# 戦-20　世界水アセスメントに関する研究　(Research on World Water Assessment)

研究予算：運営費交付金（一般勘定）
研究期間：平 18～平 20
担当チーム：水災害研究グループ　(防災)
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【Abstract】
The aim of this research project is to develop global flood risk maps. The model that hazard (H), vulnerability (V) and capacity (C) are the factors of the disaster risk (R) has been employed to be able to separately assess change in the vulnerability and progress in coping capacity development in every part of the world. We have collected and analyzed 83 index factor datasets available for the whole globe to come up with global flood risk maps. Flood risk maps have been produced combining each of representative index for hazard, vulnerability and capacity (R=H*V/C) after selection of significantly related and unbiased data sets from the 83 index factors. These world flood risk maps are expected to contribute global scale policy making.

Keywords: Flood risk, hazard, vulnerability, coping capacity, world water assessment

## 1. Introduction

Water is basis for life, often its shortage or abundance cause adverse effects to human beings. Therefore, water must be monitored and managed to make the most use of it and mitigate adverse effects of too much or too little water. With this model in mind much progress has been made through United Nations World Water Assessment Programme (UNWWAP) with the publication of World Water Development Reports and its side-publications on various critical water related themes which are very important to manage water resource. Twenty-six UN agencies and partners around the world including ICHARM/PWRI took part to come up with the publications. Besides, other agencies, national governments and NGOs are critical of the water issues especially in the light of the global changes.

Numerous efforts have been made so far to calculate the probability of disaster risk of water-related disasters, especially floods, but the problem always lies on the uniformity and reliability of the readily available data. UNDP has formulated country wise Disaster Risk Index called DRI (UNDP 2004), World Bank together with Colombia University has come up with maps showing Natural Disaster Hotspots (WB, 2006), and Dartmouth Flood Observatory with the Flood Maps of the World; all of which use the single database available, the Emergency Database (EM-DAT). EM-DAT is the only database which compiles information on disasters and the database is widely used. Unfortunately, the database does not cover every nook and corners of the world and the data source from each country is not always known. Therefore, the need arises to assess disaster risk based on more reliable data source and even there is a need to gather data and make new reliable database. In this direction, NILIM (Umemura et al, 2004) has taken an approach of assessing hazard and vulnerability from the past watershed data analysis and Munich Re (2004) has analyzed disaster risks from the disaster data of the cities but the coverage in both cases is small.

Water-related risk indicator maps are helpful to draw attention to high-risk areas that better management and many more investment should be applied to before a catastrophe occurs. The model that hazard, vulnerability and capacity are the factors of the disaster risk has been adapted to be able to separately assess change in the vulnerability and progress in coping capacity development in every part of the world.

## 2. Flood Risk Model

As pointed out in the side-publication of world water development report 3 entitled global trends in water-related disasters: an insight for policymakers (Adikari and Yoshitani, 2009), and the EM-DAT annul statistical review (Hoyois et al, 2007) that the numbers of water-related disaster are increasing and is the main constrain of the present day sustainable development. The increasing disasters can be attributed to deforestation, overexploitation of natural resources, increased and unplanned urbanization, uncontrolled land use, population increase, extreme hydro-meteorological events, and many other factors.

The United Nation's International Strategy for Disaster Reduction (UNISDR) delineates disaster risk (R) as a function of hazard (H) and vulnerability (V) [R=H*V]. This model was originally evolved by Davis (1978).

Hazards are factors attributable to natural phenomena, such as the magnitude of an earthquake. Vulnerability refers to social factors, such as seismic resistance of a structure and population. When risk is considered as a function of hazard and vulnerability, it suggests that there will be no disaster in an area without people or assets regardless of the magnitude of a hazard. In the case of water-related disasters, it is easily understood that precipitation is hazard and population in the floodplain is vulnerability. However, there is no common understanding of whether decreased flood rate due to a flood control structure is considered as a decrease in hazard or vulnerability. Also, under the R=H*V model, the effects of strengthened early warning systems and local disaster preparedness are not explicitly evaluated in many cases, often mixed with unintended vulnerability increase, such as population increase.

Our research contribution target, UNWWAP is expected to monitor the actions taken to reduce water problems. For this purpose, we separate the coping capacity from hazard and vulnerability as the International Red Cross recommends.

In principle, indicators for hazard, vulnerability, and coping capacity should be selected from those of high physical representation, such as flood peak discharge, population in the floodplain, investment in flood control. Our study has adapted a model that disaster risk is composed of hazard, vulnerability and coping capacity (C) (R=H*V/C).

## 3. Data collection and analysis

To produce global flood risk maps as an end product, we have endeavored to collect the index factor data from various sources as shown in Table 1. We collected and added 13 new index factors data set during Fiscal Year 2008 to the 70 index factor data sets collected until Fiscal Year 2007 to sum up to a total of 83 sets. Example drawings excerpted from table 1 are shown in Figs 1-6. The index factors have been then categorized into four categories, namely Risk, Hazard, Vulnerability, and Capacity. Further the index factors are categorized according to the data format: country; watershed; or grid. These index factor data are extracted from various sources as pointed out against each dataset. As previously explained, datasets used in this research are only world available datasets.

We wanted to use a dataset with high physical representation in particular for coping capacity such as country-wide investment for flood control. Some experts are aware of the necessity of this type of data and UN organizations have been trying to collect them, but no trials are successful in building good world datasets are available. Because of the unavailability of good datasets, we have used a single dataset selected from the table 1 to represent coping capacity to draw a world map.

In flood control, structural and nonstructural alternatives are considered as complimenting solutions. Then, a single factor such as flood control investment represents mostly structural measures. Therefore, factors for nonstructural alternatives will need to be considered for future study. They include level of smooth communications inside a community, individual awareness, and social systems.

Table 1. The data used for the production of risk maps (the index factors gathered in 2008 are in bold letters)

| Category | Sub-category | Available Data Format | | | Index factors | Data source |
|---|---|---|---|---|---|---|
| | | country wise | watershed | grid data | | |
| Risk | Flood factors | | ● | | Number of Flood Events by Basin (1980-2000) | EM-DAT |
| | | | ● | | Flood Frequency by Basin (1980-2000) | EM-DAT |
| | | ● | | | Number of Flood and Windstorm Events (2000-2006) | EM-DAT |
| | | | | ● | Flood Hazard | CHRR/CIESEN |
| | Flood Damage | ● | | | Number of People Killed by Flood and Windstorm Event (2000-2006) | EM-DAT |
| | | ● | | | Number of People Killed by a Single Flood and Windstorm Event (2000-2006) | EM-DAT |
| | | ● | | | Average Annual Number of People Killed by Flood and Windstorm Event (2000-2006) | EM-DAT |
| | | | | ● | Total Econommic Loss Risk by Flood | CHRR/CIESEN |
| | | | | ● | Proportional Economic Loss Risk by Flood | CHRR/CIESEN |
| | | | | ● | Flood Mortality Risk | CHRR/CIESEN |
| Hazard | Hydro-met | | | ● | Average Annual Precipitation | USGS/American Geological Institute |
| | | | | ● | Maximum Monthly Precipitation | USGS/American Geological Institute |
| | | | | ● | Difference of Maximum to Minimum Monthly Precipitaion | USGS/American Geological Institute |
| | | | ● | | Specific Discharge | Federal Institute of Hydrology, Germany |
| | | | ● | | Maximum Specific Discharge | Federal Institute of Hydrology, Germany |
| | | | | ● | **Maximum hourly precipitation** | **GS MaP** |
| | | | | ● | **Ten years probability (1 day precipitation)** | **GFAS** |
| | | | | ● | Annual Runoff | Federal Institute of Hydrology, Germany |
| | | | | ● | Difference of Maximum to Minimum Monthly Rnoff | Federal Institute of Hydrology, Germany |
| | | | ● | | Coefficient of River Regime | Federal Institute of Hydrology, Germany |
| | Topography and locality | ● | | | Percent Forest Cover | FAO/FAOSTAT |
| | | | ● | | Percent Forest Cover | IUCN, IWMI, Ramsar, WRI |
| | | | | ● | **Forestation indicator** | **UN common data base** |
| | | | | ● | NOAA/Global Vegetation Index 8 year Mean Maximum | GRID-Nairobi |
| | | | | ● | **Crop land ratio** | **sage.wisc.edu/iamdata** |
| | | | ● | | Percent Grassland, Savanna, and Shrubland | IUCN, IWMI, Ramsar |
| | | ● | | | Drylands - Percent of Total Area | FAO |
| | | | ● | | Percent Dryland | IUCN, IWMI, Ramsar |
| | | | | ● | Digital Elevation Model | USGS/GTOPO30 |
| | | | | ● | Slope | USGS/GTOPO31 |
| | | | ● | | Average Basin Slope | USGS/GTOPO32 |
| | | | | ● | **Loss of Top Soil** | **FAO** |
| | | | | ● | **Landslide posibility** | **Hot spot Columbia University** |
| | | | ● | | River Density | Federal Institute of Hydrology, Germany |
| | | | ● | | Form Factor of a Basin | Federal Institute of Hydrology, Germany |

A good index for nonstructural measures is the number of telemetered gauging stations that is again not available worldwide.

After collecting and analyzing available world's datasets on water-related index datasets shown in table 1, we have prepared world flood risk maps applying the equation of R=H*V/C with selected index datasets. Datasets used to formulate the flood risk are selected applying comprehensive criteria consists of independency between selected combination of three datasets, their physical validity as hazard, vulnerability or coping capacity, and less missing values in the dataset.

Reliability of data varies from source to source and format to format. The datasets in Table 1 are publicly available data sources and these datasets are thought to be the most accurate among presently available sources. These datasets cover wider part of the globe if not most part and are statistically independent.

Applying the above-mentioned comprehensive selection criteria, the following six datasets are selected for the production of the flood maps for this project: 1. Maximum hourly precipitation, 2. Ten year probability of one day maximum precipitation, 3. Population increase, 4. Forestation indicator, 5. GDP and 6. Number of dams, are used to produce one map each as examples as shown from Figs 1 to 6. A total of 84 datasets have been analyzed in this study.

Table 1. continued….

| Category | Sub-category | Available Data Format | | | Index factors | Data source |
|---|---|---|---|---|---|---|
| | | country wise | watershed | grid data | | |
| Vulnerability | Population | ● | | | Population Density (Country) | UN Population Division |
| | | ● | | | Total Population | UN Population Division |
| | | | ● | | Average Population Density by Basin | IUCN, IWMI, Ramsar WRI |
| | | | | ● | Population Density | CIESEN,Colombia University and CIAT |
| | | | | ● | Total Population | CIESEN,Colombia University and CIAT |
| | | | | ● | **Population increase (1990-1995)** | **UN population** |
| | | | | ● | **Population increase (1995-2000)** | **UN population** |
| | | | | ● | **Population increase (2000-2005)** | **UN population** |
| | | ● | | | Population within 100km of Coast | UNEP/DEWA/GRID-Europe |
| | Poverty | ● | | | GDP per Capita | World Bank |
| | | ● | | | Percentage of Population below US$1 per Day Consumption | World Bank |
| | | ● | | | Percentage of Population below US$2 per Day Consumption | World Bank |
| | | ● | | | Total Unemployment - Percent of Total Labor Force | ILO |
| | Private property | ● | | | Percent Durable Structure | World Bank |
| | Economic Capasity | ● | | | Volume of Nonlife Insurance | SwissRe |
| | | ● | | | Aid Dependency Ratios | World Bank |
| | | ● | | | Foregn Direct Investment | World Bank |
| | | ● | | | Economically Active Population | ILO |
| | | ● | | | Official Development Assistance and Official Aid | World Bank |
| | | ● | | | Household Final Consumption Expenditure | World Bank |
| | | ● | | | General Government Final Consumption Expenditure | World Bank |
| | | ● | | | GDP | World Bank |
| | Urbanization | | ● | | Percent Urban and Industrial Area | IUCN, IWMI, Ramsar WRI |
| | | | ● | | Number of Large Cities by Basin | IUCN, IWMI, Ramsar WRI |
| | | ● | | | Urban Population - Percent of Total Population | UNPubtionDMsbn |
| | Land-use and Industry | ● | | | Agricultural Area - Percent of Land Area | FAO |
| | | | ● | | Percent Crop Land | IUCN, IWMI, Ramsar WRI |
| | | | ● | | Percent Irrigated Crop Land | IUCN, IWMI, Ramsar WRI |
| | | ● | | | Percentage of Agricultural Production to GDP | World Bank |
| Capacity | Education | ● | | | Adult Literacy Rate | World Bank |
| | | ● | | | Net Enrollment Ratios in Primary Education | UNESCO |
| | | ● | | | Net Enrollment Ratios in Secondary Education | UNESCO |
| | | ● | | | Education Index | UNDP |
| | Communication and info net | ● | | | Number of Fixed Telephone per 1,000 People | World Bank |
| | | ● | | | Number of Mobil Telephone per 1,000 People | World Bank |
| | | ● | | | Number of Radio per 1,000 People | World Bank |
| | | | | ● | **Precipitation gauzing station with telemetry system per unit area (km2)** | **WMO** |
| | | | | ● | **Discharge gauzing station with telemetry system per unit area (km2)** | **WMO** |
| | | | | ● | **Water level gauzing station with telemetry system per unit area(km2)** | **WMO** |
| | | ● | | | Number of Television per 1,000 People | World Bank |
| | | ● | | | Digital Access Index (DAI) | International Telecommunication Union |
| | Sanitation | ● | | | Improved Drinking Water Coverage - Total Population | WHO/UN Children's Fund |
| | | ● | | | Improved Drinking Water Coverage -Urban Population | WHO/UN Children's Fund |
| | | ● | | | Improved Drinking Water Coverage - Rural Population | WHO/UN Children's Fund |
| | | ● | | | ImprovedSanitation r Coverage -All Area | WHO/UN Children's Fund |
| | | ● | | | ImprovedSanitation r Coverage - Urban Population | WHO/UN Children's Fund |
| | | ● | | | National Budget per Capita | Central Inteligence Agencfy |
| | | | ● | | **Number of Dams** | **IUCN, IWMI, Ramsar, WRI** |

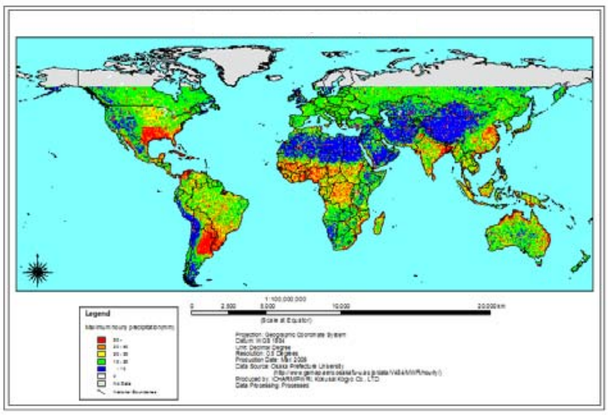

Fig. 1. A grid map of maximum hourly precipitation (mm)

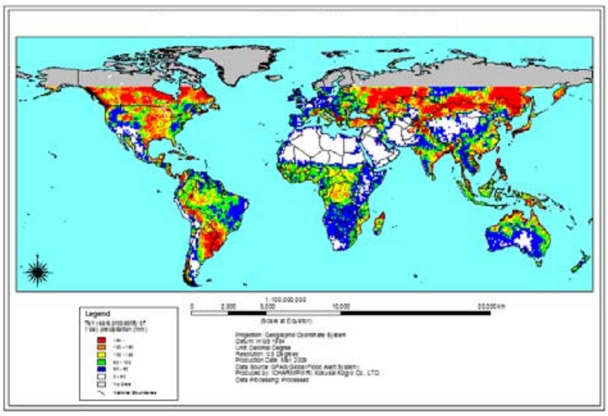

Fig. 2. Ten year probability of 1-day precipitation (mm)

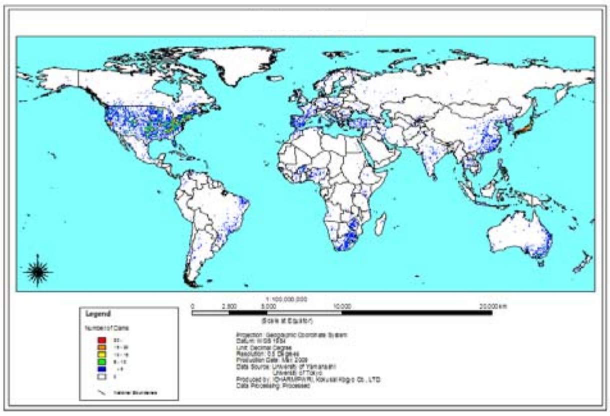

**Fig. 3. Recorded number of dams around the world**

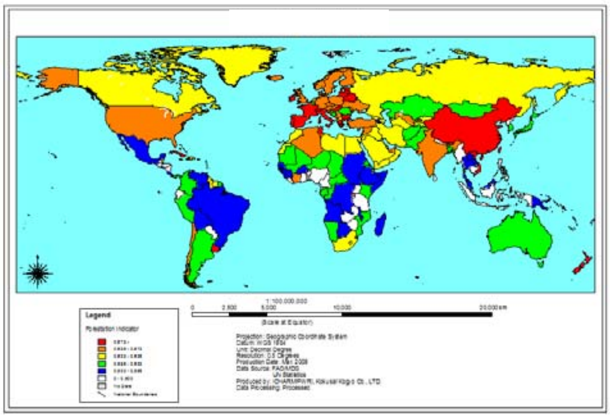

**Fig. 4. Country specific forestation indicator map**

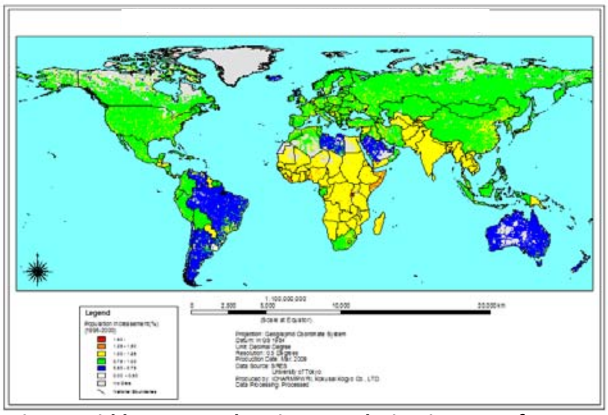

**Fig. 5. Grid base map showing population increase from 1995 to 2000**

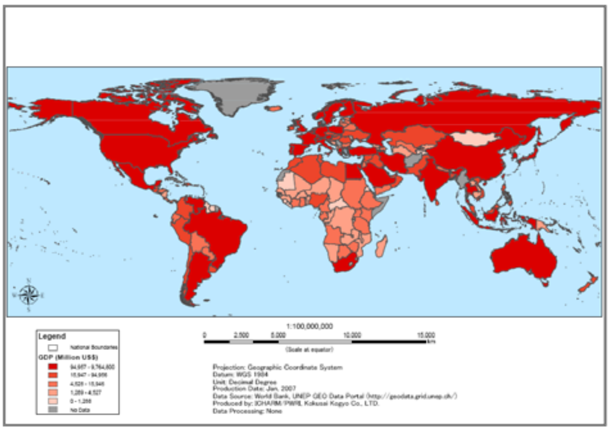

**Fig. 6. Map showing gross domestic products around the world**

## 4. Results and discussions:

Three sets of indexes are chosen to draw world flood risk maps applying the selection criteria. The first set is the combination of ten year probability of one day precipitation, population increase and storage capacity of reservoirs (1000 $m^3$). The second is the combination of landslide probability, GDP per capita and digital access index. The third is the combination of maximum hourly precipitation, population increase and the number of dams. World flood risk maps calculated from these datasets are show in Figs 7-9. Below are assessments of these maps.

In Fig. 7, the risk level in Russia is higher but is pseudo. This is because there is no discrimination snow from rain data in the dataset. In Russia, the snowfall is much more than the amount of rainfall especially in Siberia which indicates the increased flood risk in Russia. We call it "pseudo-increased flood risk". Therefore, the map in Fig. 7 is not a good

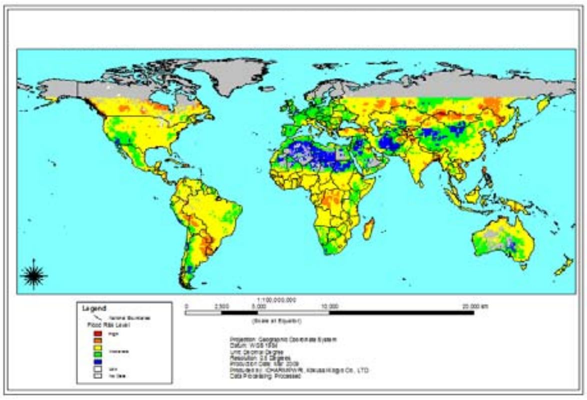

**Fig. 7. Mesh based flood risk map produced from the combination of ten year probability of one day precipitation, population increase and maximum reservoirs storage**

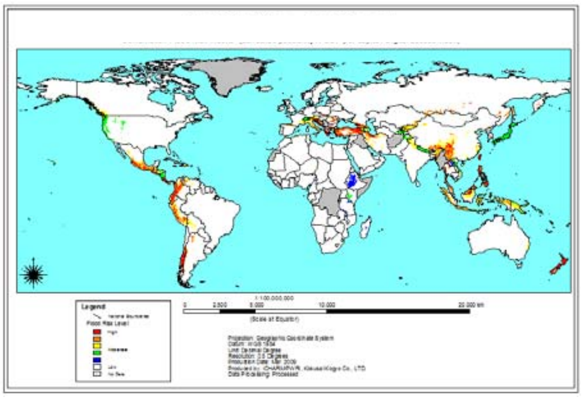

**Fig. 8. Mesh based flood risk map produced from the combination of possibility of landslides, GDP per capita and digital access index**

representative of flood risk in snowy regions.

On the other hand, the map in Fig. 8 outlines the risk of landslides in tectonic zones (the ring of fire). This map is quite accurate in terms of landslides vulnerable regions and could be used as landslide vulnerability indicator map with some improvement. Furthermore, grid datasets are used to produce this map therefore a detailed map could be produced for any region or grid if detailed data are available.

Fig. 9 is a flood risk map derived from maximum hourly precipitation, population increase and number of dams. As seen in the map, the eastern coast of China, lower Mekong Basin, Bangladesh and eastern part of India, Western Africa (near the equator), central part of South America (around Paraguay) and southern part of the USA around the Gulf of Mexico are vulnerable to flood risk; this map best fits the past events. Therefore, it is recommended to use this set of combination of hazard, vulnerability and capacity with more reliable data to draw more precise flood indicator maps.

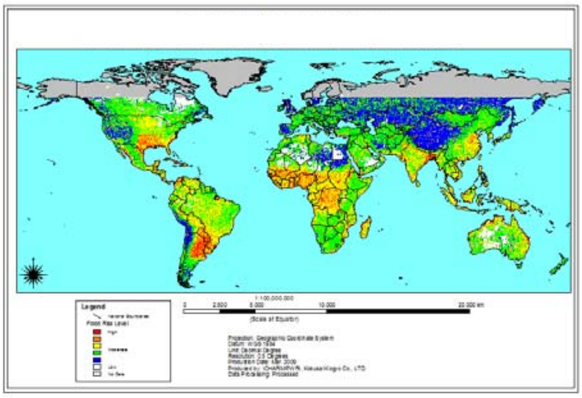

**Fig. 9. Mesh based flood risk map produced from the combination of maximum hourly precipitation, population increase and number of dams**

After collecting and analyzing available world's datasets on water-related index datasets shown in table 1, we have come up with three world flood risk maps shown in Figs 7-9 applying the equation of R=H*V/C with selected index datasets. Datasets used to formulate the flood risk are selected applying comprehensive criteria. Comparison with past disaster records suggest that Fig. 9 derived with the combination of maximum hourly precipitation, population increase and the number of dams is the most reasonable map.

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# Research on World Water Assessment

【Abstract】
The aim of this research project is to develop global flood risk maps. The model that hazard (H), vulnerability (V) and capacity (C) are the factors of the disaster risk (R) has been employed to be able to separately assess change in the vulnerability and progress in coping capacity development in every part of the world. We have collected and analyzed 83 index factor datasets available for the whole globe to come up with global flood risk maps. Flood risk maps have been produced combining each of representative index for hazard, vulnerability and capacity (R=H*V/C) after selection of significantly related and unbiased data sets from the 83 index factors. These world flood risk maps are expected to contribute global scale policy making.

**Keywords**: Flood risk, hazard, vulnerability, coping capacity, world water assessment

## 戦-20　世界水アセスメントに関する研究

この研究プロジェクトの目的は世界洪水危険地図を開発することである。災害リスク（R）の要因を加害外力（H）、脆弱さ（V）と防災力（C）で表すモデルを、世界各地での脆弱性の変化や防災力開発の進展をモニターできるように採択した。世界洪水リスク地図が、８３のデータセットの関連性や代表性から選定された後、加害外力、脆弱性、防災力それぞれを代表する指標を組合せて作成された。これらの地図は国際的な政策立案に貢献することが期待される。

**Keywords**: 洪水リスク、加害外力、脆弱性、防災力、世界水アセスメント