MarshMcLennan

Marsh McLennan Flood Risk Index

Methodology

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Overview and structure

The Marsh McLennan Flood Risk Index provides national level overviews of flood risk. Utilizing disaster risk assessment concepts as a foundation, the Index generates scores for flood hazard, exposure and vulnerability[1] to provide a holistic, quantitative assessment of flood risk in different countries:

- **Hazard** refers to a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.
- **Exposure** indicates the people, infrastructure, housing, production capacities and other tangible assets located in hazard-prone areas.
- **Vulnerability** refers to the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

The Index focuses on certain aspects that facilitate cross-component reference. Specifically, both hazard and exposure are presented independently within the contexts of river (fluvial) and coastal flooding. Pluvial flooding is excluded from the analysis.

Additionally, indicators for both the vulnerability and exposure are estimated from a combination of their human and economic components, respectively reflecting social and economic considerations.

The scores for hazard (total, riverine, coastal), exposure (total, human, economic), and vulnerability (total, human, economic) range from 1 to 10, with higher values indicating higher risk.

The Index uses a small number of national indicators to act as proxies for hazard, exposure and vulnerability. These indicators were derived from publicly available data sources and are summarized in Exhibit 1.

Hazard, exposure and vulnerability are shaped by several underlying drivers that can mitigate or exacerbate impacts of flooding events. Due to the unique set of factors that influence each component, the structure of the Index is meant to primarily support comparative analysis of countries within each indicator, rather than across.

1 United Nations. (2016). Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction.

Exhibit 1: Index components, indicators and data sources

Index component	Indicator	Data Sources
Hazard	**Riverine (fluvial) flood**	**Hazard data** Fathom,[2] accessed through ThinkHazard![3] **Administrative boundaries** Global Administrative Unit Layers (GAUL) 2015,[4] Food and Agriculture Organization of the United Nations (FAO), accessed through ThinkHazard!
	Coastal flood	**Hazard data** Muis et al. (2016),[5] accessed through ThinkHazard! **Administrative boundaries** Global Administrative Unit Layers (GAUL) 2015, FAO, accessed through ThinkHazard!
Exposure	**Human exposure** % population exposed to riverine flooding, % population exposed to coastal flooding	**Flood hazard maps** • River flood 100-year return period map: Dottori et al. (2015),[6] European Commission's Joint Research Centre (JRC) • Coastal flood 100-year return period map: Muis et al. (2016) **Population** Global Human Settlement Layer (GHSL) 2015,[7] European Commission's Joint Research Center
	Economic exposure % asset value exposed to riverine flooding, % asset value exposed to coastal flooding	**Flood hazard maps** • River flood 100-year return period map: Dottori et al. (2015), European Commission's Joint Research Centre (JRC) • Coastal flood 100-year return period map: Muis et al. (2016) **Assets** Capital Stock data from the Global Exposure Database (GED) in GAR 2015, United Nations Office for Disaster Risk Reduction (UNDRR)
Vulnerability	**Human vulnerability** Human Development Index, ratio of non-life insurance premium volume to GDP	**Human Development Index** United Nations Development Programme Human Development Data 2020[8] **Non-life insurance premium volume to GDP** The World Bank's Global Financial Development Database 2019[9]
	Economic vulnerability Quality of infrastructure, ratio of non-life insurance premium volume to GDP	**Quality of infrastructure** Executive Opinion Survey, Global Competitiveness Report 2017-2018,[10] World Economic Forum **Non-life insurance premium volume to GDP** The World Bank's Global Financial Development Database 2019

Source: Marsh McLennan Advantage

2 Fathom. (n.d.). Fathom — Flood Risk Intelligence. Retrieved July 28, 2021.

3 Global Facility for Disaster Reduction and Recovery (GFDRR). (n.d.). ThinkHazard!. Retrieved July 28, 2021.

4 Food and Agriculture Organization of the United Nations. (2015). Global Administrative Unit Layers (GAUL). Retrieved July 28, 2021. The choice of this dataset does not imply any endorsement by Marsh McLennan concerning the legal status of any country or territory or the delimitation of frontiers or boundaries.

5 Muis, S., Verlaan, M., Winsemius, H., et al. (2016). A global reanalysis of storm surges and extreme sea levels. Nature Communications 7, 11969.

6 Dottori, F., Salamon, P., Bianchi, A., Alfieri, L., Hirpa, F. A., & Feyen, L. (2016). Development and evaluation of a framework for global flood hazard mapping. Advances in Water Resources, 94, 87-102. Data retrieved from data.europa.eu.

7 Freire, S., Doxsey-Whitfield, E., MacManus, K., Mills, J., & Pesaresi, M. (2016). Development of new open and free multi-temporal global population grids at 250 m resolution.

8 United Nations Development Programme. (n.d.). Human Development Reports — Human Development Index. Retrieved July 28, 2021.

9 The World Bank. (n.d.). Global Financial Development Database. Retrieved July 28, 2021.

10 World Economic Forum. (n.d.). The Global Competitiveness Report 2017-2018. Retrieved July 28, 2021.

Selection criteria

Index indicators were selected to provide reliable and easy to understand snapshots of the components of flood risk in each country according to the following principles:

- **Robustness:** Indicators are chosen from reputable sources with the most current information available.
- **Parsimony:** A small number of indicators with high levels of explanatory power have been selected to preserve simplicity and avoid cross-indicator redundancy. Included indicators represent critical elements of flood risk based on underlying risk drivers.
- **Reliability:** High-quality datasets from reputable institutions and with global coverage.

Components and calculation

Hazard

Background

The Hazard component of the Index reflects information about the following hazard types:

- **Riverine (fluvial) flooding**, caused by overflowing of rivers due to intense precipitation, ice jams and melting of snow.
- **Coastal flooding**, triggered by storm surges and extreme tidal events.

ThinkHazard! classifies flood hazard level at the scale of local administrative units (ADM2). The classification is provided separately for coastal and river flood hazard and is based on a spatial analysis methodology which intersects raster hazard data with a "damaging intensity threshold" (based on inundation depth) and "frequency threshold" (based on return period in years). The categories used for classification, in descending order of severity, are: High, Medium, Low, Very Low.

Indicators and sources

Total hazard

- Estimated as the average of riverine and coastal hazard

Riverine hazard

- Fathom, accessed through ThinkHazard!
- Global Administrative Unit Layer (GAUL) 2015, implemented by FAO and accessed through ThinkHazard!

Coastal hazard

- Muis et al. (2016), accessed through ThinkHazard!
- Global Administrative Unit Layer (GAUL) 2015, implemented by FAO and accessed through ThinkHazard!

Calculation

Hazard categories in the raw data from ThinkHazard! were given corresponding scores for the purposes of Index calculations (see Exhibit 2).

Exhibit 2: ThinkHazard! categories and scores

ThinkHazard! Category	Corresponding Score
High	100
Medium	75
Low	50
Very low	25
No value	0 for riverine, not included for coastal

Source: Marsh McLennan Advantage

The riverine flood hazard levels were compiled at the administrative unit level (ADM2) and then averaged across the total number of ADM2s in each country. For coastal hazard, only the ADM2s affected by coastal flooding were included in the analysis.[11] This provides national-level hazard scores that reflect sub-national hazard variation. The averages of the values across ADM2s were derived using the table in Exhibit 2 without weighting the contribution of each administrative unit by its area. On testing, the scores obtained without any weighting were typically in closer agreement with the original ThinkHazard! data.

The total flood hazard level for each country was estimated by averaging the riverine and coastal hazard levels at the country level. Landlocked countries were not assigned a coastal hazard score, and their total hazard score is equal to their riverine hazard score. Care should therefore be taken when comparing the overall hazard scores of landlocked countries with those of coastally exposed countries (where the overall score equals the riverine score averaged with the coastal score).

Total, riverine, and coastal hazard scores were obtained from the hazard levels using the mapping presented in Exhibit 3.

Exhibit 3: Mapping of hazard levels to hazard scores

Hazard level	Score
0-14.99	1
15-24.99	2
25-34.99	3
35-44.99	4
45-54.99	5
55-64.99	6
65-74.99	7
75-84.99	8
85-94.99	9
95-100	10

Source: Marsh McLennan Advantage

Limitations

Due to coverage data limitations it was not possible to calculate both riverine and coastal scores for some countries. In such cases the total hazard score was set to be equal to the riverine or coastal score available. This results in some small states with no riverine hazard data having high total hazard scores derived from the coastal component.

Pluvial flooding (i.e., flash flooding and surface water flooding) was not included in the analysis due to methodological changes in the most recent dataset made available by Fathom.

Information on flood defenses was not included in the analysis.

11 Including administrative areas with no coastal hazard (i.e., not on the coast) would cause most countries to have a coastal hazard score equal to 1.

Exposure

Background

Exposure was calculated by utilizing a geospatial analysis method that intersected estimated assets and population data, from the JRC and GAR 2015 respectively, with global hazard layers of coastal and riverine flood. For the global flood maps, a 100-year return period was chosen for analysis due to its usage as a standard return period for natural hazard risk assessment.

Indicator and sources

% population exposed to riverine flooding

- Global Human Settlement Layer (GHSL) 2015, European Commission's Joint Research Center
- River flood 100-year return period map, Dottori et al. (2015), JRC, European Commission
- Country boundaries, World Bank.[12]

% population exposed to coastal flooding

- Global Human Settlement Layer (GHSL) 2015, European Commission's Joint Research Center
- Coastal flood 100-year return period map, Muis et al. (2016)
- Country boundaries, World Bank.

% assets exposed to riverine flooding

- Global Exposure Database (GED) from GAR 2015, UNDRR.
- River flood 100-year return period map, Dottori et al. (2015), European Commission's Joint Research Centre (JRC).
- Country boundaries, World Bank.

% assets exposed to coastal flooding

- Global Exposure Database (GED) from GAR 2015, UNDRR.
- Coastal flood 100-year return period map, Muis et al. (2016).
- Country boundaries, World Bank.

Calculation

Asset value point data from GAR 2015 was aggregated to raster format (1km × 1km) to intersect with the hazard layers and provide a continuous representation of exposure.

Global raster population and assets data were then clipped to the boundaries of the 100-year riverine and coastal flood maps.

A zonal statistics operation was then conducted to calculate the values of the clipped raster files within the country boundaries, hence providing a summation of exposed assets and exposed population for each country. Affected exposure was calculated separately for coastal flood and river flood.

Total assets and population from each global raster (not clipped to flood prone areas) were also summed through zonal statistics. These values were used to calculate relative and absolute exposure information for each country.

The percentages of population and assets exposed to riverine and coastal flooding were calculated for each country. These percentages were respectively mapped to human and economic exposure scores as shown in Exhibit 4. Total exposure scores were estimated from the average of the percentages of population and assets exposed for each country. The mapping in Exhibit 4 with progressively larger percentage bins was chosen for exposure to obtain a roughly normal distribution of the scores. This mapping reflects the highly skewed nature of the underlying country distributions of exposed people and assets. A simpler mapping was chosen for hazard (Exhibit 3) and vulnerability (Exhibit 5), as the distributions of the underlying indicators are not as skewed.

12 The World Bank. (n.d.). World Bank Official Boundaries — Data Catalog. Retrieved July 28, 2021. The choice of this dataset does not imply any endorsement by Marsh McLennan concerning the legal status of any country or territory or the delimitation of frontiers or boundaries.

Exhibit 4: Mapping of exposed population and assets to exposure scores, %

Percentage exposed	Score
0-0.1	1
0.1-0.25	2
0.25-0.5	3
0.5-1	4
1-2	5
2-5	6
5-10	7
10-20	8
20-50	9
50-100	10

Source: Marsh McLennan Advantage

Limitations

Due to the difficulty in estimating flood exposure, there is a limited choice of open-source datasets. Data sources chosen to calculate exposure represent best available information that can be viewed as proxies for data that would otherwise be created or utilized exclusively for the purpose of flood risk modelling and assessment.

A suitable global hazard map for pluvial flooding was not identified and hence was omitted for the Exposure component calculation in the Index.

Information on flood defenses was not included in the analysis.

Vulnerability

Background

The three indicators for the vulnerability component of the Index — the Human Development Index (HDI), quality of overall infrastructure and non-life insurance premium volume to GDP — were chosen to reflect social and economic susceptibility to flooding.

HDI captures three dimensions of human development that are highly relevant to human vulnerability: Life expectancy, access to knowledge, and per capita income.[13] The quality of overall infrastructure (transport, energy and telephony) serves as proxy for economic vulnerability of infrastructure to flooding events.[14] In the absence of global natural catastrophe insurance penetration data, non-life insurance premium volumes relative to the size of the economy provides a view of the insurance environment and corresponding levels of protection within countries. Literature indicates that countries with higher levels of insurance penetration recover more quickly from disasters. We therefore include insurance penetration in the calculation of both human and economic vulnerability scores.

13 Details regarding the calculation of HDI can be found here.

14 Respondents to the survey were asked to answer the following question — "How would you assess general infrastructure (e.g., transport, telephony, and energy) in your country? [1=Extremely underdeveloped; 7=Extensive and efficient by international standards]". Responses were then utilized to calculate scores for the indicator of "Quality of overall infrastructure", within the Global Competitiveness Index.

Indicators and sources

Human vulnerability

- Human Development Index (HDI) from the Human Development Data 2020, UNDP.
- Non-life insurance premium volume to GDP (%) from the Global Financial Development Database 2019, The World Bank.

Economic vulnerability

- Quality of overall infrastructure from the results of the Executive Opinion Survey in the Global Competitiveness Index Historical Dataset (2017-2018), World Economic Forum.
- Non-life insurance premium volume to GDP (%) from the Global Financial Development Database 2019, The World Bank.

Calculation

The Human Development Index (HDI, ranging from 0 to 1), the quality of overall infrastructure (Q, between 1 and 7), and the non-life insurance premium volume to GDP (I) were rescaled to the range 0-100, with 0 indicating the highest performance in each dimension (HDI=1, Q=7, I=Maximum among all countries) and 100 the lowest performance (HDI=0, Q=1, I=Minimum among all countries). In the case quality of overall infrastructure, data was first cleaned to account for countries with missing values.

If no data was available for the most recent year of the dataset, data from the previous year with available data was included. No data before 2015 was included.

Human vulnerability values were calculated from HDI and Non-life insurance premium volume to GDP using the following formula:

$$\frac{HDI_{RESCALED} + 0.5 \times I_{RESCALED}}{1.5}$$

Economic vulnerability values were calculated from Quality of overall infrastructure and Non-life insurance premium volume to GDP using the following formula using the following formula:

$$\frac{Q_{RESCALED} + 0.5 \times I_{RESCALED}}{1.5}$$

Total vulnerability values were calculated from the average of human and economic vulnerability in each country, thus giving:

$$\frac{HDI_{RESCALED} + Q_{RESCALED} + I_{RESCALED}}{3}$$

Total, human, and economic vulnerabilities were mapped to scores ranging from 1 to 10 using the mapping reported in exhibit 5.

Exhibit 5: Mapping of vulnerability levels to vulnerability scores

Vulnerability level	Score
0-14.9	1
15-24.9	2
25-34.9	3
35-44.9	4
45-54.9	5
55-64.9	6
65-74.9	7
75-84.9	8
85-94.9	9
95-100	10

Source: Marsh McLennan Advantage

Limitations

Vulnerability to flood risk can be represented by many indicators. The indicators included for this Index are not to be viewed as an exhaustive portrayal of global vulnerability to floods.

Note that with the mapping shown in Exhibit 5 no country is assigned total, human, or economic vulnerability scores equal to 10. This is a consequence of the fact that no country has HDI and quality of infrastructure scores equal to the their theoretical minimum values (0 and 1, respectively).

The index does not explicitly factor in mitigation, adaptation and other similar measures. Defense efforts also have an impact in shaping flood risk vulnerability.

Urban and rural areas exposed to flooding

The Marsh McLennan Flood Risk Index is accompanied by country-level statistics on the percentage of rural and urban areas exposed to flooding. These percentages were estimated using FAO's Global Land Cover SHARE (GLC-SHARE) database,[15] the 100-year return period riverine flooding hazard map provided by Dottori et al. (2015), the 100-year return period coastal flooding hazard map presented in Muis et al. (2016), and country boundaries made available by the World Bank.

Information on the percentage of the area of each grid cell covered by urban and rural area was extracted from FAO's Global Land Cover SHARE (GLC-SHARE) database.

- The resulting urban and rural rasters were intersected with the 100-year riverine (Dottori et al., 2015) and coastal (Muis et al., 2016) hazard maps.
- Using the World Bank boundary data, the areas covered by urban and rural surfaces in each country and the corresponding areas exposed to riverine and coastal flooding were estimated. These numbers were used to calculate the percentages of urban and rural areas exposed to riverine and coastal flooding. Pluvial flooding (i.e., flash flooding and surface water flooding) was not included in the analysis.
- The total percentages of urban and rural areas exposed to flooding in each country were calculated following an analogous process after combining the riverine and coastal flood maps.

15 Latham, J., Cumani, R., Rosati, I., & Bloise, M. (2014). Global land cover share (GLC-SHARE) database beta-release version 1.0-2014. FAO: Rome, Italy

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