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

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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 number of water-related disasters, affected people and the economic losses are ever increasing globally; and Asia and Africa are the most prone to these disasters. This situation demands a way out to mitigate the water-related disaster, especially the flood for which flood maps would be developed with the model that risk is a function of hazard (H), vulnerability (V) and capacity (C). The model has been employed to separately assess change in vulnerability and progress in coping capacity development in every part of the world. During the first year of the project (2006), trend analysis was conducted and the following year databases have been browsed to look for any available data. In Fiscal Year 2008, we added 13 new index factor datasets on the already-collected 70 datasets available for the entire globe to develop global flood risk maps. First, we re-sampled datasets by mesh and nation to form mesh data on the same scale and coordinates. Second, we selected one dataset from the re-sampled datasets to represent hazard, vulnerability and capacity, respectively as a case of risk map, by applying comprehensive selection criteria. Application of three trials of selection resulted in three world flood risk maps. Comparison of each world flood risk maps with past flood events concluded that one of the three seems to be the most reasonable map.

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

1. Introduction

Water is basis for life. Its shortage or abundance often caused adverse effects on 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 the United Nations World Water Assessment Programme (UNWWAP) with the publication of World Water Development Reports (WWDR) and their side-publications on various critical water-related themes, which are very important to manage water resources. Twenty-six UN agencies and partners around the world, including ICHARM/PWRI, took part in the publications. Besides, other agencies, national governments and NGOs are critical of water issues especially in the light of 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 readily available data. World Water Development Report 3 made an attempt to introduce a chapter on disaster and ICHARM contributed about some of the flood indicators such as the trends of the number of water–related disasters (Fig 1) and percent wise distribution of water-related disaster in the world (Fig 2). Furthermore, Adikari and Yoshitani, contributed for a side-publication report of WWDR3 entitled “Global Trends in Water-Related Disasters: an insight for policymakers” in which the water-related trends are compiled and analyzed. These trends are being studied until now and it is noted that Asia is the most disaster prone region in the world followed by Africa. These are some of the reasons why easy to understand flood-risk maps are thought be useful.

Furthermore, UNDP formulated country wise Disaster Risk Index called DRI (UNDP, 2004), the

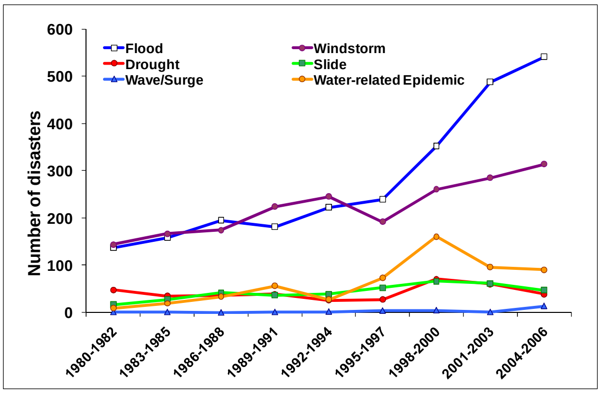

Fig. 1 The three year trend of water-related disasters from 1980 to 2006. (Adikari et al)

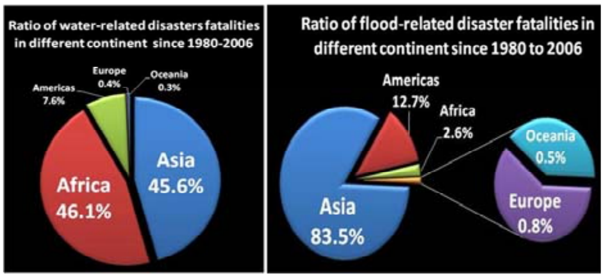

Fig 2 Global total fatalities of water- and flood-related disasters from 1980 to 2006 (Adapted from Adikari et al)

World Bank together with Colombia University developed maps showing Natural Disaster Hotspots (World Bank, 2006), and the Dartmouth Flood Observatory with the Flood Maps of the World, all of which use a single database available, the Emergency Database (EM-DAT). EM-DAT is the only publicly-available database that compiles information on disasters. Unfortunately, the database does not cover every nook and corner of the world, and data sources from each country are not always known. Therefore, the need arises to assess disaster risk based on more reliable data sources and even to gather data to make a new reliable database.

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 (H), vulnerability (V) and capacity (C) are the factors of disaster risk (R) has been adapted to separately assess change in vulnerability and progress in coping capacity development in every part of the world.

From our results during the projects we could finally adopt the three-component model in which flood risk is composed of hazard, vulnerability and coping capacity during the final year of the project. In the same, we also conducted additional dataset collection and selection, drew world flood risk maps, and evaluated the maps by receiving technical advice from the group led by Prof. Taikan Oki of the University of Tokyo, who was assigned as a coordinator for global water assessment during Fiscal Years 2007-2008.

2. Data collection and analysis

To produce global flood risk maps as an end product, we collected index factor datasets from various sources as shown in Table 1. We added 13 new index factor datasets during Fiscal Year 2008 to the 70 index factor datasets collected by Fiscal Year 2007 to sum up to a total of 83 sets. The index factors were then categorized into four categories, namely Risk, Hazard, Vulnerability, and Capacity. The index factors were further categorized according to data format; country, river basin, and grid. These index factor data were extracted from various sources as pointed out against each dataset. As previously explained, data used in this research were only world available datasets. Ideally, data with higher physical representation should have been used, such as country-wide investment in flood control and existence of early flood warning systems as indexes for coping capacity. Some experts are aware of the necessity of this type of data, and UN organizations have been trying to collect them, but so far no one has been successful to formulate such a world dataset.

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

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 have been successful in building good world datasets. Because of the unavailability of good datasets, we used a single dataset selected from 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 only. Therefore, factors for nonstructural alternatives also need to be considered for future study. The number of telemetered gauging stations can be a good index for nonstructural measures. However, this 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

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**

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. Some of the statistically independent functions of risks are presented in the figures 3-8 as maps. These maps give us the idea of the distribution of these functions around the world at a glance and are helpful for further investigation in the near future. These independent functions are later combined to come up with the flood risk maps which are described in the later section.

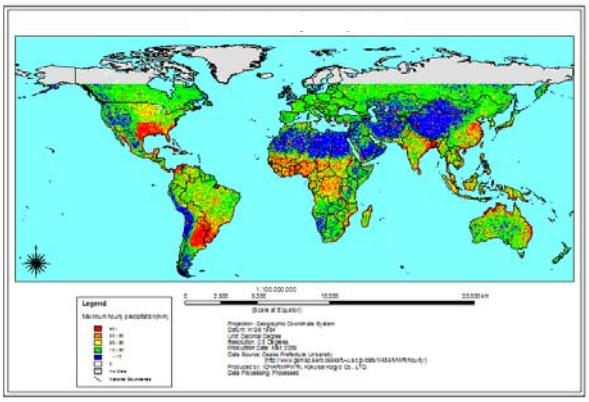

Fig. 3. A grid map of maximum hourly precipitation (mm)

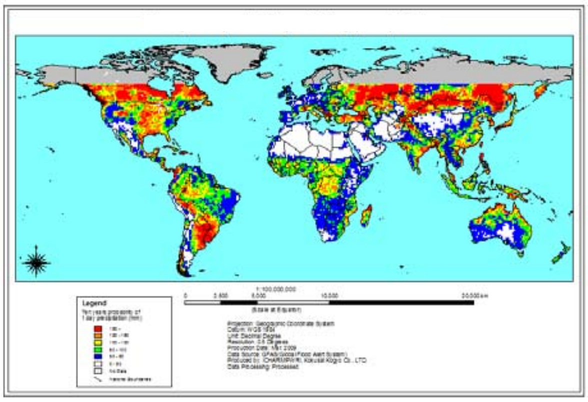

Fig. 4. Ten year probability of 1-day precipitation (mm)

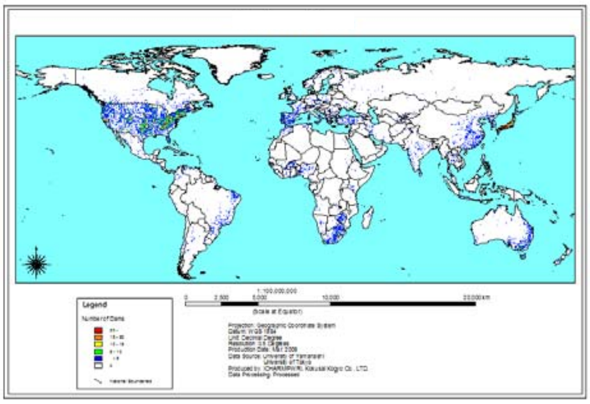

Fig. 5. Recorded number of dams around the world

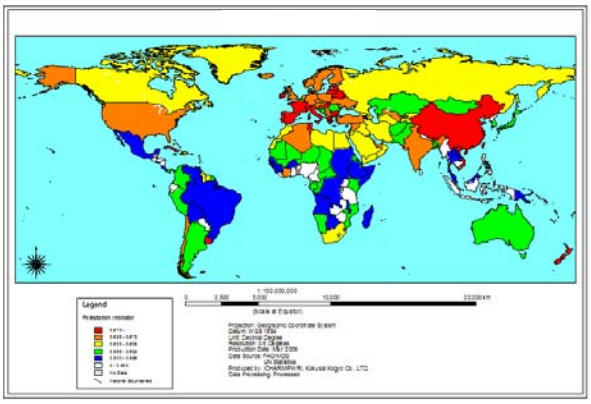

Fig. 6. Country specific forestation indicator map

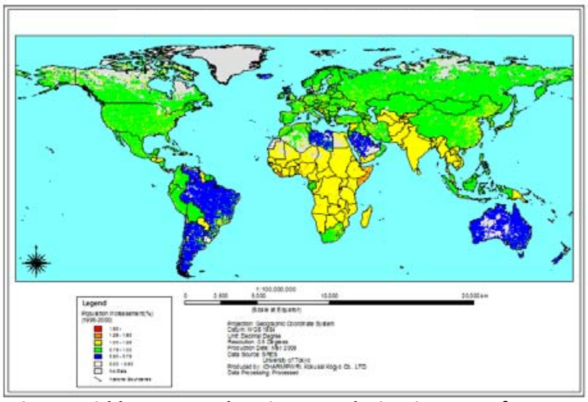

Fig. 7. Grid base map showing population increase from 1995 to 2000

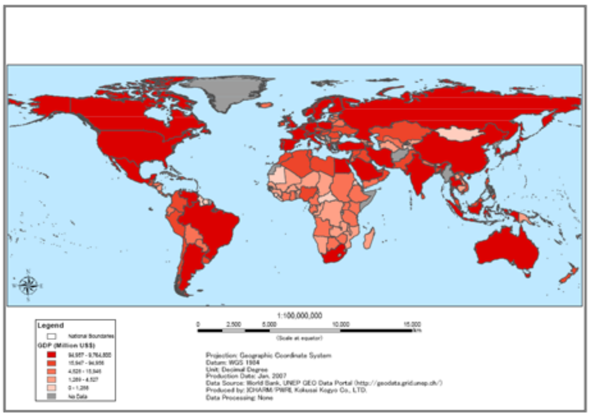

Fig. 8. Map showing gross domestic products around the world

Applying comprehensive criteria that consist of independency between selected combination of three datasets, their physical validity as hazard, vulnerability or coping capacity, and fewer missing values, three combinations for three world flood risk maps are selected as follows:

Fig.9: Ten year probability of one day precipitation (hazard), population increase (vulnerability), and storage capacity of reservoirs (coping capacity);

Fig. 10. Landslide probability (hazard), GDP per capita (vulnerability), and digital access index (coping capacity); and

Fig. 11. Maximum hourly precipitation (hazard), population increase (vulnerability), and the number of dams (coping capacity).

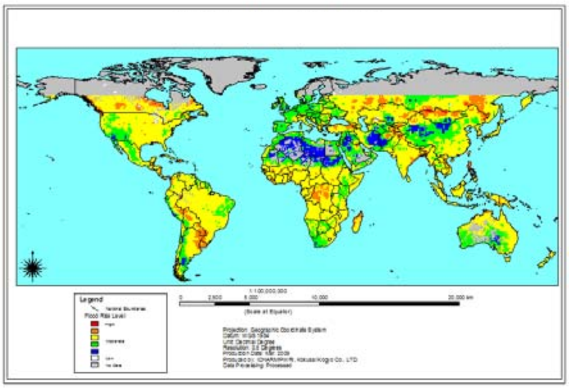

Fig. 9. Mesh based flood risk map produced from the combination of ten year probability of one day precipitation, population increase and maximum reservoirs storage

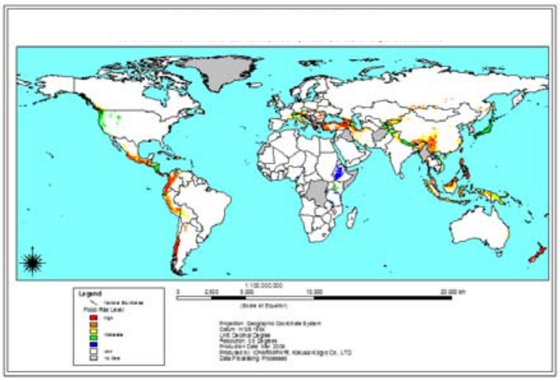

Fig. 10. Mesh based flood risk map produced from the combination of possibility of landslides, GDP per capita and digital access index

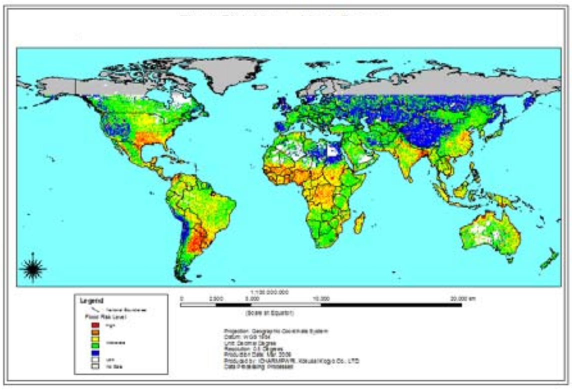

Fig. 11. Mesh based flood risk map produced from the combination of maximum hourly precipitation, population increase and number of dams

3. Assessment of world flood risk maps

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 9-11. Below are assessments of these maps.

In Fig. 9, 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. 9 is not a good representative of flood risk in snowy regions.

On the other hand, the map in Fig. 10 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. 11 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.

4. Conclusion

After collecting and analyzing the world's available datasets on water-related index datasets shown in Table 1, we produced three world flood risk maps shown in Figs 9-11 by applying the equation of R=H*V/C with selected index datasets. Datasets used to formulate flood risk were selected by applying the comprehensive criteria. Comparison with past disaster records suggested that Fig.11, developed based on the combination of maximum hourly precipitation, population increase and the number of dams, was the most reasonable map.

5. Reference

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Research on World Water Assessment

【Abstract】
The aim of this research project is to develop global flood risk maps. The number of water-related disasters, affected people and the economic losses are ever increasing globally; and Asia and Africa are the most prone to these disasters. This situation demands a way out to mitigate the water-related disaster, especially the flood for which flood maps would be developed with the model that risk is a function of hazard (H), vulnerability (V) and capacity (C). The model has been employed to separately assess change in vulnerability and progress in coping capacity development in every part of the world. During the first year of the project (2006), trend analysis was conducted and the following year databases have been browsed to look for any available data. In Fiscal Year 2008, we added 13 new index factor datasets on the already-collected 70 datasets available for the entire globe to develop global flood risk maps. First, we re-sampled datasets by mesh and nation to form mesh data on the same scale and coordinates. Second, we selected one dataset from the re-sampled datasets to represent hazard, vulnerability and capacity, respectively as a case of risk map, by applying comprehensive selection criteria. Application of three trials of selection resulted in three world flood risk maps. Comparison of each world flood risk maps with past flood events concluded that one of the three seems to be the most reasonable map.

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。水災害の発生数や影響を受ける人口、経済損失は世界中でこれまで増加し続けており、特にアジアやアフリカで顕著である。この状況から脱するためには水災害のうち特に水害を軽減する解決策が必要であり、洪水危険地図上で災害リスク（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するために採択した。平成 20 年度は既に収集した 70 の世界をカバーするデータセットに、19 の新たなデータセットを加えた。まず最初に、メッシュと国ごとのデータセットをリサンプリングし、同じ座標とスケールになるようにした。次に、リサンプリングされたデータセットから、加害外力、脆弱性、防災力のそれぞれに一つのデータセットを、総合的な選定基準を適用して選定した。この選定を 3 回行い、3 種の世界洪水リスク地図を作成した。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み合わせて作成した。これらの地図を過去の洪水記録と比較した結果、ひとつの地図が最も妥当と判断された。

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