ESTABLISHMENT OF COUNTRY-BASED FLOOD RISK INDEX

Yasuo KANNAMI* **Supervisor: Kuniyoshi TAKEUCHI****
MEE07182

ABSTRACT

This thesis offers a measure to assess the country-wise flood risk, namely Flood Risk Index (FRIc), on the basis of Pressure and Release Model (PAR model) which is expressed as the equation of "Risk = Hazard × Vulnerability" (Wisner, B. et al., 2004). In this study, Vulnerability is divided into four components hence Flood Risk Index considers five aspects of flood risk; Hazard, Exposure, Basic Vulnerability, Capacity soft countermeasures and Capacity hard countermeasures. Five components are set as Sub-index and each sub-index is composed of three kinds of datasets which are the most representable variables for each sub-index, namely Indicator. The basic equation of "R=H×V" is modified to calculate Flood Risk Index, which is expressed as;

$$\textbf{Flood Risk Index (FRIc)} = \frac{\textbf{Hazard} \times \textbf{Exposure} \times \textbf{Basic Vulnerability}}{\textbf{Capacity } \{= \textbf{(Soft countermeasures} + \textbf{Hard countermeasures)/2}\}}$$

With an application of FRIc, current potential risk of flood is assessed for 235 countries and regions. FRIc can indicate the structure of flood risk as well. Result of analysis clearly indicates the high-risk countries are in Asia such as Philippines, Myanmar, and Bangladesh, etc. Japan comes under the category of low risk thanks to low vulnerability and high capacity.

Before calculating Flood Risk Index, data of past damages is also analyzed using EM-DAT in terms of number of events, killed people, and average killed people per event. The results are shown as Flood Damage Indicator (FDIa). Accuracy of EM-DAT is also verified by comparing it with Dartmouth database and some country reports.

Finally, FRIc is compared with FDIa in order to assess correlation between them. It is indicated that FRIc has a certain correspondence to FDIa especially in Asian region. Furthermore, we can find high risk countries with less observed flood damage. It can be said that these countries have not been suffering from flood severely but have high potential to be damaged by flood. For instance Myanmar is assessed as a high risk country with a less death toll in the past. It can be said that flood risk in Myanmar was actualized in 2008 with more than 100,000 deaths by the cyclone Nargis. This implies the effectiveness of Flood Risk Index.

Keywords: Flood Risk Index, Risk assessment, Vulnerability, PAR model

INTRODUCTION

The Hyogo Framework for Action, The World Conference on Disaster Reduction (WCDR) held in Kobe, Japan, in January 2005 said that "The development of indicator systems for disaster risk and vulnerability is one of the key activities enabling decision makers to assess the possible impacts of disasters". There are lots of conceptual frameworks and studies to assess the risk or vulnerability to natural disaster (J. Birkmann, ed. 2006). One of the most common and simple conceptual models is the Pressure and Release Model (PAR model). However, there seems to be no study that uses the equation of "Risk = Hazard × Vulnerability" as it is in order to make risk index. If risk index is established using this equation as it is, it would be very understandable, easy to explain, and very informative and valid. The important thing to make index is that it should be simple and easy to understand so that common people can understand their risk or situations.

*Pacific Consultants Co., LTD. of Japan
**Director, International Centre for Water Hazard and Risk Management (ICHARM), PWRI, Japan

Flood occurs at the local level. However it is true that preparedness for natural disaster depends on the national status. For instance, critical infrastructures such as national roads, levees for big rivers, are dealt with at national level. It can be said that flood risk is basically dominated by national status. It is also true that we sometimes talk about flood risk country-wise. For example we generally mention that Bangladesh is high-risk country to flood. In international conversation, we firstly consider national status. So, country-wise flood risk assessment is essential for international activities.

ANALYSIS OF THE PAST FLOOD DAMAGE

As the consequence of the comparative analysis of three kinds of data sources, which are Dartmouth, EM-DAT and Country Report, EM-DAT was accepted for flood damage data analysis. First reason for acceptance of EM-DAT is that it seems to collect the data more widely as compared to Dartmouth database. Secondly agreement with country reports is better than Dartmouth database. Thirdly it is difficult to collect country reports of all countries. The comprehensive database like EM-DAT was essential to make the countries comparable world wide.

Here the dataset of EM-DAT during the past 23 years (from 1985 to 2007) was used to measure the damage level of the past floods. Three kinds of data were used for the measurement; number of events, killed people, and average killed people per event. All events with one killed people or over were classified into three classes by the size of death toll. Data coverage and criteria of three classes are shown in Table 1. To make the countries comparable, variables were converted to the indicators, namely Flood Damage Indicator (FDIa), by the following formula;

$$FDIa = (LN(x) - LN(Min(x))/(LN(Max(x)) - LN(Min(x))) \quad (1)$$

Where; FDIa ; Flood Damage Indicator (actualized)
x : variables (number of events (noted by N), number of killed people (noted by K), and killed people per event (noted by KperN))
Max(x) : the actual maximum value
Min(x) : the actual minimum value (If x=Min(x), FDIa=0.05)

FDIa_Com is calculated by the addition of FDIa_L, FDIa_M, and FDIa_H.

88 percent of 3,161 events in total were classified in FDIa_L. On the contrary only 13 percent of 432,960 killed people in total were in FDIa_L. On the other hand 65 percent of total number of killed people is in FDIa_H in spite of only 1 percent of total events. This shows that preventing catastrophic events is important to reduce casualties by floods. Fig.1 shows the distribution map of FDIa_Com_K. It is indicated that the countries in Asia and America have been suffering from flood severely.

Fig.1 Distribution map of FDIa_Com_K (killed people)

Table 1 Statistics of past flood damage

Class	Criteria (No. of killed people of one event)	Abbrev.	Countries covered	No. of Events (N)	No. of Killed People (K)	Average killed People per event (KperN)
Low	~100	FDIa_L	177 (100%)	2,775 (88%)	54,831 (13%)	19.8
Middle	101~1000	FDIa_M	54 (31%)	345 (11%)	97,408 (22%)	282.3
High	1000~	FDIa_H	15 (8%)	41 (1%)	280,721 (65%)	6,846.9
TOTAL		FDIa_Com	177 (100%)	3,161 (100%)	432,960 (100%)	137.0

*Ratio of each item is the ratio of each value to the total of each item

ESTABLISHMENT OF FLOOD RISK INDEX (FRIc)

Structure of Flood Risk Index (FRIc)

The basic concept of Flood Risk Index (FRIc) is based upon Pressure and Release Model (PAR model); “a disaster is the intersection of two opposing forces which are hazard and vulnerability.” (Wisner, B. et al., 2004). In this study, Vulnerability is divided into four factors hence Flood Risk Index considers five aspects of flood risk; Hazard, Exposure, Basic Vulnerability, Capacity soft countermeasures and Capacity hard countermeasures. Five components are set as Sub-index and each sub-index is composed of three kinds of datasets which are the most representable variables for each sub-index, namely Indicator (see Fig.2).

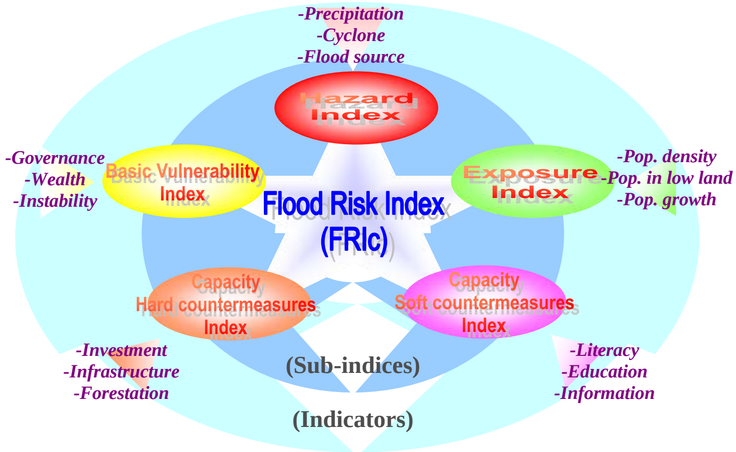

Fig.2 Structure of Flood Risk Index (FRIc)

The equations to calculate indicators, sub-indices, and Flood Risk Index are expressed as follows;

Flood Risk Index (FRIc) $= H \times E \times V / C$ (2)

Where; H: Hazard index E: Exposure index V: Basic Vulnerability index

C: Capacity index (= (Capacity Hard countermeasures index + Capacity Soft countermeasures index)/2)

Indicator = {LN(x)-LN(MIN(x))} / {LN(MAX(x)-LN(MIN(x)} (3)

Sub-Index = Indicator 1 + Indicator 2 + Indicator 3 (4)

Indicators

Indicators are selected by qualitative method; discussion with ICHARM experts, deep consideration, data availability, reviewing early studies. Selected indicators and data used are shown in Table 2. Data are collected from various kinds of sources such as Central Intelligence Agency (CIA), United Nations Common Database (UNCDB), The Food and Agriculture Organization of the United Nations (FAO), JAXA/EORC, Socioeconomic Data and Applications Center (SEDAC), United Nations Development Programme (UNDP).

Table 2 Indicators

Sub-Indices	Indicators	Data
Hazard	1. Precipitation	Average annual precipitation in depth
	2. Cyclone Proneness	Cyclone proneness considering frequency and magnitude
	3. Flood Source	Water area ratio to land area
Exposure	1. Basic Population Density	Population density in the area where population density is more than 5 people per sq. km
	2. Low Land Area’s Population Density	Population density in the area where the elevation is below 200m
	3. Population growth	Population in 2005 / in 1985
Basic Vulnerability	1. Governance	Corruption Index
	2. Wealth and information	Life Expectancy
	3. Instability	GINI coefficient
Capacity Hard Countermeasures	1. Potential Investment	GDP per Area
	2. Infrastructure	Paved Road Density
	3. Forestation	Forestation ratio in 2005 – in 1990
Capacity Soft Countermeasures	1. Literacy	Adult literacy rate (%)
	2. Education	Enrolment ratio for education (%)
	3. Information	Television receivers per one thousand inhabitants

Sub-indices (see Fig.3)

Hazard Index

Cyclone prone countries such as those in Asia, North and Central America and South Africa tend to be assessed as with high hazard. Taiwan was calculated as the most hazardous country in the world. Puerto Rico and Bahamas in Latin America and the Caribbean region were ranked at high positions because of the high value of water source indicator.

Exposure Index

Countries with high exposure can be seen mostly in Asian region. As a result of consideration of population density, higher ranks were occupied by small area countries and regions such as Macao, Singapore and Hong Kong. Surprisingly Bangladesh was ranked at number 10 in spite of its larger area of 136,035 sq. km than the other high ranked countries. Regarding other Asian countries, Taiwan was ranked at 20th with its index of 1.564, India was 23rd with 1.538, Japan was 45th 1.401, and China was 53rd with 1.369.

Basic Vulnerability Index

Many European countries, North American countries, Japan and some Oceania countries are assessed as with low Basic Vulnerability and many African countries are high. Top 20 countries except Haiti are occupied by African countries because of high corruption, high disparity, and low life expectancy.

Capacity Hard Countermeasures Index

Japan and many European countries are assessed as with high Capacity Hard Countermeasures and many African countries and South American countries are low. Small land area countries tend to be ranked high, Monaco at 1st, Singapore at 2nd, etc. Netherlands is ranked at 7th and Japan at 13th.

Capacity Soft Countermeasures Index

Canada and many European countries are assessed as with high Capacity Soft Countermeasures and many African countries and several Southwestern Asian countries are low. Only two Asian countries i.e. South Korea and Taiwan are ranked in top 20 countries.

These results seem to be acceptable, convincing and matching our feelings.

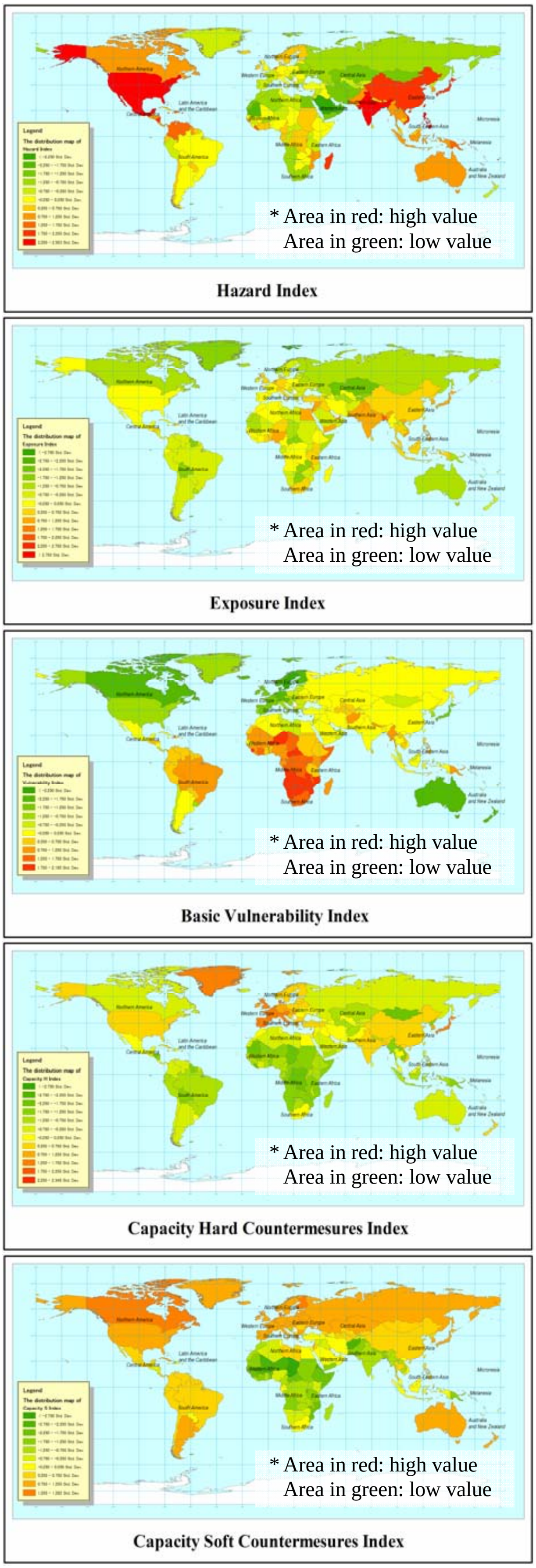

Fig.3 Distribution maps of five Sub-indices

Flood Risk Index (FRIc)

Flood Risk Index (FRIc) is calculated for 235 countries and regions. Fig.4 shows the distribution map of FRIc. A county area in red indicates high flood risk and that in green indicates low flood risk. Asian countries and several African countries are assessed as with high risk of floods. Some Central American countries are also assessed as with high risk of floods.

Haiti is assessed as the most risky country in the world due to high vulnerability and low capacity. Bangladesh stands as the runner up mainly due to its high hazard and high exposure. The places from third to eighth are occupied by African countries such as Mozambique and Gambia. Some other Asian countries are also ranked in this list such as Nepal at 9th, Philippines at 11th, Myanmar at 14th, India at 17th, and Cambodia at 18th. Taiwan is assessed as the most hazardous country. However its rank in Asian counties is 13th thanks to its low vulnerability and high Capacity.

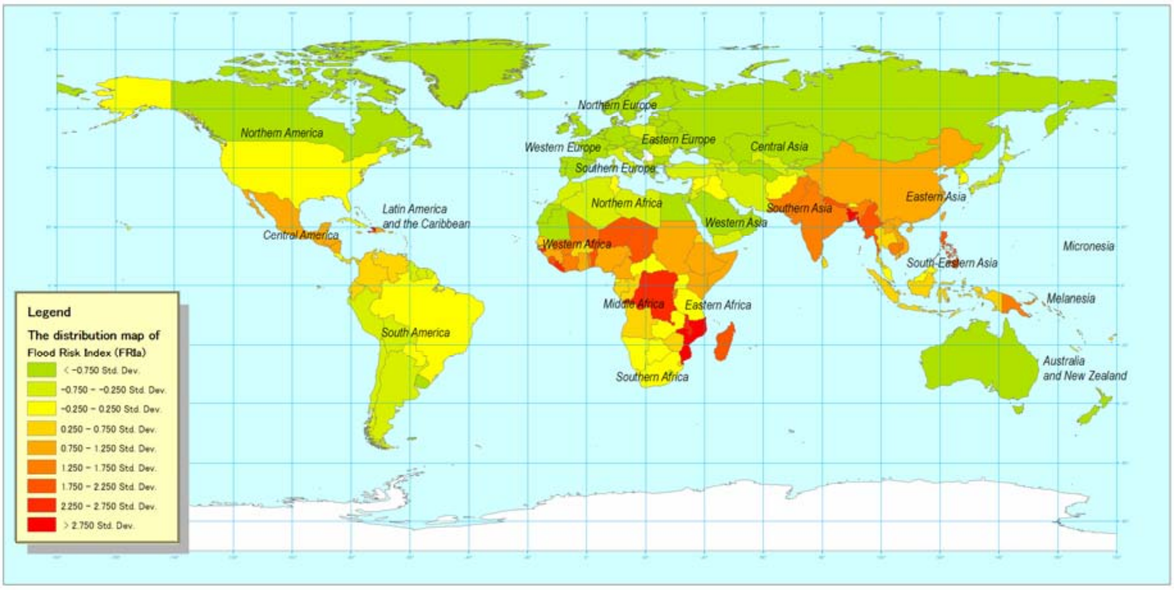

Fig.4 Distribution map of Flood Risk Index (FRIc)

COMPARATIVE ANALYSIS
BETWEEN FLOOD RISK INDEX AND PAST FLOOD DAMAGE

Calculated Flood Risk Index (FRIc) is compared with past flood damage data in order to verify agreement. Fig.5 is the scatter graph plotted by Flood Risk Index (FRIc) and Flood Damage Indicator of killed people (FDIa_Com_K). FRIc has certain correspondence with past flood damage but apparently not so significant ($R2=0.18$). One of the reasons of disagreement is that FRIc expresses the present condition of flood risk whereas FDIa indicates the consequences of past flood. The countries are classified into 8 groups by cluster analysis using FRIc, FDIa_Com_K, and the difference of them in order to make disagreement more clear. The countries in group 1 and 2 are assessed as high risk with less flood damage. In other words they have not

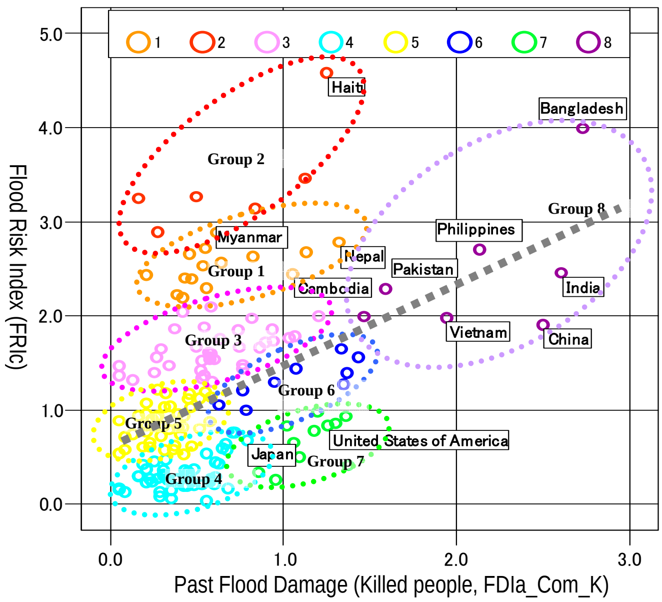

Fig.5 Comparison between FRIc and FDIa_Com_K

been suffering from flood severely in spite of their high risk. For instance, Myanmar in group 1 is assessed as with high risk but had not been damaged by flood severely upto 2007. However, in 2008, risk was actualized. Cyclone Nargis hit Myanmar and brought extremely huge damages with more than 100,000 deaths. It can be said that the countries in group 1 or 2 have not suffered from flood severely but they have high potential to be damaged by flood more severely. This implies the effectiveness of Flood Risk Index of this study.

Another advantage of FRIc is that FRIc can indicate the structure of flood risk. The methodology to make FRIc in this study allows us to analyze the reasons for high or low flood risk. Fig.6 shows the structures of FRIc about Myanmar and Japan. Myanmar and Japan has similar FDIa_Com_K (similar number of deaths during past two decades) but FRIc of Myanmar is 2.63 whereas that of Japan is only 0.68. Hazard and Exposure of Japan are higher than those of Myanmar but Flood risk of Japan is assessed as low thanks to high capacity and low vulnerability. Flood risk of Myanmar is assessed as high due to high vulnerability and low capacity. This implies that Japan should make an effort to build capacity continuously otherwise flood risk can easily increase.

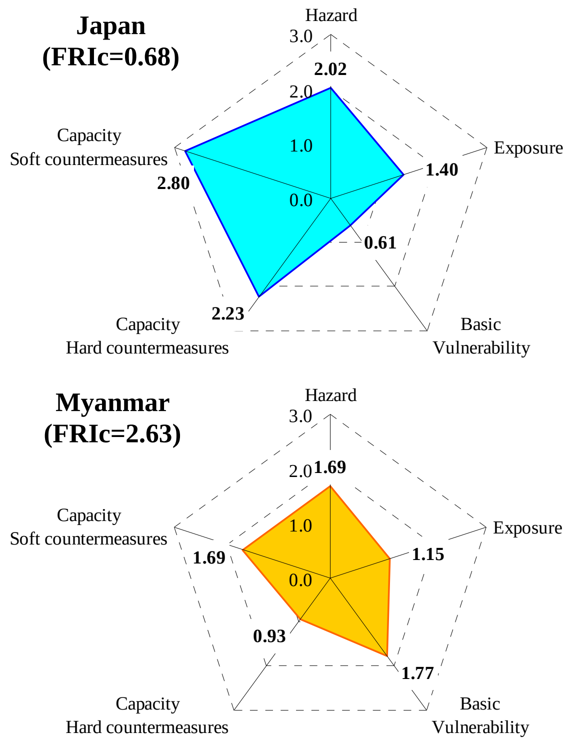

Fig.6 Structures of Flood Risk Index (FRIc)

CONCLUSIONS

Here Country-based Flood Risk Index was successfully established for 235 countries and regions. The advantages of Flood Risk Index are;

- ✓ We can assess flood risk at present time without using past flood damage data
- ✓ We can see the structure of flood risk
- ✓ We can find high risk countries which have not suffered from flood severely.

This methodology to assess flood risk is a new attempt and is very informative and valid. However, the development of how to assess flood risk is still at the initial stage. There are lots of attempts but those studies have both advantages and disadvantages. It is hoped that the outcomes of this thesis will advance our knowledge of flood risk assessment and motivate people to enhance the flood risk management activities.

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