An International Comparative Research on Environmental Carrying Capacity among Islands*

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Abstract: The aim of this research was to analyze empirically environmental carrying capacity in three islands—Jeju (Korea), Hawaii (USA), Tasmania (Australia) in terms of Environmental Impact (EI) and Ecological Footprint (EF)—on a comparative basis.

The three islands experienced change in EI for ten years from 1996 to 2005, showing a trend of increase from 1996 to 2005. Hawaii was highest in the increase, showing 2.729 times, and followed by Jeju (2.129 times) and Tasmania (1.719 times).

Jeju exceeds EF size by 15.14 times, Hawaii by 2.55 times, and Tasmania by −8.088 times. Jeju islanders require 2.044 earths, while Hawaii and Tasmania islanders require 2.239 and 2.585 earths, respectively. The size of EF the islanders occupy was different by the demographic and socio-economic profiles in each of the three islands. The factors impacting on the determination of EF size was also different by island.

Such differences in EI and EF by island might be caused by many

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factors. 'What factors arises such differences' is another research question to be conducted. Another limitation inherent in this research is that the data used are confined to particular period of years the three islands experienced. This means that this research is based on a limited number of parameters, and measurement instrument has been partially developed. To determine EI and EF, assumptions would have to take into account a long list of parameters. Further development of this model will prove useful for policy formation and management for sustainable development within environmental carrying capacity.

Ⅰ. Introduction

Industrialization since the 18th century has brought about material and cultural affluence and many of the conveniences we now enjoy. But such benefits have been achieved at the expense of nature and produced environmental problems. Contemporary society is characterized as a risk society in terms of the worldwide environmental problem, as it threatens the very existence of human beings (Beck, 1992). This means that we are the beneficiaries and victims of industrialization, and that a self-contradiction lies between industrialization and the preservation of the environment. It was the 1980s that sustainable development has emerged as a reflection on the traditional mode of industrialization.

Industrialization has been advanced in continent, and extended to islands. Thus, it may be argued that islands have two sources of environmental problems, their own one and those from continent. With such an implication, United Nations Conference on Environment and Development (UNCED) included Small Island Developing States (SIDS) in Agenda 21 adopted in 1992. Since that time, the activities of United Nations for sustainable development in island are summarized as below (UN, 2005).

In order for putting in practice of SIDS, 125 countries had a meeting in Barbados in 1994, and adopted Barbados Programme of Action on the Sustainable Development of SIDS (hereafter termed BPOA). Such international meeting for the practice of BPOA held continuously in 1997, 1999, and 2000. The World Summit on Sustainable Development (WSSD) held in 2002 reaffirmed the special case of SIDS. The issues included rising sea levels and climate change, fragile ecosystems, market access, renewable energy, tourism, information technology, and fighting disease, among others. The international meeting to review the implementation of the BPOA for the sustainable development of SIDS was held in Mauritus in 2005, bringing together island nations with other countries. One of the key objectives of the Mauritius meeting was to renew the political commitment of all countries to implement the BPOA.

In accordance with such international activities initiated by United Nations, a lot of academic research has been done on the sustainable development of island. The research has been done mostly on tourism (e.g. Sahli et al, 2007; Tsaur and Wang, 2007), natural resource (e.g. Davis, 2004), ecosystem (e.g. Davies and Wismer, 2007), and population (e.g. Lea and Connell, 2002), etc. However, no empirical research has been done on islands in terms of sustainable development as a comprehensive concept including environment, economy, and society.

With such an implication, the author conducted empirically the structure and change in sustainable development of three islands in 2009 — Jeju in South Korea, Hawaii in USA, and Tasmania in Australia — on a comparative basis (Jeong, 2009). The following two are the reasons for selecting the three islands, with an expectation that there are any similarity and/or difference in sustainable development among them. Firstly, the three islands are a special case as a semi-independent state in each country in terms of ecosystem, socio-economic structure, and the management of own development plan and environmental impact assessment, etc. Secondly, South Korea is a developing country, while USA and Australia are developed ones.

This paper as the second part aims at comparing environmental carrying capacity in the three islands. In social science, two concepts of environmental carrying have been developed. One is environmental impact, and the other is ecological footprint. For achieving the objective, this paper will review first the concept and measurement method of environmental carrying capacity in both natural and social science, and then analyze empirically environmental impact and ecological footprint of the three islands on a comparative basis.

Ⅱ. The Concept and Measurement Method of Environmental Carrying Capacity

The concept of environmental carrying capacity is originated from ‘ecological law of carrying capacity’ G. Hardin used in the 1960s. Hardin (1968) defined it “the number of animals living in a given ecosystem increase exponentially until the supply of food and other resources reach their limitation that is determined the capacity the ecosystem has”.

Since the 1960s natural and social science began to use the concept of environmental carrying capacity in a different way. Natural science uses the concept of environmental carrying capacity as the following four implications (Choi, 2000).

The capacity of natural purification: This means the amount of polluted materials that can be removed without the polluted materials being accumulated in the original quality of nature. This is based on the capacity of the self-cleaning action nature has. The suitability of development: This is a concept based on the fitness the regions have when they are developed. For example, the total amount of pollution emitted from the development of Jeju, and examines whether or not Jeju is capable of carrying out the amount of pollution. The examination includes ecosystem, altitude, geological feature, road ratio, building-to-land ratio, soil feature, potential of erosion, and danger from flood, etc. The maximum capacity of facility and equipment: This means the limited capacity that either a facility or an equipment has. The examples include the maximum carrying capacity of the beach in Jeju, and the catchment area necessary for the supply of tap water in Jeju. The tolerable amount of cumulated pollution: Like absorption capacity of soil against acid rain, this is the total amount of cumulated pollution until the components of nature lose their function. Thus, this definition is based on the fact that how much the components of nature are deteriorated from their tolerance without losing their original function.

In contrast, two concepts of environmental carrying capacity have been developed in social science. One is environmental impact, and the other is ecological footprint.

1. Environmental Impact[1].

Neo-Malthusians argue that population is the core determinant of environmental deterioration. There are other scholars who criticize neo-Malthusians' argument (e.g. Dunlap et al, 2002). The concept of environmental impact is similar to neo-Malthusians' environmental deterioration, but is different in that it measures quantitatively the impact of human activity on environment, using a time-series data.

Environmental impact is defined as the impact of a population or nation upon its environment and ecosystem (Harper, 2007: 204). Two formulae have been developed for its calculation, as below.

1. The concept and measurement method of environmental impact were recited from the author's previous paper (Jeong, 2008).

Formula 1 (Harper, 2007: 204-205): $I = P \times A \times T$

I : Environmental Impact
P : Population
A : Affluence
T : Technology

Formula 2 (Sage, 1995): $I = (PCP/PCUR) \times 100$

I : Environmental Impact
PCP : Percentage Change in Population
PCUR : Percentage Change in Use of Resource

Formula 1 is simple, robust, and useful as a framework for research. In particular, the relative impact of P, A, and T on I is determined by their changes over time. But, the three problems are inherent in Formula 1.

First; The model is linear and the effects of the different terms are proportional. This means that the model can make it difficult to identify diminishing or increasing impacts of the terms in relation to environmental impact.

Second; P, A, and T has no weighting. This means that the three factors have no difference in the determination of environmental impact, even though their impact on environment would be different.

Third; Affluence and Technology are composed of a lot of sub-factors. The examples of Affluence are GDP per capita, distribution of internet at home, and possession of own housing, etc. Technology also include a wide range such as those being applied to resource extraction, process of production, process of product distribution, and process of consumption, etc. All of the empirical data related to Affluence and Technology are not available in the three islands.

In contract, Formula 2 is even simpler than Formula 1, includes population and resource use, which are the core impacts of human activities on nature. Like Formula 1, Formula 2 also implies that the less the environmental impact, the higher the level of sustainability. However, unlike Formula 1, Formula 2 reflects the increase in environmental impact when population and resource use increase. There is an important shortcoming in Formula 2; that is, even though such case is rare empirically, environmental impact is not calculated to decrease when both population and resource use decrease.

This paper will use Formula 2 in calculating environmental impact in the three islands, because Formula 2 would have much more explanatory power than Formula 1 in that it includes relatively less shortcomings and data availability.

2. Ecological Footprint

Environmental impact data provides valuable information regarding the impact of human use of natural resources on environment as a whole, but has two shortcomings. First; as is shown in Formulae 1 and 2, it can't calculate the impact by the sector of human activity for improving material affluence and convenience in life. Second; it can't provide the information that human activity is within and/or beyond the environmental carrying capacity a region has.

The concept and calculation method of appropriated carrying capacity (hereafter ACC) has been developed for making up the two weak points inherent in environmental impact. ACC is defined as the aggregate land area in which both the capacity to continuously provide the required resources presently consumed, and to continuously absorb all associated wastes (Wackernagel et al, 1993: 10). What this means is that it is not about "How many people can the earth support?" but rather "How much land do people need to support themselves?" Such a conceptual meaning of ACC includes the following implications.

Humans extract resources from nature for survival. The resources extracted are produced as goods and services. The goods and services are distributed to humans for consumption. A lot of wastes are discharged in the process of resource extraction and production/distribution/consumption of goods and services. Nature does not have unlimited capacity in terms of providing resources with humans and absorbing the wastes discharged by humans. The limitation nature has is the ACC which is assessed by dividing the size of the ecological footprint(hereafter EF) into the area of suitable land which is available. This means that nature is like a bus having the limited number of passengers to carry.

Some empirical researches on EF estimates have been done. Examples include works by Wackernagel et al (1993) on Canada, Bicknell et al (1998) and McDonald and Patterson (2003) on New Zealand, and Chambers et al (2000) on 52 countries as a comparative study. The WRI (1992), Chambers et al (2000), and the WWF (2002) have estimated the EF for the entire world as a unit.

According to the work on EF for the entire world as a unit (e.g. WRI, 1992; Chambers et al, 2000; WWF, 2002), the earth exceeds the EF by 2.50 times. In details, average EF per capita was 3.7ha, available biocapacity per capita 0.4ha, and ecological deficit per capita 3.2ha. South Korea exceeded EF by 9.250 times in 1995 (Chambers et al, 2000: 122). Recent empirical research on South Korea identifies that her EF increases since 1995 (Wackernagel et al, 2004), and is larger than China (Chen et al, 2006).

Typically with such empirical research, critical debate arises as to its conceptual basis (e.g. Ayres, 2000; Moffatt 2000) and, the validity of the calculating method and the subsequent results (e.g. Van Kooten & Bulte, 2000; Vegara, 2000; DEAI, 2002). Meanwhile, some scholars (e.g. Van Vuuren & Smeets, 2000) argue that despite the debates, it is successful in providing an interesting basis for discussion about the environmental effects of consumption patterns of population, including those outside the national borders, and the social inequality in regard to resource access. Even recently, the strengths and weakness of EF as an ecological accounting method are still discussed (Wackernagel & Yount, 2000). In accordance with this, Wackernagel et al (2004) has tried to resolve the conceptual challenges of EF.

Recently, EF is extended in terms of its concept and methodology. In terms of the extended and/or refined concept, the concept of human appropriation of net primary production (hereafter HANPP) was suggested. The HANPP maps the intensity of societal use of ecosystems in a spatially explicit manner (Haberi et al, 2004). In addition, the concept of EF is distinguished between consumptive and productive one, between internal and external one, between the total ecological carrying capacity and the capacity that available (Dai et al, 2006). The concept of embodied exergy ecological footprint (hereafter EEF) as a modified one was suggested in 2007. The EEF serves as a modified indicator of ecological footprint toward illustrating the productions of resource, environment, population and thereby reflecting the ecological overshoot of the general ecological system (Chen and Chen, 2007).

In sum, it is no doubt that EF is a method for measuring sustainable development through ecological impact, but like most methodologies in social science, EF method still has limitations and weakness (Du et al, 2006). The original calculation of EF was based on humans-resource supply, waste absorption, and space occupied for human infrastructure. However, other items such as CO2 emission (Roberts et al, 2003) and energy use in general (Du, 2006) are included in the calculation of EF.

Different methods are applied to the calculation of EF (e.g. Dasgupta et al, 1994; Wackernagel and Rees, 1996; Folke et al, 1977; Bicknell et al, 1998; Van Vuuren and Smeets, 2000; WWF, 2002; McDonald and Patterson, 2003). They have their own methodological advantages and disadvantages, but they are all based on the methodology developed originally by Wackernagel and Rees (1996). Their approaches to EF are classified into two categories. One is based on land-use structure, and the other is based on people's consumption life in everyday life.

The approach to calculating EF from land-use structure is summarized as follows (for detail, see Wackernagel and Rees, 1996). The production of goods and services are for consumption. Land is required for the production. For example, agricultural product is produced in land. Land requirement per capita is calculated in a region. The calculation is based on the energy being consumed in the production of total agricultural products, the current land size being used for the production of total agricultural products, and total number of population. Such a calculation method is applied to all categories of consumption products. The result enables us to identify not only the EF by the category of goods and services being produced in a region, but also the total EF covering all categories (for detailed calculation method and its result, see Jeong, 2005).

The approach to calculating EF from people's consumption life in everyday life is as follows. Consumption life is defined as the purchase and consumption behavior of goods and services produced. Sample survey should be conducted with a structured questionnaire. Earthday Network[2.] has developed the structured questionnaire, which is composed of a hierarchical system in terms of the category of consumption life and different weighting

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2. Earthday Network (http://www,earthday.net) which was organized in 1970 is an international environmental organization along with Greenpeace International, and Friends of the Earth International, etc. Earthday Network has 15,000 environmental organizations as membership over 174 countries.

by the category. The different weighting by category is based on the different EF calculated from land-use structure by category when it was calculated on the basis of the world as a unit.

This paper will calculate the EF in the three islands, using the structured questionnaire developed by Earthday Network. The reason for this is that the identical empirical statistical data are not available in the three islands.

Ⅲ. Analysis of Environmental Impact

Formula 1 enables us to measure the environmental impact based on population and resource use, and to analyze the change of environmental impact when we use a time-series data. A data set of three years — 1996, 2000, 2005 — were collected from the three islands, and environmental impact was calculated (see Table 1). The reason for using the three-year data was that they were the recent available data, commonly in the three islands.

The following are found to be significant from Table 1. Tasmania was highest in Environmental Impact (hereafter EI) in 1996, and followed by Jeju and Hawaii. In 2002, Hawaii was highest in EI, and followed by Jeju. Meanwhile, the EI was reduced in Tasmania in 2002, comparing that in 1996. In 2005, Hawaii was highest in EI, and followed by Jeju and Tasmania. In sum, the general trend is that Hawaii was highest in EI during

Table 1. **Environmental Impact in the Three Islands and Its Change**

Year	Jeju				Hawaii				Tasmania			
	A	B	C	D	A	B	C	D	A	B	C	D
1996	523,736	4,226	5.001	1.000	1,203,755	36,959	4.369	1.000	474,400	14,010	5.268	1.000
2000	543,323	5,829	9.859	1.971	1,211,537	40,202	7.362	1.685	470,300	15,604	-7.594	-1.442
2005	559,474	6,934	10.649	2.129	1,273,278	54,863	11.923	2.729	486,300	17,890	9.056	1.719

Data Source: Statistical Yearbook published by the government of each island.

Note: A; Number of total population, B; GRDP (million US dollars), C; Environmental Impact D; Index of Environmental Impact when Environmental Impact in 1966 is fixed as 1.000.

the three periods of year, and followed by Jeju and Tasmania.

The implications of the difference in EI among the three islands may be examined in terms of the difference in change of population and GRDP during the three periods of year. For example, the EI in Jeju was 9.859 in 2000. The EI of 9.859 resulted from increase in population (3.7%) and GRDP (37.9%) between 1996 and 2000. Meanwhile, the EI of 10.649 in Jeju in 2005 resulted from increase in population (6.8%) and GRDP (64.1%) between 1996 and 2005. This fact explains, as is identified from Formula 1, that the higher the difference in increase between population and GRDP, the higher the EI is. Such an implication can be applied to the determination of EI in Hawaii and Tasmania. In particular, the reason for the EI of Tasmania in 2000 having been lower than in 1996 is that the difference in population and GRDP increase was high.

The index of EI when the EI in 1996 is fixed as 1.000 enables us to identify the changing process of EI in each island over the three periods of year. For Jeju, the EI increased 2.129 times for 10 years from 1996 to 2005. Meanwhile, for Hawaii and Tasmania, the EI increased by 2.729 and 1.719 times for 10 years, respectively. That is, Hawaii was highest in the increase in the impact of human activity on nature, and followed by Jeju and Tasmania.

A detailed examination on the increase in the EI for 10 years from 1996 to 2005 in the three islands explores the following to be significant. For Jeju, EI increased by 2.129 times, but GRDP by 1.641 times. That is, the effect of economic production for increasing material affluence and convenience in life was less than its impact on environment. Hawaii and Tasmania also showed the same trend as Jeju experienced, showing that their increase in EI was higher than their increase in GRDP. This would mean that all of the three islands gave priority to economic development during the 10 years than to the conservation of nature.

Hawaii was relatively highest in giving priority to economic development, and followed by Jeju and Tasmania.

In terms of the implications of sustainable development pursuing economic development within the carrying capacity of nature, the fact that the increase in EI is higher than the increase in GRDP would mean that the three islands had a deficit. Hawaii had the highest deficit, and followed by Jeju and Tasmania. Considering that tourism is the main industry in the three islands, the fact that Hawaii had the highest deficit would mean that Hawaii was relatively most active in the development of tourism industry for the 10 years from 1996 to 2005, and followed by Jeju and Tasmania.

Ⅳ. Analysis of Ecological Footprint

1. The Structure of Questionnaire for Calculating Ecological Footprint

As explained earlier, this research used the structured questionnaire developed by Earthday Network for calculating ecological footprint (hereafter EF) on the basis of people's consumption life in the three islands. The questionnaire is composed of five dimensions. They are Residence, Food, Transportation, Product Purchase, and Discharge of Wastes. Each dimension consists of some question items with different weighting being given to each category. The different weighting is given to each dimension and the category of each question item in proportion to the EF resulted from the analysis of land-use structure based on the world as a unit.

This paper selected some question items among those in each of the five dimensions. The reason for this is that the final question items should be identical ones that are applicable to the consumption life in the three islands. However, this paper used the original weighting given to the category of each question item (see the questionnaire and the weighting in Appendix).

Table 2 is the structure of number of question items by dimension, their maximum and minimum weighting when the weighting given to the category is summed up by dimension, and the composition ratio of maximum weighting by dimension.

Table 2. **The Structure of Questionnaire by Dimension of EF**

Dimension of EF	Number of Question Items	Weighting		
		Maximum	Minimum	Composition Ratio of Maximum (%)
Residence	4	125	35	16.9
Food	3	200	35	27.0
Transportation	4	260	5	35.1
Product Purchase	1	45	0	6.1
Discharge of Wastes	4	110	0	14.9
Total	16	740	95	100.0

The following are found from Table 2. The weighting given to each category of 16 question items consists of 740 at maximum and 95 at minimum. In terms of the maximum weighting, Transportation is the most important factor determining EF, showing 35.1% out of the total maximum weighting. Food is the second important factor, and followed by Residence, Discharge of Wastes, and Product Purchase. This means that EF is reduced if people enjoy Transportation life in a sustainable way.

The criterion to interpret the EF obtained from the responses to the 16 question items in sample survey is based on Table 3.

Table 3. **Criterion to Interpret the EF per Capita Obtained from Sample Survey**

Total Weighting per Capita Obtained from the Responses to the 16 Question Items	Size of EF Equivalent to Total Weighting (ha)	Number of Necessary Earth
Less than 150	Less than 2.4	1.000
151-350	2.5-5.0	1.001-2.000
351-550	5.1-7.5	2.001-3.000
551-740	7.6-10.0	3.001-4.000

Source: Earthday Network (http://www.earthday.net)

The base to calculate the number of necessary earth by the total weighting per capita obtained from the responses to the 16 question items is as follows. The land size of earth except sea is 16,100,000,000ha. Total number of population in the world is 650,000,000 as of 2005. Average land size per capita is calculated as 2.477ha (2.5ha). Therefore, for example, if the EF per capita in Jeju is less than 2.5ha, the current consumption life of Jeju people requires only one earth. Following such a calculation method, the EF per capita of 7.6-10.0ha requires four earths.

The method of matching the EF per capita with the total weighting per capita obtained from the responses to the 16 question items is as follows. As shown in Table 2, the total weighting per capita ranges from 95 to 740. The range from 95 to 740 should be divided into four categories in terms of number of necessary earth, using equal interval. This principle results in the categorization of total weighting per capita by the size of EF.

The following is a practical example to calculate EF per capita. Let us assume that the average total weighting per capita obtained from the responses to the 16 question items in Jeju is 300.

(1) It is identified from Table 3 that the 300 are between 151 and 350, and its EF is equivalent to between 2.5-5.0ha. Using the method of interpolation, the EF equivalent to the weighting of

300 is calculated as 4.3ha.

(2) Total number of population in Jeju is 563,338, and land size is 184,536ha. Then, average land size per capita is 0.328ha.

(3) Therefore, the EF exceeds by 13.110 times (4.3ha/0.328ha) in Jeju.

2. Sample Survey and the Profiles of Respondents

A sample survey was conducted in the three islands, selecting 200 samples in each island. A quota sampling method by gender and age was used for selecting the samples. The samples were selected randomly from those who meet the quota composition. Such a small sample size as 200 was inevitable due to the limited research fund. University students interviewed the samples with the structured questionnaire, under the supervision of sociology professor in each island. The fieldwork was conducted from March to July 2009 in the three islands.

The demographic and socio-economic profiles of respondents were gender, age, household monthly income before tax, educational attainment, and religion (see Table 4).

As designed in quota sampling method, the total samples are composed equally by the category of gender and age in the three islands. However, household monthly income before tax shows different composition by category. For example, the respondents whose household monthly is less than US$2,000 are 15.0% in Jeju, 34.0% in Hawaii, and 7.5% in Tasmania. Meanwhile, the respondents whose household monthly is US$6,000 and over are 13.0% in Jeju, 25.5% in Hawaii, and 34.0% in Tasmania.

For Jeju, 30.5% graduated from secondary school, and 69.5% from college/university. 20.0% in Hawaii graduated from secondary school, and 80.0% from college/university. Meanwhile, 51.5% in Tasmania graduated from secondary school, and 48.5% from college/university.

Table 4. Demographic and Socio-Economic Profiles of Respondents

Profile \ Island	Jeju (200)	Hawaii (200)	Tasmania (200)
Gender			
Male	50.0	50.0	50.0
Female	50.0	50.0	50.0
Age			
20-29	20.0	20.0	20.0
30-39	20.0	20.0	20.0
40-49	20.0	20.0	20.0
50-59	20.0	20.0	20.0
60 and over	20.0	20.0	20.0
Household Monthly Income before Tax (US$)			
Less than 2,000	15.0	34.0	7.5
2,000-2,999	16.5	12.5	13.5
3,000-3,999	23.0	7.5	14.5
4,000-4,999	16.5	10.0	16.0
5,000-5,999	16.0	10.5	14.5
6,000 and over	13.0	25.5	34.0
Educational Attainment			
Secondary School	30.5	20.0	51.5
College/University	69.5	80.0	48.5
Religion			
None	41.0	19.5	47.0
Buddhism	27.0	7.0	0.0
Christian	20.0	63.0	53.0
Others	12.0	10.5	0.0
Total	100.0%	100.0%	100.0%

By religion, the samples in Tasmania are classified into two groups. 47.0% have no religion, and 53.0% are Christians. For Jeju, 41.0% have no religion, 27.0% are Buddhism, 20.0% are Christians, and 12.0% have other religion. For Hawaii, 19.5% have no religion, 7.0% are Buddhism, 63.0% are Christian, and 10.5% have other religion.

3. Calculation of Ecological Footprint

3.1: Average Weighting per Capita

As the first stage of analysis, the weighting per capita obtained from the responses to the 16 question items was averaged by the dimension of EF. The second step was to calculate the grand average weighting as a whole, summing up the average weighting of the five dimensions. Table 5 is the result from the two stages of analysis.

Table 5. Average Weighting per Capita by Dimension of EF

Dimension of EF (Maximum Weighting)	Jeju (%)	Hawaii (%)	Tasmania (%)
Residence (125)	97.5 (78.0)	94.7 (75.8)	88.0 (70.4)
Food (200)	99.6 (49.8)	121.1 (60.6)	120.3 (60.2)
Transportation (260)	107.2 (41.2)	105.2 (40.5)	129.0 (49.6)
Product Purchase (45)	10.9 (24.2)	16.5 (36.7)	22.3 (49.6)
Discharge of Wastes (110)	48.6 (44.2)	61.3 (55.7)	56.3 (51.2)
Grand Total (740)	363.8 (49.2)	398.8 (53.9)	415.9 (56.2)

Percentage in parenthesis is the proportion to the maximum weighting of each dimension implying that the higher the percentage, the bigger the EF size people occupy.

The following are found to be significant from Table 5. The three islands are significantly different in the order of their EF size by its dimension. The difference can be examined in terms of the following three aspects.

First: Comparison of island by dimension in terms of the order of the biggest size of EF.

Second: Comparison of dimension in each island in terms of the order of the biggest size of EF.

Third: Comparison of island in terms of the grand total size of EF.

With regard to the first step of examination, Jeju is biggest in the EF of Residence, and followed by Hawaii and Tasmania. Hawaii is biggest in the EF of Food, and followed by Tasmania and Jeju. Tasmania is biggest in the EF of both Transportation and Product Purchase, and followed by Jeju and Hawaii in Transportation, and Hawaii and Jeju in Product Purchase. Meanwhile, Hawaii is biggest in the EF occupied by Discharge of Wastes, and followed by Jeju and Tasmania.

Regarding the second step based on the percentage in the parenthesis, the three islands show the same trend in terms of the order of EF size by dimension. In details, Residence is the biggest dimension occupying EF size, and followed Food, Discharge of Wastes, Transportation, and Product Purchase.

Regarding the third step based on the grand total summing up the average weighting of the five dimensions, Tasmania is biggest, and followed by Hawaii and Jeju. Their grand total is 56.2% of the maximum grand total in Tasmania, 53.9% in Hawaii, and 49.2% in Jeju.

Overall, these facts mean that Tasmania occupies the biggest EF in terms of absolute criterion, and followed by Hawaii and Jeju. Comparing the EF size occupied in Tasmania, the level of the EF size occupied in Hawaii and Jeju is 95.9% and 87.5%, respectively.

3.2: Composition Ratio of Ecological Footprint by Dimension

The composition of the average weighting per capita was compared in each island. This enables us to examine which dimension occupies relatively bigger EF size in each island. This examination is a within-group comparison, while Table 5 is a between-group comparison. Table 6 shows the within-group comparison in terms of the composition ratio of EF by dimension.

Table 6. **Composition of Average Weighting per Capita by Dimension as Within-Group Comparison**

Dimension \ Island	Jeju	Hawaii	Tasmania
Residence	97.5 (26.8)	94.7 (23.7)	88.0 (21.2)
Food	99.6 (27.4)	121.1 (30.4)	120.3 (28.9)
Transportation	107.2 (29.5)	105.2 (26.4)	129.0 (31.0)
Product Purchase	10.9 (3.0)	16.5 (4.1)	22.3 (5.4)
Discharge of Wastes	48.6 (13.4)	61.3 (15.4)	56.3 (13.5)
Grand Total	363.8 (100.0%)	398.8 (100.0%)	415.9 (100.0%)

The following are found to be significant from Table 6. For Jeju, Transportation occupies the biggest EF, showing 29.5% of the grand total, and followed by Residence, Food, Discharge of Wastes, and Product Purchase. For Hawaii, Food is the biggest dimension, and followed by Transportation, Residence, Discharge of Wastes, and Product Purchase. Meanwhile, like in Jeju, Transportation occupies the biggest EF in Tasmania, and followed by Food, Residence, Discharge of Wastes, and Product Purchase. Such differences in the EF being occupied by dimension reflect the difference in the consumption life as a lifestyle among the three islands.

3.3: The Size of Ecological Footprint

The previous two sections are the analysis of ecological footprint in terms of the average weighting per capita obtained from the responses to the 16 question items. As the final stage of analysis, the size of EF was calculated in the three islands (see Table 7), using the average weighting per capita. The calculation method and/or its implication of the five categories specified in Table 7 are as below.

(1) Land Size per Capita (ha) is calculated, dividing the total area size of each island by total population as of 2008.

(2) Average Weighting per Capita is the averaged weighting per capita obtained from the responses to the 16 question items.

(3) EF per Capita (ha) is real average size of EF each person occupies. This is calculated on the basis of the criterion in Table 3, applying the interpolation method to the Average Weighting per Capita as exampled in Table 4.

(4) Excess of EF is the difference between (1) and (3), implying how much more 'the EF each person occupies' exceeds 'the real land size per capita'.

(5) Number of Necessary Earth is how many earths are required if the islanders enjoy the current pattern of consumption life. This is calculated on the basis of the criterion in Table 3, applying the interpolation method as exampled in Table 3.

Table 7. Ecological Footprint Size

Category \ Island	Jeju	Hawaii	Tasmania
(1) Land Size per Capita (ha)	0.325	2.226	13.971
(2) Average Weighting per Capita	363.8	398.8	415.9
(3) EF per Capita (ha)	5.254	5.676	5.883
(4) Excess of EF	+4.920 (15.14 times)	+3.450 (2.55 times)	-8.088 (0.42 times)
(5) Number of Necessary Earth	2.044	2.239	2.585

Land Size: Jeju; 182,500ha, Hawaii; 2,833,700ha, Tasmania; 6,840,100ha
Population as of 2008: Jeju 561,695, Hawaii; 1,273,278, Tasmania; 489,600

Land size per capita is 0.325ha in Jeju, 2.226ha in Hawaii, and 13.971ha in Tasmania. The real EF size each person occupies through consumption life is 5.254ha in Jeju, 5.676ha in Hawaii, 5.883ha in Tasmania. Such land size and real EF size per capita enables us to find the following significant facts.

First: Jeju exceeds the size of EF by 4.920ha than the real land size of Jeju can provides each person. Hawaii exceed by

3.450ha. Meanwhile, Tasmania is rather in a room of 8.088ha.

Second: The absolute excess of EF is calculated as being exceeded by 15.14 times in Jeju, and 2.55 times in Hawaii. Meanwhile, the consumption life in Tasmania occupies 42% of the availability of real land size.

Third: The pattern of consumption life Jeju islanders enjoy currently requires 2.044 earths. Meanwhile, Hawaii and Tasmania islanders require 2.239 and 2.585 earths, respectively.

Jeju is the smallest island among the three islands, and Tasmania is the biggest one. According to the first and second findings based on the real land size of each island, Jeju is highest in the excess of EF, and followed by Hawaii. Tasmania has a room of 8.088ha per capita, which is caused by big land size with relatively small population. However, basing on the number of necessary earth calculated from the pattern of consumption life in everyday life, Tasmania occupies the biggest EF, and followed by Hawaii. Rather, Jeju occupies relatively the smallest EF.

As the final analysis of EF size, the EF size was analyzed by the profiles of the respondents. This analysis enables us to identify those who enjoy relatively bigger EF. The five profiles of the respondents described in Table 4 were used for this analysis (see Table 8)

The following are found to be significant trend from Table 8. For Jeju, males occupy EF more than females. The older the age is the smaller the EF size is. The more the household income they have, the bigger the EF size is. The higher the education they attain, the bigger the EF size is. By religion, those who have no religion occupy biggest EF, and followed by Buddhists, other religion believers. Christians occupy smallest EF.

For Hawaii, unlike Jeju, females occupy EF more than males. By age, those aged 50-59 occupy biggest EF, and followed by those aged 40-49, 20-29, and 30-39. Those aged 60 and over occupy smallest EF. By household income, the general trend is that

Table 8. Ecological Footprint Size by the Profiles of Respondents

Profiles \ Island	Jeju		Hawaii		Tasmania	
	(1)	(2)	(1)	(2)	(1)	(2)
Gender						
Male	372.0	5.353	396.3	5.646	428.7	6.037
Female	355.5	5.154	401.1	5.704	402.9	5.726
Age						
20-29	376.5	5.408	403.9	5.738	425.5	5.998
30-39	370.8	5.339	383.1	5.487	418.5	5.914
40-49	383.6	5.493	417.6	5.903	414.5	5.866
50-59	366.6	5.288	419.9	5.931	422.8	5.966
60 and over	321.3	4.742	372.4	5.353	397.8	5.664
Household Monthly Income before Tax (US$)						
Less than 2,000	310.8	4.615	363.4	5.250	347.3	5.055
2,000-2,999	365.6	5.276	407.6	5.783	382.2	5.476
3,000-3,999	364.9	5.268	422.7	5.964	405.3	5.755
4,000-4,999	375.5	5.395	411.3	5.827	408.9	5.798
5,000-5999	382.3	5.477	436.2	6.128	423.1	5.970
6,000 and over	382.3	5.477	414.4	5.865	448.8	6.279
Educational Attainment						
Secondary School	331.6	4.866	393.6	5.614	398.8	5.676
College/University	377.9	5.424	400.1	5.692	433.8	6.099
Religion						
None	374.0	5.377	378.9	5.436	431.2	6.067
Buddhism	370.4	5.334	412.9	5.847	-	-
Christian	335.8	4.917	403.5	5.733	402.1	5.716
Others	360.6	5.216	398.6	5.674	-	-
Total	363.8	5.254	398.8	5.676	415.9	5.883

(1) Average weighting per capita obtained from the responses to the 16 question items.
(2) The size of ecological footprint per capita (ha) as it being calculated in Table 7.

the more the household income, the bigger the size of EF. The higher the education they attain, the bigger the EF size is. By religion, Buddhists occupy biggest EF, and followed by Christians and other religion believers. Those who have no religion occupy smallest EF.

For Tasmania, males occupy EF more than females. The trend by age is that the younger the age, the bigger the size of EF. The higher the education they attain, the bigger the EF size is. Those who have no religion occupy more than Christians.

4. Relatively Important Determinant of Ecological Footprint Size

As analyzed in Table 7, this paper calculated the size of EF in terms of the consumption life in the three islands. As is identified in Table 8, the size of EF the islanders occupy is significantly different by their demographic and socio-economic profiles. This implies that the impact on the determination of EF size is different by the demographic and socio-economic profiles of the islanders. The difference may be termed relative importance. With such an implication, this section analyzed the relative importance impacting on the determination of EF size.

The relative importance can be measured by the coefficient of determination implying explained variance of each demographic and socio-economic profile impacting on the determination of EF per capita (ha) — 5.254ha in Jeju, 5.676ha in Hawaii, 5.883ha in Tasmania. The coefficient of determination of each demographic and socio-economic profile is as Table 9 (for the calculation method and implication of the coefficient of determination, see Jeong, 2004: 164).

Table 9. Coefficient of Determining Ecological Footprint Size

Profile \ Island	Jeju	Hawaii	Tasmania
Gender	0.190	0.206	0.211
Age	0.064	0.003	0.020
Household Monthly Income	0.091	0.084	0.323
Educational Attainment	0.111	0.001	0.114
Religion	0.052	0.099	0.107

The following are found from Table 9. Overall, the relative importance determining the size of EF is different among the three islands. In details, for Jeju, gender is the most important factor determining the EF size in Jeju, showing a determination of 19.0%, and followed by educational attainment (11.1%), household monthly income (9.1%), age (6.4), and religion (5.2%). Other profiles except gender and educational attainment have no significant difference in the determination of EF size.

For Hawaii, like in Jeju, gender is the most important factor determining the EF size, showing a determination of 20.6%, and followed by religion (9.9%), household monthly income (8.4%), age (0.3%), and educational attainment (0.1%). Other profiles except gender have no significant difference in the determination of EF size.

For Tasmania, unlike in Jeju and Hawaii, household monthly income is the most important factor determining the EF size, showing a determination of 32.3%, and followed by gender (21.1%), educational attainment (11.4%), religion (10.7%), and age (2.0%). Compared to Jeju and Hawaii, other profiles except age show relatively equal significant factors in the determination of EF size.

Ⅴ. Summary and Concluding Remarks

The aim of this research was to analyze environmental carrying capacity in three islands — Jeju (Korea), Hawaii (USA), Tasmania (Australia) — on a comparative basis. This paper reviewed first the concept and measurement method of environmental carrying capacity. Then, environmental impact (EI) and ecological footprint (EF) among the concepts of environmental carrying capacity were analyzed. The main significance of the two as a measurement of environmental carrying capacity is that they connote maximum persistently supportable load for sustainable development. In particular, they enable us to identify how strongly and/or weakly we are in sustainable development.

EF can be analyzed in terms of both land-use structure and consumption life people enjoy in everyday life. This paper analyzed EF in terms of the consumption life, using the structured questionnaire developed by Earthday Network. 200 samples were selected in each island, employing a quota sampling method by age and gender.

The three islands experienced change in EI for ten years from 1996 to 2005, showing a trend of increase from 1996 to 2005. Hawaii was highest in the increase, showing 2.729 times, and followed by Jeju (2.129 times) and Tasmania (1.719 times). The difference in the increase in EI by island was caused by the difference in the increase in population and GRDP. However, the examination on the increase in EI explored that the effect of economic production for increasing affluence and convenience in life was less than its impact on environment. This means that the islands gave priority to economic development during the ten years than to the conservation of nature. Hawaii was relatively highest in giving priority to economic development, and followed by Jeju and Tasmania.

EF as a whole reality was composed of five dimensions — Residence, Food, Transportation, Product Purchase, and Discharge of Wastes, and each dimension was composed of question items. In terms of the order of the biggest EF size being occupied by consumption life, Residence was biggest in Jeju and Tasmania, while Food was the biggest in Hawaii. Examining the order of bigger EF size within each island, the trend was that Residence was the biggest, and followed by Food, Discharge of Wastes, Transportation, and Product Purchase.

The real land size per capita is 0.325ha in Jeju, 2.226ha in Hawaii, and 13.971ha in Tasmania. However, the EF size being occupied per capita was 5.254ha in Jeju, 5.676ha in Hawaii, and

5.883ha in Tasmania. This means that Jeju exceeds EF size by 15.14 times, Hawaii by 2.55 times, and Tasmania by −8.088 times. Estimating the number of earth necessary for enjoying current pattern of consumption life from the EF size being occupied per capita in each island, Jeju islanders require 2.044 earths, while Hawaii and Tasmania islanders require 2.239 and 2.585 earths, respectively. This means that even though the EF size within internal carrying capacity is in order of Jeju, Hawaii, and Tasmania, their real EF size being occupied through consumption life is in order of Tasmania, Hawaii, and Jeju.

In terms of the EF size by the demographic and socio-economic profiles of the islanders, the general trend is as follows. Males occupy bigger EF than females. The older the age is, the bigger the EF size is. The higher the household income is, the bigger the EF size is. The higher the educational attainment is, the bigger the EF size is. The Christians show a trend to occupy lower EF size than other religious beliefs and those who have no religion.

Relatively important determinant of EF size was different by island. Gender was the most important determinant in Jeju and Hawaii, while household monthly income is the most important determinant in Tasmania. However, the order of important determinant except the most important one was different by island.

As summarized above, significant differences in EI and EF were found by island. What are the major factors arising such differences? Four factors — number of population, GRDP, land size, citizens' consumption life — were used for estimating EI and EF. However, the differences can't be explained by the four factors, because there are so many factors determining the states of the four factors being patterned through a mutual casual mechanism. The examples include the need citizens have for the enjoyment of material affluence and convenience in life, the pattern of citizens' lifestyle, and the development policy each island has advanced, etc. In this sense, this research still remains in descriptive level for fact-finding.

The question — why such differences exist in the three islands — is further research question to be conducted. This research question is a base to upgrade the research on environmental carrying capacity to explanatory level.

Another limitation inherent in this research is that the ten-year time series data used for estimating EI and the sample survey with 200 residents represent the particular experience in the three islands. Therefore, if the experience is different, the findings will lead to different estimations of EI and EF. To determine EI and EF, assumptions would have to take into account a long list of parameters such as longer than ten-year time series data and more question items for measuring EF size. However, the results cited here are based on a limited number of parameters, and a complex measurement instrument has been partially developed. Further development of this model will prove useful for policy formation and management for sustainable development within environmental carrying capacity.

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<Appendix>

Questionnaire for Measuring Ecological Footprint

Note: the number in parenthesis is the weighting given to the category of each question item

Dimension 1: Residence

Q1. How many people live in your household?

1 ························ 1 (30)   4 ························ 4 (15)
2 ························ 2 (25)   5 and over ·········· 5 (10)
3 ························ 3 (20)

Q2. What energy do you use for heating house?

Gas······················ 1 (30)   Oil ······················ 3 (50)
Electricity ·········· 2 (40)
Renewable energy (solar, wind power, etc) ········ 4 (00)

Q3. How many water taps do you have in your household?

Less than 2 ······· 1 (05)   9 - 10 ················· 4 (20)
3 - 5 ···················· (10)   11 and more ······· 5 (25)
6 - 8 ·················· 3 (15)

Q4. Which housing type best describes your home?

Apartment/Condominium ···· 1 (20)
General house ····················· 2 (40)

Dimension 2: Food

Q5. Are you a vegetarian?

Yes ····················· 1 (00)   No ······················· 2 (50)

Q6. On average, how often do you eat meals cooked in home a week?
Less than 9 meals ························ 1 (25)
10 - 13 meals ································ 2 (20)
14 - 18 meals ································ 3 (15)
19 meals and more ······················ 4 (10)

Q7. How often do you purchase domestic agricultural foodstuff produced in USA?
Always domestic product ············ 1 (025)
Always not domestic product ····· 2 (125)
Sometimes domestic product ······ 3 (050)
Almost not domestic product ····· 4 (100)
Do not know ································ 5 (075)

Dimension 3: Transportation

Q8. How many motor cars do have in your home?
0 ························ 1 (005)   3 ························ 4 (075)
1 ························ 2 (025)   4 and more ······· 5 (100)
2 ························ 3 (050)

Q9. On average, what transportation do you use when you go out?
Private car/Motor Bicycle ····· 1 (50)   By walk ········ 4 (00)
Public transportation ············ 2 (25)   Bicycle ·········· 5 (00)
Commuter/School bus ··········· 3 (20)

Q10. Where did you spend your holiday last year?
Did not spend holiday ·· 1 (00)
In Hawaii ·· 2 (10)
Outside Hawaii in USA ·· 3 (30)
Neighboring country (Canada and Pacific Island

country) ………………………………………… 4 (40)
Other country than neighboring one ……………… 5 (70)

Q11. How many times did you enjoy outdoor picnic last summer?
No outdoor picnic … 1 (00)
1 - 3 times……………2 (10)
4 - 6 times ………… 3 (20)
7 - 9 times …………… 4 (30)
10 times and more…… 5 (40)

Dimension 4: Product Purchase

Q12. How many electronic products did your home purchase last year?
No purchase……… 1 (00)
1 - 3 products …… 2 (15)
4 - 6 products …………… 3 (30)
7 products and more … 4 (45)

Dimension 5: Discharge of Wastes

Q13. Have your home tried to reduce the wastes generated from home?
Yes ………………… 1 (00)
No ………………… 2 (30)

Q14. Is your lavatory a flush toilet?
No ………………… 1 (00)
Yes ………………… 2 (30)

Q15. Does your home do the separate removal of wastes?
Yes ………………… 1 (00)
No ………………… 2 (20)

Q16. On average, how many waste packs does your home discharge a week? (Pack unit: 20 liters)
0 pack ………… 1 (00)
2 packs ……………… 4 (20)

0.5 pack ··········· 2 (05)	3 packs and more··· 5 (30)
1 pack ············· 3 (10)	

Demographic and Socio-Economic Background of Respondent

Q17. Gender

Male ························ 1	Female ··························· 2

Q18. Age

20 - 29 ···················· 1	40 – 49 ·························· 3
30 - 39 ···················· 2	50 – 59 ·························· 4
40 - 49 ···················· 3	60 and over ···················· 5

Q19. Educational attainment

Primary School ······· 1
Secondary School ···· 2
College/University ··· 3

Q20. Religion

None ························ 1	Christian ······················· 3
Buddhism ················ 2	Others ··························· 4

Q21. Household monthly income before tax is deducted

Less than $999 ····· 01	$5,000 - $5,999 ··········· 06
$1,000 - $1999 ······ 02	$6,000 - $6,999 ··········· 07
$2,000 - $2,999 ····· 03	$7,000 - $7,999 ··········· 08
$3,000 - $3,999 ····· 04	$8,000 - $8,999 ··········· 09
$4,000 - $4,999······· 05	$9,000 and more ········· 10

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