INVESTIGATING THE RELATIONSHIP BETWEEN ECOLOGICAL FOOTPRINT AND QUALITY OF LIFE IN THE U.S.

by

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LIST OF ABBREVIATIONS

Abbreviation	Full Term
CF	Carbon Footprint
CO2	Carbon Dioxide
EASI	Easy Analytics Software Inc
EF	Ecological Footprint
EWEB	Efficient Well-Being
GDP	Gross Domestic Product
HCF	Household Carbon Footprint
OLS	Ordinary Least Squares
QoL	Quality of Life
SE	Spatial Error
SL	Spatial Lag
SLSE	Spatial Lag + Spatial Error
SWB	Subjective Well-Being

I. INTRODUCTION

In the 20th century the human population grew from 1.5 billion to 6.1 billion. As of 2018, humans have multiplied to over 7 billion (Roser and Ortiz-Ospina 2018). This extreme rate of growth demands more from the planet than ever before with the burden placed on the planet's resources exacerbated by the problem of human activity releasing carbon into the atmosphere at levels unseen in the last 800,000 years (National Oceanic and Atmospheric Administration 2018). These realities demand that societies become more responsible for how natural resources are consumed. Societies must consider the options that may lead to a more sustainable way.

Sustainability gained notoriety in the late 1980's when, in 1987, the United Nations World Commission on Environment and Development released "Our Common Future" a work that would later become known as The Brundtland Report. Since its publication, this document has provided the quintessential and most commonly used definition of sustainability: "meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations 1987). Simply put, we must go about our lives now in a way that will not impede future human survival.

Since the time of the Brundtland Report the world has witnessed twelve of the hottest years on record, with the three hottest being the three most recent years

(NOAA 2017). Recent reports from NASA also reveal that there is currently more CO_2, a major greenhouse gas contributing to climate change, in the atmosphere than there has been in over 400,000 years (The National Aeronautics and Space Administration 2018). These factors, along with many others, highlight the urgency that underscores much of the current discussion around sustainability.

Though often politicized to represent only environmental conservation, sustainability encompasses far more. Typically referred to as the three pillars of sustainability; people, planet, profits- these concepts involve social, environmental, and economic considerations. Sustainability can be seen as aiming to maximize outcomes in all three of these areas (figure 1), or in only one realm (figure 2). For our purposes we approach sustainability with an integrated understanding, striving for maximization of each dimension. One example of the interrelated nature of the three realms is the installation of residential solar panels. Installing solar panels can reduce dependence on coal which is good for the environment through the reduction of greenhouse gas emissions (GHG). Likewise, this practice is beneficial for people through reduced exposure to pollution and less GHGs in the atmosphere (from coal), and brings economic advantages as the consumer will spend less on energy in the long run. Because of the far-ranging potential of sustainability, many governments, nonprofits, and businesses have made the issue of sustainability a core concern.

A large-scale example of this focus on sustainability is the United Nations' Sustainable Development Goals. The UN recognizes the need for integrating sustainability as a key component of growth and development and provides 17 goals as a blueprint for achieving what they see as a sustainable future. The UN views sustainability as far-reaching, so much so that the goals are designed to address issues spanning from climate and environmental degradation all the way to poverty and justice (United Nations 2018).

On the opposite end of the spectrum, local-level organizations have also begun to include sustainability as part of their standard operating practices. At one non-profit providing affordable housing in Austin, Texas, sustainability is included as a core value of the organization and has been integrated into all levels of operations (Foundation Communities 2018).

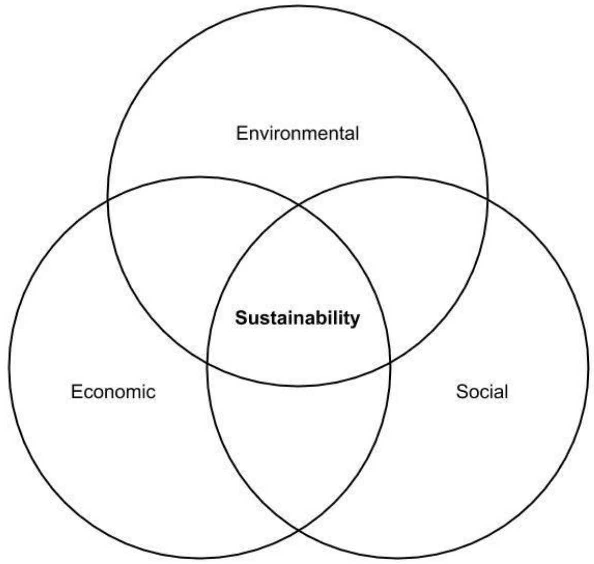

Figure 1. Three dimensions of sustainability

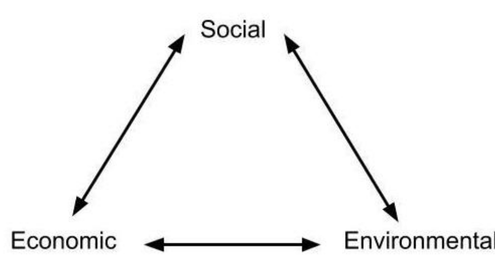

Figure 2. Three dimensions of sustainability, non-overlapping model.

Though there is much to be celebrated about the increased attention to sustainability, with this greater focus comes the need to more clearly understand what it means to be sustainable.

Leslie Paul Thiele tackles the idea of sustainability by taking the Brundtland Report's definition a step further, explaining "sustainability as meeting current needs in a way that does not undermine future welfare" (Thiele 2013: 2). Yet this definition may be better understood by further defining future welfare as meaning future viability. Thiele (2013: 2) refers to the multifaceted nature of sustainability when saying that "a practice, relationship, or institution is not sustainable if it undermines the social, economic, or environmental conditions of its own viability." So, living sustainably means organizing human societies in a way that increases the viability of life, resources, and the regenerative capacity of the earth. Moran, Wackernagel, Kitzes, Goldfinger, and Boutaud (2008: 471) put it thusly, "A necessary condition for sustainability is that society metabolizes resources into waste no faster than the biosphere can convert this waste back into resources." As is clear by these explanations, the availability of natural resources is paramount to sustainability. One implication of this dependence on natural capital is that in order to ensure sustainability, we must be able to measure the level of human impact on the planet's resources and regenerative capacity. A measure such as the ecological footprint provides one way to accomplish this.

The ability to measure and monitor the progress made toward sustainability, or lack thereof, will become vital for making informed policy decisions and developing a future for all generations. Although it is important to understand the physical and environmental impacts that a policy decision or action may have, it is also critical to consider the implications for individuals. This is a practical issue, as research indicates that people who are happier tend to live in a more sustainable way (Brown et al. 2005). It seems then that quality of life and sustainability can be linked, for better or worse. For example, in the United States there is a common assumption that living more sustainably will require sacrifices of life quality and many people are unwilling to make sacrifices for something they believe won’t affect them personally (Forbes 2018; Hall et al. 2018; Oskamp 2000; The Verge 2018). These views likely impede adoption of more sustainable practices. The goal of this research is to investigate the relationship between quality of life and sustainability, as measured by the Ecological Footprint, with the intent of assessing the compatibility between sustainability and quality of life.

II. LITERATURE REVIEW

Ecological Footprint

The Ecological Footprint (EF), originally conceptualized by Rees and Wackernagel (1996), is a tool which measures an activity's or population's impact on natural resources. It does so by estimating the natural resources required for a given subject and translating that into a representative land area. The result is a theoretical physical representation of the resources required to sustain the population or activity at its current rate of consumption and waste production. Rees and Wackernagel (1996: 229) define Ecological Footprint as "the total area of productive land and water required continuously to produce all the resources consumed and to assimilate all the waste produced, by a defined population, wherever on earth that land is located." Or, as the Global Footprint Network puts it, ecological footprint is a measure of "how much of the biological capacity of the planet is required by a given human activity or population."

The original calculations for Ecological Footprint were based on five consumption related areas, "food, housing, transportation, consumer goods and services - and on eight major land use categories" (Rees and Wackernagel 1996: 230). As Rees and Wackernagel make clear, EF is a "land-based surrogate" and as such, is measured in global hectares. Being measured in such a way makes the Ecological Footprint easily translatable across borders and accounts for land use wherever it may be located. This aspect of the EF is one of its strengths, as it is important to factor in environmental impacts outside of whatever particular borders one is considering. Doing so is critical to developing a clearer picture of sustainability, as externalities and outsourced pollution (and waste) can be difficult to account for, and are often overlooked. However, there are critiques against even this dimension of the ecological footprint

Van Den Bergh and Grazi (2010) offer harsh criticism of the ecological footprint as a relevant measurement tool. They say that because EF measures a "hypothetical land area, there is a danger that it is interpreted as realistic or… actual land use" (2010: 4843). This is because EF accounts for use as if it were done sustainably, not how it may be used in current reality. Fiala (2008) echoes this sentiment, arguing that EF fails to differentiate between intensive and extensive land use. Van Den Bergh and Grazi (2010: 4843) also claim that because the sole output of ecological footprint is land area, the idea expresses an "implicit land value theory" that puts the availability of land above all other factors for sustainability. Along these lines, there is the concern that EF does not include enough factors of human impact on the environment (Van Den Bergh and Grazi 2010; Rees and Wackernagel 1996), such as noise pollution, toxic emissions, and water pollution, thereby misrepresenting the actual environmental toll. Rees and Wackernagel (1996) have themselves acknowledged the critique that the ecological footprint is a simple measure in that it does not account for the dynamism of nature or economics. However, they address this criticism by pointing out that predictive capability was never their intent for EF (Rees and Wackernagel 1996). Instead, they say the simplicity of the ecological footprint is one of its strengths. Rees and Wackernagel (1996: 230, 231) see the ecological footprint as a visual tool that makes understanding environmental impact accessible and that can provide a "snapshot of our current demands on nature". They see this as a positive aspect of EF and one that makes it particularly suited for use in policy making as it allows for multiple "snapshots" to be taken at different points in time as a way of monitoring progress, or across nations as a comparative tool.

Many studies have indeed been conducted using the ecological footprint in just such a way. Moran et al (2008) used EF as an indicator for sustainable consumption, along with an indicator for development, as a way to measure the sustainable development of nations. Their findings showed that it is possible to increase development without enlarging one's ecological footprint. However, they acknowledge that only a very few, low income countries have shown this increase in development without an accompanying increase in ecological footprint and that "high income countries have exhibited the opposite trend, away from sustainability" (2008: 474). This is consistent with the literature, including Jorgenson and Clark's (2011: 240) finding that "more urbanized nations have higher levels of consumption-based environmental impacts" and

Figge, Oebels, and Offerman's (2016) article demonstrating that more globalized nations also have larger ecological footprints.

Evert Van De Vliert and Charles Vlek (2015) considered the relationship between ecological footprint, wealth, protection of the environment, and climatic demands. Their findings support those of Moran et al (2008) and Jorgenson and Clark (2011) in that they found richer countries to have larger ecological footprints. They also show that countries with harsher climates have a larger EF. Interestingly, countries that have high amounts of precipitation generally had a lower ecological footprint, "an effect that even seems to overrule the impact of extreme climatic temperatures" (Vliert and Vlek 2015: 954). They conclude that "climatic demands reinforce the relationship between wealth resources and ecological footprint… EF is generally larger for societies living under climates with more demanding winters, summers, or both" (Vliert and Vlek 2015: 954).

One aspect of ecological footprint is the carbon footprint (CF). While EF is a representation of natural capital required for the specific group, activity, or item being evaluated, CF is typically a representation of carbon emissions produced by said group, activity, or item. When part of an ecological footprint, CF is translated into the amount of land required to sequester those emissions. According to the Global Footprint Network, reducing humanity's carbon footprint is critical to global sustainability (Footprintnetwork.org).

As previously discussed, perception holds that higher life quality in the United States is coupled with higher carbon footprints. Part of that perceived relationship likely stems from research relating CF with affluence. Clement, Pattison, and Habans (2017) used zip code level carbon footprint data to evaluate the correlation between affluence and CF at the local level. Their results revealed a positive relationship between the two, confirming the perception.

While ecological footprints provide a picture of demand on natural capital, they say very little about how those resources are used for social benefit. Though it is not necessary for EF to serve both as an indicator of resource demand and the quality of life afforded by the use of such resources, it would be helpful to measure both if policy applications are to be considered. The shortcomings of EF as an indicator of life quality can be made up for with the added use of quality of life measures.

Quality of Life and Subjective Well-Being

There are two dominant measures of human life quality used in the literature, Quality of Life (QoL) and Subjective Well-Being (SWB). SWB is frequently used interchangeably with 'happiness' (Camfield and Skevington 2008, Veenhoven 2001) and most often refers to work involving survey data. In contrast, QoL typically utilizes indices of weighted proxies for well-being. These proxies are often location specific. For example, one commonly used variable is crime rate. With this measure, a negative correlation would be assumed between the crime rate for a geographic area and the life quality of a person living in the same area. Weather is another example of a location-based proxy and is often heavily weighted in QoL indices. QoL therefore provides a way to theoretically determine the life quality of individuals based on geographic location, while SWB asks the individual directly how they rate their life.

Moro, Brereton, Ferreira and Clinch (2008: 449) claim to demonstrate that SWB can be used instead of QoL indices "to rank quality of life among different locations." Their findings reveal that there is no statistically significant difference between standard SWB rankings and SWB rankings designed to model weighted QoL indices by including weighted location based proxies. This suggests that it may be possible to use SWB alone as a measure of QoL. However, Ruut Veenhoven (2001) argues that SWB is only a subset of the larger umbrella that is quality of life. Veenhoven (2001) concludes that while happiness does coincide with some aspects of quality of life, having more of these aspects does not necessarily mean more happiness.

The distinction between QoL and SWB is often blurry as they are frequently used interchangeably in the literature (Camfield and Skevington 2008; Moro et al 2008; Veenhoven 2001). However, most commonly in sociological contexts, SWB is used to refer to an individual's perception of their own satisfaction with life, while QoL indicates a set of proxy measures that in theory relate to the quality of an individual's life.

While there is a wealth of research using the Ecological Footprint (EF), as well as work relating SWB and QoL, fewer studies have considered the relationship between EF and QoL or SWB. Most research in this area relies on subjective well-being (SWB).

Scott Cloutier, Lincoln Larson, and Jenna Jambeck (2014) compared four different sustainability indices to the Gallup Healthways Well-Being Index for major cities across the U.S. The authors ranked cities in order of best to worst, highest to lowest for The Green City Index, SustainLane US City Rankings, Popular Science US City Rankings, Our Green Cities Index, and the Gallup Healthways Well-being index. The benefit of using all four sustainability indices is that each one measures a different aspect of sustainability. The Green City Index evaluates cities based on environmental performance, such as energy, land use, waste, and CO2; SustainLane is designed to measure how prepared a city is for an unknown future by evaluating such factors as public transport ridership, air quality, land use, local food and agriculture, and housing affordability, among others; The Popular Science index exclusively considers electricity, transportation, green living, and recycling and green perspective; and Our Green Cities looks at the number of different sustainability related programs a city has undertaken (Cloutier et al. 2014). The results of their research indicate that all four sustainability measures were positively correlated with the happiness index, with two having a significant correlation (Cloutier et al. 2014). Christopher L. Ambrey and Peter Daniels (2017) also reveal a positive association between increased sustainability and increased happiness. In a nation-wide study, data from a household panel survey to evaluate well-being and carbon footprints in Australia found carbon footprints and well-being to have an inverse relationship (Ambry and Daniels 2017).

The associations between individual components of both sustainability and happiness indices have also been looked at by some researchers. Lenzen and Cummins (2013) attempt to identify common aspects of SWB and carbon footprint, using survey data of Australian lifestyles. In alignment with previous research, they found that higher income levels are associated with increased emissions. However, as Lenzen and Cummins (2013) mention, other researchers have found that once gross income reaches $100k carbon emissions continue to increase but well-being does not. Lenzen and Cummins (2013) also conclude that while owning a vehicle was associated with increased well-being, living in an area with a high level of vehicle ownership was associated with a decrease in SWB. Interestingly, their research shows that a higher level of academic qualification was associated with an increase in emissions. They attribute this to the increase in socio-economic level that usually accompanies increasing level of education.

Verhofstadt, Ootegem, Defloor, and Bleys (2016: 80) used survey data from a region of Northern Belgium to look at the link between the “environmental sustainability of an individual’s lifestyle” using ecological footprint and certain factors of subjective well-being (SWB). Their findings indicated no overall significant correlation between the two but did identify that “the main item that is good for both SWB and EF is the consumption of seasonal products and fresh products” and that not using electricity for home heating both “reduced EF and increased SWB” (Verhofstadt et al. 2016: 83-84). While it may sound like an undesirable conclusion that there was no overarching significant correlation, it is not necessarily so. No significant correlation means that “having a lower footprint is not associated with reporting a higher level of well-being” but also, and importantly, that “having a lower footprint does not reduce one’s level of subjective well-being” (Verhofstadt et al. 2016: 83). In a related study, using ecological footprint to account for environmental stressors as part of their model for Efficient Well-Being (EWEB), Dietz, York, and Rosa (1999: 119) found “no evidence that adversely stressing the environment improves human well-being, net of affluence and human capital.”

Two other factors that have been identified as being positive for both SWB and sustainability are empathy and compassion (Ericson, Kjonstad and Barstad 2014). Ericson et al. (2014) suggests that at least part of the relationship may be explained by how both empathy and compassion can make caring for the environment to be an ethical issue, and that framing it this way might be more likely to inspire action. Empathy and compassion might also play into sustainability in another way, in that they are known to increase pro-social behavior and this may spill over into making more pro-environmental choices. Pro-environmental consumption choices have been identified by some research as contributing to a rise in life satisfaction (Welsch and Kuhling 2011).

As has been presented, most research in this area has used subjective well-being, rather than quality of life, as a measure to compare human life quality and environmental sustainability. While frequently used interchangeably in the literature, there can be a notable distinction between the two. Subjective well-being measures, as the name implies, are subjective assessments of individual life quality as reported by the individual, while quality of life measures consist of composite indices designed to theoretically evaluate life quality. The theoretical nature of QoL allows for evaluation free from the social and cultural biases, that can often plague SWB. This also makes QoL a useful tool for policy decisions, particularly in relation to ecological footprint as both can be used to take the sort of snapshots on progress mentioned in the previous discussion of EF. Using the two together allows for the same population to be measured in the same way over time, something that is generally lacking with SWB measures (Lenzen and Cummins 2013).

Gaps in the Literature

The Ecological Footprint has shown to be a useful tool toward measuring sustainability. While there are weaknesses to EF, its strength of providing a 'snapshot' in time, communicating its message in a simple manner, and being translatable across borders have made the ecological footprint a valuable tool. EF has been used as an indicator in research to compare sustainable development between nations, to evaluate the link between sustainability, wealth, and environmental protection, and to look at the effects of globalization and urbanization on the sustainability of countries. Some research has been done in the interest of understanding the link between EF and well-being, with more work having been done using other indicators of sustainability.

It is clear that there is still a need for more research in this area to fully explore the connections between the ecological footprint and human well-being. Specifically, more work is needed to further investigate the relationship between sustainability, as measured by EF, and quality of life. While most studies have focused on SWB, it is essential to better understand the relationship between QoL and ecological footprint. While SWB can only be calculated if there are individuals to survey, QoL indices can be projected based on available data. As the world moves toward more sustainable futures, being able to anticipate the impact possible circumstances may have on the daily life of individuals in a given location will be of paramount importance.

As we have reviewed, researchers have compared SWB to various sustainability indices and found that higher SWB scores are associated with higher sustainability scores (Cloutier et al. 2014). Ecological footprint has also been compared with SWB scores leading to the conclusion that lower EF does not mean lower SWB (Verhofstadt et al. 2016). And higher carbon footprints have been found to be associated with lower SWB (Ambry and Daniels 2017). All of these studies have used SWB as the indicator of life quality. At this time there appears to be no literature in which QoL is evaluated as the life quality indicator. Of the literature utilizing SWB, the single large-scale study of the U.S. considered only major cities and thereby ignored rural and less populated areas entirely.

Investigation into EF and QoL could be beneficial on a more localized scale, one that includes both rural and high density urban areas. Comparing ecological footprint and quality of life at a more local, or zip code level could be particularly insightful. With this small unit of analysis it would be easier to separate out confounding factors, thus allowing for a contribution to the literature on the relationship between EF and QoL. In addition, a local-level analysis provides the opportunity to more closely evaluate social and economic elements in a way that may elude more large-scale analysis. Any such study should be limited to only one geopolitical region at a time so as to minimize the influence of lifestyle differences across regions.

III. RESEARCH QUESTIONS

The Ecological Footprint (EF) has been shown to be a useful tool toward measuring sustainability and has been used as an indicator in research to compare sustainable development between nations, to evaluate the link between sustainability, wealth, and environmental protection, as well as to evaluate the effects of globalization and urbanization on the sustainability of countries. However, while some studies have looked at the relationship between the EF and subjective well-being, little if any research has been conducted using quality of life measures. Only using SWB to evaluate life quality is potentially problematic as survey methodology can often introduce bias through the choice of survey questions, wording of the survey, and response bias, among others. The self-reported nature of SWB also presents the issue of social and cultural biases which may potentially skew the data (Camfield and Skevington 2008; Moro et al. 2008; Veenhoven 2001). While the use of SWB can inform studies of self-perception of environmental impact, with data that are comparable across space, the use of QoL measures can offer a more standardized approach, free from the biases of SWB. This research seeks primarily to add to the body of literature on sustainability, as measured by the EF and quality of life by looking for relationships between the two. Further, it is hoped this study will identify locations where a low EF occurs in conjunction with high quality of life to demonstrate that the two are not intrinsically at odds.

Waldo Tobler's (1970) first law of geography says that all things are related, but closer things more so. Based on this principle it is expected that both ecological footprint scores and quality of life scores will be clustered geographically. Demographic factors contributing to this clustering will be investigated. However, the primary focus of this study is in exploring the relationship between ecological footprint and quality of life. Based on the literature, our hypothesis is as follows:

Hypothesis: There is an inverse relationship between ecological footprint and quality of life at the zip code level within the U.S.

IV. ANALYSIS

Data and Methods

As our primary interest is that of informing opinions within the United States, our analysis will only consider U.S. zip codes and will be done by merging two independent datasets, both at the level of zip code. National level studies of EF and SWB have been done, but we are unaware of any that have specifically looked at the U.S., or at EF and QoL together, as opposed to EF and SWB. Zip code level analysis was chosen because it is a smaller unit of analysis than other studies on well-being, done at the regional level, and more focused than the most common unit for which EF is used, typically country or state. The advantage of this more local-level analysis is that it allows for a more thorough investigation of social and environmental factors, and may provide previously unrecognized patterns, particularly as it relates to carbon emissions.

The data for quality of life value will come from the Easy Analytic Software Inc (EASI) Quality of Life index. This is a weighted composite developed by EASI which is comprised of the EASI Weather Index, EASI Total Crime Index, Earthquake Index, Culture Index, Amusement Index, Restaurants Index, Medical Index, Religion Index, and Education Index to create a proxy measure for quality of life. The indexes for culture, amusement, restaurants, medical, religion and education are based on the availability of these resources to a given locale and are measured by number of people employed in each pursuit; EASI Weather

Index uses the closest weather station to determine a proxy score for the impact of weather and is based on numerous factors including annual maximum temperature, mean number of days of snow, and average annual precipitation; EASI Crime index models the likelihood of various types of crime to occur in a given area; the Earthquake index is based on the measure of effective peak acceleration, the same factor used in federal building requirements (www.easidemographics.com). These proxies are in line with those used in previous research using Quality of Life (Moro et al. 2008). EASI Quality of Life index will be accessed through Simply Analytics and imported into ArcGis Arcmap for analysis.

The second dataset utilized for this study is from research done by Kevin Ummel (2014, 2016) for The Citizens Climate Lobby (CCL) and contains a measure from which average household carbon footprint (CF) at the zip code level can be obtained. The CCL's estimation of average household carbon footprint is based on direct emissions, like those from electricity use, natural gas, or gasoline consumption; as well as indirect emissions resulting from the production of other items and services consumed by the household. A formula was provided by Ummel to derive the average household carbon footprint per zip code from the data on carbon tax impact. Because carbon footprint represents 60% of the overall human Ecological Footprint (footprintnetwork.org) this is a viable proxy for EF.

Lastly, we will use demographic variables provided by Simply Analytics for our various controls. These variables will be at the zip code level and include median household income, percent with a bachelor's degree or above, percent age 25 or older, median household size, race (percent white), unemployment rate, and population density. All control data is taken from 2012, the same year used in the CCL dataset to adjust for inflation and the last year of data collection for Ummel's analysis.

Table 1. Variables and Sources of Data

Variable	**Source**
Household Carbon Footprint	Citizens' Climate Lobby
Quality of Life	Simply Analytics
Population Density	Simply Analytics
Median Income	Simply Analytics
Median Household Size	Simply Analytics
Percent Unemployment	Simply Analytics
Percent Bachelor's Degree or Higher	Simply Analytics
Percent Age 25 yrs or Older	Simply Analytics
Percent White (race)	Simply Analytics

To investigate the relationship between quality of life and ecological footprint we acquired a dataset of average household carbon footprint (HCF) at the zip code level to which we joined our dataset of control variables. To ensure our datasets could be reasonably compared all control data was taken from the same year

(2012), the most recent year of data collection for the carbon footprint measure. In total, our dataset consisted of information on 33,144 United States zip codes. Datasets were joined by zip code in ArcGIS to create one comprehensive file before being imported into GeoDA for analysis.

To determine the relationship between QoL and EF, we performed multiple regressions: A standard ordinary least squares (OLS) estimation model, a spatial error (SE) model, and a spatial lag (SL) model. As a supplemental analysis, we ran a spatially weighted two stage least squares model accounting for spatial lag and spatial error (SLSE). For the OLS, SE, and SL models a univariate Moran's I scatter plot was also run, using the residuals. Each of our four models used the CCL carbon footprint value as dependent variable and quality of life index value, median household size, median income, age, attained education level, percent unemployment, race, and population density as independent variables.

Results

In each regression model, all variables presented statistical significance. The initial OLS regression model results showed positive correlations between carbon footprint and median income, median household size, and percent white; and negative correlations for quality of life, percent unemployed, percent with a bachelor's degree or beyond, percent 25 years of age and older, and population density with a Moran's I for the residuals of .3002. For the spatial error model, quality of life, population density, median income, median household size, percent with a bachelor's degree or above, and percent white were all positively associated with carbon footprint while percent unemployed and percent 25 years of age and over, were negatively correlated to carbon footprint. This model had a Moran's I for the residuals of -.0433. Outcomes for both the spatial lag and our auxiliary spatial lag plus spatial error models were similar. Both models showed inverse relationships for carbon footprint and quality of life, percent unemployment, percent with a bachelor's degree or beyond, percent 25 years of age and over, and population density; with a positive association between carbon footprint and median income, median household size, and percent white. The Moran's I for the spatial lag model was .0203. We were unable to run a Moran's I for the SLSE model due to the size of the dataset.

Because Moran's I is a measure of spatial autocorrelation, how interdependent one object is to nearby objects, it is important for the result of Moran's I of the residuals to be as close to zero as possible. A low Moran's I for the residuals indicates that our model is successfully controlling for spatial relatedness of the variables. Of our models, the spatial lag model produced the lowest Moran's I from the residuals. The spatial lag model also closely mirrors our spatial lag plus spatial error model which would theoretically produce an even lower Moran's I result. The low Moran's I of the spatial lag model and its similarity to our supplementary lag plus error model make it a better model than either the OLS or SE models.

Results from the spatial lag model indicate that in the United States, carbon footprint and quality of life are inversely related at the zip code level, though weakly (-.0085), confirming our hypothesis.

Table 2 . Results: Four Regression Models

		Model 1 - OLS			**Model 2 - SE**			**Model 3 - SL**			**Model 4 - SE +SL**	
Variable		b	Std. Error		b	Std. Error		b	Std. Error		b	Std. Error
Dependent Variable												
HH CO2 footprint												
Independent/ Control Variables												
Quality of Life		-.0067	.0014		.0207	.0023		-.0085	.00124		-.0067	.0014
Population Density		-.0002	1.0204		9.2139	1.5834		-.0001	9.0679		-.0001	.00001
Median Income		.0002	3.5269		.0002	3.9375		.0001	3.20859		.0001	.00001
Median Household Size		3.4509	0.1128		2.3189	0.1199		2.84319	.1001		2.9022	.1503
Percent Unemployment		-.202	.0104		-.1001	.011		-.1131	.0092		-.1129	.016
Percent Bachelor's or Higher		-.0327	.0053		.0428	.0058		-.0188	.0047		-.008	.0069
Age 25 years or over		-.1096	.0051		-.1231	.0055		-.058	.0045		-.0767	.0074
Percent White		.0578	.0028		.0228	.0035		.0297	.0025		.0331	.0037
Constant		31.8617	.1544		32.6242	.1696		13.3161	.2528		16.9406	.8082
Rho								0.4717	0.0053		0.3813	0.0183
Lambda					.6613	.0052					.2325	.0228
Morans I (residuals)		.3002			-.0433			.0203				
N		33144			33144			33144			33144	

V. DISCUSSION

The goal of this study was to investigate the relationship between ecological footprint and quality of life within the U.S after controlling for socio-demographic variables and spatial clustering.

Ecological Footprint and Quality of Life

The results indicate a small but significant inverse relationship between household carbon footprint and quality of life. This suggests that places with a higher quality of life have a lower carbon footprint. In a Western Capitalist society such as the US, it is often generalized that a lower carbon footprint would be associated with lower economic wealth and affluence, both of which are linked to a higher carbon footprint due to increased spending on goods, services, energy use, and transportation. Lower income levels also tend to be seen as having a lower quality of life than their more financially endowed counterparts. Contrary to this assumption, our results indicate the relationship between EF and QoL to be inverse, existing even when controlling for income.

Finding QoL and HCF to be negatively associated serves as a counter to the common narrative that living in a more sustainable way requires sacrifices in the short term while only benefiting future generations. While sustainability is inherently an intergenerational issue, our findings reveal that there may be real and quantifiable short-term benefits to reducing carbon footprints as well. These results suggest that one can increase their quality of life, while lowering their environmental impacts as measured by the ecological footprint. Such a narrative is somewhat counterintuitive in modern thinking, but the decoupling of quality of life and ability to consume goods is supported by a concept known as the Easterlin Paradox. In the early 1970's Easterlin found that income does increase perceived life satisfaction, but only to a point. Once an individual reaches a certain point, the effect of money on happiness levels off (Easterlin 1974). Easterlin's idea therefore serves as a counter to the prevailing notion of GDP being an appropriate measure of quality of life within a nation.

GDP, or gross domestic product, has long been the primary measure of a nation's economic performance and is often applied to represent a nation's general well-being. However, many have found fault with the way the concept is utilized. Tim Jackson (2008) points out that since 1950 income in the United States has tripled, but rates of depression have doubled each decade across North America. This would seemingly indicate that monetary gains, as could be represented by GDP, do not accurately reflect quality of life. This idea was echoed by David E. Kaun when he argued that typical American consumer lifestyles may actually contribute to decreasing well-being (Kaun 2005). In 2008 then president of France, NIcholas Sarkozy, found such a fault with GDP as an indicator of well-being that he created a special commission tasked with evaluating GDP as a measure of economic and social progress and considering more inclusive alternatives. Critiques of the use of GDP as a means for representing well-being have existed since as far back as the 1930's and income is now considered neutral in terms of well-being by at least some economists (Cavalletti and Corsi 2016).

Our finding supports the idea that GDP is not an accurate indicator of life quality by showing that QoL is not intrinsically intertwined with financial standing and implies that the stuff of consumerist American lifestyles - the stuff people fear a more sustainable lifestyle will take from them - may not actually be related to quality of life or well-being at all. In fact, one study found that self-sufficiency better predicts well-being than GDP does (Cavalletti and Corsi 2016).

Other Variables

We found population density (per square mile) to be inversely associated with HCF. This is in line with the literature and the discussion surrounding cities as the forefront of a sustainable future. However, many studies involving population density and CF have had conflicting results (Ergas, Clement, McGee 2016; Jones and Kammen 2014; Miche, Scheumann, Jones, Kammen, Finkbeiner 2016). Christopher Jones and Daniel M. Kammen (2014) looked at HCFs across the U.S. and found that carbon intensity of suburbs may overrule the lower carbon footprints of population dense city centers. They discovered that both the population dense core of a city and the rural area outside of the city's suburbs had similar footprints, compared to suburban areas of the city, and that these effects varied by city size. They state income as the primary influencing variable for HCF, not density.

As was expected, our results showed income to be positively associated with carbon footprint. This result is interesting as Ummel's (2016) carbon footprint data had, to a degree, already controlled for affluence within the calculation itself. Ummel (2016) recognizes that more affluent households may spend more for the same product than less affluent households. He uses the example of a $30 pair of shoes purchased at a major big-box retailer versus a $600 pair of luxury brand shoes. Both purchases would fall under the same expenditure category but are not likely to have grossly different carbon footprints, as a non-controlled formula would attribute them to have (Ummel 2016). So, income is still associated with carbon footprint even when controlled for at multiple points in the analysis. This finding is in line with Clement, Pattison, and Habans' (2017) results showing that affluence and carbon footprint are positively related at the zip code level. Other researchers have found the same effect (Kennedy, Krahn, and Krogman 2013).

While some research points to co-housing, or multiple people living together, as being more sustainable, our results show that carbon footprint gets larger as household size increases. However, this finding may not be contradictory to the literature in that while the household footprint increases, it may not be as large as if the individuals in the household were living separately, due to decreasing economies of scale (Miehe et al. 2016).

Unemployment rate was negatively associated with carbon footprint. This could possibly be explained by less job-related transportation use, or by decreased spending.

While Lenzen and Cummins (2013) found that emissions increased with education level, our results indicate a negative relationship between education and carbon footprint, indicating perhaps that those who are educated are more aware and conscientious regarding the environment.

The variable we used for age was percent of the population age 25 or older. We found a negative relationship between the age variable and CF. This is likely due to children living at home and the increase in CF associated with an increase in household size.

Interestingly, we found that the percent of the population identified as white was positively associated with carbon footprint.

Implications and Applications

While this study does not prove that a lower carbon footprint will result in higher quality of life or vice versa, it does show correlation between ecological footprint and quality of life implying that improvements in our quality of life can have the effect of improving our carbon footprints and that lowering of carbon footprints does not automatically translate to a lower life quality. This is at odds with common arguments that living more sustainably requires sacrifice. The results of this study, in fact, point to the opposite being true. However, in the general population it is often thought that increasing sustainability is inconvenient and compromises the lived experience. These results question that assumption. There are many examples where gains in sustainability may be made with little to no inconvenience, or sacrifice of life quality. One such example is switching to renewable energy. Austin Electric in Austin, Texas provides its residential and business customers the option to choose 100% wind energy as the source of their electric. For residential customers this option adds a minimally inconvenient .0075 cent to each kilowatt hour used. According to Austin Energy's data, customers choosing their renewable energy program prevented 379,000 metric tons of carbon from being released (Austin Energy 2018). Similarly, the increased availability of electric and hybrid vehicles allows drivers to persist in individual travel while causing fewer emissions. Many hybrid vehicles can be purchased for a price comparable to non-hybrid models. Though mass transit would ideally be utilized as a way of reducing emissions, driving a less polluting vehicle, such as electric or hybrid, requires no sacrifice of routine or habit and yet reduces the carbon footprint of one's travel. Perhaps a more vivid example of where a more sustainable option has no discernable decrease in life quality is the implementation of low-flow toilets. With the installation of a low-flow toilet functionality is maintained with less water usage at no noticeable difference to the user. Similarly, the switch from incandescent to CFL bulbs requires no sacrifice and saves both energy and money over the long-term.

Limitations

One potential limitation of this study is the way in which quality of life is measured. For our quality of life measure we used an index value provided by EASI and Simply Analytics, which predetermined how quality of life was assessed. The EASI QoL index is a weighted composite of other indexes related to life quality. The potential limitations here are threefold. First, it is possible there are other factors that greatly contribute to quality of life which were not included in the index. Second, the way the indexes are weighted within the QoL index may place an unreasonably heavy value on some factors compared to others. And lastly, it is possible there could be a better methodology for how the indexes for the individual QoL factors are derived.

A second limitation of this study is that while the carbon footprint data used is extensive in geographical coverage it is not an exhaustive measure of CF, but rather an estimate. Ummel's (2016) calculations for CF are based on average expenditures, not an exact item for item accounting of every household in every zip code. This method allows for the study of large geographical regions, regions in which it would be impractical to survey each individual household. However, because the measure is an estimate, it may not represent the exact use of each household.

Lastly, there is the potential limitation of the Ecological Footprint itself as the measure does not account for the ecological intensity of production. For example, lettuce produced in a hydroponic growing tower uses less water and land than the same crop grown in a traditional manner in a field. However, the ecological footprint would represent both scenarios as having the same footprint since intensity is not considered.

VI. CONCLUSION

In conclusion, this study has found Carbon Footprint and Quality of Life to be inversely related within the United States. This result contradicts the belief that a more sustainable way of life requires sacrifices in quality of life. Recognizing that the two are not necessarily positively linked is important for policy considerations. Policy framed around increasing quality of life has the potential to reduce carbon footprint and would likely be more well-received than policy aimed at directly reducing consumption or affluence. This study provides a groundwork for further research on quality of life and ecological footprints. In the future, research should consider more specifically how carbon footprint affects quality of life and identify areas of greatest impact. If focus can be shifted to the potential increase in quality of life associated with carbon footprint reduction, more action in terms of reducing carbon emissions may be achieved.

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