INVESTIGATING MAJOR FACTORS TO AFFECT HUMAN CASUALTIES OF NATURAL DISASTERS AND REVIEWING RECOVERY POLICIES

***Novia Budi Parwanto*[1, 2], *Tatsuo Oyama*[1]**

[1] *National Graduate Institute for Policy Studies (GRIPS), Minato-ku, Tokyo 106-8677, Japan*
[2] *BPS, Statistics Indonesia, Jl. Dr. Sutomo 6-8 Jakarta 10710, Indonesia*
noviabudi@bps.go.id, oyamat@grips.ac.jp

Keywords: Natural Disasters, Stochastic, Human Casualties, Recovery Policy.

Abstract

The timing and magnitude of natural disasters are unpredictable, and thus are stochastic. Number of death and missing people (D&M) caused by natural disasters are often used to measure the magnitude of the disasters. By using statistical analysis, we investigate the relationship between the D&M inflicted and some parameters of natural disasters with case studies of earthquakes and tsunamis occurred in Japan and Indonesia from 1900 to 2012. The parameters under investigation are the epicenter location, earthquake magnitude, depth of hypocenter, and water height. We found that the earthquake magnitude and water height are positively affect the D&M inflicted, while the epicenter location and hypocenter depth have significant and negative effect. In addition, we also review the recovery process from the 2004 Aceh tsunami and the 2011 Tohoku tsunami, especially in the agriculture sector.

1 Introduction

In the last four decades, based on the International Disaster Database (EM-DAT), between 1970-1979 and 2000-2012, the number of natural disaster events[1] reported globally increased significantly from 837 to 4,939 or increased almost six times. Over the whole period of 1970-2012, 40.8 percent of these natural disasters occurred in Asia. Figure 1 portrays the increasing of natural disasters reported by region of continent. Such increases are allegedly associated with the increasing of population exposed to hazards [1].

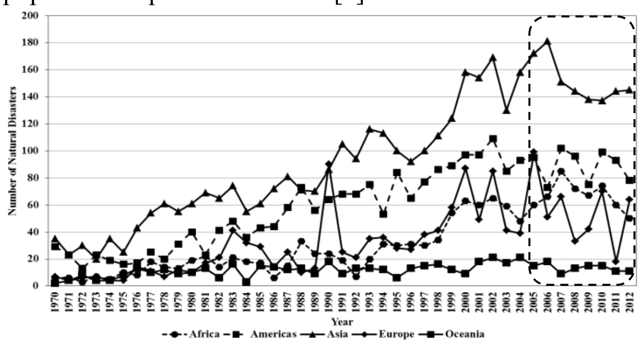


Figure 1. Number of natural disaster reported, 1970-2012.

Figure 1 also portrays that the frequencies of natural disaster from 1970 to 2005 shows increase trend in all regions. Nevertheless, it seems that there is a turning point in 2005, in which from 2005 in most of the regions, the frequencies of natural disaster started to show declining trend, a fairly significant decline could be seen in Asia, namely, the average growth of natural disaster events (slope of the regression line) in Asia has decreased from 3.86 into -5.02. Only in Africa that the number of natural disaster during 1970-2012 shows consistent increase, whilst in Oceania the trend is rather flat. In terms of casualties, however, Asia was proportionally hit harder. Of all the number of D&M caused by natural disasters in the world from 1970 to 2012, as much as 57.45% is in Asia, followed by Africa (21.65%) and Americas (15.07%) as described in Table 1.

Table 1. Natural disasters events and impacts, 1970-2012.

Region	Events	Death and Missing people	Affected People (000)	Damage (US$ millions)
Africa	1,388	710,821	438,219	26,104.53
Americas	2,599	494,744	243,672	914,442.81
Asia	4,082	1,885,899	5,900,107	1,137,363.40
Europe	1,431	185,311	38,400	333,816.11
Oceania	505	5,964	20,957	70,669.17
Total	10,005	3,282,739	6,641,355	2,482,396.01

Given the damage and costs that natural disasters can bring, it is important to understand the "nature" of disasters in order to assist policy makers and planners who are involved in disaster preparedness and mitigation [2]. Many studies have been conducted to investigate the natural disasters, especially earthquakes and tsunamis, yet, to our best knowledge, nothing has been done on investigating the influence of the parameters of earthquake and tsunami to the number of D&M. The parameters may include the epicenter location, earthquake magnitude, depth of hypocenter, and water height. It should be note that not every earthquake and tsunami that occurs will inflict D&M and/or property loss. Earthquake or tsunami that occurred in the unpopulated region is certainly not a natural disaster, but rather just a natural phenomenon. This study is also significant as part of the disaster risk analysis and assessment, moreover Japan faces the highest tsunami risk followed by Indonesia [3].

Therefore, this study aims to analyze the parameters of earthquake and tsunami that influence the emergence of D&M. Our study will also review the recovery process in Aceh and Tohoku, especially in the agriculture sector. It is given that; the tsunami had destroyed most of the agricultural areas, which in turn will threaten the sustainability of domestic food availability. Finally, we conclude our study with some policy recommendations.

---

[1] The natural disasters include geophysical, climatological, hydrological, and meteorological.

2 Scale of natural disasters in a global perspective

The number of victims, which comprise of number of deaths and missing people and affected people, and amount of property damages caused by natural disasters often used to scale and categorize the disasters. Figure 2 shows the trend of natural disasters which categorized by number of victims (killed and affected). During the period of 1970 and 2012, there was an increase in all categories of natural disasters victims. Natural disasters creating less than 1,000 victims remained the most numerous during the entire period. Their increase is the most pronounced. With the average of events equal to 61, their number increased three times between 1970 and 2012. Before 1992, there is no distinction between the numbers in the categories of disasters causing between 1,000 and 999,999 victims. However, starting from 1992, natural disasters causing 1,000 to 9,999 and 10,000 to 99,999 victims show significant increases which differentiate them from those causing 100,000 to 999,999 victims. In 1997-2008, the differentiation between these categories of natural disasters becomes clear as well as the differentiation in the evolution of their numbers. Natural disasters causing 1,000 to 9,999 victims show the most pronounced evolution. Their number increased nine times from 1970 to 2012. Natural disasters inflicting 10 million victims or more remained rare, yet, their occurrence increased around two times between 1970 and 2012.

If we grouping these six categories into three groups of victims' scale, namely small, medium and large, in which the 1st and 2nd category can be regarded as small, the 3rd and 4th as medium, and the 5th and 6th as large. Then we can see that after experiencing increase trend from 1970, there also a turning point in 2005, where the small group shows declining trend, while the medium group moves into different direction, and the large group is relatively stable. Thus, it can be implied that the cause of the declining trend of the number of natural disasters in most of all regions in Figure 1 after 2005 is the declining trend of frequency of the number of victims in the small group.

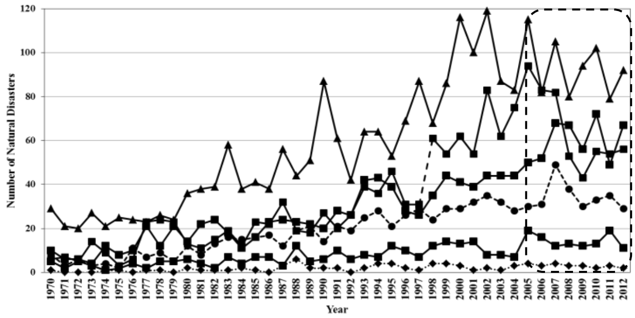


Figure 2. Natural disasters categorized by number of victims, 1970-2012.

During 1970-2012, 40.8% of natural disasters occurred in Asia, Figure 3 shows that the three most frequent natural disasters in Asia during this period is floods, followed by storms and earthquakes, whilst the landslide and other natural disasters (drought, extreme temperature, volcano, and wildfire) are not frequent to occur. However, the order of the three most frequent natural disasters become reversed in terms of number of D&M inflicted by these natural disasters, as in Figure 4, earthquakes claim the highest percentage of D&M (48.46%), followed by storms (38.96%) and floods (10.06%), respectively. Figure 3 also gives clear background of the cause of declining trend in Asia from 2005 as depicted in Figure 1. As the first and second most frequent natural disasters in Asia, flood and storm, show declining trend of events.

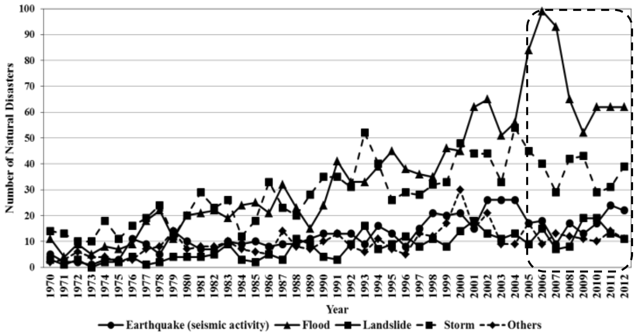


Figure 3. Total number of natural disasters by type of natural hazard in Asia, 1970-2012.

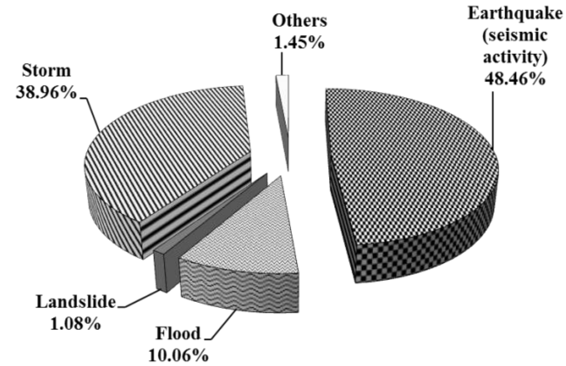


Figure 4. Percentage number of killed people by type of natural disasters in Asia, 1970-2012.

In this regard, the 2004 Aceh Tsunami and the 2011 Tohoku Tsunami are a well-known and latest example of these compound disasters. According to the Significant Earthquake Database (SED) both of these tsunamis was triggered by earthquakes with magnitude 9 Mw, in which the first was occurred of the west coast of Aceh, Indonesia and the latter was occurred of the Pacific coast of Tohoku, Japan. The epicenters of these great earthquakes are located on the ring of fire, and it is not a coincidence, because according to the U.S. Geological Survey, about 90% of the world's Earthquakes and 81% of the World's Largest Earthquakes occur along the Ring of Fire. Japan and Indonesia, in fact, lies on the Ring of Fire. Both of these earthquakes and tsunamis have caused not only destruction of property but also have inflicted large number of deaths in Japan and Indonesia, namely 19,648 and 172,761 D&M in Japan and Indonesia, respectively.

3 Earthquakes and tsunamis in Japan and Indonesia

As case study, this paper will use data of earthquakes and tsunamis from 1900 to 2012 for Japan and Indonesia, respectively. For earthquakes, we use the Significant

Earthquake Database (SED), whilst for tsunamis; the Global Historical Tsunami Database (GHTD) will be used. The database lists the date, cause, primary magnitude, coordinate of epicenter location, depth of hypocenter, maximum water height, and number of D&M. Based on the coordinate of epicenter location given, then we can categorize whether the earthquake is sea earthquake or mainland earthquake.

Figure 5 portrays the number of D&M caused by earthquakes and earthquake magnitude by location of epicenter in Japan and Indonesia, with the exception of the Great Kanto Earthquake in 1923. In Figure 5, most of the earthquakes in Japan and Indonesia have epicenter locations at offshore/sea, namely 78.4% and 63.9% for Japan and Indonesia, respectively. However, not all these earthquakes caused human casualties; in Japan, only 58-recorded earthquakes caused D&M, while in Indonesia only 90-recorded earthquakes did so.

In general, Figure 5 describes that earthquakes, which caused considerable D&M in Japan and Indonesia, are those with magnitude above 6.0 Mw. In addition, if we analyze further, of these earthquakes, earthquakes with magnitude between 6.0 and 7.4 Mw mostly have epicenters on the mainland, while earthquakes with magnitude 7.5 Mw and above mostly have epicenters at offshore/sea. This is a kind of evidence where the location of epicenter is a significant factor in causing D&M, an issue we will return in section 4.

The numbers of D&M inflicted by tsunamis from 1900 to 2012 in Japan and Indonesia are presented in Figure 6, with the exception of the 2004 Aceh tsunami and the 2011 Tohoku tsunami. As derived from the Japanese word, in Japan, the tsunami resulted in many human casualties in the initial period; however, this number seen began to decline in the mid-period. By contrast, in Indonesia, ranging from the mid-period, the death toll caused by tsunamis start to increase. At glance, Figure 6 shows a sort of "mirror" in which the number of human victims in Indonesia nowadays is a reflection of the human toll in Japan in the past. This could be a warning that the number of people threatened by tsunamis in Indonesia has increased.

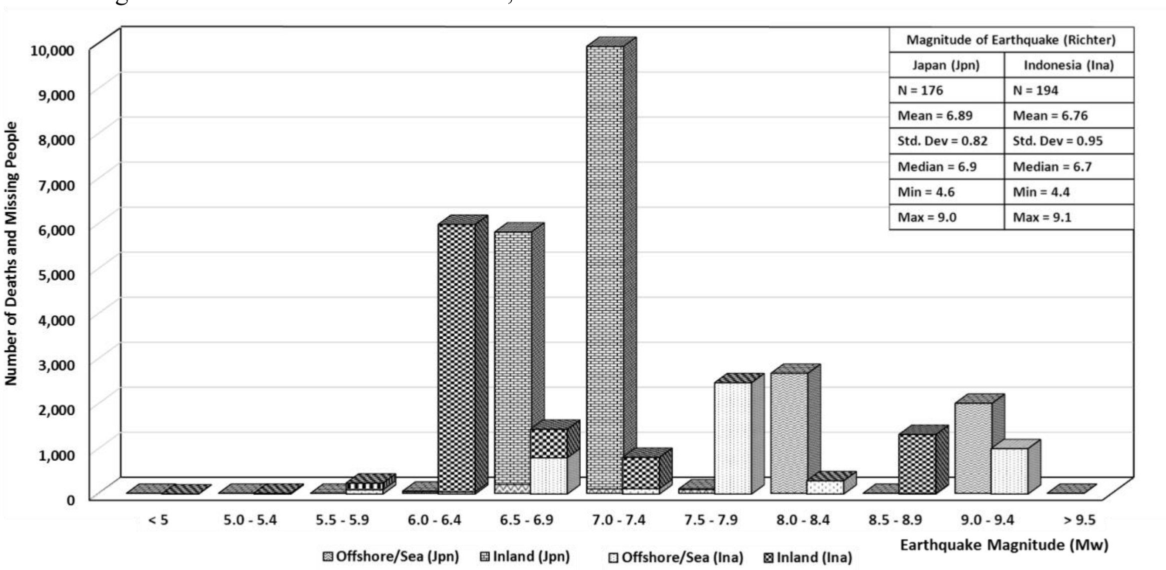


Figure 5. Number of deaths and missing people caused by earthquakes in Japan and Indonesia by magnitude of earthquakes and location of epicenter, 1900-2012

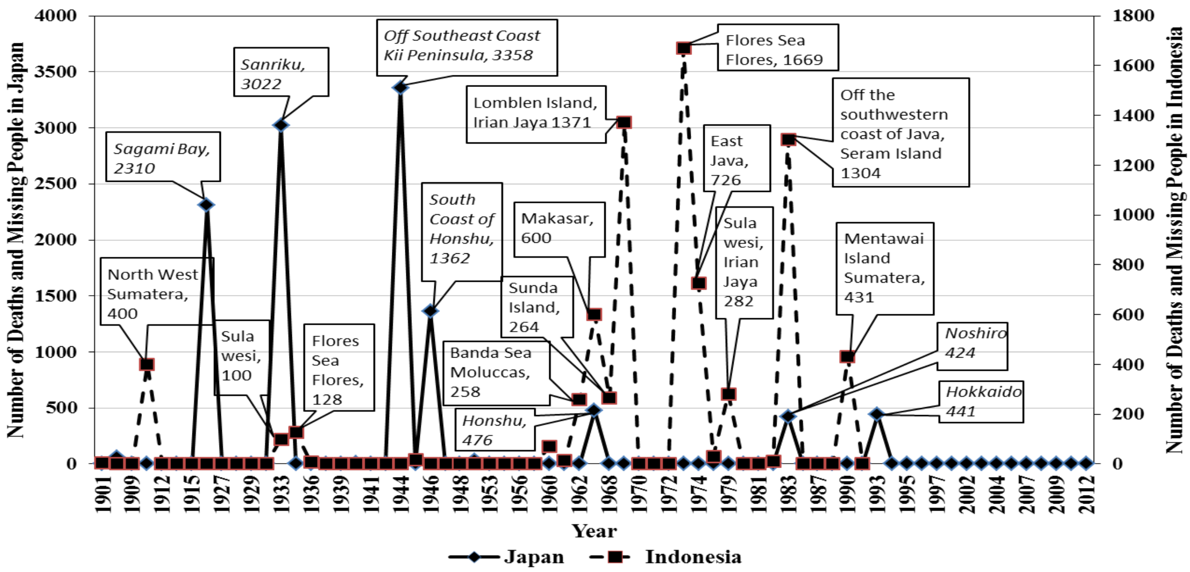


Figure 6. Number of deaths and missing people caused by tsunamis in Japan and Indonesia

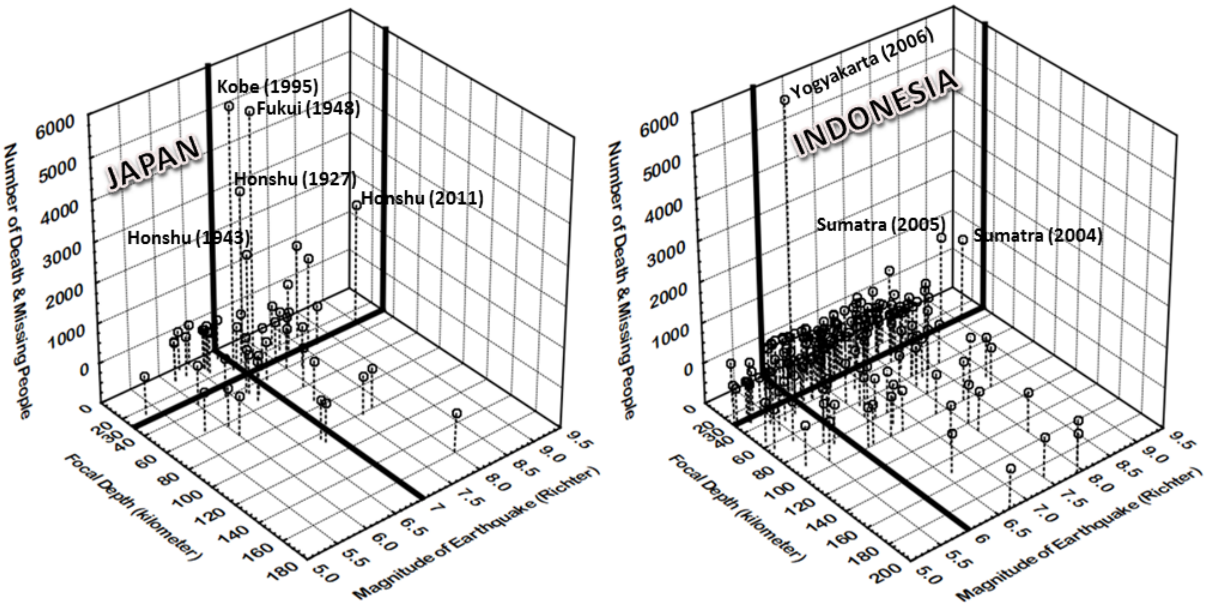


Figure 7. 3D Scatterplot of number of deaths and missing people caused by earthquakes.

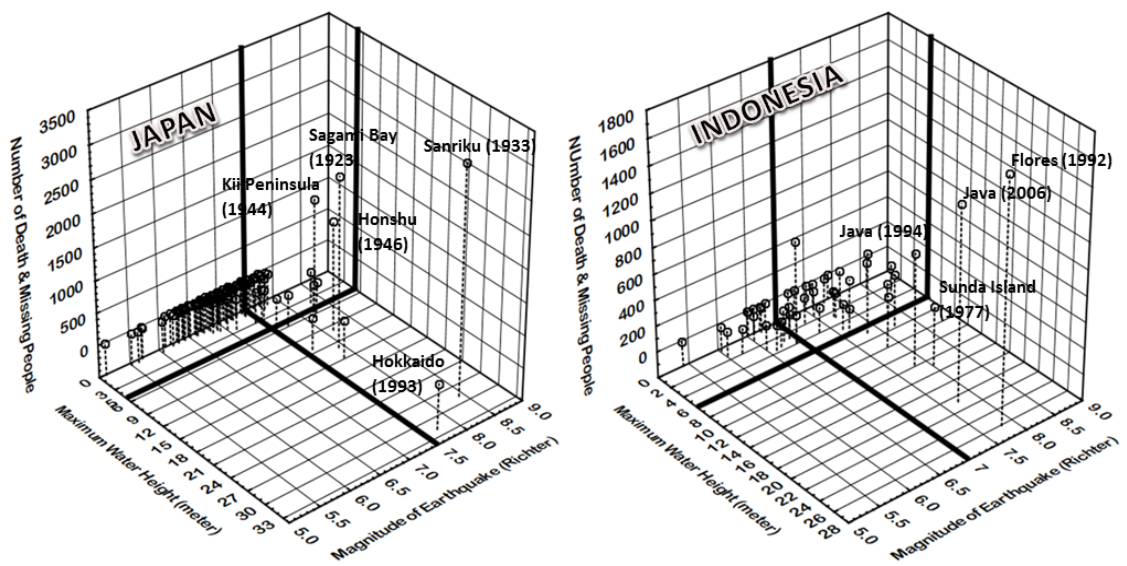


Figure 8. 3D Scatterplot of number of deaths and missing people caused by tsunamis.

As has been stated earlier that there are many factors contribute to the death toll from the earthquake and tsunami, Figure 7 and 8 depict some of these factors. Figure 7 shows the relationship between earthquake magnitude, focal depth, and number of D&M caused by earthquakes in Japan and Indonesia, with the exception of the Great Kanto Earthquake (1923). Whilst Figure 8, with the exception of tsunamis in Tohoku (2011) and Aceh (2004), has clearly described the relationship between earthquake magnitudes, maximum water height and number of D&M inflicted.

4 Mathematical models to estimate D&M in Japan and Indonesia

In section 3, we have discussed and described several parameters of earthquake and tsunami that reasonably alleged of having influence on the emergence of fatalities. To analyze the relationship among these parameters we apply the statistical method, namely the Analysis of Covariance (ANCOVA). ANCOVA is a multivariate statistical method in which the dependent variable is a quantitative variable and the independent variables are a mixture of quantitative variables and qualitative variables [7, 8]. Thus, we will analyze the number of D&M for two epicenter locations while controlling parameters (covariates) of earthquakes and tsunamis by using the following model:

For earthquakes:

$$E(DM)_t = \beta_0+\beta_1 Mag_t + \beta_2 Depth_t + \beta_3 Loc_t + \varepsilon_t \,, \qquad (1)$$

And for tsunamis:

$$E(DM)_t = \beta_0+\beta_1 Mag_t+\beta_2 Depth_t+\beta_3 Height_t+\beta_4 Loc_t+\varepsilon_t \,, \qquad (2)$$

where:

DM = number of death and missing people (D&M),
Mag = magnitude of earthquake (Mw),
Depth = focal depth of hypocenter (kilometer),
Height = maximum water height (meter),
Loc = location of the epicenter, namely offshore/sea (o) and inland (m).
ε_t = error term.

A summary of the computational formulae associated with the analysis of covariance for the completely randomized design is presented in Table 2 [8].

The summary results of the regression model using ANCOVA for earthquakes and tsunamis are presented in Table 3 and 4, respectively. Note that all the models as a whole for both earthquakes and tsunamis in Japan and Indonesia are statistically significant. However, not every explanatory variable is statistically significant. This evidence, in fact, reveals some characteristics of each natural disaster in each country. In Table 3, the earthquake magnitude has a significant effect on the number of D&M in Japan and Indonesia. However, only in Japan does the location of epicenter have a significant effect on D&M.

In addition, parameter values of magnitude for Japan is greater than Indonesia, this implies that in average the number of casualties caused by earthquakes in Japan is higher than in Indonesia. One possible cause is the population density in Japan is higher than in Indonesia, for example, the population density in 2010 in Japan is 337 people per km^2 and in Indonesia is 124 people per km^2. Meanwhile, the negative sign of the location variable implies that the closer the location of the epicenter to the mainland, the greater the likelihood of casualties inflicted.

Table 2. Analysis of Covariance for Completely Randomized Design.

Source of Variation	Sum of Squares and Cross Products XX	XY	YY	Adjusted Sum of Squares	Degrees of Freedom	Adjusted Mean Square	Expected Mean Square	F-Ratio
Group/ Treatment	--	--	--	$B_{YY(ADJ)}$	K-1	$\frac{B_{YY(ADJ)}}{K-1}$	$\sigma^2_{\varepsilon\mid\beta} + \frac{\sum N_I \sigma_I^2}{K-1}$	$\frac{MST_{(ADJ)}}{MSE_{(ADJ)}}$
Error	E_{XX}	E_{XY}	E_{YY}	$E_{YY(ADJ)}$	N-K-1	$\frac{E_{YY(ADJ)}}{N-K-1}$	$\sigma^2_{\varepsilon\mid\beta}$	
Total	T_{XX}	T_{XY}	T_{YY}	$T_{YY(ADJ)}$	N-2			

$$E_{XX} = \sum\sum\left(X_{ij} - \bar{X}_i\right)^2$$
$$E_{XY} = \sum\sum\left(X_{ij} - \bar{X}_i\right)\left(Y_{ij} - \bar{Y}_i\right)$$
$$E_{YY} = \sum\sum\left(Y_{ij} - \bar{Y}_i\right)^2$$
$$T_{XX} = \sum\sum\left(X_{ij} - \bar{X}\right)^2$$
$$T_{XY} = \sum\sum\left(X_{ij} - \bar{X}\right)\left(Y_{ij} - \bar{Y}\right)$$
$$T_{YY} = \sum\sum\left(Y_{ij} - \bar{Y}\right)^2$$
$$E_{YY(adj)} = E_{YY} - E_{XY}^2/E_{XX}$$
$$T_{YY(adj)} = T_{YY} - T_{XY}^2/T_{XX}$$
$$B_{YY(adj)} = T_{YY(adj)} - E_{YY(adj)}$$
$$b_w = E_{XY}/E_{XX}$$

Table 3. Summary results of the regression model for earthquakes.

Dependent Variable: DM

Source	**Japan** Type III Sum of Squares	**DF**	**Mean Square**	**F value**	**Pr > F**	**Indonesia** Type III Sum of Squares	**DF**	**Mean Square**	**F value**	**Pr > F**
Model	8304770.627	3	2768256.876	7.348	0.000	373058.734	3	124352.911	4.645	0.004
Error	64424558.230	171	376751.803			5059856.303	189	26771.726		
Total	72729328.857	174				5745406.000	193			
	R-Squared = 0.114 (Adjusted R-Sq = 0.099)					R-Squared = 0.069 (Adjusted R-Sq = 0.054)				

Parameter		**Japan** Estimate	**T for H_0: Parameter=0**	**Pr > |T|**	**Std Error of Estimate**	**Indonesia** Estimate	**T for H_0: Parameter=0**	**Pr > |T|**	**Std Error of Estimate**
Intercept		-873.445*	-2.163	0.032	403.768	-257.180	-3.017	0.003	85.231
Mag		206.117***	3.309	0.001	62.291	48.518***	3.673	0.000	13.208
Depth		-1.224	-1.681	0.095	0.728	-0.180	-1.096	0.275	0.164
Loc	o	-475.840*	-4.042	0.000	117.712	-32.873	-1.246	0.214	26.377
	m	0	.	.	.	0	.	.	.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4. Summary results of the regression model for tsunamis.

Dependent Variable: DM

Source	Japan					Indonesia				
	Type III Sum of Squares	DF	Mean Square	F value	Pr > F	Type III Sum of Squares	DF	Mean Square	F value	Pr > F
Model	4858089.682	4	1214522.421	12.504	0.000	4021051.096	4	1005262.77	43.830	0.000
Error	11752457.747	121	97127.750			940364.557	41	22935.721		
Total	17135126.000	126				5647056.000	46			
	R-Squared = 0.292 (Adjusted R-Sq = 0.269)					R-Squared = 0.810 (Adjusted R-Sq = 0.792)				

Parameter		Japan				Indonesia			
		Estimate	T for H_0: Parameter=0	Pr > |T|	Std Error of Estimate	Estimate	T for H_0: Parameter=0	Pr > |T|	Std Error of Estimate
Intercept		-850.165	-2.290	0.024	371.224	305.324	1.245	0.220	245.175
Mag		116.971*	2.267	0.025	51.592	-49.382	-1.463	0.151	33.746
Depth		-0.978	-0.622	0.535	1.573	-0.290	-0.904	0.371	0.321
Height		27.114***	5.178	0.000	5.236	56.553***	12.697	0.000	4.454
Loc	o	82.764	0.579	0.563	142.829	-31.691	-0.518	0.607	61.131
	m	0	.	.	.	0	.	.	.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Furthermore, Table 4 shows that the maximum water height is the most important factor in a tsunami event, which can claim number of D&M. This variable is highly statistically significant. Although tsunami is more frequent in Japan than Indonesia, however the D&M caused by tsunami in Indonesia tend to increase, therefore, both governments should take more precautionary efforts in order to mitigate the number of victims and damages/ losses due to tsunami events. Moreover, the magnitude of earthquakes also plays a significant role in causing D&M.

This evidence could be a warning for those people who live near the shore or coastal areas, since they would be the first victims to be stricken if there is a tsunami. Based on the tsunami data from GHTD, the maximum water height of the tsunami when reached the shore in Aceh and in Tohoku were 50.9 m and 38.9 m, respectively. Therefore, there should be some rules related with the safe distance to build residences from the shoreline, or if there are some people who live in areas with a supposedly dangerous tsunami threat, the government should relocate them to some other safe places and/or build tsunami walls.

5 Recovery policies for the 2004 Aceh tsunami and the 2011 Tohoku tsunami

The recovery process involves the actions taken in the long term after the immediate impact of the disaster has passed to stabilize the community and restore some semblance of normalcy [9]. Generally, the recovery phase is divided into two phases, namely rehabilitation and reconstruction. Rehabilitation is any activity with the objective to restore normalcy in conditions caused by the disaster. Reconstruction defines as the repair and construction of a property undertaken after a disaster. The common principle/slogan for to the recovery process is "building back better." The recovery process covers all sectors affected by the disaster, and one of the sectors that get the top priority to be immediately restored is the agricultural sector, given that agricultural affected lands need to be quickly rehabilitated to restore the production capacity of farmers and ensure food security [10]. In addition, in Aceh, on a sectoral basis, outside of oil and gas, agriculture has the largest share of Aceh GDP at 32%. Almost half the people in Aceh (47.6%) are working in agriculture sector [11]. Likewise, the economy of most prefectures in Tōhoku Region remains dominated by traditional industries, such as agriculture, fishing, and forestry [12].

The Japan's agriculture sector suffered $30 billion in losses from the March earthquake and deadly tsunami, which deluged crops, and radiation releases from the Fukushima Daiichi plant [12]. According to the Japanese government 21,476 hectares of farmland was inundated by the tsunami in the Tohoku and Kanto regions, Miyagi Prefecture suffered the worst damage, with 14,341 hectares of farmland in five cities flooded by seawater—more than 50 percent of the total farmland in those cities. Places where tsunami waters receded quickly suffering relatively minor damage to the soil.

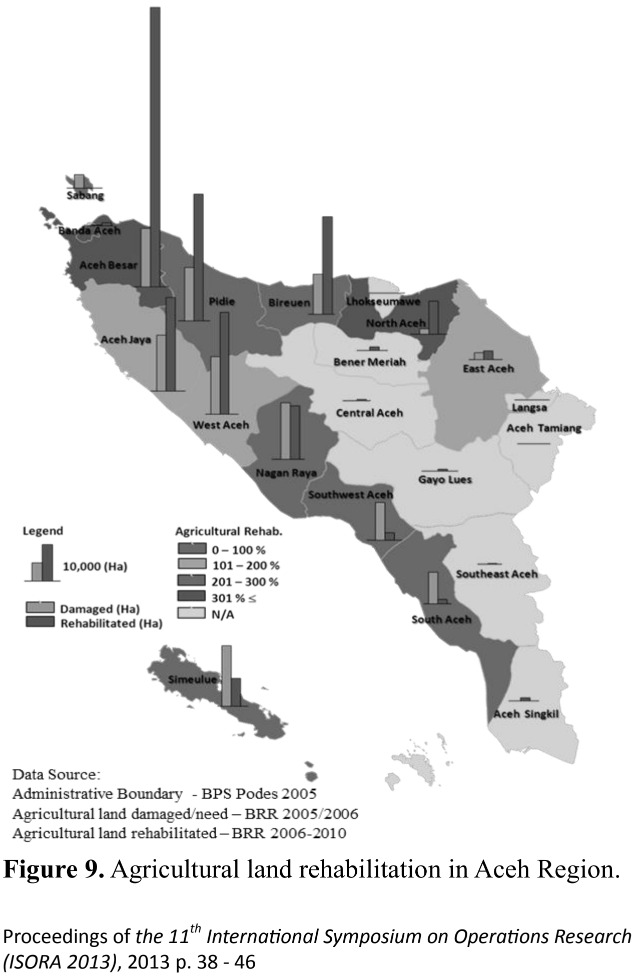
Whilst in Aceh Province, the damage of farmland area was estimated 61,816 hectares, which scattered in 11 districts out of 21 districts. Aceh Besar suffered the most extensive damage to agricultural land, namely 16,320 hectares, followed by Aceh Jaya with 11,868 hectares. Places were farmland remained flooded for some time and salt was deposited in the soil into the suffered significant soil damage that would require at least a year to restore. Table 5 describes the estimated areas of agricultural land damaged due to the 2004 Aceh tsunami and the 2011 Tohoku tsunami.

Table 5. Estimated areas of agricultural land damaged due to Aceh and Tohoku tsunami.

The 2004 Aceh Tsunami, Indonesia [a]				The 2011 Tohoku Tsunami, Japan [b]			
District	**Harvested Area (Ha)**	**Damaged Area**		**Prefecture**	**Harvested Area (Ha)**	**Damaged Area**	
		Ha	**%**			**Ha**	**%**
Simuelue	8,456	3,489	41.26	Aomori	46,900	77	0.16
East Aceh	30,477	2,119	6.95	Iwate	54,500	725	1.33
West Aceh	17,079	4,084	23.91	Miyagi	66,400	14,341	21.60
Aceh Besar	37,334	16,320	43.71	Fukushima	64,400	5,462	8.48
Pidie	40,953	5,932	14.48	Ibaraki	77,100	208	0.27
Bireuen	40,675	2,685	6.60	Chiba	60,500	663	1.10
North Aceh	43,639	1,836	4.21	**Total**	**369,800**	**21,476**	**5.81**
Southwest Aceh	22,253	7,838	35.22				
Nagan Raya	29,506	5,520	18.71				
Aceh Jaya	13,342	11,868	88.95				
Banda Aceh	174	125	71.84				
Total	**283,888**	**61,816**	**21.77**				

Source:
[a] BPS, Statistics of Indonesia and Rehabilitation and Reconstruction Agency (BRR) for Aceh.
[b] Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF).

In Aceh Province, in order for the rehabilitation and reconstruction process can run smoothly and can realize better condition than before the disaster, the Indonesian Government has mandated the Rehabilitation and Reconstruction Agency (BRR) to coordinate and be responsible for the recovery process in Aceh. The BRR's headquarter was in Banda Aceh city, capital of Aceh. The BRR commenced operations in May 2005 until 2009. Until the closure of BRR in April 2009, many activities of rehabilitation and reconstruction have been completed, including in the agricultural sector. Figure 9 portrays one of the achievements of recovery in the agricultural sector by districts in Aceh region. While Figure 10 shows the productivity progress of paddy plants in Aceh region.



Data Source:
Administrative Boundary - BPS Podes 2005
Agricultural land damaged/need – BRR 2005/2006
Agricultural land rehabilitated – BRR 2006-2010

Figure 9. Agricultural land rehabilitation in Aceh Region.

In general, Figure 9 shows that the implementation of the principle of recovery in the agricultural sector in the districts of Aceh Province has been performing well, in which the agricultural land rehabilitation in most districts has exceed 100%. Productivity of paddy plants in Aceh has decreased in the year when the tsunami occurred and the following year. However, the productivity of paddy plants in Aceh started to increase from the second year after the tsunami as depicted in Figure 10.

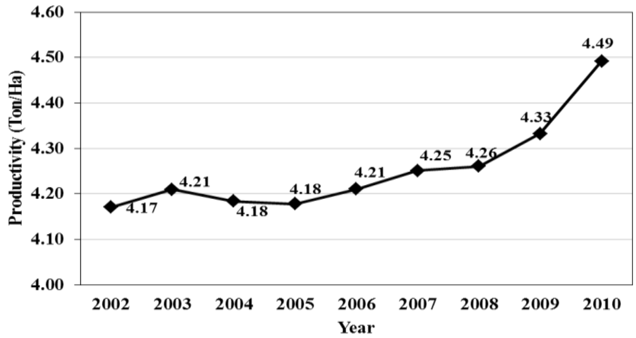


Figure 10. Productivity (Ton/Ha) of paddy plants in Aceh Region, 2000-2010.

The Great East Japan Earthquake, which occurred on March 11, 2011, was a natural catastrophe that not only devastated an extremely large area of eastern Japan together with following massive tsunamis, but also compounded with the nuclear power plant accident, making them as one of the most expensive compound disasters ever recorded in the history. Accordingly, the Japanese Government set up an advisory panel of intellectual figures under the name of the Reconstruction Design Council in Response to the Great East Japan Earthquake and its Study Group for engaging in broad discussions of a framework for formulating governmental reconstruction guidelines. The "Seven Principles for the Reconstruction Framework" were formulated as a set of recognitions shared by all its members in the Reconstruction Design Council at its 4th session held on May 11, 2011 ahead of the issuance of its report of recommendations and serve as the guiding philosophy in the report of the Council.

There have been significant progresses made towards rebuilding and revitalizing areas affected by the Great East Japan Earthquake disaster. Nevertheless, in the disaster-hit areas and elsewhere in the country, many people's lives are still greatly inconvenienced because of the damage caused. This includes those who are still unable to return to their homes even now because of the nuclear accident. In the agricultural sector, the restoration plan for farming is on schedule, aiming to have approximately 90% of farmland back in operation by 2014, while the fisheries sector is also on its way to a full-scale recovery. There have also been numerous initiatives that support revitalization of local economies through public-private partnerships, many of which are leveraging advanced technologies such as information and communication technology (ICT) and clean energy, as well as high-tech agricultural initiatives.

Figure 11 displays the production of paddy in the Tohoku region from one year before and one year after the disaster occurred. In 2011, the year when the disaster occurred, all prefectures, except Akita, experienced decreasing in production of paddy. Fukushima experienced the largest decreasing in paddy production, followed by Miyagi, Iwate, Yamagata, and Aomori. From prefectures that experienced decreasing in paddy production, Aomori has the fastest recovery in production of paddy, namely the production of paddy in 2012 already surpass the production in 2010. In addition, Fukushima has the slowest recovery in paddy production. One of the reasons is beside the earthquake and tsunami, Fukushima also suffered from the nuclear power plant accident. In which, have made many people to leave their hometown and for the health safety reason the production of paddy also has been deliberately reduced.

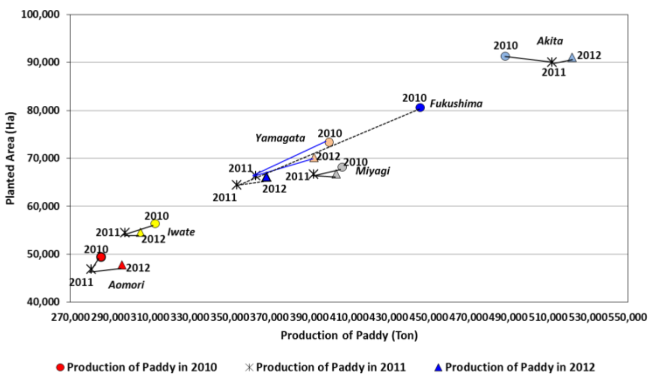


Figure 11. Production of paddy in Tohoku Region.

6 Conclusions and Policy Recommendations

In the last four decades, namely from 1970 to 2012, the number natural disaster events has been significantly increased over the globe; such increases are allegedly associated with the increasing population exposed to hazards. This increase is generally due to a significant increase of the small category of natural disasters, namely the natural disasters that resulted in the number of victims of less than 10,000 people. In addition, 40.8 percent of these natural disasters occurred in Asia.

Nevertheless, in 2005 a turning point took place, in which most of the regions the frequencies of natural disasters started to decline. A fairly significant decline could be seen in Asia, namely, the average growth of natural disaster events (slope of the regression line) in Asia has decreased from 3.86 into -5.02. Only in Africa that the number of natural disaster during 1970-2012 shows consistent increase, whilst in Oceania the trend is rather flat. In terms of casualties, however, Asia was proportionally hit harder. Of all the number of D&M caused by natural disasters in the world from 1970 to 2012, as much as 57.45% is in Asia, followed by Africa (21.65%) and Americas (15.07%).

In Asia, the three most frequent natural disasters in Asia during 1970 to 2012 are floods, followed by storms and earthquakes. However, in terms of D&M, earthquakes claim the highest percentage of D&M (48.46%), followed by storms (38.96%) and floods (10.06%), respectively. In addition, the cause of the declining trend of number of natural disasters in Asia was the declining trend of occurrences of flood and storm in Asia.

Regarding the relationship between D&M inflicted and some parameters of natural disasters, the study found that the magnitude of earthquake, focal depth of hypocenter, and location of epicenter has significant effect on the D&M inflicted in the case of earthquakes. In addition, parameter values of magnitude for Japan (178.78) is greater than Indonesia, this implies that in average the number of casualties caused by earthquakes in Japan is higher than in Indonesia (64.34). One possible cause is the population density in Japan is higher than in Indonesia.

Whilst, in the case of tsunamis, factors that have significant effect on D&M are maximum water height and magnitude of earthquake. Where the parameter value of water height in Indonesia (56.55) is higher than Japan (27.11), imply that, although, tsunami is more frequent in Japan than Indonesia, however the D&M caused by tsunami in Indonesia tend to increase. This evidence could be a warning for those people who live near the shore or coastal areas, since they would be the first victims to be stricken if there is a tsunami. There should some rules related with the safe distance to build residences from the shoreline, or if there are some people who live in areas with a supposedly dangerous tsunami threat, the government should relocate them to some other safe places and/or build tsunami walls.

Some disaster preparation activities should also be carried out on a regular basis, such as disaster drills, strengthening of buildings, and which also not less important is to convince and bring awareness to the community to be a safe community. In addition, the authorities should provide a reliable early warning system (EWS) containing accurate parameter information. EWS can become very useful means in risk mitigation, such as for earthquakes [13]. Hence, when a disaster occurred, people instantly know what to do and what not to do. The cause of high number of D&M is unpreparedness when disaster strikes, resulting panic.

In general, the process of rehabilitation and reconstruction in Aceh and Tohoku, especially in the agricultural sector, has been going very well. The amount of area of rehabilitated agricultural land have been similar to pre-disaster conditions, even in some areas, the agricultural land area, currently, have been surpass the agricultural land area pre-disaster. This condition can be achieved solely because of good cooperation and directional of all parties involved in the recovery process. The lessons learned that can be drawn from this recovery process is, that with the willingness to work together, respect each other, and put aside ego, the large and heavy work can be carried out with remarkable results.

References

[1] United Nations – Economic and Social Commission for Asia and Pacific (UN-ESCAP), The Asia Pacific Disaster Report: Protecting Development Gains, 2010.

[2] Oyama, T and T. Uriu, Quantitative Data Analysis for Natural Disasters Mitigation, Paper presented at *the Japan-China Joint Workshop on Accident Prevention and Disaster Mitigation Policy* in Tokyo, Japan, 2011.

[3] Suppasri A, et al. Lessons Learned from the 2011 Great East Japan Tsunami: Performance of Tsunami Countermeasures, Coastal Buildings, and Tsunami Evacuation in Japan, *Journal of Pure and Applied Geophysics* 2012, pp. 1-26, <www.Springerlink.com> [accessed 08.12.12].

[4] Hallegatte S, and Przyluski P., The Economics of Natural Disasters: Concepts and Methods, *World Bank Working Paper 2010*, <http://econ.worldbank.org> [accessed 01.14.12].

[5] Dore M, and Etkin D., The importance of measuring the social costs of natural disasters at a time of climate change, *Australian Journal of Emergency Management*, 2000, pp. 46-51.

[6] Nanto DK, Cooper WH, and Donnelly JM., Japan's 2011 Earthquake and Tsunami: Economic Effects and Implications for the United States. *Congressional Research Service 2011*, <www.fas.org/sgp/crs/row/R41702.pdf> [accessed 02.06.12].

[7] Lewis-Beck, Alan B, and Tim FL., Social Science Research Methods, Vol. 1, California: Sage Publications, Inc., 2004.

[8] Wildt, Albert R. and Olli T. Ahlota, Analysis of Covariance. Sage University Paper on Quantitative Applications in the Social Sciences, 07-012. Newbury Park, CA: Sage. 1978.

[9] Altay, N. and Walter G. Green III, OR/MS Research in Disaster Operations Management, *European Journal of Operational Research* 175 (2006), pp. 475-493.

[10] FAO, 2005. Framework for Soil Reclamation and Restart of Cultivation, Aceh-Indonesia. Version 2: 1-16.

[11] Bappenas-Indonesia(National Development Planning Board), Preliminary Damage and Loss Assessment: The December 26, 2004 Natural Disaster, Jakarta, 2005.

[12] Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF), *Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheries*, various edition.

[13] Wenzel F, et al., Potential of Earthquake Early Warning System, *Journal of Natural Hazards* 2001, 23: 407-416.

[14] EM-DAT, The International Disaster Database by Centre for Research on the Epidemiology of Disaster (CRED), www.emdat.be.

[15] National Geophysical Data Center/World Data Center (NGDC/WDC) Significant Earthquake Database, Boulder, CO, USA. (Available at http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=1&d=1).

[16] National Geophysical Data Center/World Data Center (NGDC/WDC) Global Historical Tsunami Database, Boulder, CO, USA. (Available at http://www.ngdc.noaa.gov/hazard/tsu_db.shtml).

[17] BPS, Statistics of Banda Aceh, Indonesia, *Aceh Province in Figures*, various editions.

[18] Rehabilitation and Reconstruction for Aceh and Nias (BRR), *Tsunami Recovery Indicators Package*, various editions, Banda Aceh.

[19] Reconstruction Design Council. Towards Reconstruction "Hope beyond the Disaster", Report to the Prime Minister of the Reconstruction Design Council in response to the Great East Japan Earthquake. Tokyo, Japan, 2011. <www.cas.go.jp/jp/fukkou/english/pdf/report20110625.pdf> [accessed 27.05.13].

[20] Reconstruction Agency. Progress to date. <http://www.reconstruction.go.jp/english/topics/2013/03/industry-and-economy.html> [accessed 05.29.13]

[21] Suppasri A, et al., Lessons Learned from the 2011 Great East Japan Tsunami: Performance of Tsunami Countermeasures, Coastal Buildings, and Tsunami Evacuation in Japan, *Journal of Pure and Applied Geophysics*, 2012, pp. 1-26, <www.Springerlink.com> [accessed 08.12.12].

[22] UNESCO. Learning from the Great East Japan Earthquake and Tsunami 2012, <http://www.unesco.org/new/en/natural-sciences/ioc-oceans/single-view-oceans/news/learning_from_the_great_east_japan_earthquake_and_tsunami/> [accessed 05.05.12].

[23] Cameron, A. Colin and Pravin K. Trivedi, *Microeconomics Using Stata*, Texas: Stata Press. 2009.

[24] Winston WL., *Operations Research Applications and Algorithms*, 4th ed., California: Duxbury Press, 2003.