Overview

This repository includes instructions and code to replicate estimates of the population at high risk from climate-related hazards using R and Stata. There are two types of data used: (1) data from household surveys and related national/subnational data, and (2) spatial data.

Data Availability

Some data cannot be made publicly available.

Spatial data

Access to some input spatial datasets is restricted and processing this data is very resource intensive (> 14 days, 1 TB storage recommended). Therefore, intermediate spatial data is provided for replication. Instructions to access input data files are provided below and all code used to process them is included in the package.

Data.Name	Location	Provided	Citation	Accessed
Fathom Global v2	02.input/flood_fathom/	FALSE	Sampson et al. (2015)	November 2023
Deltares Global Flood Map	02.input/flood_deltares/	FALSE	Deltares (2021)	November 2023
FAO Historic Drought Frequency	02.input/drought_fao/	FALSE	FAO (2023)	August 2023
STORM tropical cyclone wind speed return periods	02.input/cyclone_storm/	FALSE	Russell (2024) Bloemendaal et al (2023)	April 2024
CCKP Environmental Stress Index (ESI) max 5-day heatwave	02.input/heatwave_cckp/	FALSE	World Bank, Climate Change Knowledge Platform (2024)	April 2024
GHS-POP - R2023A	02.input/population_ghsl	FALSE	Schiavina et al. (2023)	August 2023
GHS-SMOD - R2023A	02.input/degurban_ghsl	FALSE	Schiavina M., Melchiorri M., Pesaresi M. (2023)	August 2023
SDSN RAI Inaccessibility Index	02.input/rai_sdsn/	FALSE	Guilherme et al. (2024)	June 2024
World Bank AM24 VUL boundaries	02.input/boundaries/	TRUE	World Bank (2024)	July 2024
Intermediate data included in the replication package				
Combined hazard and Degree of Urbanization	03.intermediate/Hazard/	TRUE		
RAI population	03.intermediate/RAI/	TRUE		

A list of data files for each “Data.Name” is included in **spatial_data_files.csv**.

“Fathom Global v2” flood hazard data was obtained from the World Bank Development Data Hub. The FATHOM Global Flood Hazard Data has been supplied to the World Bank under a perpetual license for internal use only. The data remains confidential to The World Bank and FATHOM Ltd. All terms of the General World Bank Data Policy for confidential data apply. The Data may not be resold or made publicly available. The Data may not be shared with subcontractors, external consultancies or any other firms or individuals beyond the World Bank without written specific agreement from FATHOM. FATHOM retains all Intellectual Property Rights in the Data. The full clause of caution that accompanies the Data and describes the limitations and uncertainties surrounding the Data must be read before using the Data.

Within the World Bank, the Fathom Global flood hazard dataset can be requested from https://datacatalog.worldbank.org/int/search/dataset/0021728/Global-Flood-Hazard--FATHOM- A URL provides users with access to an internal SharePoint folder containing 231 .zip files, one for each country or region (AD_andorra.zip; AE_UAE.zip; ...). These contain .tif format files for different return periods and flood types. Data for all flood types, return periods and regions are required.

The data files (263 GB) should be saved here: **02.input/flood_fathom/**

License: Custom license (see above).

Citation: Sampson et al. (2015)

“Deltares Global Flood Map” coastal flood hazard data was obtained from The Microsoft Planetary Computer Data Catalog. The data is produced by Deltares and hosted by Microsoft via Azure Blob Storage. The “MERITDEM”, “90m” resolution version of data for the current climate (2018 sea level) are required for return periods ranging between 5 and 100 years.

The direct download links are:
https://deltaresfloodssa.blob.core.windows.net/floods/v2021.06/global/MERITDEM/90m/GFM_global_MERITDEM90m_2018slr_rp0005_masked.nc
https://deltaresfloodssa.blob.core.windows.net/floods/v2021.06/global/MERITDEM/90m/GFM_global_MERITDEM90m_2018slr_rp0010_masked.nc
https://deltaresfloodssa.blob.core.windows.net/floods/v2021.06/global/MERITDEM/90m/GFM_global_MERITDEM90m_2018slr_rp0025_masked.nc
https://deltaresfloodssa.blob.core.windows.net/floods/v2021.06/global/MERITDEM/90m/GFM_global_MERITDEM90m_2018slr_rp0050_masked.nc
https://deltaresfloodssa.blob.core.windows.net/floods/v2021.06/global/MERITDEM/90m/GFM_global_MERITDEM90m_2018slr_rp0100_masked.nc

The .nc format files (5.3 GB) should be saved here: **02.input/flood_deltares/**

License: Community Data License Agreement - Permissive, Version 1.0
https://cdla.dev/permissive-1-0/

Citation: Deltares (2021)

"FAO Historic Drought Frequency" data was obtained from FAO Agricultural Stress Index System. The data files were downloaded via Google Earth Engine after requesting access by sending an email to giews1@fao.org, following the instructions here: https://www.fao.org/giews/earthobservation/access.jsp?lang=en The data is available with an open license allowing redistribution subject to specific terms (see below).

The cropland and pasture Historic Drought Frequency data files for season 1 and season 2, and both available thresholds (>30% land affected, >50% land affected) are required. At the time data was accessed, these covered 1984-2022.

The .tif format files (185 MB) should be saved here: **02.input/drought_fao/**

License: Creative Commons Attribution-NonCommercial-ShareAlike 4.0 (CC BY-NC-SA 4.0) https://creativecommons.org/licenses/by-nc-sa/4.0/

Additional terms of use for datasets: https://www.fao.org/contact-us/terms/db-terms-of-use/en

Citation: FAO (2023)

"STORM tropical cyclone wind speed return periods" data was obtained from https://doi.org/10.5281/zenodo.10931452 (Version v2). The global GeoTIFFs for the present-day scenario were derived with minimal processing from the dataset created by Bloemendaal et al (2023), released with a CC0 license.

The STORM_FIXED_RETURN_PERIODS.zip (1.1 Gb) includes all data files. Only data files for the present day, baseline climate scenario are required for the analysis. These have the filename pattern: STORM_FIXED_RETURN_PERIODS_CONSTANT_{STORM_RP}_YR_RP.tif, where STORM_RP is ranges between 10 and 10000.

The .tif format files (228 MB) should be saved here: **02.input/cyclone_storm/**

License: CC0 1.0 https://creativecommons.org/publicdomain/zero/1.0/

Citation: Russell (2024)

"CCKP Environmental Stress Index (ESI) max 5-day heatwave" data was obtained from the World Bank Climate Change Knowledge Portal (CCKP) team who produced the dataset for this project. The data are based on the ECMWF ERA5 reanalysis (Hersbach H. et al. 2017), which is distributed with an open license (CC BY 4.0). These ESI data files will be provided by

the project team on request and are not available from the CCKP platform. The "median" version data files for return periods ranging between 5 and 100 years are required.

The .nc format files (5 MB) should be saved here: **02.input/heatwave_cckp/**

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Citation: World Bank, Climate Change Knowledge Platform (2024)

"GHS-POP - R2023A" gridded population data is obtained from the European Commission, Joint Research Centre (JRC) Global Human Settlement Layer (GHSL), available from: https://human-settlement.emergency.copernicus.eu/download.php?ds=pop. The "2020" epoch global data file with "3 arcsec" resolution ("WGS84" coordinate system) is required. This data is required for replication from the intermediate spatial data.

The .tif format data file (11 Gb) should be saved here: **02.input/population_ghsl/**

License: The GHSL has been produced by the EC JRC as open and free data. Reuse is authorised, provided the source is acknowledged. For more information, please read the use conditions European Commission Reuse and Copyright Notice.

Citation: Schiavina et al. (2023)

"GHS-SMOD - R2023A" gridded degree of urbanization data is obtained from the European Commission, Joint Research Centre (JRC) Global Human Settlement Layer (GHSL), available from: https://human-settlement.emergency.copernicus.eu/download.php?ds=smod. The "2020" epoch global data files with "1 km" resolution ("Mollweide" coordinate system) is required.

The .tif format data file (18 Mb) should be saved here: **02.input/degurban_ghsl/**

License: The GHSL has been produced by the EC JRC as open and free data. Reuse is authorised, provided the source is acknowledged. For more information, please read the use conditions European Commission Reuse and Copyright Notice.

Citation: Schiavina M., Melchiorri M., Pesaresi M. (2023)

"SDSN RAI Inaccessibility Index" data is obtained from the UN Sustainable Development Solutions Network (SDSN). The dataset is produced as part of tracking SDG Indicator 9.1.1 Rural Access Index by the UN SDSN and provided directly to the project team. The data can be accessed through Google Earth Engine using the code and instructions at https://gee-community-catalog.org/projects/rai/, and is hosted by the "awesome-gee-community-catalog".

The .tif format file (5.8 GB) should be saved here: **02.input/rai_sdsn/**

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Citation: Guilherme et al. (2024); Roy et al. (2024)

"World Bank AM24 VUL boundaries" data were produced by the project team. The dataset is derived from administrative boundary data sources including Global Administrative Unit Layers (GAUL) 2015, Nomenclature of Territorial Units for Statistics (NUTS), GADM, United Nations Common Operational Datasets, and National Statistical Offices (NSOs). The boundary data is required for replication from the intermediate spatial data.

The replication package includes the .gpkg format file (110 MB) here: **02.input/boundaries/**

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Citation: World Bank (2024)

Intermediate spatial data

"Combined hazard and Degree of Urbanization" intermediate data is included for replication. It is derived from the input datasets using code included in the replication package. The data includes one .tif format file (1.4 GB) and auxiliary .csv files here: **03.intermediate/Hazard/**

"RAI population" is provided as intermediate data for replication. It is derived from the input datasets using code included in the replication package. The .tif format data file (1.9 GB) is located here: **03.intermediate/RAI/**

Survey and other data

Data.Name	Location	Provided	Citation	Accessed
Joint Monitoring Programme (JMP)	02.input/jmp/data/	TRUE	JMP	April 2024
Global Electricity Database	02.input/GED	TRUE	GED	March 2024
UNESCO	02.input/UNESCO	TRUE	UNESCO	April 2024
Findex	02.input/Findex	TRUE	Findex	March 2024
WDI	02.input	TRUE	WDI	March 2024

Global Monitoring Database (GMD)		FALSE	World Bank, GMD (2024)	June 2024
Luxembourg Income Study Database (LIS)		FALSE	LIS	June 2024
Intermediate data included in the replication package				
Poverty and Inequality Platform	03.intermediate/PIPinput	TRUE	World Bank (2024), Poverty and Inequality Platform	September 2024

"Joint Monitoring Programme (JMP)" data on access to drinking water was obtained from the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP), available from: https://washdata.org/data/downloads#WLD. R scripts included in 02.input/jmp/code/ were used to download and combine data for all countries from the "country file" and "inequality" excel files available from the website. The combined formatted .xlsx data file is included in the replication package here: **02.input/jmp/data/**

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Citation: WHO/UNICEF Joint Monitoring Programme (2024)

"Global Electricity Database" data on electricity access was obtained from the IEA, IRENA, UNSD, World Bank and WHO 2023 Tracking SDG 7: The Energy Progress Report. The data are available from: https://trackingsdg7.esmap.org/downloads. The SDG7.1.1 - Access to Electricity.xlsx file was downloaded and is included in the replication package here: **02.input/GED/**

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Citation: IEA, IRENA, UNSD, World Bank, WHO (2023).

"UNESCO" data on education completion was obtained from the UNESCO Institute for Statistics (UIS), available from the UIS.Stat Bulk Data Download Service: https://apiportal.uis.unesco.org/bdds.

License: Attribution-Sharealike 3.0 Intergovernmental Organization (CC BY-SA 3.0 IGO) https://creativecommons.org/licenses/by-sa/3.0/igo/

Citation: UNESCO Institute for Statistics (UIS) (2024).

"Findex" data on financial inclusion was obtained from the World Bank Microdata Library. Registered uses can download the 2021 data file (in .dta format) from

https://microdata.worldbank.org/index.php/catalog/4607. Before gaining access, users are asked to register and to read and agree to Public Use Files conditions (see below). The data file is included in the replication package here: **02.input/Findex/**

License: Public Use Files, see: https://microdata.worldbank.org/index.php/terms-of-use

Citation: Demirgüç-Kunt et al. (2022); Development Research Group, Finance and Private Sector Development Unit (2022).

"WDI" World Development Indicators (WDI) data was obtained from the World Bank, available using the API through the Stata package *wbopendata* and R package *wbstats*. Data for the following variables are called from the code: EG.ELC.ACCS.ZS, SP.POP.TOTL.

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https://creativecommons.org/licenses/by/4.0/

Citation: World Bank (2024).

"Global Monitoring Database (GMD)" data is obtained from the World Bank Datalibweb platform using the Stata package *datalibweb*. Access to the Survey data in the Global Monitoring Database (GMD) is provided only for World Bank staff working with Bank managed computers, and the data is not available for external users. Most of the surveys in the GMD is available internally, however for some data users need to request access to the data in the Datalibweb platform. Users need to install the *datalibweb* ado package following the instructions in the About tab of the Datalibweb website.

License: Restricted access, exact license varies across surveys.

Citation: World Bank (2024).

Additional GMD Datasets:

1. Survey_price_framework.dta
Source: Datalibweb, World Bank
Access Code: dlw, country(support) year(2005) type(gmdraw)
filename(Survey_price_framework.dta) files surveyid(Support_2005_CPI_v11_M)
Location: After running the code, add the dataset to 02.input/Survey_price_framework.dta.

2.Final_CPI_PPP_to_be_used.dta
Source: Datalibweb, World Bank

Access Code: dlw, country(support) year(2005) type(gmdraw)
filename(Final_CPI_PPP_to_be_used.dta) files surveyid(Support_2005_CPI_v11_M)

Location: After running the code, add the dataset to 02.input/Final_CPI_PPP_to_be_used.dta.

3. repo_AM24all.dta
Source: Datalibweb, World Bank
Access Code: dlw, country(support) year(2005) type(gmdraw) filename(repo_AM24all.dta) files surveyid(Support_2005_CPI_v11_M)
Location: After running the code, add the dataset to 02.input/repo_AM24all.dta.

"Luxembourg Income Study Database (LIS)" data was obtained using the remote-execution system LISSY. More details can be found at https://www.lisdatacenter.org/data-access/lissy/.

License: There are restrictions on data use and access. Users must agree to the LIS Microdata User Agreement.

Citation: Luxembourg Income Study (2024).

"Poverty and Inequality Platform" data was obtained from the World Bank Poverty and Inequality Platform (PIP) using the Stata package *pip* to access the API. Documentation for the package is available here: https://worldbank.github.io/pip/.

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Citation: World Bank (2024).

Instructions for Replicators

Replication from intermediate spatial data

Follow these steps to reproduce results from the intermediate spatial data:

1. Clone the reproducibility package (see folder structure below)
2. Run the R master script "01.code/R/00_MASTER.R"
3. Open the Stata master do-file "01.code/dofile/MASTER dofile.do"
4. Change the current directory on line 4 to the reproducibility package path
5. Run the Stata do-files following the sequence in the Excel sheet "Stata code" in the Excel file "Read me - folder and file structure.xlsx".

Replication from source spatial data

Note, the size of all input spatial data files exceeds 400 GB. It is recommended that 1TB of storage is available for intermediate and temporary data files generated when processing

these input files. The total run time is likely to exceed 14 days but will depend on system specifications. To prepare the intermediate spatial data from source data files and run the analysis, do the following instead of step 1 above:

1. Access and download all datasets described in the Data Availability "Spatial data" section that are not included in the reproducibility package. Data files should be placed in the specified folders.
2. Run the R script "01.code/R/00_MASTER.R" after changing line 13 "`from_intermediate = TRUE`" to "`from_intermediate = FALSE`"

List of Exhibits

The provided code reproduces:

Exhibit name	Output filename	Script	Note
Climate risk scorecard vision indicator	Tables_CSC.xlsx	2-8 Get tables for CSC.do	Found in: 04.output/For CSC/

Requirements

Computational requirements

The R master script (from intermediate spatial data) was run on a MacBook Air M2 (2022) with 16 GB Memory, running macOS Sonoma 14.5. The run time was 116 minutes.

Software requirements

Stata version 16
Datalibweb package version 2 (July 2024), see the "About" tab for more instructions of Datalibweb, installation of Stata package, it is available at https://datalibweb2.worldbank.org/home

R version 4.4.1 (2024-06-14)
RStudio Version 2024.04.2+764
Platform: aarch64-apple-darwin20
Running under: macOS Sonoma 14.5

The R package *renv* is used to help create a reproducible environment by installing the same version of all packages required.

Memory, Runtime and Storage Requirements

From intermediate spatial data:
Memory: at least 16 GB
Storage: at least 20 GB available

Run time: 116 minutes (R master script) + 10 hours (Stata do-files)

For replication from input spatial data files, the following are recommended:
Memory: at least 32 GB
Storage: ~ 1 TB available
Run time: > 14 days

Code Description

R

R Script	Description
00_MASTER.R	Install packages using *renv* and run scripts to replicate
01_prep_flood_fathom.R	Prepare Fathom flood data
02_prep_flood_deltares.R	Prepare Deltares flood data
03_prep_flood_combine.R	Combine flood hazard data
04_prep_cyclone_drought_heatwave.R	Prepare cyclone, drought and heatwave hazard data
05_prep_degurban.R	Prepare Degree of Urbanization data
06_prep_rai.R	Prepare accessibility/Rural Access Index (RAI) data
07_classify_hazards.R	Define thresholds and produce categorical hazard data
08_combine_hazards.R	Combine hazard data for scenarios defined by return periods and exposure thresholds for each hazard type
09_combine_hazards_degurban.R	Combine hazard data and Degree of Urbanization data to produce categorical raster
10_extract_exposed_pop.R	Get estimates of exposed population, population with low accessibility and total population in each region
11_clean_exposed_pop.R	Rescale population estimates to match WDI at country level and save clean exposure data (.csv) for Stata

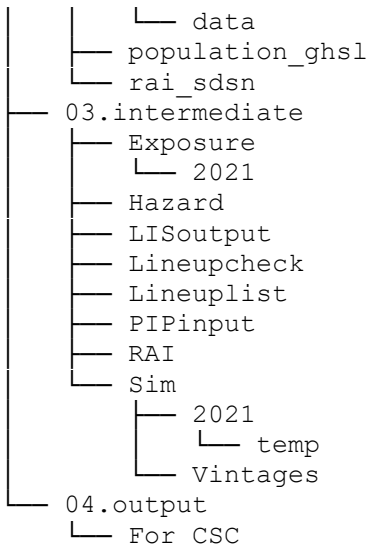
Stata

Seq.	Dofile	Description
	MASTER dofile.do	Sets globals
	GMD list.ps1	Powershell ISE to get file list
	0.3 - get catalog powershell.do	Make repo from Powershell list
1	**0-0 GMD datacheck.do**	Check the variable contents of all GMD data files
2	**0-1 Get PIP nat lineup number.do**	Get poverty lineup estimates at the national level from PIP
3	**0-2 Update pop class region.do**	Update population, income class from PIP
4	**0-7a Findex_quintiles 2021.do**	Prepare Findex data overall and for a lineup year 2021
5	**0-7b Prep ASPIRE.do**	Prepare ASPIRE data overall and for a lineup year
6	**0-7c Prep JMP.do**	Prepare JMP data overall and for a lineup year
7	**0-7d Prep GED.do**	Prepare GED data overall and for a lineup year
8	**0-7e Prep UNESCO.do**	Prepare UNESCO data overall and for a lineup year

9	**0-8 Water and Elec WDI.do**	Prepare water and electricity from WDI
10	**0-3 Prep data for coverage.do**	Prepare data list for all years with all inputs
11	**0-4a Coverage check.do**	Check coverage
12	**1-1 Get list for LISSY.do**	Get a list for LIS
13	**1-2 Get list for GMD full.do**	Get a list for GMD
15	**2-1a Estimate national vul rate for LISSY data.do**	Estimate national vulnerable from LISSY
16	**2-1b Estimate vul rate for LISSY data.do**	Estimate subnational vulnerable from LISSY
17	**2-1c Extract national data - for LISSY data.do**	Extract national vulnerable from LIS output text file
18	**2-1d Extract subnat data - for LISSY data.do**	Extract subnational vulnerable from LIS output text file
19	**2-2 Estimate vul rate for CHN data 2021.do**	Estimate subnational vulnerable for CHN 2021
20	**2-3 Estimate vul rate for GMD data full.do**	Estimate subnational vulnerable for GMD surveys
21	**2-4 Estimate vul rate for IND data 2021.do**	Estimate subnational vulnerable for IND 2021
22	**2-5 Combine vul estimates full.do**	Combine vulnerable estimates from GMD, LIS, special cases
23	**2-6a Merge exposure and vul estimates.do**	Merge exposure and vulnerable
24	**2-7 Vul_Exp - Get tables and figures.do**	Prepare tables and figures
25	**2-8 Get tables for CSC.do**	Prepare Scorecard table

Folder structure

```
├── 01.code
│   ├── R
│   │   └── renv
│   ├── ado
│   └── dofile
├── 02.input
│   ├── 2021
│   ├── ASPIRE
│   ├── CHN
│   ├── Findex
│   ├── GED
│   ├── IND
│   ├── UNESCO
│   ├── boundaries
│   ├── cyclone_storm
│   ├── degurban_ghsl
│   ├── drought_fao
│   ├── flood_deltares
│   ├── flood_fathom
│   ├── heatwave_cckp
│   ├── jmp
│   │   ├── code
```


└── data
├── population_ghsl
└── rai_sdsn
├── 03.intermediate
├── Exposure
└── 2021
├── Hazard
├── LISoutput
├── Lineupcheck
├── Lineuplist
├── PIPinput
├── RAI
└── Sim
├── 2021
└── temp
└── Vintages
└── 04.output
└── For CSC

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