

An Integrated Self-Sufficiency Index: An Alternative to Carrying Capacity

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During their day-to-day academic lives, geography professors and their students examine and discuss a multitude of concepts, principles, theories, models, and explanations that frequently go unquestioned and are often accepted outright as being factual, accurate and defensible. This is probably true of the concept, “carrying capacity.” In reality, the carrying capacity of a country, or the world for that matter, is nothing more than a vague theoretical concept that cannot be calculated, although some have attempted. I argue that we should not accept the concept, “carrying capacity,” as found in contemporary geography textbooks, at its face value, because a value for carrying capacity cannot be calculated, and that there are better methods of measuring national self-sufficiency, sustainability, and vulnerability, that can be calculated, and trusted. One of those is an integrated self-sufficiency index. **Key Words: carrying capacity, population/resource interface, integrated self-sufficiency index.**

Introduction

Geographic aspects of population have been part of professorial lectures in introductory, human, and other geography courses for decades. Most geographers have taught students about a variety of concepts that are frequently associated with our understanding of population and its relationship to resource use. Terms such as “overpopulation,” “crude density,” “arithmetic density,” “physiological density,” and “carrying capacity,” are frequently presented as methods of expressing human pressure on a country’s resource base. Most students, of course, never question the usefulness of these concepts. After all, the professor acknowledges their importance, and these concepts can be found in the textbook. What is more disturbing, perhaps, is that the professors themselves do not question the validity of such concepts as useful explanations of the human/resource interface. Again, after all, are there not even maps, for example, that show the variable nature of “crude density” or “carrying capacity?” Mapped data surely must accurately display empirically-based calculations and analyses!

Yet, maps, as geographers know, are intriguing visual devices that do, on occasion, cause one to question the spatial distributions and analyses that are being portrayed. The curiosity of the geographer is that if he or she determines that a map can display the distribution of a certain phenomenon for one location, he or she might be led to ask, why cannot that phenomenon be created for other locations? The logical assumption is that it can! But, does the observed distribution really exist, and can it be shown to exist elsewhere?

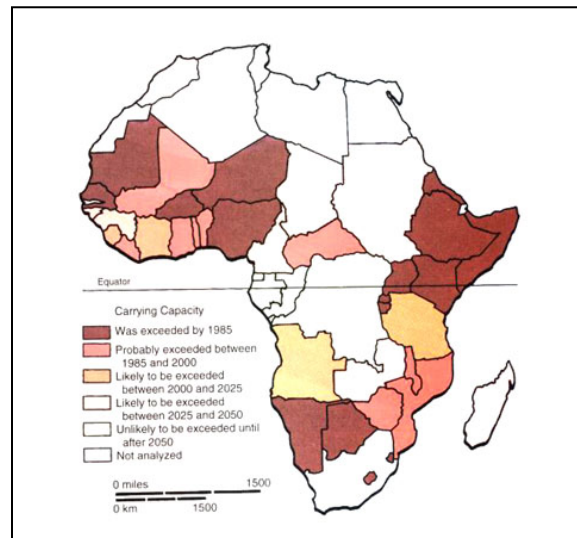
Some years ago, after observing and trying to analyze Figure 6.25, *Carrying capacity and potentials in sub-Saharan Africa*, in Getis, Getis, and Fellmann’s *Introduction to Geography* (2004, 220), I thought to myself, “I would like to see a similar map for the entire world.” Therefore, I began to search for such a map, but after a thorough search, I was not able to find one. I then thought to myself, “If someone generated a map of Africa which showed carrying capacity for each country, surely I could generate a similar map that showed the carrying capacity for each country on earth. All I need to do is to find the equation for carrying capacity and go to work.” But, a workable equation to calculate carrying capacity was just as elusive as was a world map of carrying capacity. I finally concluded that the concept of “carrying capacity” was nothing more than a hypothetical, theoretical, conceptual value, and that it could not be calculated. Yet, and more troublesome, was the realization that “carrying capacity” was being perpetuated in the literature as the best method of understanding the human/resource interface.

The remainder of this paper focuses on the concept of “carrying capacity”—what it is, how it is defined, how it has been abused, and how some scholars have attempted to create theoretical mathematical models of it based on speculation, assumption, and supposition. I then present, what I believe is be a better, more empirically sound, method of understanding the relationship between employment, resource needs, and self-sufficiency – an integrated self-sufficiency index.

The Carrying Capacity Problematic

According to one definition, carrying capacity refers to “the numbers of any population that can be adequately supported by the available resources upon which that population subsists; for humans, the numbers supportable by the known and utilized resources—usually agricultural—of an area (Getis, Getis, and Fellmann 2006, 505). As alluded to above, the concept, “carrying capacity,” is widely used and can be found in most, if not all, contemporary introductory and human geography textbooks. Rubenstein (1992, 545), for example, writes:

“Just as a good farmer knows how many animals can be fed on a parcel of land, a scientist can pinpoint the constraints that resources place on population density or economic development in a particular region. This type of study is called carrying capacity analysis.” Similarly, Salter and Hobbs (2003, 38), state that “In ecological terms, the expanding food surplus of the Agricultural Revolution raised Earth’s carrying capacity—that is, the size of a species’ population (in this case, humans) that Earth’s ecosystems can support.” Additionally, Getis, Getis, and Fellmann (2006, 206), note that “Overcrowding is a reflection not of numbers per unit area but of the carrying capacity of land—the number of people an area can support on a sustained basis given the prevailing technology.” They further argue, “... carrying capacity is related to the level of economic development” (206).



Illustrated above is *Figure 6.25, Carrying capacity and potentials in sub-Saharan Africa* from Getis, Getis, and Fellmann’s (2006, 206) *Introduction to Geography*. The legend, which explains the varying colors of African countries, reads: “Carrying Capacity 1) Was exceeded by 1985; 2) Probably exceeded between 1985 and 2000; 3) Likely to be exceeded between 2000 and 2025; 4) Likely to be exceeded between 2025 and 2050; and 5) Unlikely to be exceeded until after 2050” (220).

One other example comes from Austin, Honey, and Eagle’s *Human Geography* (1987, 287) wherein they state, “By raising crops people multiplied the carrying capacity of their land...”

Geographers, of course, are not the only scientists to have had an interest in the concept, “carrying capacity.” Demographers, human ecologists, biologists, and variety of agencies within the United Nations, have written extensively about carrying capacity. For example, in 1982, the Food and Agriculture Organization of the United Nations published *Land Resources for Populations of the Future*, which concluded that “... of 117 developing countries examined, no less than 64 would be unable to meet the food needs of their expanded populations in the year 2000 without the use of fertilizers, pesticides, improved seeds or improved conservation measures” (Internet 2004). Nachtergaele (2004) maintains that Getis, Getis, and Fellmann may have drawn from this study for Figure 6.25.

Muir (2003) wrote:

“The size at which a theoretical population would stabilize ... is referred to as the carrying capacity. The carrying capacity is the theoretical equilibrium population size at which a particular population in a particular environment will stabilize when its supply of resources remains constant. It can also be thought of as the maximum sustainable population size; the maximum size that can be supported indefinitely into the future without degrading the environment for future generations.”

From the Carrying Capacity Network Website (2003), we find, “In fact, the criterion for determining whether a region is overpopulated is not land area, but carrying capacity.” From the same site, “Carrying capacity refers to the number of individuals who can be supported in a given area within natural resource limits, and without degrading the natural social, cultural and economic environment for present and future generations. The carrying

capacity for any given area is not fixed. It can be altered by improving technology.” Therein lies one of the problems with carrying capacity - constantly varying variables prevent it from being calculated – it is only a theoretical concept and not a value that can be calculated.

Some scholars have recognized carrying capacity as problematic. Muir (2003) argues, “Logistic growth is very idealized, of course. K [carrying capacity] is not likely to be constant (for example, year-to-year changes in weather effect food production; the richer a life we desire, the lower K for humans is likely to be, etc.). However, the model is useful conceptually.” Muir (2003) concludes by noting, “It is unlikely, however, that we can define a specific K (that is, an actual number) for humans. (People seem to enjoy trying though!)” Hardin (2003) expresses similar concerns. He maintains, “There is no hope of ever making carrying capacity figures as precise as, say, the figures for chemical valence or the value of the gravitational constant.” “As a result,” he writes, “... any particular figure for carrying capacity has a substantial element of the arbitrary in it.”

To their credit, some scholars have continued to attempt to formulate an equation that can be used to calculate carrying capacity. Two are noted here.

First, Meyer and Ausubel (1999) maintain they formulated “... a model where carrying capacity K of a system increases dynamically, but in a distinct pulse” (209 – 210). But, they recognize, “... the carrying capacity $K(t)$ itself [was] a logistic function of time” (210). In other words, not only were there fluid resource and population variables, but also change through time complicates “calculations” of carrying capacity. They also state, “Finding convincing or widely agreed upon estimates and models for carrying capacity, especially for humans, is difficult” (209), and “... models of growth for human systems based on *fixed* resource limits or single, unchanging carrying capacity are unrealistic” (209). Further, Meyer (2003) states, “... I would find a fixed carrying capacity estimate for a country to be misleading.” And, “... we apply the model to historical data mainly to make our main point: that human carrying capacities are not fixed. In order to apply the model to predict future carrying capacities would be difficult.”

Second, Cohen (1995) likewise understood that “The future of the human population, like the future of its economies, environment, and cultures, is highly unpredictable” (341). While he noted “... a probabilistic measure of human carrying capacity has been developed for local populations in the Amazon, no probabilistic approach to global human population carrying capacity has been developed” (343). He further maintains, “In basic and applied ecology, the carrying capacity of nonhuman species has been defined in at least nine different ways, none of which is adequate for humans” (343). The problem with calculating human carrying capacity is that

“Human carrying capacity depends both on natural constraints, which are not fully understood, and on individual and collective choices concerning the average level and distribution of material well-being, technology, political institutions, economic arrangement, family structure, migration and other demographic arrangements, physical, chemical, and biological environment, variability and risk, the time horizon, and values, tastes, and fashions” (343).

Cohen (1995, 343) rightly argues, “Human carrying capacity cannot be defined for a nation independently of other regions if that nation trades with others and shares the global resources of the atmosphere, oceans, climate, and biodiversity.” Finally, Cohen describes “... idealized mathematical models for the race between the human population and human carrying capacity (343), but only after stating, “If a current human carrying capacity could be defined” (343), and, “Suppose that it is possible to define a current human carrying capacity $K(t)$ as a numerical quantity measured in numbers of individuals” (343).

In a slightly different, yet nonetheless important context, within recent years, scholars at the International Institute for Applied Systems Analysis and at the Food and Agriculture Organization of the United Nations, have used an agro-ecological zones methodology (AEZ) to assess and inventory land resources (Fischer et al 2002). AEZ, they argue, provides, 1) “... a standardized framework for the characterization of climate, soil, and terrain conditions relevant to agricultural production,” 2) procedures to identify crop-specific limitations of prevailing climate, soil, and terrain resources, under assumed levels of inputs and management conditions,” and 3) “... the framework for various applications ... such as quantification of land productivity, extents of land with rain-fed or irrigated cultivation potential, estimation of the land’s population supporting capacity, and multi-criteria optimization of the use and development of land resources” (p. xviii).

Yet, what appears to be promising falls short because the authors have not provided any estimates “... of the land’s population supporting capacity.” While Nachtergaele (2004) argues that “results of more recent and more sophisticated studies allow for more georeferenced outputs pinpointing problem areas within countries,” one must conclude, therefore, as have many other scholars, that a carrying capacity statistic, for each country across the globe, cannot be calculated and that carrying capacity is not an empirically-based concept that is useful in assisting us in

understanding the relationship between humans and their environment. While on the surface the concept appears sound, logical, understandable, and calculable, it is none of these and should be abandoned.

An Integrated Self-Sufficiency Index

What then, can be used to provide a way to measure the interaction and relationship between a nation's economic structure, resource base, and consumption needs? I propose here an index that measures a nation's self-sufficiency, or in other words, an index that measures the economic capacity for what I call "integrated self-sufficiency." That is, a country reaches a certain level of "integrated self-sufficiency" if it can produce a portion of its needs and is integrated sufficiently into the global economy which enables it to import and export, thus securing external items for self-sufficiency and selling externally to generate necessary purchasing power.

The Integrated Self-Sufficiency Index (ISI) measures a country's ability to produce and secure its consumption needs. The higher a country's ISI, the greater the mismatch between what that country was able to produce and secure and what it consumes. A high ISI identifies a country that may not possess "integrated self-sufficiency," while a low ISI indicates that a country appears to have attained some level of "integrated self-sufficiency." A country, therefore, is not adequately integrated globally and cannot be self-sufficient if it is not able to provide adequately for its citizenry.

The ISI is a rather simple equation that compares the percentage that the economic sectors - agriculture, industry, and services - contribute to the total Gross Domestic Product (GDP) in a country or territory. To calculate the ISI, one assumes that a state's lack of self-sufficiency is greater when one or a few large sectoral divergences from the global percentages occur than it is with several small deviations (Yorgason 2003).

The ISI is calculated according to the following formula:

$$v \\ ISI = \sum_{i=1} P_i (1 - LQ_i)^2$$

Regarding the equation, LQ is a locational quotient - the percentage of a country's GDP resulting from an economic sector divided by the percentage of the global GDP derived in that sector. If, for example, a country had 18 percent of its GDP derived from the Primary sector of the economy while the global level was 24 percent in that sector, the locational quotient for the Primary sector in that country would be 0.75. The Primary sector for that country would then fall within v , the set of economic sectors for a country in which the locational quotient was less than one. This set, v , constitutes the economic sectors where a country was likely to be unable to produce its consumption needs.

In the equation, v is a set of economic sectors for a country in which the LQ is less than 1.0. These constitute the economic sectors in which a country is not self-sufficient (the percentage of the country's GDP in that sector is lower than the global percentage for that sector).

In the equation, P is the percent of the global GDP derived in an economic sector (12 percent = 12, not 0.12). According to the CIA's *World Factbook* (2005), the current percentages derived in the Primary, Secondary, and Tertiary sectors of the global economy are 4, 32, and 64, respectively. Instead of adding the total divergences from the global average (based on the locational quotients) within the set v , the squares of the divergences are added, after being multiplied by P to reflect the economic sector's importance in the global economy as a whole.

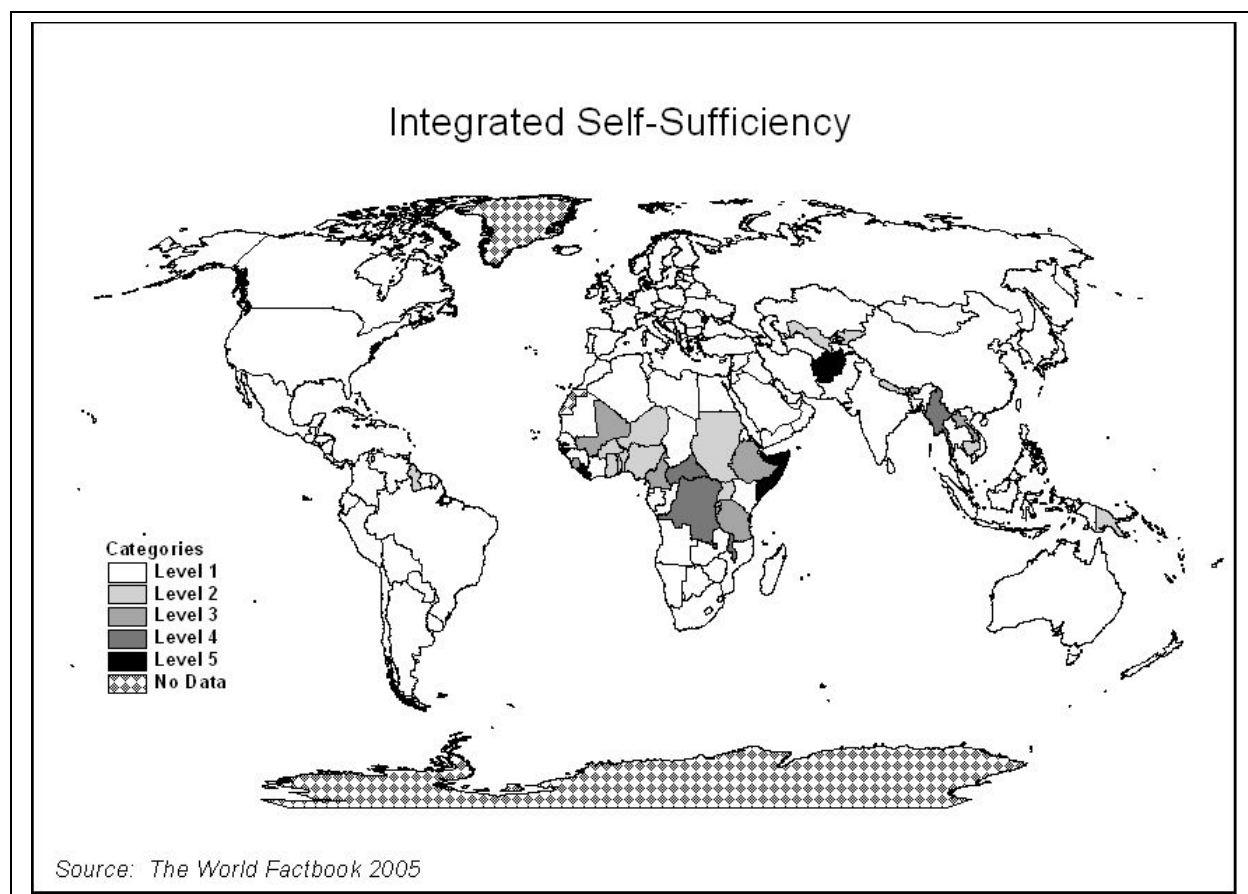
The Analysis and Distribution

An Integrated Self-Sufficiency Index was calculated, where data were available, for 206 political units—sovereign countries and many of their territories (CIA *World Factbook* 2005). The calculated indices were then categorized into five Levels of Integrated Self-Sufficiency and mapped as shown in Figure 1.

Level 1 includes those 170 countries and territories (82.5 percent of the total) that we may conclude are self-sufficient; they are the most capable of supporting their own citizenry. The indices for places in Level 1 ranged from 0 to 1271.77. Level 1 places are widely scattered across the globe, and include such countries as Finland, Hungary, South Korea, Slovakia, and Spain.

Level 2 includes those 17 countries and territories (8.3 percent of the total) that are slightly less self-sufficient with indices ranging from 1295.66 to 3538.07. Level 2 places are also widely scattered, and include such countries as North Korea, Sudan, and Rwanda.

Level 3 includes those 10 countries and territories (4.9 percent of the total) that are moderately not self-sufficient with indices ranging from 3795.24 to 6505.38. Level 3 places are scattered, but generally clustered in Africa. Countries in this level include Tanzania, Mali, and Ethiopia.



Level 4 includes those 5 countries and territories (2.4 percent of the total) that are strongly not self-sufficient with indices ranging from 6615.56 to 9792.04. Three of the Level 4 places are found in Africa (Malawi, Central African Republic, and Democratic Republic of the Congo). The other two are Burma and the Federated States of Micronesia.

Level 5 includes those 4 countries and territories (1.9 percent of the total) that are absolutely not self-sufficient with indices ranging from 11,762.81 to 25546.11. Three Level 5 countries are found in Africa - Guinea-Bissau, Liberia, and Somalia, and one is found in South Central Asia - Afghanistan.

A more careful analysis clearly shows that the percent of the GDP derived in the Primary Sector of a country's economy plays a significant role in determining the ISI. It was found that the correlation between the percent of the GDP derived in the Primary Sector and the ISI was .821 and was significant at the .01 level. Thus, we can safely conclude that as the percent of the GDP derived in the Primary Sector increases, so does the ISI. Conversely, as the percent of the GDP derived in the Secondary and Tertiary Sectors increase, the ISI goes down—countries become more self-sufficient. The correlation between the percent of the GDP derived in the Secondary Sector and the ISI was found to be -.322, significant at the .01 level. The correlation between the percent of the GDP derived in the Tertiary Sector and the ISI was found to be -.533, significant at the .01 level. These data demonstrate that as a country's GDP is derived more from manufacturing and construction, but more importantly, in the service sector, that a country's level of self-sufficiency increases. From a policy and development standpoint, Level 1 countries interested in improving economies and alleviating the conditions found in countries in Levels 4 and 5, would focus on improving the service sector and reducing the percent of the GDP derived in the Primary Sector.

Conclusion

Like all other academic disciplines, geography has built a conceptual base that most frequently is useful as we continue to study, analyze, and understand the environmental and cultural characteristics on the surface of the earth. However, as demonstrated in this article, one must be vigilant in not accepting all concepts at face value, no matter how appealing they may sound nor how widely accepted. Additionally, there may be better, more accurate methods of explanation as one carefully searches, explores, and analyzes spatial variability. This is certainly true of the concept “carrying capacity.” Hypothetical conclusions are important, but occasionally we must step back and examine the reality and usefulness of those conclusions. Because of the carrying capacity problematic, it has become important that geography professors ensure that their students do not misinterpret its meaning and intent and that their students understand that there may be better, more statistically sound, methods of expressing the relationship of a country’s population, economy, and its ability to provide for its citizenry. I propose here that the Integrated Self-Sufficiency Index is an acceptable place to begin.

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