildings are more pleasant and productive places to live, work, and play.

Seek creative ways to finance public transportation, reducing the need for fossil fuel-based transportation and providing alternatives for people who are not able to own or drive cars. As mentioned in Chapter VI, a person living close to major malls had a bigger mobility footprint than a person living far away. Therefore, local government agencies could require major malls to provide shuttle bus systems to cover neighborhood communities and provide business owners with a variety of sales-tax incentives to expand their existing shuttle bus capacity.

Promoting consumption of local products and locally-grown foods as a way to reduce the transportation required for food from more distance locations. This also helps support local farmers and their efforts to maintain small family farms. To achieve this goal, local governments could construct an internet-based shopping mall to foster the direct transaction of locally grown products and foods between producers and consumers. Additionally, local government agencies could allow residents to use public open space for kitchen gardens, which would be effective for residents living close to parks and major lakes throughout the County because the study revealed that a person living close to natural resources was more likely to have a smaller food footprint than a person living far away.

Promoting recycling is always a good policy tool to save natural resources, not only for individuals but also for businesses. For example, the local government could explore ways to help local industries work together and re-use waste products through eco-industrial park development. Such development could reduce costs for participants while resulting in more efficient use of energy and other resources.

Finally, promoting planting is another policy option which local governments could implement to increase the capacity of their forest land. Local governments could require housing developers to use sustainably harvested wood products and recycled content building materials where possible and encourage the re-use of building materials from demolished structures.

7.3. Study Limitations and Future Study

This study has several limitations. Although this study provides a greater understanding of how to develop local environment plans to reduce environmental impacts, it is a primer for research to investigate the topic in Dallas County.

First, the measurement of the per capita ecological footprint for Dallas County residents was very conservative due to the limited number of questions in the survey, "EF Quiz," while capturing many consumption items in a relatively simple quiz. Therefore, depending on the residents' actual lifestyle in the County, the per capita EF could be higher or lower, particularly in the goods and services footprint. Additionally, the quiz did not provide information about land use categories such as cropland and pasture land, built-up land, forest, fish, and carbon assimilating capacity, which are used to support the County's economic activities. Therefore, future study needs to be conducted based on more advanced measurement tools, e.g., Household Ecological Footprint Calculator, for more detailed consumption categories.

Second, in explaining the ecological deficit, this study compared the total ecological footprint of the County with its actual area and graphically illustrated how much the County's residents depend on natural resources which are produced outside the County. Although it provides us with an intuitively overall understanding of the degree of the County's natural resource dependence, we did not have detailed information about the supply side of EF analysis for the County. In other words, we have no information about the size of the County's bio-capacity. Therefore, a future study could use GIS and remote sensing technologies to develop an estimate of Dallas County's ecological capacity. Given an estimated per capita ecological footprint per household member, an approximation of resident carrying capacity deficit or reserve of the region could be obtained.

Third, the future phase of this study should deal with the spatial autocorrelation issue which is a unique autocorrelation problem frequently encountered in spatial research. Spatial autocorrelation is concerned with the degree to which objects at one place on the earth's surface are similar to other objects located nearby. The spatial autocorrelation is very likely present in the EF study because the per capita EF account as a dependent variable is measured as a point value in a certain location throughout Dallas County. As illustrated in Appendix 7-11, income and ethnic groups are clustered in a unique pattern. Overall, the white and high income households reside in the north central parts and outside of the County; however, the non-white and low income households are largely clustered in the south eastern parts and the center of the urban core. It is supposed that personal consumption behavior varies with neighborhood quality. Thus, location might be one of the crucial factors influencing variance in the personal footprint score. If there is a spatial autocorrelation in the footprint data, it would lead to a spatial correlation of residuals in the regression models. The consequences of spatial autocorrelation are the same as those of time series autocorrelations: the (OLS) estimators are unbiased but inefficient, and the estimates of the variance of the estimators are biased (Dubin, 1998). This misleads statistical inference results (Leung, et al. 2000). If spatial autocorrelation is present, it will violate the assumption about the independence of residuals and call into question the validity of hypothesis testing.

Particularly, the spatial autoregressive model (SAR) would help to enhance the low model fit of this study.

Fourth, this study is a cross-sectional research which provides a snapshot of how much Dallas County's residents depend on natural resource to support their lifestyle as of 2004. A future study could conduct a temporal analysis to examine the changes in EFs in response to new policies. In other words, a certain policy impact could be documented in terms of the additional (or reduced) EF that the policy makes necessary.

Finally, future phases of the study should develop more variables in each explanatory variable group and also add additional categories that are not included in this study. In measuring the land-use patterns, a more advanced landscape structure metrics could be utilized such as fragmentation and contagion indices. This study used the degree of development density to describe how much of the residents' surrounding areas are converted into built-up land. However, it could not provide any further information about whether the land-use patterns are fragmented or contiguous surrounding a particular household. Those indices could be a measurement tool to calculate the leapfrog land development pattern.

REFERENCES

Barrett, J., & Scott, A. (2003). The application of the ecological footprint: a case of passenger transport in Merseyside. *Local Environment, 8,* 167-183.

Bernick, M., & Cevero, R. (1997). *Transit villages in the 21st century*. New York: McGraw-Hill.

Best Foot Forward. (2002). *City limits: a resource flow and ecological footprint analysis of Greater London.* (http://www.citylimitslondon.com).

Best Foot Forward. (1999). *Oxfordshire's ecological footprint: a report to Oxfordshire County Council.* (http://www.bestfootforward.com/articles/oxon5.htm).

Bicknell, K. B., Ball, R. J., Cullen, R., & Bigsby, H. R. (1998). New methodology for the ecological footprint with an application to the New Zealand economy. *Ecological Economics, 27,* 149–160.

Boarnet, M. G., & Sarmiento, S. (1998). Can land-use policy really affect travel behavior? A study of the link between non-work travel and land-use characteristics, *Urban Studies, 35,* 1155-1169.

Brody, S. D., Highfield, W., & Alston, L. (2004). Does location matter? Measuring environmental perceptions of creeks in two San Antonio watersheds. *Environment and Behavior, 35*, 1-22.

Brody, S. D., & Ryu, H. C. (2005). Measuring the educational impacts of a graduate course on sustainable development. *Environmental Education Research* (submitted).

Brower, M., & Leon, W. (1999). *The consumers guide to effective environmental choices: practical advice from the Union of Concerned Scientists*. New York: Three Rivers Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognitions and the Culture of Learning. *Educational Researcher, 18*, 32-42.

Brown, L., Flavin, C., & French, H. (1997a). *State of the World*. World Watch Institute. New York: W.W. Norton.

Brown, L., Flavin, C., & French, H. (1997b). *Vital Signs*. World Watch Institute. New York: W.W. Norton.

Burchell, R. W., Shad, N. A., Listokin, D., Phillips, H., Downs, A. et al. (1998). The *costs of sprawl – Revisited.* Transit Cooperative Research PROGRAM Reoprt 39.

Washington, DC: National Academy Press.

Buttell, F. H. (1987). New directions in environmental sociology. *Annual Review of Sociology, 13,* 465-488.

Calthorpe, P. (1993). *The next American metropolis.* New York: Princeton Architectural Press.

Camani, R., Gibelli, M. C., & Rigamonti, P. (2002). Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion. *Ecological Economics, 40,* 1999-216.

Cevero, R. (1996). Jobs/housing balance revisited: trends and impacts in the San Francisco Bay Area. *Journal of the American Planning Association, 62,* 492-511.

Cevero, R. (1989). Jobs/housing balancing and regional mobility. *Journal of the American Planning Association, 55,* 136-150.

Chambers, N., Simmons, C., & Wackernagel, M. (2000). *Sharing nature's interest: ecological footprints as an indicator of sustainability*. London: Earthscan.

Christensen, P. (1998). *Multiple identities, differences in lifestyles and how it affects our ecological footprint.* Paper presented at the Fifth Biennial Meeting International Society for Ecological Economics. November 15-19, 1998, Santiago, Chile.

City of Helsinki. *Local Agenda 21 in Helsinki, Finland.* (http://www.hel.fi/ymk/agenda/eng/index.html).

Clugston, R. M., & Calder, W. (1999). Critical dimensions of sustainability in higher education. In W. L. Filho (Ed.), *Sustainability and University Life*. Peter Lang: New York. (http://www.ulsf.org/pdf/Critical_dimensions_SHE.pdf).

Cohen, J. E. (1995). *How many people can the earth support?* New York: W.W. Norton & Co.

Costanza, R. (2000). The dynamics of the ecological footprint concept. *Ecological Economics, 32,* 341–345.

Crane, R. (1996). Cars and drivers in the new suburbs: linking access to travel in neotraditional planning. *Journal of American Planning Association, 62,* 51-65.

Crompton, S., Roy, R., & Caird, S. (2002). Household ecological footprinting for active distance learning and challenge of personal lifestyles. *International Journal of Sustainability in Higher Education, 3,* 313-323.

Danielsen, K. A., Lang, R. E., & Fulton, W. (1999). Retracting suburbia: smart growth and the future of housing. *Housing Policy Debate*, *10,* 513-540.

Dillman, D. A. (1978). *Mail and telephone surveys: the total design method*. New York: A Wiley-Interscience Publication.

Downs, A. (1998). The costs of sprawl and alternative forms of growth. (http://www1. umn.edu.cts/trg/adowns.html).

Duany, A., Plater-Zyberk, E., & Speck, J. (2000). *Suburban nation: the rise of sprawl and the decline of the American dream*. New York: North Point Press.

Dubin, R. A. (1998). Spatial autocorrelation: a primer. *Journal of Housing Economics, 7,* 304-327.

Easterbrook, G. (1999). Comment on Karen A. Danielsen, Robert E. Lang, and William Fulton's 'Retracting suburbia: smart growth and the future of housing.' *Housing and Policy Debate, 10,* 541-547.

Ewing, R., Pendall, R., & Chen, D. (2003). *Measuring sprawl and its impact.* Smart Growth America. (http://www.smartgrowthamerica.org).

Ewing, R. (1997). Alternative views of sprawl: counterpoint is Los Angeles-style sprawl desirable? *Journal of the American Planning Association, 63*, 107-126.

Ferng, J. J. (2002). Toward a scenario analysis framework for energy footprints. *Ecological Economics, 40,* 53–69.

Ferng, J. J. (2001). Using composition of land multiplier to estimate ecological footprints associated with production activity. *Ecological Economics, 37,* 159–172.

Flint, K. (2001). Institutional ecological footprint analysis: a case study of the University of Newcastle, Australia. *International Journal of Sustainability in Higher Education, 2,* 48-62.

Folke, C., Jasson, A., Larsson, J., & Costanza, R. (1997). Ecosystem appropriation by cities. *Ambio, 26*, 167-172.

Fricker, A. (1998). The ecological footprint of New Zealand as a step towards sustainability. *Futures, 30,* 559-567.

Gallagher, P. (2001). The environmental, social, and cultural impacts of sprawl. *NR&E, Spring,* 219-223.

Goldsmith, W. W. (1999). *Resisting the reality of race: land use and social justice in the metropolis.* Cambridge, Mass.: Lincoln Institute of Land Policy.

Gordon, P., & Richardson, H. W. (2000). Critiquing sprawl's critics. *Cato Policy Analysis 365.*

Gordon, P., & Richardson, H. W. (1997). Are compact cities a desirable planning goals? *Journal of the American Planning Association, 63,* 95-106.

Gordon, P., & Richardson, H. W. (1994). Congestion trends in metropolitan areas. In *Curbing Gridlock: Peak-Period Fees to Relieve Traffic Congestion,* (pp. 1-31). National Research Council. Washington D.C.: National Academy Press.

Guagano, G.A., & Markee, N. (1995). Regional differences in the sociodemographic determinants of environmental concern. *Population and Environment*, *17,* 135-149.

Haberl, H., Erb, K. H., & Krausmann, F. (2001). How to calculate and interpret ecological footprints for long periods of time: the case of Austria 1926–1995. *Ecological Economics*, *38,* 25–45.

Hawken, P., Lovins, A., & Lovins, L. H. (1999). *Natural capitalism: creating the next industrial revolution.* Boston: Back Bay Books.

Hayward, S. (1998). Legends of the sprawl. *Policy Review, 91,* 26-32.

Helling, A. (2002). Transportation, land use, and the impacts of sprawl on poor children and families. In G. D. Squires (Ed.): *Urban sprawl: causes, consequences & policy response,* (pp. 119-139). Washington D.C.: The Urban Institute Press.

Holtzclaw, J., Clear, R., Dittmar, H., Goldstein, D., & Haas, P. (2002). Location efficiency: neighborhood and socio-economic characteristics determine auto ownership and use – studies in Chicago, Los Angeles and San Francisco. *Transportation Planning and Technology, 25,* 1-27.

Howell, S. E., & Laska, S. B. (1992). The changing face of the environmental coalition: a research note. *Environment and Behavior*, *24,* 134-144.

Inglehart, R. (1997). *Modernization and postmodernization: cultural, economic and political change in 43 societies*. Princeton: Princeton University Press.

Inglehart, R. (1990). *Culture shift in advanced industrial society*. Princeton: Princeton University Press.

Johnson, M. P. (2001). Environmental impacts of urban sprawl: a survey of the literature and proposed research agenda. *Environment and Planning A, 33,* 717-735.

Jones, R. E., & Dunlap, R. E. (1992). The social bases of environmental concern: have they changed over time? *Rural Sociology, 57,* 28-47.

Jucker, R. (2002). Sustainability? Never Heard of it! Some basics we shouldn't ignore when engaging in education for sustainability. *International Journal of Sustainability in Higher Education, 3*, 8-18.

Kahn, M. E. (2001). Does sprawl reduce the black/white housing consumption gap? *Housing Policy Debate, 12,* 77-86.

Kempton, W. J. S. B., & Hartley, J. A. (1996). *Environmental values in American culture*. Cambridge: The MIT Press.

Kumar, A., Prasad, D., Hennecke, W., & Plume, J. (2001). Information technology for integrated sustainable urban development: GIS and ecological footprint. *Proceedings of the International Seminar on Urbanization at the Information Age*, organized by the University of Melbourne & Universitas Indonesia at Depok, Jakarta, Indonesia.

Lenzen, M., & Murray, S. A. (2001). A modified ecological footprint method and its application to Australia. *Ecological Economics, 37,* 229-255.

Leung, Y., Mei, C. L., & Zhang, W. X. (2000). Testing for spatial autocorrelation among the residuals of the geographically weighted regression. *Environment and Planning A, 32,* 871-890.

Lewan, L., & Simmons, C. (2001). *The use of ecological footprint and biocapacity analyses as sustainability indicators for sub-national geographical areas: a recommended way forward.* Final report for European Common Indicators Project. EUROCITIES/Ambiente Italia 27th August 2001.

Martinez-Alier, J. (1987). *Ecological economics: energy, environment, and society.* Oxford: Basil Blackwell.

Mauch M., & Taylor, B. D. (1997). Gender, race, and travel behavior: analysis of household-serving travel and commuting in San Francisco Bay Area. *Transportation Research Record, 1607,* 147-153.

Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: the 30-year update*. Vermont: White River Junction.

Mears, D. P., & Ellison, C. G. (2000). Who buys new age materials? Exploring sociodemographic, religious, network, and contextual correlates of new age consumption.

Sociology of Religion, 61, 289-313.

Merkel, J. (2003). *Radical simplicity: small footprints on a finite Earth*. Gabriola Island, Canada: New Society Publishers.

Mills, E. S., & Hamilton, B. W. (1994). *Urban economics* (5th ed.). New York: HarperCollins.

Newman, P. W. G., & Kenworthy, J. R. (1989). Gasoline consumption and cities: a comparison of U.S. cities with a global survey. *Journal of the American Planning Association, 55,* 24-37.

Onisto, L. J., Krause, E., & Wackernagel, M. (1998). *How big is Toronto's ecological footprint?* Toronto, Canada: Centre for Sustainable Studies and the City of Toronto.

Orr, D. (1994). What is education for? Chapter 1 in *Earth in mind: on education, environment, and the human prospect.* Washington, DC: Island Press.

O'Toole, R. (1999). Dense thinking. *Reason, January,* 44-52.

Ottensmann, J. R. (1977). Urban sprawl, land values and the density of development. *Land Economics, 53*, 389-400.

Pallant, J. (2001). *SPSS survival manual: a step by step guide to data analysis using SPSS for Windows (Versions 10 and 11).* Philadelphia: Open University Press.

Parker, P. (1998). An environmental measure of Japan's economic development: the ecological footprint. *Geographiche Zeitschirft, 86,* 106-119.

Peiser, R. B. (1989). Density and urban sprawl. *Land Economics, 65,*193-204.

Professional Researcher's Encyclopaedia. (2004). (http://www.pro-researcher.co.uk /encyclopaedia/english/dallas__texas).

Raudsepp, M. (2001). Some socio-demographic and socio-psychological predictors of environmentalism. *TRAMES*, *5,* 355-367.

Real Estate Research Corporation. (1974). *The costs of urban sprawl: detailed cost analysis*. Washington, DC: U.S. Government Printing Office.

Redefining Progress. (2004). *Ecological footprint of nations*. (http://www.Redefining Progress.org).

Redefining Progress. (2002). Ecological footprint quiz. (http://www.myfootprint.org/).

Rees, W. E. (2003). Impending sustainability? The ecological footprint of higher education. *Planning for Higher Education, 31,* 88-98.

Rees, W. E., & Wackernagel, M. (1996). Urban ecological footprints: why cites cannot be sustainable – and why they are a key to sustainability. *Environmental Impact Assessment Review, 16,* 223-248.

Richmond, H. R. (1995). *Regionalism: Chicago as an American region.* Chicago, IL: John D. and Catherine T. MacArthur Foundation.

Ross, C. L., & Dunning, A. E. (1997). *Land use transportation interaction: an examination of the 1995 NPTS Data.* U.S. Department of Transportation. Federal Highway Administration. (http://cta.ed.ornl.gov/npts/1995/doc/publication/landuse3.pdf).

Ryu, H. C., & Brody, S. D. (2005). Can higher education influence sustainable behavior? - examining the impacts of a graduate course on sustainable development using ecological footprint analysis. *International Journal of Sustainability in Higher Education* (submitted).

Scheaffer, R. L., Mendenhall III, W., & Ott, R. L. (1996). *Elementary survey sampling* (5th ed.). Duxbury Press.

Schmidt, H. G. (1993). Foundation of problem-based learning: some explanatory notes. *Medical Education, 27,* 422-432.

Scott, D., & Willets, F. K. (1994). Environmental attitudes and behavior. *Environment and Behavior, 26,* 239-261.

Shin, S. Y. (2002). *Spatial dimensions of workplaces and the effects on commuting: the case of metropolitan Dallas-Fort Worth*. Ph.D. Dissertation, Texas A&M University.

Sierra Club. (2000). *Sprawl costs us all: how you taxes fuel suburban sprawl.* San Francisco: Sierra Club.

Sierra Club. (1999). *Sierra Club sprawl report*. (http://www.sierraclub.org/sprawl/report99).

Simmons, C. (2002). *Executive five cites footprint: estimating the ecological footprint of Aberdeen, Dundee, Edinburgh, Glasgow & Inverness*. Best Foot Forward. (http://www.bestfootforward.com).

Simmons, C., & Lewis, K. (2000). *Two feet-two approaches: a component-based model of ecological footprinting*, Best Foot Forward. (http://www.bestfootforward.com/articles/twofeet.htm).

Simmons, C., & Chambers, N. (1998). Footprinting UK households: how big is your ecological garden? *Local Environment, 3,* 355-362.

Snyder, G. (1990). *The practice of the wild.* San Francisco: North Point Press.

Speir, C., & Stephenson, K. (2002). Does sprawl cost us all? Isolating the effects of housing patterns on public water and sewer costs. *Journal of American Planning Association, 68,* 56-70.

Squires, G. D. (2002). Urban sprawl and the uneven development of metropolitan America. In G. D. Squires (Ed.), *Urban sprawl: causes, consequences & policy response*. Washington, DC: The Urban Institute Press.

Steinemann, A. (2003). Implementing sustainable development through problem-based learning: pedagogy and practice. *Journal of Professional Issues in Engineering Education and Practice, 129,* 216-224.

Sustainable Sonoma County and Redefining Progress. (2002). *Report on the Sonoma County: Ecological footprint project.*

The Golbal Development Research Center. (2005). Urban and ecological footprint. (http://www.gdrc.org/uem/footprints/index.html).

The Institute for Location Efficiency. (2002). Location efficient mortgage®. (http://www.locationefficiency.com/).

The University of Texas, Dallas. (2003). Project three demographic analysis of DFW Texas USA. (http:// http://www.utdallas.edu/~clr022000/maps/Demographic.htm).

Třebický, V. (2000). *Ecological footprint: An aggregate indicator of resource consumption and waste assimilation*.(http://www.ecsd.vsb.cz/DOCs/Ecol_footprint.doc).

UCS (Union of Concerned Scientists). (1992). *World scientists' warning to humanity.* (http://www.ucsusa.org/ucs/about/page.cfm?pageID=1009).

UNDP (United Nations Development Program). (1994). *Annual human development report.* New York: Oxford University Press.

Vadali, S. R., & Sohn, C. (2001). Using a geographic information system to tract changes in spatially segregated location premiums: alternative method for assessing residential land use impact of transportation projects. *Transportation Research Record, 1768,* 180-192.

Van den, B., Jeroen, C. J. M., & Verbruggen, H. (1999). Spatial sustainability, trade and indicators: an evaluation of the ‘ecological footprint.’ *Ecological Economics, 29,* 61–72.

Van Liere, K. D., & Dunlap, R. E. (1980). The social bases of environmental concern: a review of hypotheses, explanations and empirical evidence. *Public Opinion Quarterly, 44,* 181-197.

Van Vuuren, D. P., & Smeets, E. M. W. (2000). Ecological footprints of Benin, Bhutan, Costa Rica and the Netherlands. *Ecological Economics, 34,* 115–130.

Venetoulis, J. (2001). *Consuming the earth: Money, values, land use, & ecological footprints in Los Angeles*. Ph. D. Dissertation, Claremont Graduate University.

Warburton, K. (2003). Deep learning and education for sustainability. *International Journal of Sustainability in Higher Education, 4,* 44-56.

Wackernagel, M., Monfreda, C., & Deumling, D. (2002). *Ecological footprint of nations: how much nature do they use? How much nature do they have?* Redefining Progress. (http://www.redefiningprogress.org/publications/ef1999.pdf).

Wackernagel, M., & Yount, J. D. (2000). Footprints for sustainability: the next steps. *Environment, Development and Sustainability, 2,* 21-43.

Wackernagel, M., Lewan, L., & Hansson, C. B. (1999a). Evaluation the use of natural capital with the ecological footprint: applications in Sweden and subregions. *AMBIO, 28,* 604-612.

Wackernagel, M., Onisto, L., Bello, P., Linares, A. C., Falfán, I. S. L. et al. (1999b), National natural capital accounting with the ecological footprint concept. *Ecological Economics, 29,* 375-390.

Wackernagel, M., & Yount, J. D. (1998). The ecological footprint: an indicator of progress toward regional sustainability. *Environmental Monitoring and Assessment, 51,* 511-529.

Wackernagel, M., Onisto, L., Bello, P., Linares, A. C., Falfán, I. S. L. et al. et al. (1997). *Ecological footprint of nations: how much nature do they use? How much nature do they have?* (http://www.ecouncil.ac.cr/rio/focus/report/ english/footprint).

Wackernagel, M., & Rees, W. (1996). *Our ecological footprint: reducing human impact on the earth*. Gabriola Island, Canada: New Society Publishers.

Wackernagel, M. (1994). *Ecological footprint and appropriated carrying capacity: a tool for planning toward sustainability*. Ph.D. Dissertation, The University of British Columbia.

Wackernagel, M., McIntosh, J., Rees, W. E., & Woollard, B. (1993). *How big is our ecological footprint? A handbook for estimating a community's appropriated carrying capacity*. Draft. The UBC Task Force on Healthy and Sustainable Communities, The University of British Columbia.

WCED (World Commission on Environment and Development). (1987). *Our Common Future.* New York: Oxford University Press.

Wilhelmsson, M. (2000). The impact of traffic noise on the values of single-family houses. *Journal of Environmental Planning and Management, 43,* 799-815.

Williams, J. (2002). Shared living: reducing the ecological footprint of individuals in Britain. *Journal of Planning Literature, 17,* 262-331.

Wilson, J. (2001). *The Alberta GPI accounts: ecological footprint*. Report #28. The Pem bina Institute.

Wolfe, V. L. (2001). A survey of the environmental education of students in non-environmental majors at four-year institutions in the USA. *International Journal of Sustainability in Higher Education, 2,* 301-315.

Wooldridge, J. M. (2000). *Introductory econometrics: a modern approach*. South-Western College Publishing.

WRI (World Resources Institute). (1996). *World resources 1996-1997.* World Resources Institute, UNEP, UNDP, The World Bank, Washington D.C.

Wright, J. (2003). Introducing sustainability into the architecture curriculum in the United States. *International Journal of Sustainability in Higher Education, 4,* 100-105.

WWF (World Wildlife Fund). (2002). *Living planet report 2002*.

Yeh, A. G., & Li, X. (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. *Photogrammetric Engineering & Remote Sensing, 67*, 83-90.

APPENDIX

Appendix 1. Institutional Review Board (IRB) Approval Letter

VPR Office of the Vice President for Research

Date March 22, 2004

MEMORANDUM

TO:	Hyung-Cheal Ryu LAUP MS 3137
FROM:	Dr. E. Murl Bailey, CIP, Advisor Institutional Review Board MS 1112
SUBJECT:	IRB Protocol Review

Title: "Ecological Footprint Analysis in the Case of Dallas County, Texas"

Protocol Number: 2003-0428
Review Category: Exempt from Full Review
Approval Date: March 22, 2004 **to** March 21, 2005

The approval determination was based on the following Code of Federal Regulations http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm

________	**46.101(b)(1)**	________	**46.101(b)(4)**
✓	**46.101(b)(2)**	________	**46.101(b)(5)**
________	**46.101(b)(3)**	________	**46.101(b)(6)**

Remarks:

Amendment to decrease participants, change date of survey, include financial incentive for participants, and include information in questionnaire has been approved.

The Institutional Review Board – Human Subjects in Research, Texas A&M University has reviewed and approved the above referenced protocol. Your study has been approved for one year. As the principal investigator of this study, you assume the following responsibilities:

Renewal: Your protocol must be re-approved each year in order to continue the research. You must also complete the proper renewal forms in order to continue the study after the initial approval period.

Adverse events: Any adverse events or reactions must be reported to the IRB immediately.

Amendments: Any changes to the protocol, such as procedures, consent/assent forms, addition of subjects, or study design must be reported to and approved by the IRB.

Informed Consent/Assent: All subjects should be given a copy of the consent document approved by the IRB for use in your study.

Completion: When the study is complete, you must notify the IRB office and complete the required forms.

fice of Research Compliance
Administration and Special Programs
Academy for Advanced Telecommunication and Learning Technologies
Institute for Scientific Computation
Laboratory Animal Resources and Research
Microscopy and Imaging Center
Office of Business Administration
Office of Graduate Studies
Office of Sponsored Projects
Texas A&M University Research Park

Texas A&M University
1112 TAMU
Administration Building
College Station, Texas
77843-1112

Appendix 2. Mail Survey Cover Letter

Information Sheet

Title of Study: Ecological Footprint Analysis in the Case of Dallas County, TX

You have been asked to participate in a research study to investigate personal consumption behaviors. You were selected to be a possible participant because you live in Dallas County, TX. A total of 800 people have been asked to participate in this study, which is designed to identify major factors influencing consumption behaviors.

If you agree to be in this study, you will be asked to answer some questions about your consumption behaviors associated with food, goods, shelter, mobility, and environmental attitudes. You will also be asked about your basic socio-economic and demographic background. It will only take 10–15 minutes to answer these questions. The questionnaire poses no physical or psychological risk to you.

This study will provide $50 to four respondents randomly selected from the participants who complete all of the questions asked in the questionnaire. A summary of the results will be sent to you if you are interested it. Additionally, research results will broadly contribute to the scientific understanding of environmental planning to achieve an environmentally sound and sustainable society.

Since this study will be treated confidentially, the replies will be coded into a database for statistical analysis and data will be reported at an aggregated level. There will be no problem relating to anonymity. The records will be stored securely and only Hyung-Cheal Ryu will have access to them.

Your decision whether or not to participate will not affect your current or future relations with Texas A&M University, including the Department of Landscape Architecture and Urban Planning. If you decide to participate, you are free to refuse to answer any of the questions that may make you uncomfortable. You can withdraw at any time without your relations with the university, job, benefits, etc., being affected.

For any questions about this study, you can contact Hyung-Cheal Ryu at 979-862-3945 or at hryu@tamu.edu and Dr. Samuel D. Brody at 979-458-4623 or at sbrody@archone.tamu.edu.

This research study has been reviewed by the Institutional Review Board- Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, you can contact the institutional Review Board through Dr. Michael W. Buckley, Director of Research Compliance, Office of Vice President for Research at (979) 845-8585 (mwbuckley@tamu.edu).

After reading the above information and having any questions answered to your satisfaction, please keep a copy of this information sheet for your records. By filling out this questionnaire, you consent to participate in this study.

Sincerely,

Ryu Hyung Cheal

Hyung-Cheal Ryu, Ph.D. Candidate
Principal Investigator

Date: 3/23/04

Approved by
Texas A&M University IRB
MAR 2 2 2004
Expires 3-21-05
Protocol # 2003-0428

Appendix 3. Ecological Footprint Survey Instrument

Individual Ecological Footprint in Dallas County

"Ecological Footprint" is an indicator which shows how much humans depend on natural resources. This survey helps to provide a better understanding of how much Dallas County residents impact the Earth. Your answers will remain anonymous and your input will help to achieve an environmentally sound and sustainable society. ***Please***, answer ***ALL*** of the questions and try to ***return this survey within 7 days***.

Hyung-Cheal Ryu, Ph.D. Candidate
Texas Transportation Institute, Room 401B
Texas A&M University 3135 TAMU College Station, TX 77843-3135
Phone: (979) 862-3945 **Project No.: EF______**
Email: hryu@neo.tamu.edu

Any person, 18 years old or older, can fill the questionnaire out, whether s/he is the homeowner, his/her spouse, or a renter.

Food Footprint:

1. How often do you eat animal based products? (e.g., Beef, pork, chicken, fish, eggs, dairy products)
① Never (vegan)
② Infrequently (no meat, and eggs/dairy a few times a week) (strict vegetarian)
③ Occasionally (no meat or occasional meat, but eggs/dairy almost daily)
④ Often (meat once or twice a week)
⑤ Very often (meat daily)
⑥ Almost always (meat and eggs/dairy at almost every meal)

2. How much of the food that you eat is processed, packaged and not locally grown (from more than 200 miles away)?
Note: Please, see the "map 1" provided.

① Most of the food I eat is processed, packaged, and from far away
② Three quarters
③ Half
④ One quarter
⑤ Very little. Most of the food I eat is unprocessed, unpackaged and locally grown.

Goods Footprint:

3. Compared to people in your neighborhood, how much waste do you generate (e.g., newspapers, packaging, cans, bottles, plastic containers, and motor oils, etc.)?
① Much less ② About the same ③ Much more

Shelter Footprint:

4. How many people live in your household?
① 1 person ② 2 people ③ 3 people ④ 4 people
⑤ 5 people ⑥ 6 people ⑦ 7 people ⑧ or more people (_____ people)

5. What is the size of your home?
① 2500 square feet or larger ② 1900-2500 square feet
③ 1500-1900 square feet ④ 1000 -1500 square feet
⑤ 500-1000 square feet ⑥ 500 square feet or smaller

Appendix 3. (continued)

6. Which housing type best describes your home?
① Free standing house without running water
② Free standing house with running water
③ Multi-story apartment building
④ Row house or building with 2-4 housing units
⑤ Green-design residence

7. Do you have electricity in your home?
① No ② Yes ③ Yes, with energy conservation and efficiency

Mobility Footprint:

8. On average, how far do you travel on ***public transportation*** each week (bus, train, and subway)?
① 200 miles or more ② 75-200 miles ③ 25-75 miles
④ 1-25 miles ⑤ 0 miles

9. On average, how far do you go by ***motorbike*** each week (as a driver or passenger)?
① 200 miles or more ② 75-200 miles ③ 25-75 miles
④ 1-25 miles ⑤ 0 miles

10. On average, how far do you go by ***car*** each week (as a driver or passenger)?
Note: The average car-driving American travels about 14,000 vehicle miles per year, or 270 miles per week.
① 400 miles or more ② 300-400 miles ③ 200-300 miles
④ 100-200 miles ⑤ 10-100 miles ⑥ 0-10 miles

11. Do you bicycle, walk, or use animal power to get around?
① Most of the time ② Sometimes ③ Seldom

12. Approximately how many hours do you spend flying each year?
Note: Every year, Americans fly an average of 4.7 hours per person on commercial airline. This is roughly equivalent to one round trip flight between Washington, DC and Chicago each year.
① 100 hours (approximately 1 coast-to-coast U.S. roundtrip *Each Month*)
② 25 hours (approximately 2-3 coast-to-coast U.S. roundtrip *Each Year*)
③ 10 hours (approximately 1 coast-to-coast U.S. roundtrip *per Year*)
④ 3 hours ⑤ Never fly

13. How many miles per gallon (MPG) does your ***motorbike*** get?
Note: If you do not own a motorbike, do not answer this question.
① More than 80 miles per gallon ② 65 - 80 miles per gallon
③ 45-65 miles per gallon ④ 30-45 miles per gallon ⑤ less than 30 miles per gallon

14. How often do you ride your motorbike with someone else, rather than alone?
Note: If you do not own a motorbike, do not answer this question.
① Almost never ② Occasionally (about 25%) ③ Often (about 50%)
④ Very often (about 75%) ⑤ Almost always

15. How many miles per gallon (MPG) does your ***car*** get?
Note: The average U.S. resident is "15-25 mpg". If you do not own a car, estimate the average fuel efficiency of the cars you ride in.
① More than 50 miles per gallon ② 35-50 miles per gallon
③ 25-35 miles per gallon ④ 15-25 miles per gallon
⑤ Fewer than 15 miles per gallon

Appendix 3. (continued)

16. How often do you drive in a car with someone else, rather than alone?
① Almost never ② Occasionally (about 25%) ③ Often (about 50%)
④ Very often (about 75%) ⑤ Almost always

Environmental Values and Attitudes:

Note: *For each statement, please indicate whether you strongly agree, agree, disagree, strongly disagree, or have no opinion.*

17. We are approaching the limit of the number of people that the Earth can support.
① Strongly agree ② Agree ③ Disagree
④ Strongly disagree ⑤ No opinion

18. The balance of nature is very delicate and easily upset.
① Strongly agree ② Agree ③ Disagree
④ Strongly disagree ⑤ No opinion

19. When humans interfere with nature, it often produces disastrous consequences.
① Strongly agree ② Agree ③ Disagree
④ Strongly disagree ⑤ No opinion

20. The earth is like a spaceship with only limited room and resources.
① Strongly agree ② Agree ③ Disagree
④ Strongly disagree ⑤ No opinion

21. There are limits on growth beyond which our industrialized society cannot expand.
① Strongly agree ② Agree ③ Disagree
④ Strongly disagree ⑤ No opinion

22. Mankind is severely abusing the environment.
① Strongly agree ② Agree ③ Disagree
④ Strongly disagree ⑤ No opinion

23. To maintain a healthy environment we will have to develop a steady-state economy where industrial growth is controlled.
① Strongly agree ② Agree ③ Disagree
④ Strongly disagree ⑤ No opinion

Background Information:

24. How would you describe the area where you live? Urban ______ Rural ______

25. How many years have you lived in your current residence? ______ Years _____ Months

26. Please indicate your:

a. Occupation: ____

b. Age: ______ Years **c. Gender:** Male ____ Female____

d. Ethnic/Racial identity:
① African American ② Caucasian ③ Hispanic
④ Asian/Pacific Islander ⑤ Other (   )

Appendix 3. (continued)

27. Please, indicate the number of people in each age category currently living with you in your family (***including yourself***):

a. Under 6 years old: ____ People **b**. Between 6 and 16 years old: ____ People
c. Between 16 and 64 years old: ____ People **d**. 65 years old and over: ____ People

28. Total number of "Males: _______" and "Females: _______" in your family (***including yourself***).

29. Your highest level of education obtained:
① Less than high school ② High school/ GED ③ Some college/ vocational school
④ College graduate ⑤ Graduate/ professional school

30. Your marital status:
① Married ② Single (Never married) ③ Divorced ④ Widowed

31. *If you married*, are you and your spouse both working (a dual-income family)? Yes___ No___

32. What do you estimate the one-way distance, ***in miles***, from your home to your work? ____ Miles
Note: Please, see the "map 2" provided.

33. On average, how many minutes does it take you to travel to work? _____ Minutes

34. Please, enter your 5 digit ***Workplace***'s zip code: __ __ __ __ __ and your spouse's zip code for workplace if he/she is working: __ __ __ __ __ (Ex.: 77840)

35. ***Approximately,*** what do you estimate the one-way distance, ***in miles***, from your home to each of the followings that are ***most frequently*** used?

Note: Please, see the "map 2" provided.

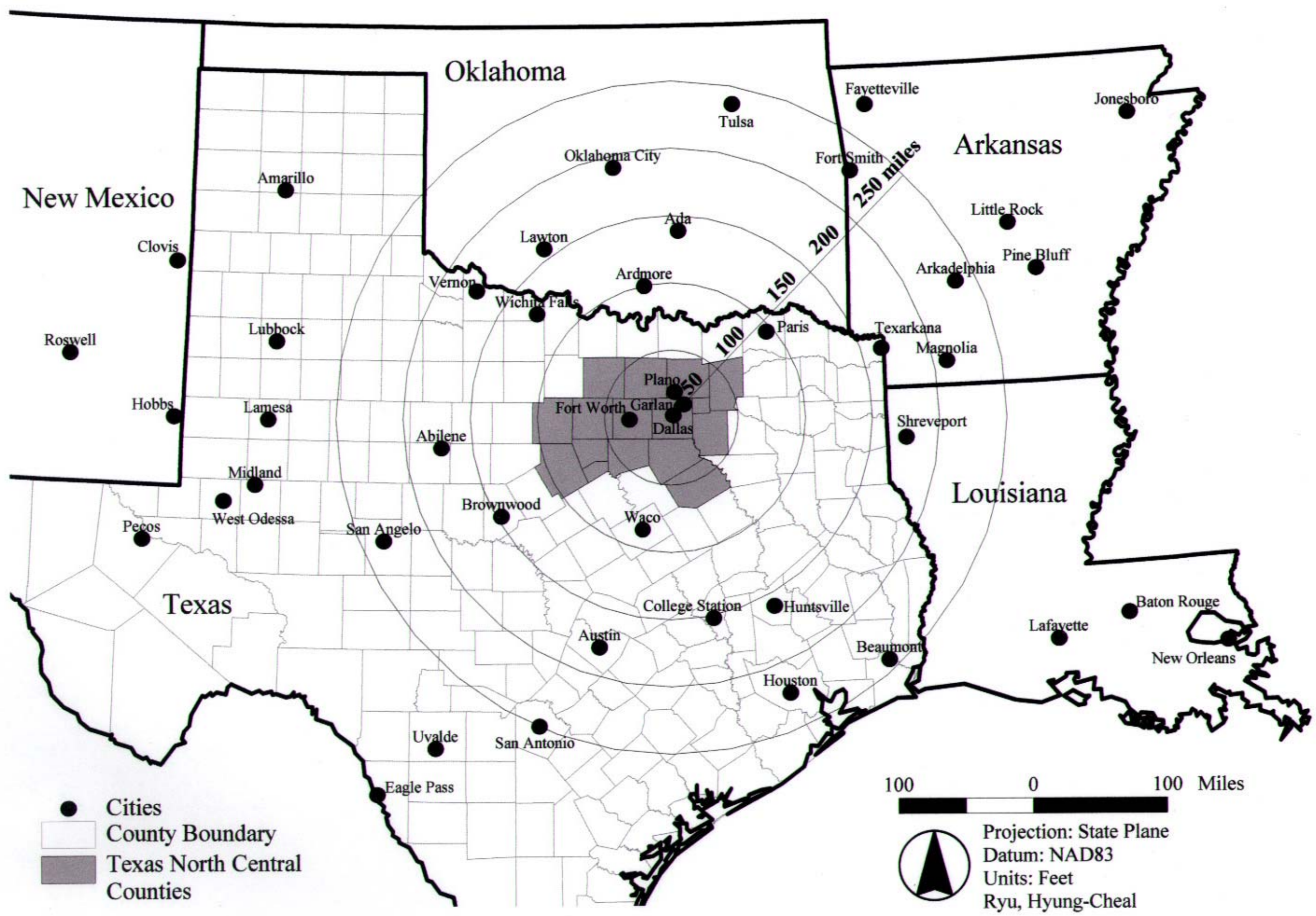
① Grocery Market: ____ miles ② Major Shopping Mall: ____ miles
③ Elementary School: ____ miles ④ Bank: ____ miles ⑤ Post Office: ____ miles
⑥ Hospital: _____ miles ⑦ Nearest Park: ____ miles

36. Your yearly household income before taxes last year:
① Less than $14,000 ② $14,000 - $23,999 ③ $24,000 - $ 34,999
④ $35,000 - $ 49,999 ⑤ $50,000 - $ 69,999 ⑥ $70,000 - $ 100,000
⑦ Over $100,000

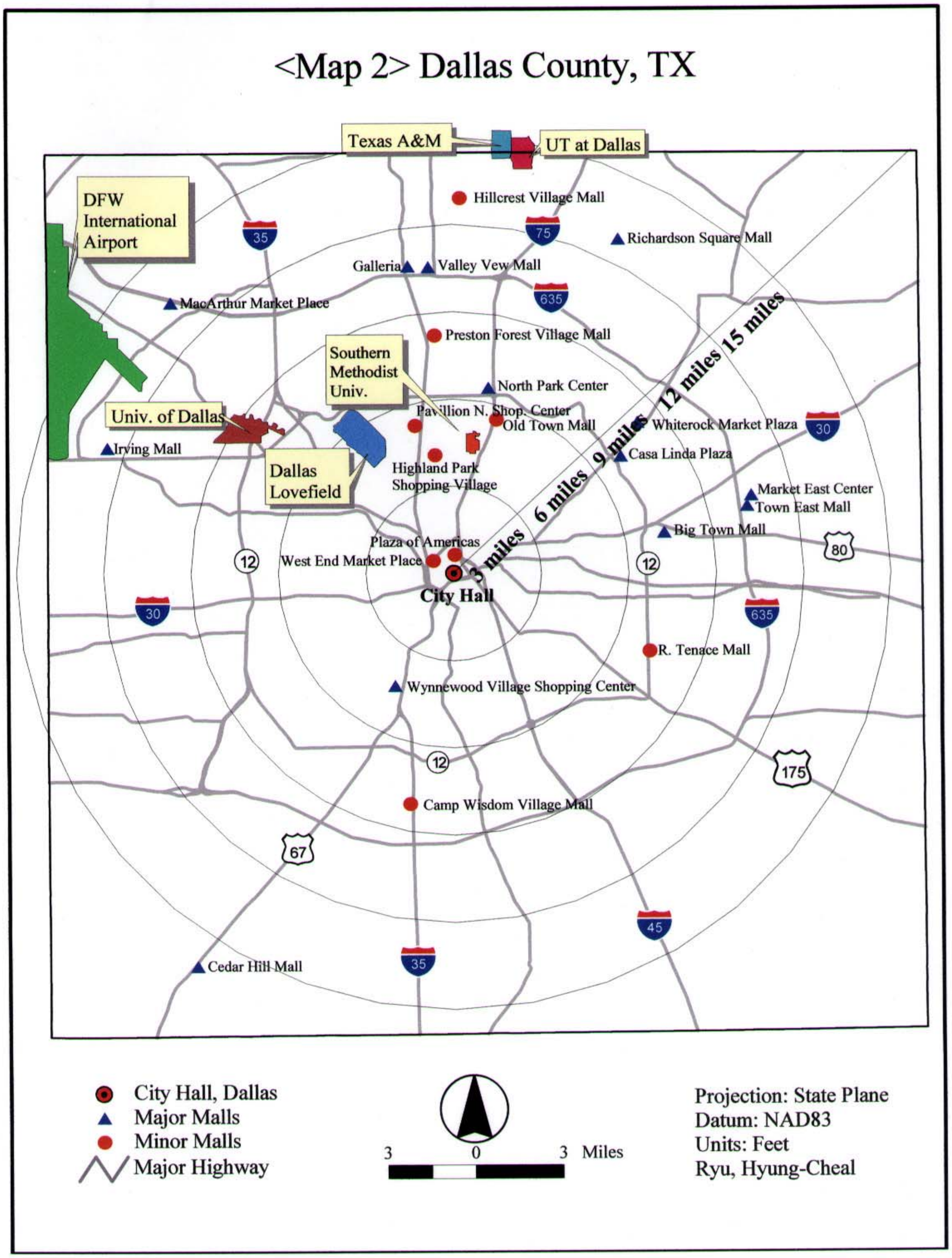
Thank you for your participation. Your answer will be treated confidentially.
Please, return your completed questionnaire within 7 days in the pre-addressed, postage-paid envelope provided.

Appendix 3. (continued)

<Map 1> Distribution of Major Cities surrounding Dallas County, TX



Appendix 3. (continued)



<Map 2> Dallas County, TX

Appendix 4. The Sample Distribution by ZIP Code

ID	ZIP code	Housing Type				Sub total	ID	ZIP code	Housing Type				Sub total	ID	ZIP code	Housing Type				Sub total
		111	121	131	221				111	121	131	221				111	121	131	221	
1	**75001**	2	0	1	0	3	27	**75137**	8	0	0	0	8	53	**75220**	7	0	1	0	8
2	**75006**	13	2	1	1	17	28	**75141**	1	0	0	0	1	54	**75223**	5	0	0	1	6
3	**75019**	15	0	0	1	16	29	**75146**	6	0	0	0	6	55	**75224**	10	0	0	0	10
4	**75038**	2	1	1	0	4	30	**75149**	23	0	0	1	24	56	**75225**	9	0	2	0	11
5	**75040**	23	0	0	1	24	31	**75150**	19	0	0	1	20	57	**75227**	17	0	0	1	18
6	**75041**	11	0	0	0	11	32	**75154**	3	0	0	0	3	58	**75228**	21	0	1	0	22
7	**75042**	12	0	0	0	12	33	**75159**	4	0	0	0	4	59	**75229**	13	0	0	1	14
8	**75043**	19	1	2	0	22	34	**75172**	1	0	0	0	1	60	**75230**	9	1	3	1	14
9	**75044**	16	1	0	0	17	35	**75180**	7	0	0	0	7	61	**75231**	4	0	4	0	8
10	**75048**	5	0	0	0	5	36	**75181**	8	0	0	0	8	62	**75232**	12	0	0	0	12
11	**75050**	10	0	0	0	10	37	**75201**	0	0	1	0	1	63	**75233**	4	0	0	0	4
12	**75051**	9	0	1	0	10	38	**75203**	4	0	0	0	4	64	**75234**	11	0	1	0	12
13	**75052**	25	1	0	1	27	39	**75204**	2	1	2	0	5	65	**75235**	3	0	1	0	4
14	**75060**	14	0	0	1	15	40	**75205**	7	0	2	1	10	66	**75236**	2	0	0	0	2
15	**75061**	11	0	1	0	12	41	**75206**	6	0	3	2	11	67	**75237**	1	0	0	0	1
16	**75062**	12	0	1	0	13	42	**75208**	10	0	0	1	11	68	**75238**	10	0	0	0	10
17	**75063**	7	0	0	0	7	43	**75209**	7	0	1	0	8	69	**75240**	3	1	1	0	5
18	**75080**	14	0	1	0	15	44	**75210**	3	0	0	0	3	70	**75241**	10	0	0	0	10
19	**75081**	13	0	1	0	14	45	**75211**	19	0	0	1	20	71	**75243**	8	1	5	0	14
20	**75082**	1	0	0	0	1	46	**75212**	8	0	0	0	8	72	**75244**	4	0	0	0	4
21	**75088**	12	0	0	0	12	47	**75214**	14	0	1	2	17	73	**75248**	12	0	3	0	15
22	**75089**	12	0	0	0	12	48	**75215**	7	0	0	1	8	74	**75249**	4	0	0	0	4
23	**75104**	17	0	0	1	18	49	**75216**	22	0	0	0	22	75	**75253**	3	0	0	0	3
24	**75115**	17	0	0	1	18	50	**75217**	26	0	0	0	26	76	**75254**	2	0	2	0	4
25	**75116**	7	0	0	0	7	51	**75218**	11	0	0	1	12		**Subtotal (%)**	**715** (89.4)	**11** (1.4)	**50** (6.3)	**24** (3.0)	**800** (100)
26	**75134**	5	0	0	1	6	52	**75219**	1	1	6	1	9							
															Total	800				

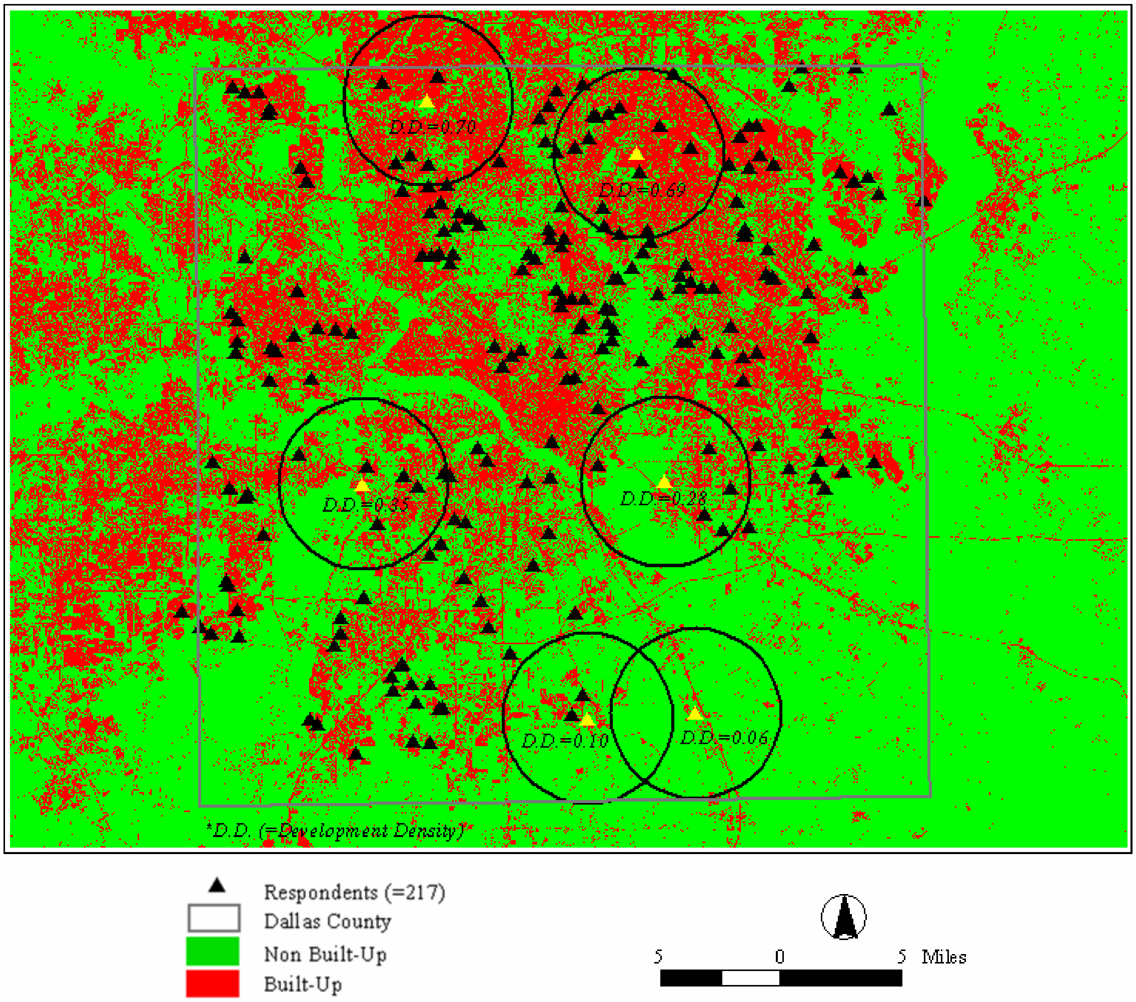
Note: Housing Type Code
111: Single Family Residences (SFR) **121:** SFR Townhouses **131:** SFR condominiums
211: Multi Family Residences Apartments (i.e., small apartments, fourplex or more) **221:** MFR duplexes

Appendix 5: Band Wavelengths and Ground Resolution of ETM+ NLAPS Image

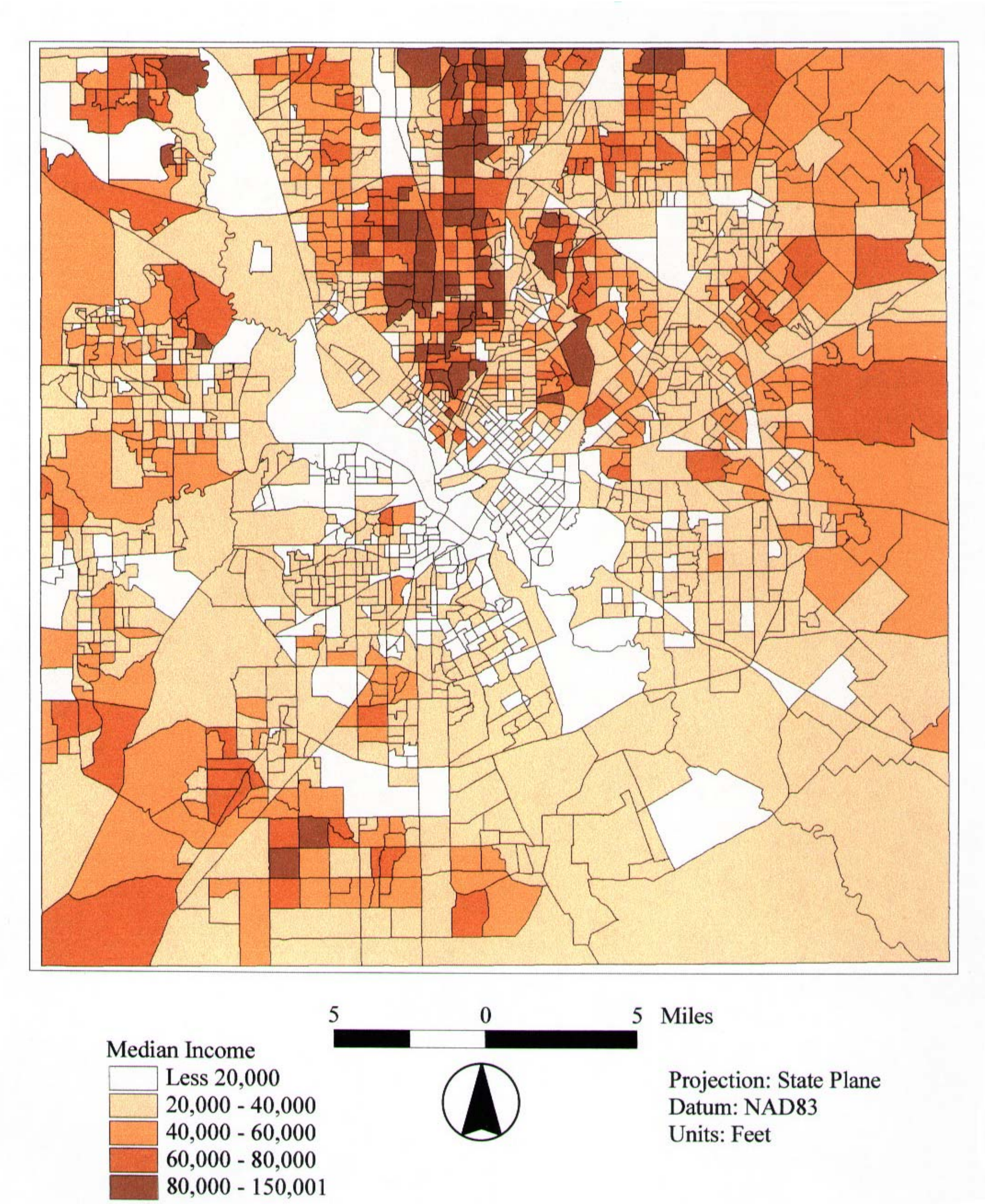
Band Number	Band Type	Spectral Range (microns)	Ground Resolution (meters)
B1	Visible Blue	0.45 – 0.52	30
B2	Visible Green	0.52 – 0.61	30
B3	Visible Red	0.63 – 0.69	30
B4	Near Infrared (IR)	0.75 – 0.90	30
B5	Mid IR	1.55 – 1.75	30
B6	Thermal IR	10.40 – 12.50	60
B7	Mid IR	2.09 – 2.35	30
B8	Panchromatic	0.52 – 0.90	15

(USGS: http://edc.usgs.gov/products/satellite/band.html)

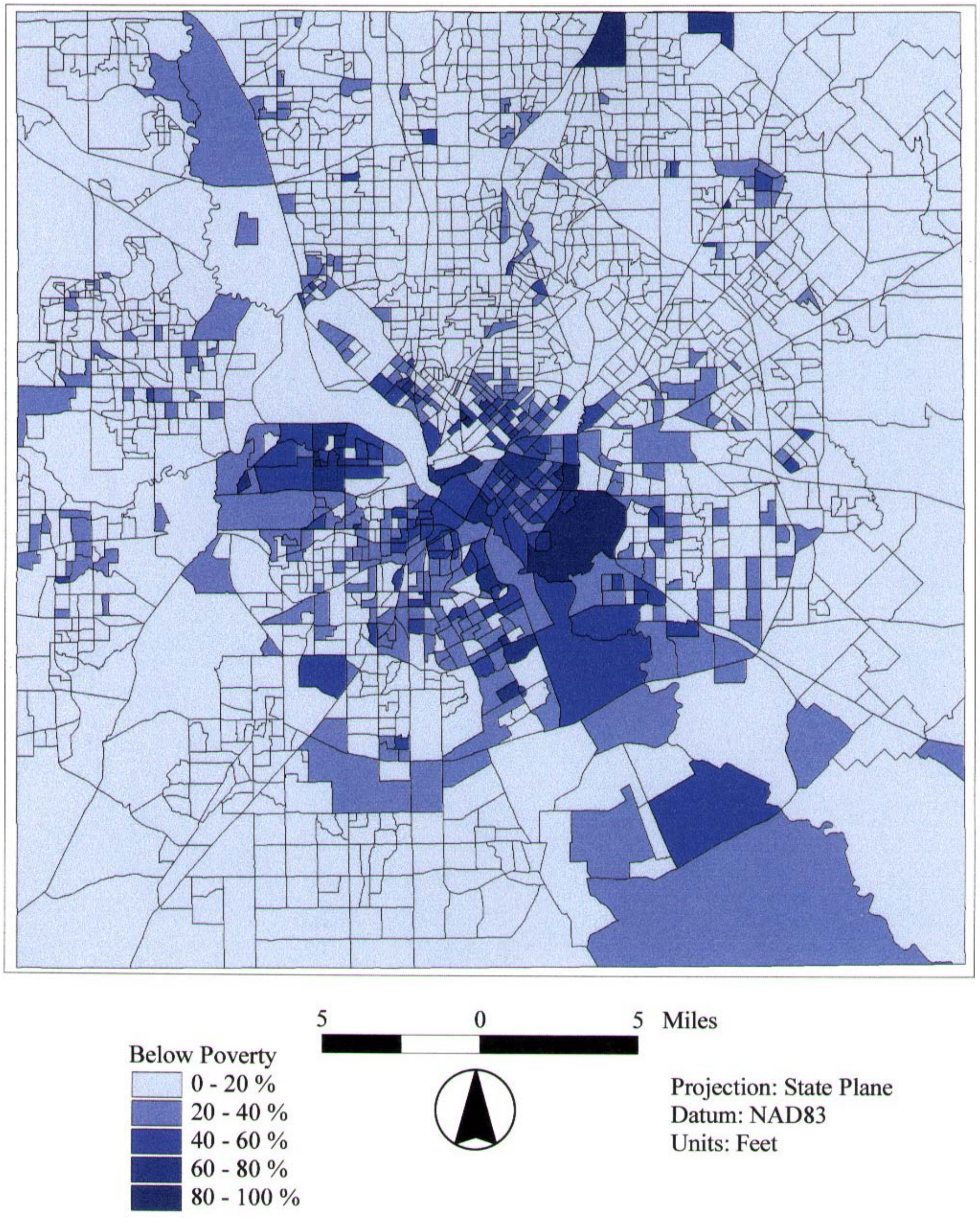
Appendix 6: Dallas County Classification and Development Density



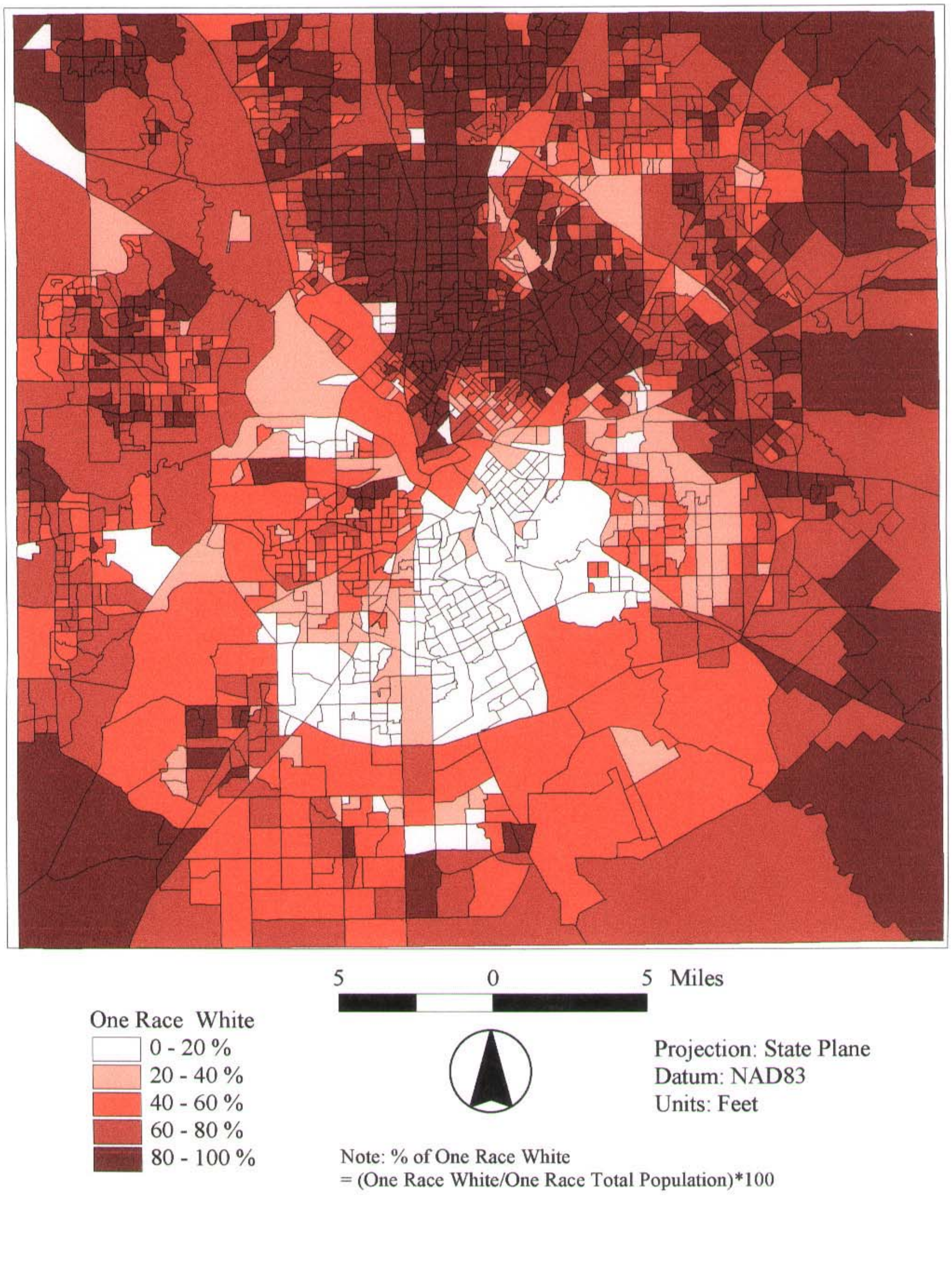
Appendix 7: Distribution of Median Household Income in Dallas County, TX



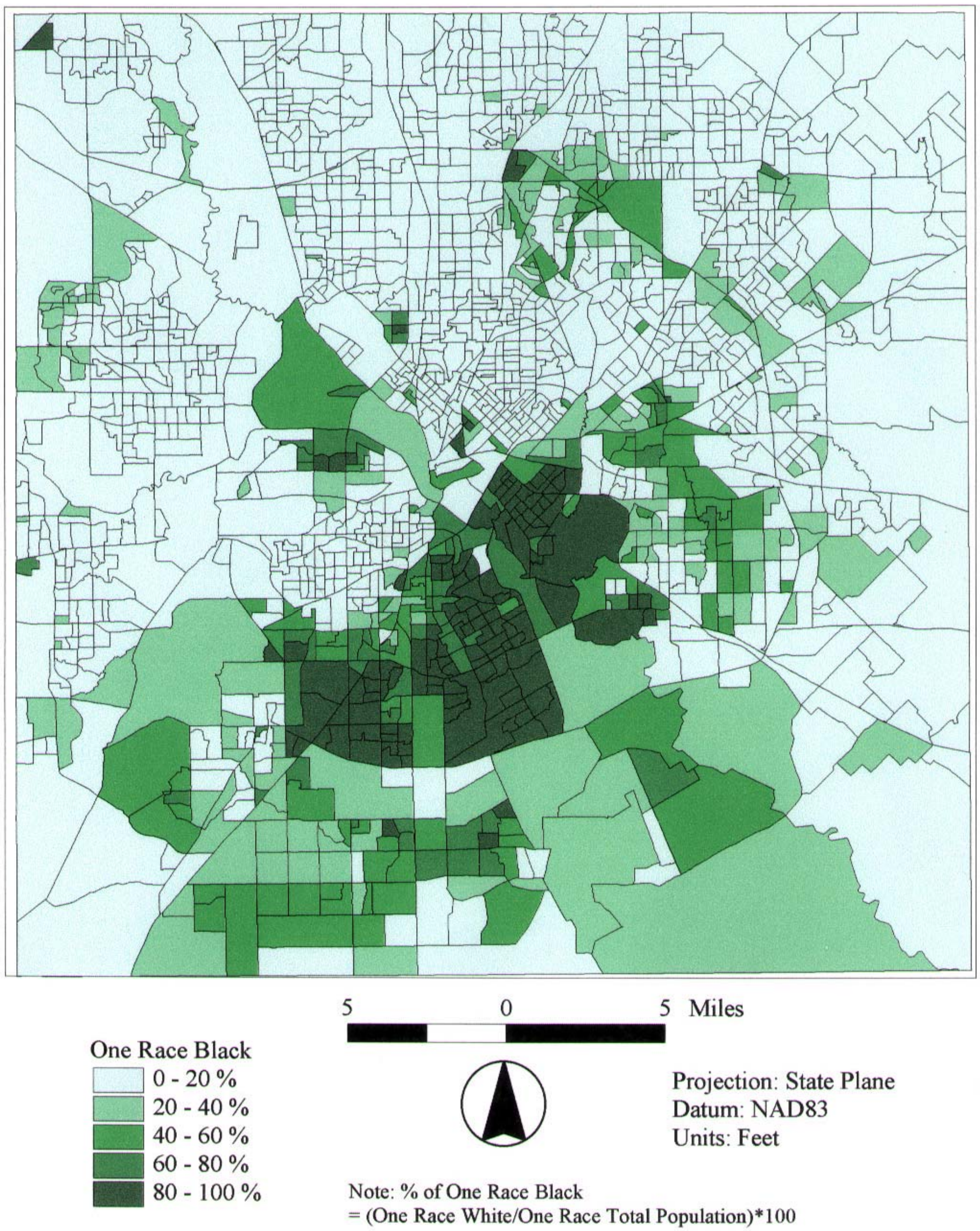
Appendix 8: Distribution of Income Below Poverty Level in Dallas County, TX



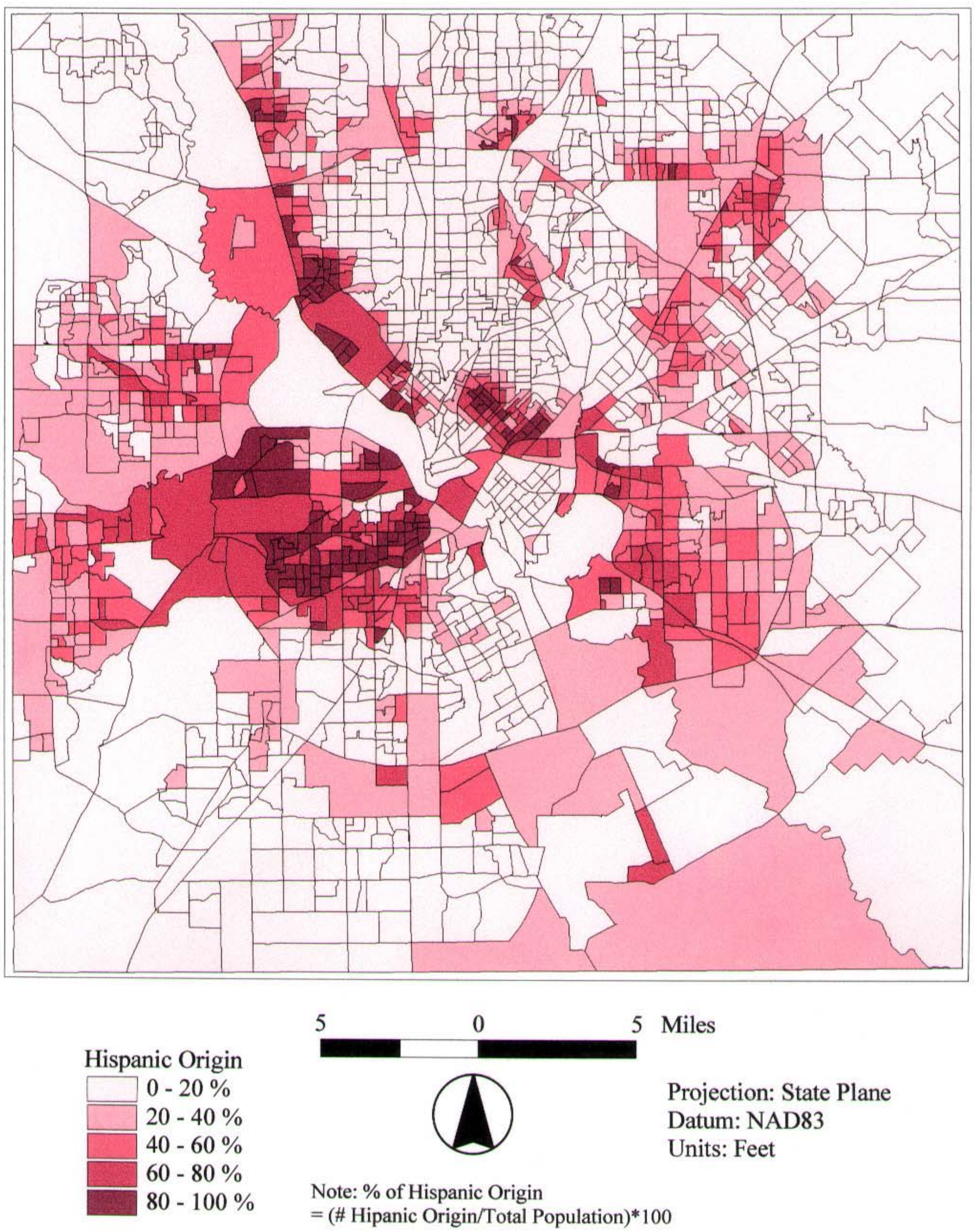
Appendix 9: Distribution of White Population in Dallas County, TX



Appendix 10: Distribution of Black Population in Dallas County, TX



Appendix 11: Distribution of Population of Hispanic Origin in Dallas County, TX



Appendix 12. Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11
1. Composite EF	1										
2. Food EF	0.10	1									
3. Mobility EF	0.58**	-0.02	1								
4. Car EF	0.83**	-0.08	0.15*	1							
5. Shelter EF	0.98**	0.01	0.58**	0.78**	1						
6. Goods EF	0.48**	0.17**	0.8**	0.08	0.46**	1					
7. Age	0.02	-0.01	-0.35**	0.22**	0.00	-0.22**	1				
8. Gender	0.13*	0.09	0.15*	0.02	0.14*	0.14*	0.04	1			
9. Race	0.27**	0.05	0.05	0.29**	0.26**	0.03	0.21**	0.00	1		
10. Marital	-0.10	0.10	0.06	-0.21**	-0.06	0.03	-0.08	0.35**	-0.02	1	
11. Edu. Year	0.4**	-0.07	0.28**	0.37**	0.42**	0.06	-0.21**	-0.05	0.25**	0.12	1
12. HH Income	0.37**	-0.06	0.46**	0.19**	0.4**	0.22**	-0.33**	0.13	0.23**	0.21**	0.53**
13. Ecovalue	0.13	0.14*	0.22**	-0.01	0.11	0.25**	-0.05	0.29**	0.01	0.05	0.07
14. Pop. Density	0.08	-0.05	0.06	0.09	0.09	-0.11	0.05	-0.09	0.14*	-0.08	0.2**
15. Dev. Density	0.09	-0.01	0.05	0.10	0.09	-0.02	0.13*	-0.01	0.19**	-0.02	0.06
16. Mixedness	-0.10	0.04	0.01	-0.11	-0.11	0.03	0.00	-0.04	0.00	-0.13	-0.08
17. Job/Housing	0.08	-0.09	-0.01	0.11	0.08	-0.07	0.15*	-0.02	0.11	-0.09	0.06
18. CBD	-0.01	0.10	0.04	-0.05	-0.01	0.16*	-0.04	0.14*	0.13*	0.13*	-0.08
19. Freeway	0.01	0.13	0.10	-0.07	0.01	0.11	-0.14*	0.00	0.01	0.02	-0.01
20. LRT Stations	-0.07	0.01	-0.02	-0.10	-0.07	0.03	-0.14*	0.03	-0.06	0.06	-0.08
21. DFW Airport	-0.07	0.02	0.03	-0.12	-0.08	0.08	-0.14*	0.06	-0.18**	0.03	-0.18**
22. Major Malls	-0.07	0.02	-0.17**	-0.02	-0.07	-0.05	0.00	0.04	-0.04	0.05	-0.16*
23. Parks	0.02	-0.07	0.08	-0.01	0.03	0.05	-0.01	0.07	-0.07	0.03	0.01
24. Major Malls	-0.14*	0.14*	-0.19**	-0.10	-0.14*	-0.11	0.09	-0.01	-0.15*	0.03	-0.11

* =< .05 and ** =< .01

1. Log of Ecological Footprint; 2. Square of Food Footprint; 3. Log of Mobility Footprint; 4. SQRT of Shelter Footprint; 5. Log of Goods and Services Footprint; 6. SQRT of Car Footprint; 7. Age; 8. Gender (1=male, 0=female); 9. Race (1=white, 0=non-white); 10. Marital Status (1=married, 0=non-married); 11. Education Years (=educational attainment); 12. Household Income (= 1,000 dollars); 13. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 14. Population Density (= within 3.5 mile buffer); 15. Development Density (= within 3.5 mile buffer. built-up/non built-up); 16. Mixedness (= within 0.25 mile buffer. 4 land-use types); 17. Job/Housing Ratio (= within 5.0 mile buffer); 18. CBD (=nearest distance to CBD); 19. Freeway (=nearest distance to freeways); 20. Light Rail Transit (= nearest distance to LRT); 21. Dallas/Fort Worth Airport (= nearest distance to DFW); 22. Major Malls (= nearest distance to major malls); 23. Parks (= nearest distance to parks); and 24. Major Lakes (= nearest distance to major lakes)

Appendix 12. (continued)

	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Comp. EF													
2. Food EF													
3. Mobility EF													
4. Car EF													
5. Shelter EF													
6. Goods EF													
7. Age													
8. Gender													
9. Race													
10. Marital													
11. Edu. Year													
12. HH Inc.	1												
13. Ecoval.	0.16*	1											
14. Pop. Den.	0.17**	0.06	1										
15. Dev. Den.	0.11	0.02	0.7**	1									
16. MXD	-0.10	0.09	0.14*	0.23**	1								
17. Job/Hs	0.02	-0.04	0.28**	0.45**	0.16*	1							
18. CBD	0.02	-0.01	-0.67**	-0.26**	-0.07	-0.5**	1						
19. Freeway	0.14*	-0.13	-0.15*	-0.01	-0.01	-0.08	0.3**	1					
20. LRT	-0.02	-0.08	-0.7**	-0.49**	-0.08	-0.3**	0.58*	0.16*	1				
21. DFW	-0.04	0.04	-0.23**	-0.4**	-0.18**	-0.69**	0.22*	0.10	0.22*	1			
22. Maj. Mall	-0.13	-0.13*	-0.66**	-0.56**	-0.14*	-0.23**	0.41*	0.01	0.46*	0.31**	1		
23. Parks	0.11	0.00	-0.18**	-0.19**	-0.08	-0.11	0.21*	0.23*	0.06	0.10	0.15*	1	
24. Maj. Mall	-0.16*	-0.09	-0.15*	0.01	0.01	0.22**	-0.02	0.12	0.03	-0.03	0.10	-0.01	1

* =< .05 and ** =< .01

1. Log of Ecological Footprint; 2. Square of Food Footprint; 3. Log of Mobility Footprint; 4. SQRT of Shelter Footprint; 5. Log of Goods and Services Footprint; 6. SQRT of Car Footprint; 7. Age; 8. Gender (1=male, 0=female); 9. Race (1=white, 0=non-white); 10. Marital Status (1=married, 0=non-married); 11. Education Years (=educational attainment); 12. Household Income (= 1,000 dollars); 13. Ecovalue (= environmental awareness. 1 to 4 scale. The higher the value, the weaker the environmental awareness.); 14. Population Density (= within 3.5 mile buffer); 15. Development Density (= within 3.5 mile buffer. built-up/non built-up); 16. Mixedness (= within 0.25 mile buffer. 4 land-use types); 17. Job/Housing Ratio (= within 5.0 mile buffer); 18. CBD (=nearest distance to CBD); 19. Freeway (=nearest distance to freeways); 20. Light Rail Transit (= nearest distance to LRT); 21. Dallas/Fort Worth Airport (= nearest distance to DFW); 22. Major Malls (= nearest distance to major malls); 23. Parks (= nearest distance to parks); and 24. Major Lakes (= nearest distance to major lakes)

Appendix 13: Explaining the "Per Capita Composite EF"

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
1	(Constant)	2.167	.188		11.504	.000
	Age	.003	.002	.131	1.921	.056
	Gender	.155	.052	.193	2.968	.003
	Race	.098	.060	.107	1.619	.107
	Marital Status	-.218	.056	-.252	-3.861	.000
	Education Years	.042	.011	.276	3.808	.000
	Household Income	.003	.001	.292	3.788	.000
	N = 196 F(6, 189) = 14.062 Prob.> F = .000 Adj.R^2=.287					
2	(Constant)	2.141	.203		10.548	.000
	Age	.003	.002	.131	1.921	.056
	Gender	.150	.055	.186	2.729	.007
	Race	.098	.060	.107	1.618	.107
	Marital Status	-.216	.057	-.250	-3.811	.000
	Education Years	.042	.011	.275	3.786	.000
	Household Income	.003	.001	.289	3.723	.000
	Ecovalue	.016	.044	.023	.350	.727
	N = 196 F(7, 188) = 12.015 Prob.> F = .000 Adj. R^2=.283					
3	(Constant)	2.125	.213		9.967	.000
	Age	.003	.002	.125	1.795	.074
	Gender	.143	.055	.177	2.589	.010
	Race	.094	.061	.103	1.537	.126
	Marital Status	-.232	.058	-.267	-4.006	.000
	Education Years	.045	.011	.290	3.887	.000
	Household Income	.003	.001	.282	3.588	.000
	Ecovalue	.024	.045	.035	.539	.590
	Pop. Density	.000	.000	-.108	-1.210	.228
	Development Density	.350	.306	.110	1.142	.255
	Mixedness	-.125	.095	-.085	-1.322	.188
	Job/Housing Ratio	-.003	.022	-.010	-.137	.891
	N = 196 F(11, 184) = 7.911 Prob.> F = .000 Adj. R^2=.280					
4	(Constant)	2.360	.384		6.152	.000
	Age	.003	.002	.128	1.797	.074
	Gender	.137	.056	.170	2.424	.016
	Race	.105	.068	.116	1.558	.121
	Marital Status	-.226	.059	-.260	-3.847	.000
	Education Years	.046	.012	.301	3.928	.000
	Household Income	.003	.001	.293	3.567	.000
	Ecovalue	.015	.047	.022	.323	.747

Appendix 13: (continued)

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
4	Pop. Density	.000	.000	-.318	-1.807	.072
	Development Density	.576	.423	.181	1.364	.174
	Mixedness	-.108	.097	-.074	-1.118	.265
	Job/Housing Ratio	-.004	.043	-.012	-.088	.930
	CBD	-.010	.015	-.103	-.693	.489
	Freeway	.005	.029	.012	.174	.862
	Light Rail Transit	-.011	.012	-.086	-.922	.358
	Major Mall	-.008	.017	-.043	-.490	.625
	DFW Airport	.005	.006	.075	.754	.452
	Parks	-.052	.101	-.035	-.518	.605
	Major Lakes	-.011	.011	-.069	-1.003	.317

N = 196   F(18, 177) = 4.941   Prob.> F = .000   Adj. R^2*=.267*

Appendix 14: Explaining the "Per Capita Food EF Component"

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
1	(Constant)	31.974	5.618		5.692	.000
	Age	-.052	.054	-.078	-.967	.335
	Gender	1.450	1.560	.071	.929	.354
	Race	2.673	1.796	.116	1.488	.138
	Marital Status	2.661	1.684	.121	1.580	.116
	Education Years	-.319	.333	-.082	-.960	.338
	Household Income	-.023	.023	-.091	-.997	.320
	N = 196 F(6, 189) = 1.286 Prob.> F = .265 Adj.R^2=.009					
2	(Constant)	28.015	6.004		4.666	.000
	Age	-.050	.053	-.075	-.946	.345
	Gender	.597	1.622	.029	.368	.713
	Race	2.694	1.785	.117	1.509	.133
	Marital Status	2.905	1.680	.132	1.729	.085
	Education Years	-.339	.331	-.087	-1.024	.307
	Household Income	-.027	.023	-.107	-1.182	.239
	Ecovalue	2.359	1.313	.135	1.797	.074
	N = 196 F(7, 188) = 1.577 Prob.> F = .145 Adj. R^2=.020					
3	(Constant)	26.293	6.325		4.157	.000
	Age	-.052	.054	-.078	-.955	.341
	Gender	.615	1.638	.030	.375	.708
	Race	2.497	1.811	.108	1.379	.170
	Marital Status	2.661	1.716	.121	1.550	.123
	Education Years	-.301	.341	-.077	-.885	.377
	Household Income	-.027	.023	-.108	-1.168	.244
	Ecovalue	2.249	1.332	.129	1.689	.093
	Pop. Density	.000	.000	-.044	-.424	.672
	Development Density	10.110	9.091	.125	1.112	.268
	Mixedness	.492	2.811	.013	.175	.861
	Job/Housing Ratio	-.794	.664	-.098	-1.197	.233
	N = 196 F(11, 184) = 1.186 Prob.> F = .300 Adj. R^2=.010					
4	(Constant)	34.645	10.989		3.153	.002
	Age	-.052	.054	-.078	-.961	.338
	Gender	1.187	1.615	.058	.735	.464
	Race	3.119	1.938	.135	1.609	.109
	Marital Status	2.413	1.681	.110	1.436	.153
	Education Years	-.409	.338	-.105	-1.210	.228
	Household Income	-.018	.023	-.071	-.765	.446
	Ecovalue	2.741	1.340	.157	2.045	.042

Appendix 14: (continued)

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
4	Pop. Density	.000	.001	-.031	-.158	.875
	Development Density	4.036	12.108	.050	.333	.739
	Mixedness	-.020	2.766	-.001	-.007	.994
	Job/Housing Ratio	-2.445	1.237	-.300	-1.977	.050
	CBD	-.083	.429	-.033	-.194	.846
	Freeway	1.752	.842	.164	2.081	.039
	Light Rail Transit	-.343	.341	-.106	-1.004	.317
	Major Mall	.113	.479	.023	.236	.814
	DFW Airport	-.336	.185	-.204	-1.816	.071
	Parks	-4.390	2.904	-.115	-1.512	.132
	Major Lakes	.790	.301	.205	2.625	.009
	N = 196 F(18, 177) = 1.682 Prob.> F = .046 Adj. R^2*=.059*					

Appendix 15: Explaining the "Per Capita Mobility EF Component"

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
1	(Constant)	.259	.501		.517	.606
	Age	-.013	.005	-.185	-2.682	.008
	Gender	.340	.139	.162	2.443	.015
	Race	.000	.160	.000	.002	.998
	Marital Status	-.222	.151	-.099	-1.475	.142
	Education Years	.033	.030	.082	1.106	.270
	Household Income	.010	.002	.375	4.740	.000
	N = 194 F(6, 189) = 12.085 Prob.> F = .000 Adj.R^2=.256					
2	(Constant)	-.113	.535		-.211	.833
	Age	-.013	.005	-.185	-2.699	.008
	Gender	.258	.145	.123	1.780	.077
	Race	.000	.159	.000	.003	.998
	Marital Status	-.198	.150	-.088	-1.321	.188
	Education Years	.032	.030	.079	1.069	.287
	Household Income	.009	.002	.358	4.535	.000
	Ecovalue	.223	.117	.125	1.907	.058
	N = 194 F(7, 186) = 11.024 Prob.> F = .000 Adj. R^2=.267					
3	(Constant)	-.327	.564		-.580	.563
	Age	-.013	.005	-.193	-2.752	.007
	Gender	.240	.146	.115	1.641	.103
	Race	-.027	.162	-.011	-.165	.869
	Marital Status	-.221	.154	-.098	-1.432	.154
	Education Years	.040	.031	.100	1.304	.194
	Household Income	.009	.002	.359	4.490	.000
	Ecovalue	.231	.119	.129	1.948	.053
	Pop. Density	.000	.000	-.122	-1.327	.186
	Development Density	1.112	.824	.135	1.349	.179
	Mixedness	.023	.251	.006	.090	.928
	Job/Housing Ratio	-.019	.061	-.022	-.303	.762
	N = 194 F(11, 182) = 7.151 Prob.> F = .000 Adj. R^2=.260					
4	(Constant)	-.058	.997		-.058	.953
	Age	-.013	.005	-.183	-2.617	.010
	Gender	.199	.146	.095	1.368	.173
	Race	-.019	.174	-.008	-.107	.915
	Marital Status	-.182	.153	-.081	-1.190	.235
	Education Years	.043	.031	.107	1.398	.164
	Household Income	.009	.002	.342	4.166	.000
	Ecovalue	.155	.121	.087	1.279	.203

Appendix 15: (continued)

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
4	Pop. Density	.000	.000	-.238	-1.329	.185
	Development Density	.384	1.126	.047	.341	.734
	Mixedness	.061	.250	.016	.244	.808
	Job/Housing Ratio	.148	.118	.174	1.253	.212
	CBD	.031	.039	.118	.784	.434
	Freeway	-.018	.077	-.016	-.234	.815
	Light Rail Transit	-.036	.031	-.108	-1.160	.248
	Major Mall	-.126	.043	-.252	-2.908	.004
	DFW Airport	.032	.017	.188	1.871	.063
	Parks	.095	.262	.024	.363	.717
	Major Lakes	-.036	.027	-.091	-1.332	.185
	N = 194 F(18, 175) = 5.197 Prob.> F = .000 Adj. R^2*=.281*					

Appendix 16: Explaining the "Per Capita Car EF Component"

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
1	(Constant)	1.610	.384		4.193	.000
	Age	-.007	.004	-.146	-1.866	.064
	Gender	.213	.107	.147	1.990	.048
	Race	.110	.123	.068	.894	.372
	Marital Status	-.055	.115	-.036	-.479	.633
	Education Years	-.020	.023	-.073	-.884	.378
	Household Income	.004	.002	.220	2.471	.014
	N = 195 F(6, 190) = 3.542 Prob.> F = .002 Adj.R^2=.073					
2	(Constant)	1.216	.407		2.992	.003
	Age	-.007	.004	-.143	-1.866	.064
	Gender	.127	.110	.088	1.158	.248
	Race	.113	.121	.070	.932	.352
	Marital Status	-.030	.114	-.020	-.266	.790
	Education Years	-.022	.023	-.080	-.974	.332
	Household Income	.003	.002	.196	2.216	.028
	Ecovalue	.234	.089	.190	2.635	.009
	N = 195 F(7, 187) = 4.125 Prob.> F = .000 Adj. R^2=.101					
3	(Constant)	1.054	.421		2.506	.013
	Age	-.006	.004	-.134	-1.732	.085
	Gender	.097	.109	.067	.889	.375
	Race	.102	.121	.063	.844	.400
	Marital Status	-.063	.115	-.041	-.553	.581
	Education Years	-.007	.023	-.026	-.317	.751
	Household Income	.004	.002	.212	2.408	.017
	Ecovalue	.249	.089	.202	2.808	.006
	Pop. Density	.000	.000	-.291	-2.935	.004
	Development Density	1.062	.604	.186	1.757	.081
	Mixedness	.072	.187	.028	.386	.700
	Job/Housing Ratio	-.029	.045	-.049	-.639	.524
	N = 195 F(11, 183) = 3.524 Prob.> F = .000 Adj. R^2=.125					
4	(Constant)	1.577	.741		2.129	.035
	Age	-.007	.004	-.139	-1.797	.074
	Gender	.067	.109	.046	.616	.539
	Race	.103	.130	.064	.796	.427
	Marital Status	-.042	.113	-.027	-.374	.709
	Education Years	-.003	.023	-.012	-.150	.881
	Household Income	.004	.002	.211	2.352	.020
	Ecovalue	.199	.090	.162	2.215	.028

Appendix 16: (continued)

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
4	Pop. Density	.000	.000	-.478	-2.524	.012
	Development Density	.506	.811	.089	.624	.533
	Mixedness	.098	.185	.038	.531	.596
	Job/Housing Ratio	.054	.084	.091	.634	.527
	CBD	.024	.029	.132	.825	.411
	Freeway	.017	.056	.023	.306	.760
	Light Rail Transit	-.058	.023	-.256	-2.561	.011
	Major Mall	-.079	.032	-.231	-2.474	.014
	DFW Airport	.017	.012	.147	1.385	.168
	Parks	-.065	.194	-.024	-.334	.739
	Major Lakes	-.016	.020	-.060	-.809	.420
	N = 195 F(18, 176) = 2.989 Prob.> F = .000 Adj. R^2*=.156*					

Appendix 17: Explaining the "Per Capita Shelter EF Component"

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
1	(Constant)	.385	.365		1.055	.293
	Age	.014	.003	.270	3.944	.000
	Gender	.171	.101	.110	1.692	.092
	Race	.173	.117	.099	1.485	.139
	Marital Status	-.502	.109	-.301	-4.595	.000
	Education Years	.109	.022	.368	5.051	.000
	Household Income	.002	.001	.102	1.311	.191
	N = 196 F(6, 189) = 13.558 Prob.> F = .000 Adj.R^2=.279					
2	(Constant)	.552	.392		1.410	.160
	Age	.014	.003	.268	3.930	.000
	Gender	.207	.106	.134	1.961	.051
	Race	.172	.116	.098	1.479	.141
	Marital Status	-.513	.110	-.307	-4.678	.000
	Education Years	.110	.022	.371	5.092	.000
	Household Income	.002	.001	.111	1.425	.156
	Ecovalue	-.100	.086	-.075	-1.164	.246
	N = 196 F(7, 188) = 11.837 Prob.> F = .000 Adj. R^2=.280					
3	(Constant)	.581	.412		1.410	.160
	Age	.014	.004	.266	3.814	.000
	Gender	.199	.107	.128	1.860	.064
	Race	.172	.118	.098	1.462	.145
	Marital Status	-.541	.112	-.324	-4.841	.000
	Education Years	.113	.022	.382	5.097	.000
	Household Income	.002	.002	.104	1.316	.190
	Ecovalue	-.085	.087	-.064	-.981	.328
	Pop. Density	.000	.000	-.071	-.791	.430
	Development Density	.425	.592	.069	.717	.474
	Mixedness	-.252	.183	-.089	-1.379	.170
	Job/Housing Ratio	-.012	.043	-.020	-.282	.778
	N = 196 F(11, 184) = 7.723 Prob.> F = .000 Adj. R^2=.275					
4	(Constant)	1.024	.736		1.391	.166
	Age	.013	.004	.265	3.723	.000
	Gender	.193	.108	.124	1.782	.076
	Race	.191	.130	.109	1.468	.144
	Marital Status	-.535	.113	-.321	-4.748	.000
	Education Years	.116	.023	.391	5.120	.000
	Household Income	.002	.002	.123	1.494	.137
	Ecovalue	-.089	.090	-.067	-.996	.321

Appendix 17: (continued)

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
4	Pop. Density	.000	.000	-.287	-1.635	.104
	Development Density	1.363	.811	.222	1.680	.095
	Mixedness	-.217	.185	-.077	-1.168	.244
	Job/Housing Ratio	-.058	.083	-.093	-.696	.487
	CBD	-.037	.029	-.191	-1.285	.200
	Freeway	-.019	.056	-.023	-.339	.735
	Light Rail Transit	-.010	.023	-.040	-.429	.668
	Major Mall	.030	.032	.080	.921	.358
	DFW Airport	.003	.012	.023	.232	.817
	Parks	-.076	.195	-.026	-.392	.695
	Major Lakes	-.025	.020	-.087	-1.263	.208

N = 196   F(18, 177) = 5.010   Prob.> F = .000   Adj. R^2*=.270*

Appendix 18: Explaining the "Per Capita Goods and Services EF Component"

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
1	(Constant)	.697	.250		2.783	.006
	Age	.005	.002	.127	1.887	.061
	Gender	.202	.069	.187	2.904	.004
	Race	.127	.080	.104	1.589	.114
	Marital Status	-.246	.075	-.212	-3.285	.001
	Education Years	.060	.015	.289	4.019	.000
	Household Income	.004	.001	.305	3.986	.000
	N = 196 F(6, 189) = 14.768 Prob.> F = .000 Adj.R^2=.298					
2	(Constant)	.688	.270		2.549	.012
	Age	.005	.002	.127	1.884	.061
	Gender	.200	.073	.185	2.742	.007
	Race	.127	.080	.104	1.585	.115
	Marital Status	-.246	.075	-.212	-3.258	.001
	Education Years	.060	.015	.289	4.003	.000
	Household Income	.004	.001	.305	3.946	.000
	Ecovalue	.005	.059	.006	.092	.927
	N = 196 F(7, 188) = 12.593 Prob.> F = .000 Adj. R^2=.294					
3	(Constant)	.660	.283		2.330	.021
	Age	.004	.002	.120	1.745	.083
	Gender	.190	.073	.176	2.597	.010
	Race	.121	.081	.099	1.494	.137
	Marital Status	-.267	.077	-.230	-3.473	.001
	Education Years	.063	.015	.304	4.109	.000
	Household Income	.004	.001	.297	3.804	.000
	Ecovalue	.018	.060	.019	.294	.769
	Pop. Density	.000	.000	-.114	-1.288	.199
	Development Density	.502	.407	.117	1.234	.219
	Mixedness	-.172	.126	-.088	-1.368	.173
	Job/Housing Ratio	-.003	.030	-.007	-.098	.922
	N = 196 F(11, 184) = 8.321 Prob.> F = .000 Adj. R^2=.292					
4	(Constant)	.982	.510		1.927	.056
	Age	.004	.003	.123	1.741	.083
	Gender	.184	.075	.171	2.456	.015
	Race	.142	.090	.117	1.583	.115
	Marital Status	-.258	.078	-.223	-3.315	.001
	Education Years	.065	.016	.314	4.127	.000
	Household Income	.004	.001	.306	3.748	.000
	Ecovalue	.010	.062	.010	.155	.877

Appendix 18: (continued)

Model	Variables	Per Capita Composite EF				
		B	S.E.	Beta	t	Sig.
4	Pop. Density	.000	.000	-.332	-1.899	.059
	Development Density	.900	.562	.211	1.602	.111
	Mixedness	-.149	.128	-.076	-1.163	.246
	Job/Housing Ratio	-.016	.057	-.036	-.272	.786
	CBD	-.019	.020	-.138	-.935	.351
	Freeway	.011	.039	.020	.287	.775
	Light Rail Transit	-.012	.016	-.070	-.763	.447
	Major Mall	-.006	.022	-.021	-.249	.804
	DFW Airport	.005	.009	.056	.567	.572
	Parks	-.035	.135	-.017	-.260	.795
	Major Lakes	-.014	.014	-.068	-.987	.325

N = 196   F(18, 177) = 5.160   Prob.> F = .000   Adj. R^2*=.277*

VITA

Hyung Cheal Ryu

ADDRESS

285-123 Shinsanri, Nammyun, Yang-Ju, Gyeonggi Province, Korea

EDUCATION

Ph.D. Urban Regional Science, Texas A&M University, TX, 2005.
M.A. Urban Planning, University of Southern California, CA, 2001.
M.A. Urban Administration, University of Seoul, Seoul, Korea, 1998.
B.A. Urban Administration, University of Seoul, Seoul, Korea, 1995.

PROFESSIONAL EXPERIENCE

Graduate Research Assistant, Environmental Planning and Sustainability Research Unit, Texas A&M University, June 2004 – May 2005.
Graduate Research Assistant, Texas Transportation Institute, Texas A&M University, September 2001 – May 2004.
Graduate Research Assistant, School of Policy, Planning, and Development, University of Southern California, September 2000 – May 2001.
Teaching Assistant, Department of International Relations, University of Seoul, Seoul, Korea, May 1996 – May 1999.

SELECTED PAPERS

Ryu, H. C., & Brody, S. D. (2005). Can higher education influence sustainable behavior? - examining the impacts of a graduate course on sustainable development using Ecological Footprint analysis. *International Journal of Sustainability in Higher Education* (submitted).

Brody, S. D., & Ryu, H. C. (2005). Measuring the impact of a graduate course in sustainable development. *Environmental Education Research* (submitted).

Ryu, H. C., & Brody, S. D. (2004). Examining socioeconomic/demographic, environmental value, land-use, and spatial impacts on the Ecological Footprint for Dallas County, Texas. Presentation in Association of Collegiate Schools of Planning 45th Annual Conference. Portland, Oregon.