Developing economic vulnerability indices of environmental disasters in small island regions

Luky Adrianto[1] and Yoshiaki Matsuda

Department of Marine Social Sciences, Faculty of Fisheries, Kagoshima University, Shimoarata 4-50-20, Kagoshima City 890-0056, Japan

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Abstract

We apply the gross island products (GIP) approach to assess the economic vulnerability of islands region to environmental disasters. In this study, two types of environmental disasters, sea level rise and natural disasters (typhoon, heavy rain and others), are identified and assessed.

By using the case of Amami Islands of Japan, the results show that the economic loss related to environmental disasters is relatively small, ranging from 0.17% to 2.27% of the GIP. The results of vulnerability analysis indicate that, in terms of GIP-based value, Kikaijima is the most vulnerable island with the composite vulnerability index (CVI) of 0.737. However, in terms of per capita-based value, Okinoerabujima has the highest vulnerability with CVI of 0.910.

We also found that these islands have relatively high income per capita, which may convey the impression of their strong economy (high resilience). However, the economies of such islands are highly exposed to the impacts of environmental disasters.

Author Keywords: Economic vulnerability index; Environmental disasters; Small islands region; Amami Islands

Article Outline

1. Introduction

It is widely known that environmental changes such as typhoon, hurricanes, heavy rains, volcanic explosion and sea level rise are the most well-known environmental disadvantages of small islands,[2] which have been given much attention by government and policymakers around the world (Debance, 1998). At the global level, the UN-Commission on Sustainable Development has mentioned that small islands are especially vulnerable to climate change and concomitant sea level rise because their populations, agricultural land and infrastructure tend to be concentrated in the coastal zones (United and United). Furthermore, Briguglio (1995) also stated that, although environmental disasters occur in non-island country, the impact of a disaster on island economy is expected to be relatively larger in terms of damage per unit area and cost per capita, due to the small area of the islands.

The potential physical effects of environmental disasters need to be evaluated in terms of their potential economic implications (Edwards, 1987). Certainly, concern is heightened by the fact that much of small island's economic bases and population occur near the coast. As they also suffered from environmental disasters, this problem is regarded as crucial disadvantage of the islands, and special policy and governance to the islands community is a major concern (Cross and Nutley, 1996). This paper makes an attempt to assess economic vulnerability of small islands especially from environmental disasters by using an ecological economic approach suggested by Constanza et al. (1996). Ecological economic approach is concerned with extending and integrating the study and management of nature's household (ecology) and humanity's household (economy). Using Briguglio's definition, economic vulnerability in this paper is defined as the potential for attributes of a system (small island economy) to be damaged by exogenous impacts (environmental disasters) (Briguglio, 2000).

The study on vulnerability indices was pioneered by Briguglio (1995) after several discussions and meeting, most of them were in international level, to identify the problems associated with small islands and small islands states. Even if it was initially advocated for small islands developing states (SIDS), it has also a degree of suitability for application to general islands including those located within a country or state (small island regions). By this, small islands are seen as the general “region” or “area,” which, if compared with non-island entities, have relatively more clearly natural and administrative boundaries, and also have some particular economic and environmental advantages as well as disadvantages.

In this paper, we apply the concept of vulnerability to general entities, in this case are small islands, whether they are members of SIDS or not. This is mainly because we argue that small islands have a general characteristic both in terms of economic and environmental point of view. State, region or other administrative boundary is a matter of scale and policy response to their problems. In other words, policy response may come from and for the whole of state (in the case of SIDS) or only from the central government for a partial region (for small islands as a region within a state). In addition, the idea of vulnerability in this study is placed more on sustainability contexts and issues, which generally can be divided into global, national and regional or local level (Graaf et al., 1999; Nijkamp and Vreeker, 2000).

According to Graaf et al. (1999), although one can strive for a sustainable development on all levels, there are major differences when it comes to elaboration on these various levels. On the global scale, the main issue is how lower-scale sustainable development can contribute to the sustainability of the earth. On the regional scale, sustainable development means not only taking into account aspects of local sustainable development, but also preventing unsustainability on the global scale. The procedure to estimate the economic vulnerability of the environmental disasters elaborated here focuses on scales lower than global and national. This makes it possible to focus on incorporating the sustainability aspects of higher scales into lower-scale decision-making (Graaf et al., 1999).

From the above description, this paper aims to assess and develop an economic vulnerability index (EVI) from environmental disasters for small islands, especially in regional level as proposed in the case study. Recently, a rising interests in research, which moves away from global sustainability analysis towards empirical policy-relevant research at the regional and urban level, has been identified (Nijkamp and Vreeker, 2000).

This new interest in regional sustainability analysis is caused by several factors: (1) a region is a properly demarcated area with some degree of homogeneity, which allows for a more operational empirical investigations; (2) a region is usually subject to properly regulated administrative competence and control, so that there is more scope for a relevant policy analysis of sustainability issues; and (3) the statistical data based at regional level is often more appropriate for monitoring, analyzing and modeling the economy and ecology of an area (Nijkamp, 2000). In this context, this paper attempts to reach a level of contribution in the regional sustainability issues through the study of vulnerability of small islands.

The paper is organized as follows. In Section 2, a concise description on issues of small islands sustainable development and the need of vulnerability indicators are offered. After a concise description of the materials and methodological issues on environmental impact valuation and analysis, which is then followed by the presentation of an operational framework for determining the vulnerability of small island to the environmental disasters (Section 3), the analysis proceeds with the presentation of an empirical impact assessment of environmental disasters using the case of Amami Islands of Japan (Section 4). The paper concludes with a final evaluative section described in Section 5.

2. Vulnerability indices and small island sustainable development

Issue of vulnerability is generally related with the topic of sustainable development. As Nijkamp and Vreeker (2000) has addressed, vulnerability concept is a part of sustainability constraints together with, for example, the concept of safe minimum standards, quality standards, carrying capacity, eco-capacity, maximum sustainable yield, critical loads, environmental utilization space, etc. All such concepts may be useful for a policy analysis. Moreover, Van Pelt (1992) mentioned that a sustainability constraint has at least four attributes: (1) it is expressed in one or more measurable parameters; (2) these parameters are linked to sustainability targets; (3) the parameters have a proper geographical scale; (4) these parameters have also a relevant time dimension. It is also stated that ideally these parameters should be mapped out in quantitative factors, but in reality it is often confronted with qualitative, fuzzy and incomplete information (Nijkamp and Vreeker, 2000).

In the last decade, a number of studies on the issues of small island sustainable development have been increasing (see Cole; Beller; Hein; Matsumoto; Brander and Erickson and some other authors). Most of them are based on the idea that small islands provide a special case in development, largely due to special characteristics of their natural resources, economies and, in many cases, their cultures. Hein (1990) identified some characteristics of small islands especially from economic point of view, including: (1) a few option on economically and ecologically sustainable development; (2) provision of utilities and public services is difficult and costly; (3) human resources are scarce, especially for very small islands whose area is less than 1000 km^2 and under 10,000 population; (4) little economic development has occurred without outside intervention. As addition, Briguglio (1995) also identified and elaborated some economic disadvantages associated with small islands and SIDS, especially those that are related with (1) small size, (2) insularity and remoteness, (3) proneness to natural disasters and (4) environmental factors.

Apart from their economic pressure on development, some authors focused more on another perspective that small islands and SIDS also have problems associated with their geographical, natural characteristics and environmental disadvantages. McLean (1980), for example, mentioned that there are several respects in which small islands are specialized environments. Small islands are open to wave action from all sides, being relatively small to the larger land masses, they have small catchments so that a high proportion of eroded material is commonly lost into the sea. In cyclone-prone regions, islands, too small either to deflect cyclones or to entrain less moisture charged air and thus modify the circulation, are particularly vulnerable. Environmentally, even more than economically, small islands are very exposed to external forces (Brookfield, 1990). In terms of island sustainability, this kind of forces could be included in the concept of stresses and shocks to the system (Atkinson et al., 1997).

There is, moreover, one class of small islands that is particularly vulnerable to the effects of long-term climatic change, also now expected as consequence of the anthropogenic addition of carbon dioxide and other gases to the atmosphere. Coral atolls and sand cays, and the low-lying littorals of many small islands, for example, are very vulnerable to a rise in sea level. United and United concluded that environmental change, whether the result of present-day variability or future problems such as global warming and sea level rise, presents a serious threat to the sustainable development of small island regions. Small islands and SIDS are vulnerable to environmental disasters because their population, agricultural land and infrastructure tend to be concentrated in the coastal zone. Their vulnerability has increased over time due to anthropogenic activities. In this context, studies on vulnerability assessment have become an essential topic for policy analysis for regions such as small islands.

In policy field, up to 1990, there is no attempts to present the disadvantages faced by small islands and SIDS in a composite index to serve as a yardstick that could measure the degree of overall vulnerability of these regions (Briguglio, 1995). The issue of vulnerability indices for small islands and SIDS then was raised and discussed in some length during the International Conference on Islands and Small States, which was held in Malta on 23–25 May 1991. In its final statement, the conference encouraged to construct a vulnerability index for supplementing GDP per capita index characterized from special problems related to islands and small states (Briguglio, 2000). Briguglio (1995) pioneered the works on developing vulnerability indices and followed by Chander (1996) and Wells (1997).

3. Methodological issues—a case study approach

The methodology of assessing economic vulnerability of environmental disasters basically started by the calculation of economic impacts of its main components, i.e., (1) the potential economic impact of sea level rise and (2) the total economic impact of natural disasters (typhoon, storm, etc). Section 4 gives the detailed calculation process, which started by the process of calculation of the potential impact of sea level rise, followed by the process for natural disasters, integration of those two components of vulnerability using standardization process and finally ended by weighting process of vulnerability indices.

The potential effects of the increases in relative sea level need to be evaluated in terms of their potential economic implications. Certainly, concern is heightened by the fact that much of coastal island's economic base and population occurs near the coast. The oceanic island (Pacific Ocean), such as Amami Islands of Japan, is also threatened by the sea level rise. Its impact is evaluated by employing the gross island product (GIP)-based valuation model suggested by Edwards (1987). The general formula to estimate the sea level rise (real value, RV) impact is given as follows (Edwards, 1987):

(1)

$$\mathrm{RV}_{jt}=(t/T)G_{jt}(1+g_j)^t$$

where RV_{jt}=real value of sea level impact at year t for island j; t=year t (1, 2, …, n), t=1 for the base year 1990; T=the estimated years of 0.3-m sea level rise; G_{jt}=the estimated GIP at year t impacted by sea level rise for island j; g_j=the economic growth rate of island j.

In this study, we use the scenario of CGER (1996) that estimated the 0.3-m sea level rise during 1990–2100 (therefore, T=110, 1990=base year). The value for GIP affected value (G_{jt}) was taken from Matsui et al. (1995), which is calculated as 11.88% for area-based economic activities, 2.96% for population-based economic activities and 2.37% for industrial-based economic activities [3] for the potential economic impact of sea level rise in the islands of southern Japan (Pacific Ocean). In this term, the sea level rise is a gradual and cumulative process so that, in the first year (1990), a small percentage of economic activity will be affected during the first year, and so on as reflected by the above formula (Ortiz, 1994).

To reveal the effect of projections of sea level rise in the future, we examine the present value (PV) of impact by employing the following equation for small island j and year t. By doing this transformation, it will also allow us to integrate the calculation with the other type of environmental disaster (i.e., natural disasters), which is calculated in the real time (present-day impact).

(2)

$PV_{jt}=RV_{jt}(1+r)^{-t}$

The second type of environmental disaster used in this vulnerability assessment is the natural disasters, which came from the present-day impact such as typhoon, storm, heavy rain, etc. To estimate the economic loss of natural disasters, we used a set of data on the natural disasters in Amami Islands provided by Kagoshima Prefecture's Small Islands Promotion and Development Office (2000). The total value of impacts is derived by this simple formula:

(3)

$NDI_{tj}=SUM_{(t,1-10)}[S_{itj}]$

where NDI_{tj}=total natural disasters impact for small island j at year t; S_{itj}=impact of natural disasters on i sector (agriculture, economic facilities, etc) for small island j at year t (1990–2000).

The next step is to make an index for the islands' vulnerability subjected to environmental disasters (sea level rise and natural disasters) by using two bases of calculation, i.e., GIP and per capita value as reflected in these simple formulas:

(4)

DI_{mjt}(GIP-based value)=$[X_{mjt}/GIP_{jt}]100$; $m=1,2$

where DI_{mjt}=index of environmental disaster m for small island j at year t; GIP_{jt}=total GIP of the small island j for year t; X_{mjt}=total impact of environmental disaster m for island j at year t.

In order to make an adjustment with the island's population scale, we also use the term per capita value for all single variables mentioned above (sea level rise and natural disaster) for comparison with GIP-based value. To do this, a ratio between the total economic impact per capita will be used instead of GIP value as revealed from this formula:

(5)

DI_{mjt}(per capita-based value)=$[X_{mjt}/P_{jt}]100$; $m=1,2$

where DI_{mjt}=index of environmental disaster m for small island j at year t; P_{jt}=total population of small island j for year t; X_{mjt}=total impact of environmental disaster m for island j at year t.

In this paper, we use a 1990–2000 time-span analysis for both sea level rise and natural disasters' impact. Finally, the average value is used as input for calculating the EVI of small islands.

To render the index sensitive to the scale of measurement used, a standardization model (deprivation unit model) is used as suggested by Briguglio (1995) and Atkinson et al. (1997):

(6)

$SI_{mj}=(X_{mj}-\min X_m)/(\max X_m-\min X_m)$; $0<EVI_{mj}<1$; $m=1,2$

where SI_{mj}=standardized index for m-th disaster for small island j; X_{mj}=the value of m-th disaster included in the vulnerability index for small island j; min X_m=minimum value of m-th disaster for all of small islands in the index; max X_m=maximum value of m-th disaster for all of small island in the index.

A single composite index for each island is then made by employing weighting method for each variable (sea level rise impact and natural disasters impact). In this case, there are two standardized sub-indices, which represent different dimensions of vulnerability and which are combined together to yield a single value. To do this, we follow Briguglio (1995) for testing a variance weight value due to the importance of three vulnerability variables of small islands. The variance-weighted values are given as:

(7)

$$\mathrm{EVI}_j=(X1_j*0.3)+(X2_j*0.7)$$

where EVI_j=economic vulnerability index of the small island j; $X1_j$=standardized index of sea level rise impact for small island j; $X2_j$=standardized index of natural disaster for small island j.

The reason for the usage of those variance-weighted values is that small islands in Japan are more prone to natural disasters rather than sea level rise in terms of their time-scales and frequencies, where natural disasters such as typhoon is categorized as the present-day variability and has short-time impact, while sea level rise has long-time impact or future problems. Based on this reason, weighted value for natural disaster's variable would be higher than the sea level rise. Finally, as a consequence from Eq. (6), the composite index of island's vulnerability to environmental disasters will be between 0 and 1 (Briguglio and Briguglio).

4. Model application: results and discussions for the case of Amami Islands, Japan

4.1. Amami Islands: the economics and environments

Kagoshima prefecture, which is situated in the southern mainland of Japan, consists of some small island chains especially those located in the southern part of the prefecture. At a high level of generalization, their historical experience provides much evidence for the stereotype outlined above. They are small in size and population, categorized as peripheral compared with the mainland, much dependent on economy of the mainland in terms of external finance (development subsidies). One of the important groups of islands of Kagoshima, especially in terms of their history and culture, is Amami Islands, which geographically consist of eight islands namely Amami Oshima (719.9 km^2), Kakeromajima (77.15 km^2), Yoroshima (9.48 km^2), Ukeshima (13.70 km^2), Kikaijima (56.9 km^2), Tokunoshima (247.9 km^2), Okinoerabujima (93.6 km^2) and Yoronjima (20.5 km^2) (NIJI, 2000). However, administratively, Kakeromajima, Yoroshima and Ukeshima islands are included in the Amami Oshima Island. Therefore, in this paper, Amami Islands refers to the five small islands of Amami Oshima, Kikaijima, Tokunoshima, Okinoerabujima and Yoronjima (see Fig. 1 and Table 1).

Full-size image (20K)

Fig. 1. Location of the case study (not to scale).

Table 1. Baseline data of small islands within the Amami Islands

Island	Area (km^2)	Coastline (km)	Population (people)
Amami Oshima (AMO)	719.9	461.0	73,643
Kikaijima (KIKA)	56.9	50.0	9268
Tokunoshima (TOKU)	247.9	89.2	29,156
Okinoerabujima (OKI)	93.6	55.8	15,325
Yoronjima (YOR)	20.5	23.7	6210

Source: Kagoshima Prefecture Office (2000).

This group of islands has some special considerations as the case study. First, Amami Islands is the most insular islands in terms of economic and social distance from the Kagoshima mainland. Secondly, Amami Islands is one of the groups of islands, which is administered by the special national law, namely the Amami Islands Development Act (AIDA) No. 89/1954[4] (NIJI, 1996).

In Amami Islands, typhoons (*taifu*) are the dominating type of natural disasters, which usually occur yearly. Others are landslides (*jisuberi*), tornado (*tatsumaki*) and heavy rain (*ooame*) (Kagoshima Prefecture Office, 2000). According to the local government office for small island studies, the frequency of typhoon in Amami Islands is about 20 times per year. In Japan, typhoon disaster is numbered by order of its occurrence, so that there will be typhoon numbers 1, 2, 3 and so on. The typhoon season is usually between September and October annually. However, not all typhoon disasters have significant impacts to the islands' economies. Table 2 presents a set of time series data on the frequency of natural disasters, which occurred in Amami Islands and their total damage values during 1980–2000.

Table 2. Frequency and total damage value of natural disasters in Amami Islands

Source: Kagoshima Prefecture Office (various years).

Matsui et al. (1995) have identified and estimated the potential sea level rise impacts on coastal zone in Japan, including the islands of southern Japan, as about 200 trillion JPY in 1995. It showed that sea level rise and global climate changes were considered as the main constraints for small island economies not only for the SIDS (United and United), but also for the small island economies as part of archipelagic states such as Japan.

According to the United and United, the impact of sea level rise on island environment is coastal inundation. The inundation of coastal zones can result in: (a) a loss of agricultural land, a common concern because agriculture is still the primary source of income in many small islands in Japan, increasing its vulnerability to sea level rise; (b) loss of exclusive economic zone (EEZ), a common concern because sea level rise will also reduce the EEZ, thereby reducing its resource base. The differential problem of this coastal inundation is salt-water intrusion, potentially, which can have negative impacts on the agricultural sector. Statistical data provided by the Japan Oceanographic Data Center (JODC) for 24 years (1970–1994) revealed that the average annual sea level in Amami Islands is 2.4 m, the annual highest level is 2.9 m and the lowest level is 1.1 m.

The AIDA is established for Amami Islands due to their handicaps, such as highly remoteness and their high dependence on central and prefectural government, in terms of development subsidies. In general, government subsidies given to these islands are higher than those regulated in Remote Islands Development Act (RIDA) No. 72/1953.[5] The other national laws established in Japan, which are related to small islands development, are Okinawa Islands Development Act and Ogasawara Island Development Act.

As mentioned in the AIDA, there are several objectives relating to the development of this island. The main objectives are: (1) to conserve the status of natural and environmental quality in the area of Amami Islands and (2) to increase the economic welfare of islanders (local community) in Amami Islands. Based on those objectives, about 12 plans have also been decided by the Japanese government described as follows (Kagoshima Prefecture Office, 2000):

1. Developing the real plan for Amami Islands development.

2. Maintaining and developing the local industry such as agriculture, forestry and fisheries or other industries, which are suitable for Amami Islands.

3. Developing the potential of tourism industry including marine ecotourism.

4. Securing transportation system including harbors, roads, airport and other transportation facilities.

5. Maintaining the life of natural resources.

6. Improving health and sanitation quality system in the islands.

7. Improving welfare system for aged people and other community members.

8. Securing the medical treatment services for local communities.

9. Protecting the country's territory.

10. Protecting the environment from pollution.

11. Developing and securing the level of education for local communities and also their cultures.

Because of its economic and ecological disadvantages, the basic policy for the island's economic development is to increase the quality of life among islanders in Amami Islands by improving its infrastructure and industrialization, hence eliminating backwardness based on special situation and realizing special measures for exerting the works, as mentioned in RIDA (Hasegawa, 2000). It should be noted that the economy of small islands in Japan generally relies on external finance (e.g., government subsidy) rather than local incomes for their development.

From 10 years time series data provided by Kagoshima Prefecture Office (1988–2000), it revealed that the composition of development finance in the five biggest islands in Amami showed a relative dependence on external finance, which is calculated in average at the range of 80–85% of the total finance. It also showed that, among Amami Islands, Kikaijima has the highest percentage of 85.56%, followed by Yoronjima as 83.96%, Tokunoshima 83.22%, Okinoerabujima 82.08% and Amami Oshima 81.35%. Logically, it can be said that national or prefecture government is the most important body in island governance as indicated by Hasegawa (2000). In his recent paper, he mentioned that the RIDA was a fruit of lobby guided by governors of several prefectures, which have a lot of islands, elected representatives in the local and national assemblies and some islanders' association.

In terms of GIP, the economic growth showed a positive trend in 1981–1997 period. In that period, on the average, the economic growth rose from 2% into 4% in the period of analysis, but negatively declined to about 1.2% in 1997 (Kagoshima Prefecture, 1999). Fig. 2 presents the 1987–1998 data of GIP of the five biggest islands chain of Amami.

Full-size image (7K)

Fig. 2. Historical data of gross island products of Amami Islands.

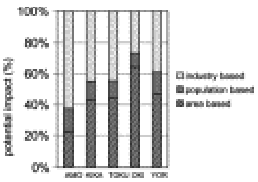
Talking about economic sectors, services sector predominates the whole islands economy and calculated as about 40% of total GIP in all of the islands. It can be said that Amami Islands economy relies on the nondirect production sector, as in the primary and secondary sectors of the economy. This condition is consequently identified as the main characteristic of small island economies according to Hein (1990). He stated that, in almost SIDS, services sector constitutes a higher proportion of GDP than in non-island country or region. Table 3 presents the dominant economic sector in Amami Islands. From the general description of island economy above, it may be concluded that the Amami Islands have several main characteristics, i.e., (1) relying on external finance for development, (2) dominated by service sectors and (3) the gap of income per capita is calculated as 70% from regional level and about 50% from national level. These economic characteristics are important in this study, since economic valuation and vulnerability analysis in this paper are conducted based on GIP value.

Table 3. The three most dominant economic sectors in Amami Islands (1997)

Source: Kagoshima Prefecture Office (1999).
The figure in the bracket indicates sector's share to GIP (%).

4.2. Sea level rise impact

By employing Matsui's estimation data to Amami Islands' economic data, a composition of GIP potentially affected by sea level rise is presented in Fig. 3. As we can see from this figure, potential impacts of sea level rise were dominated by industrial-based activities in Amami Oshima and Kikaijima, but in the case of Tokunoshima, Okinoerabujima and Yoronjima, area-based economic sector has the most impacts from sea level rise. The percentage of this impact to the area-based activities is calculated between 20% and 60% from the total impact. The next step of valuation method is to convert the approximations for total affected economic activities into the RV and the PV as formulated in (1) and (2). The incremented value for each year and total RV and PV are presented in Table 4.



Full-size image (11K)

Fig. 3. Percentage of GIP potentially affected by sea level rise.

Table 4. Real and present value of affected GIP by sea level rise (1990–2000)a

Year	Island				
	AMO		KIKA		TOKU
	RV	PV	RV	PV	RV
1990	35,128.72	33,455.92	4650.81	4429.34	15,365.28
1991	72,723.47	65,962.33	9539.74	8652.83	31,673.99
1992	112,914.10	97,539.45	14,675.94	12,677.63	48,969.57
1993	155,836.52	128,207.09	20,068.86	16,510.70	67,297.25
1994	201,632.97	157,984.71	25,728.28	20,158.78	86,704.09
1995	250,452.35	186,891.40	31,664.31	23,628.39	107,239.09
1996	302,450.43	214,945.87	37,887.40	26,925.87	128,953.21
1997	357,790.22	242,166.50	44,408.36	30,057.33	151,899.52
1998	416,642.23	268,571.30	51,238.37	33,028.71	176,133.19
1999	479,184.86	294,177.94	58,388.97	35,845.76	201,711.64
2000	545,604.68	319,003.75	65,872.10	38,514.05	228,694.60
Total	2,930,360.54	1,689,902.51	364,123.13	250,429.39	1,244,641.42

Full-size table (31K)

PV=present value, RV=real value.

In terms of impact density and RV, Yoronjima has the biggest impact of JPY 11,500,000/km^2, followed by Okinoerabujima (JPY 11,449,000/km^2), Kikaijima (JPY 6,399,000/km^2), Tokunoshima (JPY 5,020,000/km^2) and Amami Oshima (JPY 4,070,000/km^2). The other ratios are also made based on the PV and the results are presented in Table 5. For this case, Kikaijima has the highest ratio of JPY 9,146,380/km^2, followed by Yoronjima (6,721,460/km^2) and Okinoerabujima (JPY 6,572,001/km^2). These results indicate that the smaller islands relatively have bigger impact of sea level rise than the big islands.

Table 5. The impact density of sea level rise in Amami Islands

Island	Area (km^2)	Total value (000 JPY)		Total value per area (000 JPY/km^2)	
		RV	PV	RV	PV
AMO	719.9	2, 930, 360	1, 689, 902	4070.51	2347.41
KIKA	56.9	364, 123	520, 429	6399.35	9146.38
TOKU	247.9	1, 244, 641	720, 815	5020.74	2907.68
OKI	93.6	1, 071, 715	615, 140	11, 449.95	6572.01
YOR	20.5	235, 755	137, 790	11, 500.24	6721.46

AMO=Amami Oshima Island, KIKA=Kikaijima Island, TOKU=Tokunoshima Island, OKI=Okinoerabujima Island, YOR=Yoronjima Island, RV=real value, PV=present value.

4.3. Natural disasters

By using Eq. (3), total value of impact of natural disasters in Amami Islands during the period of analysis (1980–2000) is calculated and shown in Table 6. In average, Amami Oshima Island has the highest value of damage (JPY 2,211,950,000 per year), followed by Tokunoshima (JPY 719,598,000 per year) and Okinoerabujima (JPY 422,502,000 per year). The other islands, Kikaijima and Yoronjima, have relatively small damage value as estimated at JPY 224,644 per year and JPY 86,147,000 per year, respectively.

Table 6. Historical impact value of natural disasters in Amami Islands (000 JPY)

Year	AMO	KIKA	TOKU	OKI	YO
1980	870.518	80.738	1,042.515	288.029	62
1981	1,799.068	94.851	1,508.597	418.257	186
1982	1,679.556	314.241	522.532	107.364	15
1983	2,202.346	26.169	94.595	62.153	83
1984	1,891.852	78.251	1,338.232	611.266	69
1985	827.756	72.910	640.954	59.449	12
1986	1,231.782	181.097	827.599	609.298	156
1987	1,647.079	273.816	686.056	742.061	162
1988	723.363	38.037	114.766	85.617	29
1989	611.494	15.691	63.661	68.853	[illegible]
1990	13,347.474	1,606.492	1,313.471	301.223	129
1991	3,790.973	38.523	604.901	185.380	45
1992	4,622.640	366.798	524.504	119.197	9
1993	2,384.461	407.514	2,042.916	105.573	61
1994	793.707	101.654	320.739	61.318	11
1995	984.094	319.452	194.500	0	
1996	1,692.670	44.006	407.366	986.714	214
1997	1,891.519	473.025	986.431	2,661.730	156
1998	1,152.894	135.754	295.718	46.261	16
1999	1,312.558	34.596	537.991	669.910	87
2000	993.155	14.332	1,043.519	682.889	296
Average	2,211.950	224.664	719.598	422.502	86
S.D.	2,738.346	347.614	521.065	590.155	82
Maximum	13,347.474	1,606.492	2,042.916	2,661.730	296
Minimum	611.494	14.332	63.661	0	

Source: Kagoshima Prefecture Office (various years). S.D.=standard deviation, AMO=Amami Oshima, KIA=Kikaijima, TOKU=Tokunoshima, OKI=Okinoerabujima, YOR=Yoronjima.

The value of total impact of natural disasters based on their subject of damages (S_{itj} in Eq. (3)) is presented in Table 7. It contains the impact of natural disasters to houses, public facilities, agriculture products and other damages.

Table 7. Composition of damages of natural disasters in Amami Islands (1999)a

Island	Damage					
	House	Primary products	Public facilities	Other facilities	Agriculture	Others
AMO	3710	506,574	768,760	3,390	22,124	8000
KIKA	0	500	10,000	0	24,096	0
TOKU	5100	77,300	165,440	3855	286,296	0
OKI	12,780	800	20	2500	47,660	3150
YOR	14,370	503	0	400	69,707	2430
Total	35,960	585,677	944,220	10,145	449,883	13,580

Full-size table (10K)

Source: Kagoshima Prefecture Office (2000).

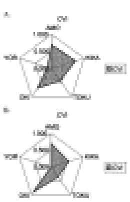
4.4. Vulnerability results

By using the results of sea level rise (PVs of impacts) and natural disasters impacts analysis to the islands economy, the EVI to environmental disasters are assessed and its result is given in Table 8. Based on the results of (4) and (5), a comparison between GIP based-ratio and population-based ratio index are presented together with standardization results (Eq. (6) and composite vulnerability index (CVI) of each island, which is calculated by using a set of weight values as reflected in Eq. (7). Graphically, the results of vulnerability indices are shown in Fig. 4. From Table 8 and Fig. 4, we can see that, in terms of GIP-based value, economic vulnerability in Kikaijima has the highest level as estimated for 0.737. However, in terms of per capita-based value, Okinoerabujima is considered as the most vulnerable island with the CVI of 0.737.

Table 8. Single variable, standardization result and composite vulnerability indices

Island	Single Vulnerablity				Standardization				CVI	
	ND		SLR		ND		SLR			
	G	P	G	P	G	P	G	P	G	P
AMO	2.271	37.271	0.128	2.397	1.000	1.000	0.000	0.031	0.700	[illegible]
KIKA	2.245	32.345	0.144	2.442	0.979	0.781	0.172	0.054	0.737	[illegible]
TOKU	1.621	24.660	0.161	2.637	0.463	0.439	0.355	0.152	0.430	[illegible]
OKI	1.761	34.381	0.221	4.320	0.579	0.872	1.000	1.000	0.705	[illegible]
YOR	1.061	14.780	0.167	2.335	0.000	0.000	0.419	0.000	0.126	[illegible]

ND=natural disasters, SLR=sea level rise, CVI=composite vulnerability index, G=GIP based value, P=per capita based value, AMO=Amami Oshima Island, KIKA=Kikaijima Island, TOKU=Tokunoshima Island, OKI=Okinoerabujima Island, YOR=Yoronjima Island.



Full-size image (12K)

Fig. 4. Composite vulnerability index for GIP-based value (A) and per capita-based value (B).

4.5. Islands' vulnerability and policy implication

The economic losses of natural disasters and sea level rise vary among islands within Amami Islands. However, these losses still have a relatively small fraction of the GIP of the affected area. MacDonald (1999) estimated that, for the case of natural disasters, the approximately estimated loss is about 1.5% of the total GIP. In our case, as indicated in Table 8, the economic losses of natural disasters range from 1.06% to 2.27% of the GIP. The highest fraction is calculated for Amami Oshima (2.27%), followed by Kikaijima (2.24%), Okinoerabujima (1.76%), Tokunoshima (1.62%) and Yoronjima (1.06%).

A different picture can be found for the case of sea level rise. The economic impacts of sea level rise are estimated between 0.12% and 0.22% of the GIP. The highest fraction was found in Okinoerabujima of 0.22%, followed by Yoronjima (0.17%), Tokunoshima (0.16%), Kikaijima (0.14%) and the lowest fraction was found in Amami Oshima of 0.13%. However, as indicated in Fig. 4, except for Amami Oshima, area-based economic activities such as agriculture, fisheries and forestry in the other smaller islands have the most impact of sea level rise. Due to the fact that most of islanders in Amami Islands still depend on the primary sector to generate their income, this impact should not be negligible. The support for this argument also came from the Amami Islands Development Plan 1999–2003 (Kagoshima Prefecture Office, 2000). In their plan, there are five main policies regarding the future development of the Amami Islands. The one important policy, as written there, is to promote the characteristic of industry in the island economy. In this regard, in order to maintain independence from the mainland, an optimal use of natural resources such as agriculture, fisheries and forestry is promoted.

The results of economic vulnerability analysis reveal that the smaller islands seem to be more vulnerable than the relatively bigger island. This conclusion is not surprisingly due to some similar indicating conclusions, which were found in several other studies such as in Briguglio (1995), Chander (1996) and Wells (1997). For our case, we reveal that Okinoerabujima and Kikaijima have relatively higher vulnerability indices than the bigger islands, such as Amami Oshima or Tokunoshima. However, an exception was found for the case of Yoronjima. This island, in fact, is the smallest island in Amami Islands in terms of area, where it has less vulnerability compared with other islands. Considering this fact, we can conclude that size of the island may not have direct relationship with its vulnerability to environmental disasters, but it can be indicated as small island disadvantage especially when we consider the impact density (Briguglio and Hein).

The need to compute an index with vulnerability scores for different entities, especially for the case of small islands, arose principally because of interest on the extent to which the economy of small islands is exposed to forces outside its control, including environmental disasters (Briguglio, 1995). Moreover, the stimulus for developing this index came mostly from this type of region, because some of them tend to register the impression of their economic strength, when in reality they have such an intrinsic vulnerability. As a matter of fact, Okinoerabujima and Kikaijima have relatively higher average income per capita in the Amami Islands (Table 9). However, in terms of environmental disasters, these islands are the most vulnerable islands in terms of economic value of impacts. Therefore, a set of regional policy should be strengthened to make an adjustment of this condition.

Table 9. Level of income of Amami Islanders and its gap with the average regional and national level of income per capita

Island	Income per capita (JPY/year)	Regional level (%)	National level (%)
Amami Oshima	1,757,871	75.19	50.10
Kikaijima	1,619,706	69.30	52.30
Tokunoshima	1,421,474	60.77	45.90
Okinoerabujima	1,852,623	78.70	59.85
Yoronjima	1,386,453	59.30	44.80

Source: Kagoshima Prefecture (2000).

In terms of regional policy related to the island's vulnerability to environmental disasters, Kagoshima Prefecture as the administrator for the Amami Islands has conducted several initiatives regarding the environmental disasters problems as also mentioned in the National Law for the Prevention of Natural Disasters (Act No. 223/1961)[6] such as:

• Establish and strengthen regional disasters mitigation and preparedness management agencies, measures and programs.

• Establish and strengthen mechanisms for the sharing experience, information, resources and expertise with regard to disasters preparedness, prevention, mitigation and response between small islands in different region in Japan.

• Facilitate effective precautionary and response strategies to natural disasters.

• Support affected small islands in the context of national efforts to combat desertification and drought (Kagoshima Prefecture Office, 2000).

Based on this discussions, it could be stated that vulnerability indices achieved by this study should be seen as the preliminary judgment due to some problems associated with the measure of vulnerability. There are three main problems, i.e., (1) their subjectivity mainly for the choice of compounding variables, (2) problems with measurement and (3) the weighting procedure (Briguglio, 1995). However, there are two principal benefits that can be derived from the construction of a CVI, namely (1) the index can attract attention towards the issue of vulnerability of certain small islands and (2) it can present a single-value measure of vulnerability based on the meaningful criteria, which can be considered by central or regional government to make some decisions regarding the small islands development policy.

5. General conclusions

In this study, we have described the methodology approach to estimate the small islands economic vulnerability from environmental disasters and compare them with other existing facts of regional policy and development to the case of the Amami Islands, Kagoshima Prefecture, Japan. It has been argued also that certain islands have relatively high income per capita, which may convey the impression of their strong economy (high resilience), however, the economies of such islands are dominantly being exposed to the impacts of environmental disasters.

Despite the two principal benefits potentially obtained by developing economic vulnerability indices for small islands, in this paper, we also should state some limitations mainly regarding the scope of analysis, which is only attempted to particular cases of environmental disasters, i.e., sea level rise and natural disasters. For example, we agree that the global warming issue on small islands may give another scope of probability of using other variables in assessing small islands economic vulnerability. Further researches are also encouraged especially in the development of methodology mainly in the variable measurement and composite method.

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[1] Permanent address: Department of Socio-Economics, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Lingkar Kampus 1, Darmaga Campus, Bogor City 16680, Indonesia.

Corresponding author. Tel.: +81-99-286-4270; fax: +81-99-286-4297; email: adriant.luky@angel.fish.kagoshima-u.ac.jp

[2] There are several definitions of small islands. This paper uses international definition as the islands with population of 500,000 or less and a land area of approximately 10,000 km^2 or less. In Japan, definition of small islands (*ritou*) refers to those islands located separately from mainland. Actually, the literal meaning of *ritou* is remote islands (see Hasegawa, 2000).

[3] We followed Edwards (1987) to determine the area-based activities, such as agriculture, forestry and fisheries. Population-based activities consist of construction and power and water supply, while industrial-based activities include manufacture, finance and services.

[4] Revised in 1994.

[5] Revised by the Act No. 8 1993.

[6] Revised by the Act No. 99/2000.

Vitae

Adrianto: *Luky Adrianto* is Assistant Professor at the Department of Socio-Economics, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Indonesia. He was born in Pati, a small coastal-side town in Java Island, in 1969. He earned his MS in Fisheries Economics from the Fisheries Graduate School of Kagoshima University, Japan, under the supervision of Professor Yoshiaki Matsuda of International Marine Policy Program, Kagoshima University. He is currently doctoral candidate in Marine Policy at the Chair of Marine Production and Environmental Studies, United Graduate School of Kagoshima University. His research interests include fisheries economics, islands studies (nissology), coastal zone management and ocean governance.

Matsuda: *Yoshiaki Matsuda* was born in Kobe, Japan, in 1939. He received his BS in Aquaculture from Hokkaido University in 1966 and his MS in the same subject in 1968. He obtained his master's degree in Agricultural Extension Education in 1973 and his PhD in Agricultural Economics in 1976 from the University of Georgia, USA. As a postdoctoral fellow, he joined the Marine Policy and Ocean Management Program at Woods Hole Oceanographic Institution (1976–1979) and the Ocean's Project at the East West Center (1979–1980) in the United States. In October 1980, he joined the International Marine Policy Program at the Kagoshima University, Japan. At present, he is the Professor of International Marine Policy at the Kagoshima University and the President of the Japan International Fisheries Research Society.