

README file for Reproducibility Package.

Paper title: Future Housing Needs: Projecting Global Housing Stock, Quality, and Climate Hazard Exposure (2025–2100)

Last Run

Notebook	Date
1	July 3, 2026
2	July 3, 2026 [I found the GEM datasets in Github is been updated; I recommend the reproducibility validation to use data in data_pocessed/GEM – as original data in GEM github may continue to change.]
3	July 3, 2026
4-1	NA – this cell is to get massive data from Google Earth Engine. Given token limitations, I suggest not to run for reproducibility package. Instead, the reproducibility check may use files in data_processed/GEE_heat
4-2	NA – same reason a s above, to use files in data_processed/GEE_flood
4-3	July 3, 2026
5	July 4, 2026
5-1	July 4, 2026
6	July 6, 2026
6-1	July 4, 2026
7	July 4, 2026
8	July 4, 2026

Overview

This package projects global housing needs from 2025 to 2100 under five Shared Socioeconomic Pathways (SSP1–SSP5), combining:

1. **Household size projections** at the country/subnational level, driven by GDP, urbanization, and demographic structure (Notebook 1).
2. **Building stock quality and replacement cost** benchmarks from the Global Exposure Model (GEM) (Notebook 2).
3. **Gridded population and housing stock** at 1 km resolution, reconciled with SSP household-size projections (Notebook 3).
4. **Climate and geophysical hazard layers** — heat (indoor WBGT), flood (WRI Aqueduct), storm (STORM), and earthquake (GEM) — collected via Google Earth Engine and harmonized to a common 1 km grid (Notebooks 4.1–4.3).

5. **A cohort-based housing stock model** that ages, retires, and reconstructs housing by structural quality tier (Fragile/Medium/Robust), under two policy pathways (Business-As-Usual vs. Resilient), overlaid with hazard exposure and land/greenfield expansion analysis (Notebook 5), with lifespan, governance-capacity, and hazard-threshold sensitivity checks (Notebook 5.1).
6. **Visualization** of global, regional, and country-level results (Notebook 6), plus GIS raster exports for mapping in ArcGIS (Notebook 6.1).
7. **Replacement cost and fiscal burden analysis**, expressing construction costs as a share of GDP (Notebook 7).
8. **A "Triple Burden" country classification** combining housing demand pressure, hazard exposure, and fiscal incapacity into a composite index (Notebook 8).

How to proceed: Run the 12 notebooks in script/ in the numbered order below — each notebook consumes outputs from earlier notebooks.

Data Availability

☑ **Some data cannot be made publicly available** (large gridded population/settlement datasets must be downloaded directly from their source portals due to size and license terms; they are not redistributed in this package).

Data Sources

#	Filename(s)	Source	URL	Notes
1	World Bank Official Boundaries - Admin 0.gpkg, World Bank Official Boundaries - Admin 1.gpkg, World Bank Official Boundaries - Admin 0_all_layers.gpkg, CLASS.xlsx	World Bank Official Boundaries / WB Country and Lending Groups	<i>Development Data Hub:</i> https://datacatalog.worldbank.org/int/search/dataset/0038272/world-bank-official-boundaries [Accessed on December 9, 2025] List of Economies: https://databankfiles.worldbank.org/public/ddpext_download/site-content/CLASS.xlsx [Accessed on November 13, 2025]	Admin 0/1 boundaries, WB region and income-group classification
2	API_NY.GDP.PCAP.PP.KD_DS2_en_csv_v2_1584.csv, API_SP.URB.TOTL.IN.ZS_DS2_en_csv_v2_608.csv, API_SP.POP.0014.TO.ZS_DS2_en_csv_v2_51.csv, API_SP.POP.65UP.TO.ZS_DS2_en_csv_v2_3	World Bank World Development Indicators (WDI)	https://databank.worldbank.org/source/world-development-indicators [Accessed on November 13, 2025]	GDP per capita (PPP), urban population %, population

	30.csv, API_NY.GDP.MKTP.PP.CD_DS2_en_csv_v2_79.csv			0–14 %, population 65+ %
3	SUBNATIONAL_BOUNDARIES_CORESIDENCE_PROJECT.gpkg, A0_CORESIDENCE_NATIONAL_DATASET_2024.csv, A2_CORESIDENCE_SUBNATIONAL_HARMONIZED_DATASET_2024.csv	CORESIDENCE Project	https://zenodo.org/records/8142652 [Accessed on January 21, 2026]	National and subnational average household size
4	undesapd_2022_hh-size-composition.xlsx	UN DESA, Population Division	https://www.un.org/development/desa/pd/data/household-size-and-composition [Accessed on December 9, 2025]	Household size and composition, 2022 revision
5	1721734326790-ssp_basic_drivers_release_3.1_full.xlsx SSP-Urbanization-2024-review-phase-3.xlsx	IIASA SSP Database (SSP Basic Drivers, release 3.1)	https://tntcat.iiasa.ac.at/SspDb/ [Accessed on January 30, 2026]	GDP, population, age- structure, and urbanization projections (IIASA- WIC POP 2023, IIASA GDP 2023, OECD ENV- Growth 2023)
6	GEM Global Exposure Model residential exposure CSVs (Exposure_Res_*_Adm1.csv)	GEM Foundation, Global Exposure Model	https://github.com/gem/global_exposure_model (commit da2131a3309d160514e66db89818690239d51dbd, pinned in Notebook 2)	Fetches programmatically at run time; not stored in data_raw/
7	hazus-gem_mapping.csv, gem_taxonomy_fields.json, gem-to-vulnerability_mapping_per_hazard.xlsx, building_class_to_vulnerability_mapping.csv, country_vulnerability_classes.csv	GEM Foundation/ methodology of R. Middelani	https://github.com/rmiddelani/global-unbreakable-model Accessed October 23, 2025	Support files for taxonomy decoding and vulnerability

		s (Global Unbreakable Model)		y class assignment
9	GEM-GSHM_PGA-475y-rock_v2023/v2023_1_pga_475_rock_3min.tif	GEM Global Seismic Hazard Map	https://www.globalquakemodel.org/product/global-seismic-hazard-map [Accessed on January 25, 2026]	Peak ground acceleration, 475-year return period
10	GHS_WUP_POP_E{year}_GLOBE_R2025A_54009_1000_V1_0.tif (per target year)	Global Human Settlement Layer (GHSL), JRC European Commission	https://ghsl.jrc.ec.europa.eu/ [Accessed on January 25, 2026]	Baseline and projected population grids, 1 km, Mollweide
11	FuturePop_{SSP}_1km_v0_2/FuturePop_{SSP}_{year}_1km_v0_2.tif (per SSP × year)	WorldPop Future Population	https://www.worldpop.org/ [Accessed on February 7, 2026]	SSP-consistent gridded population projections, 1 km
12	STORM_FIXED_RETURN_PERIODS_constant_100_YR_RP.tif, STORM_FIXED_RETURN_PERIODS_{GCM}_100_YR_RP.tif (4 GCMs)	STORM global tropical cyclone wind speed dataset	https://zenodo.org/records/10931452 [Accessed on March 31, 2026]	100-year return period wind speed, present and future (RCP8.5/SSP5, 2050)
13	NASA/GDDP-CMIP6 (ee.ImageCollection('NASA/GDDP-CMIP6'))	NASA Earth Exchange Global Daily Downscaled Projections,	https://developers.google.com/earth-engine/datasets/catalog/NASA_GDDP-CMIP6 March 2026	Daily climate variables for indoor WBGT heat hazard

		accessed via Google Earth Engine		computation
14	WRI/Aqueduct_Flood_Hazard_Maps/V2, accessed via Google Earth Engine	WRI Aqueduct Flood Hazard Maps	https://developers.google.com/earth-engine/datasets/catalog/WRI_Aqueduct_Flood_Hazard_Maps_V2 March 2026.	Riverine/coastal flood inundation depth
15	MODIS/006/MOD44W/2015_01_01, accessed via Google Earth Engine	MODIS Land/Water Mask	https://developers.google.com/earth-engine/datasets/catalog/MODIS_006_MOD44W March 2026.	Land mask used in heat and flood processing

Input files located in data_raw/GEM/wb_adm1_2024oct_revised complete_v20260114/ (produced by Eigo Tateishi)

This folder contains a manually revised version of the World Bank Official Boundaries Admin 1 layer (WB_GAD_ADM1). Because GEM uses a different list of subnational administrative units than the World Bank, the WB Admin 1 polygons were manually edited in QGIS to produce a set of subnational unit boundaries that correspond to GEM's subnational government list. The underlying World Bank Official Boundaries data are included in data_raw/WB_Official_Boundaries/. No code is available for these adjustments, as they were performed interactively in QGIS.

Statement about Rights

☒ I certify that the author(s) of the manuscript have legitimate access to and permission to use the data used in this manuscript.

Instructions for Replicators

1. **Get the raw data.** Most data_raw/ sources must be downloaded manually from the links in the table above and placed in the matching subfolder. GEM residential exposure data and Earth Engine hazard layers are fetched programmatically and do not need manual download.

Note: For reproducibility check, I suggest using downloaded and processed GEM files and GEE files (below, instead of collecting them through programming), as original source may have changed.

- data_processed/GEM
 - data_processed/GEE_flood
 - data_processed/GEE_heat
2. **Set up Google Earth Engine access.** Notebooks 4.1 and 4.2 require a GEE account and a registered Cloud project (the notebooks currently reference project heat-yasuhiro — replace with your own project ID).
 3. **Update directory paths.** Every notebook currently hardcodes:
 4. BASE_PATH = '/content/drive/MyDrive/WB_Study/Future_housing_needs'

Update this to the location of the Future_housing_needs base folder in your own environment (Google Drive path if using Colab, or a local/cloud path if adapting to run outside Colab).

5. **Run the 12 notebooks in order:** 1 → 2 → 3 → 4-1 → 4-2 → 4-3 → 5 → 5-1 → 6 → 6-1 → 7 → 8
Each notebook reads outputs written by earlier notebooks in data_processed/ and/or results/.
6. Expect **multi-hour to multi-day total runtime** given the raster processing.

List of Exhibits

The provided code reproduces:

☒ **Selected tables and figures in the paper, as explained and justified below**

Output filename	Notebook	Explanations	Paper exhibit #
data_processed/HH_model/All_Model_Coefficients_For_Stage3.csv	1	Global model coefficients	Table 1
data_processed/HH_model/Between_Within_Decomposition.csv	1	Coefficient Comparison Across Specifications	Table A2.1.
data_processed/HH_model/RandomSlopes_GDP_Results.csv	1	Random Slopes Model: GDP per Capita Slope	Table A2.2.
data_processed/HH_model/Validation_Coverage_National.csv	1	Coverage of data for back casting analysis (national level)	Table A4-1
data_processed/HH_model/Validation_Coverage_Subnational.csv	1	Coverage of data for back casting analysis(sub-national level)	Table A4-2
data_processed/HH_model/Backcasting_Validation_Cutoff2005.png	1	Back-casting validation results (Cutoff = year 2005: Primary)	Figure A4-1

data_processed/HH_model/Backcasting_Validation_Cutoff2008.png	1	Back-casting validation results (Cutoff = year 2008: Secondary)	Figure A4-2
data_processed/HH_model/Backcasting_Hierarchical_Summary.csv data_processed/HH_model/Backcasting_Breakdown_By_Level.csv	1	Back-casting validation – key results	Table 5
results/integrated_statistics/housing_quality_results_validated.xlsx	5	Future housing stock, population, household size projection table for countries and global	Key numbers for Global Housing Stock Trajectories (2025–2100) section
results/integrated_figures/ Figure_01_Global_Housing_Population_HHSize.png	6	Global Housing Stock, Population, and Household Size Trajectories (2025-2100)	Figure 2
results/integrated_figures/maps/Map_01b_Housing_Stock_Change_2025_to_2100.png	6	Percentage change in housing stock from 2025 baseline to 2100 (GHSL scenario)	Figure 3 (top)
results/integrated_figures/ Figure_09A_SSP2_Regional_Stock_Population_HHSize.png	6	Regional figures of housing stock, population, and household size (2025-2100)	Figure 3 (bottom)
results/integrated_figures/ Figure_14_Global_Existing_vs_Undeveloped.png	6	Global Housing Expansion: Built-Up Area vs Undeveloped Land (2025-2100)	Figure 4
results/integrated_figures/ Figure_03C_Global_Construction_BAU_vs_Resilient_SSP135.png	6	Global Construction demand: BAU vs Resilient Policy (SSP1, 3, 5)	Figure 5 (top)
results/integrated_figures/ Figure_09B_SSP2_Regional_Construction_BAU_vs_Resilient.png	6	Regional Construction demand: BAU vs Resilient Policy (SSP2)	Figure 5 (bottom)
results/integrated_figures/ Figure_05A_Housing_Quality_GHSL.png	6	Housing Quality Composition: BAU vs Resilient Policy Scenarios (GHSL)	Figure 6
results/integrated_figures/maps/Map_03_Fragile_Stock_Avoided_2050.png	6	Number of Fragile Stock Avoided (BAU-Resilient) in 2050 (Millions of units in SSP3)	Figure 7 (top)
results/rasters/Map2_PolicyDividend_FragileReduction.tif	6-1	Figure 7 (bottom) is produced in ArcGIS using this tiff file.	Figure 7 (bottom)
results/integrated_figures/ Figure_15_Regional_Existing_vs_Undeveloped_Grouped.png	6	Regional Housing Expansion: Existing Built-up vs Undeveloped Land (SSP3)	Figure A5-1
results/integrated_figures/maps/ Map_02_Hazard_Exposure_Proportion_2025_2100.png	6	Global maps: Annual Average Housing Construction in Hazard Exposed Zones (2025-2100) SSP3	Figure 8 (top)
results/rasters/Map1_CumulativeConstruction_2030_2050.tif	6-1	Figure 8 (bottom) is produced in ArcGIS using this tiff file.	Figure 8 (bottom)
results/integrated_figures/ Figure_10A_Global_Stock_Exposure_by_Scenario.png	6	Global Projection of Housing Stock Exposure to Natural Hazards	Figure A5-2
results/integrated_figures/ Figure_12_MultiHazard_Summary_SSP3.png	6	Housing Stock and New Construction in Hazard Zones: Comparison between BAU and Resilient Pathways (SSP3)	Figure 9
results/cost_analysis/fig2_global_bau_vs_resilient_abs_cost.png	7	Global Annual Housing Construction Cost (Billion USD PPP): BAU vs Resilient Policy	Figure 10
results/cost_analysis/fig4_regional_additional_cost_ssp_band.png	7	Cost Comparison of BAU and Resilient by Region	Figure 11

results/triple_burden/fig_global_map_triple_burden.png	8	Triple Burden Index Across All Analyzed Countries (2025-2100)	Figure 12
results/triple_burden/fig_main_triple_burden.png	8	Composite Index Decomposition	Figure A3-1
results/triple_burden/fig_individual_burden_rankings.png	8	Individual Burden Rankings	Figure A3-2
results/triple_burden/fig_supplementary_scatter.png	8	Bivariate relationships between triple burden index components	Figure A3-3
results/sensitivity_analysis/sensitivity_analysis_main.xlsx	5-1	Sensitivity Analysis results	Table 2, Table 3, Table 4

Requirements

Computational Requirements

- **Platform:** Developed and tested on **Google Colab** (Python 3) with data stored on **Google Drive**.
- **GPU:** Not required.
- A **Google Earth Engine** account with a registered Cloud project is required for Notebooks 4.1 and 4.2.

Software Requirements

- Python 3 (Colab default runtime)
- Core scientific stack: numpy, pandas, scipy, scikit-learn, statsmodels, linearmodels
- Geospatial: geopandas, rasterio, shapely, pyproj
- Earth Engine: earthengine-api, geemap
- Utilities: pycountry, joblib, tqdm, openpyxl
- Visualization: matplotlib, seaborn

Approx Runtime

Notebook	Approx. runtime (as documented in-code)
1 — AHS projection & validation	Approx. 15-30 min
2 — GEM subnational	Approx. 5 min
3 — Population & Housing Stock	Approx. 7 hours
4.1 — GEE Heat (Indoor WBGT)	Over 10 hours

4.2 — GEE WRI Aqueduct (Flood)	Several hours
4.3 — Multi-Hazard data cleanup	Approx. 45 min -1 hour
5 — Cohort Model & Hazard Analysis	Approx. 16-18 hours
5.1 — Sensitivity Analysis	~ 1 hour
6 — Visualization Figures	~30 min
6.1 — Map Export for GIS	~ 5 min
7 — Replacement cost analysis	~ 5 min
8 — Triple Burden	~ 5 min

Storage: Global 1 km rasters (housing stock, hazard masks, cohort model outputs across 6 population scenarios × 9 years × 2 policies) are the dominant storage cost — expect on the order of tens of GB in data_processed/ alone, plus the raw GHSL/WorldPop/STORM downloads. Colab local/temporary storage is also used for interim reprojected rasters that are not persisted to Drive.

Code Description

All scripts are Jupyter notebooks in script/, intended to be run **in sequence**.

Notebook	Purpose	Key inputs	Key outputs
_1_AHS_projection_and_validation.ipynb	Models average household size (AHS) via log-log OLS on GDP/urbanization/age structure; validates via backcasting; computes hierarchical subnational/national offsets; projects AHS to 2100 under 5 SSPs (+ between-effects sensitivity)	WB WDI indicators, CORESIDENCE, UN DESA, SSP basic drivers & urbanization, WB boundaries	data_processed/HH_model/*, data_processed/HH_projections/* (incl. SSP_AHS_Projections_2100_Integrated.gpkg), data_processed/HH_projections_FE_sensitivity/*
_2_GEM_subnational.ipynb	Fetches GEM Global Exposure Model residential building data, decodes construction taxonomy, assigns vulnerability/fragility class, aggregates to subnational (ADM1) and country level	GEM GitHub repo (live fetch), HAZUS-GEM mapping, GEM taxonomy/vulnerability mapping files, WB ADM1 shapefile	data_processed/GEM/GEM_aggregated_raw_with_QID.csv, GEM_aggregated_country_level.csv, GEM_Subnational_Housing_Metrics_Mollweide.gpkg, GEM_Country_Housing_Metrics_Mollweide.gpkg

_3_Population ___Housing_S tock.ipynb	Builds the master 1 km Mollweide grid; reprojects WorldPop/GHSL population to it; generates housing-unit rasters (population ÷ household size) for 6 scenarios × 9 years; builds country ID and GEM region ID rasters; aggregates baseline population/housing by country	GHSL, WorldPop, Notebook 1 output (SSP_AHS_Projections_2100_Integrated.gpkg), Notebook 2 output (GEM.gpkg)	data_processed/master_grid_template.tif, data_processed/housing_stock/{scenario}/*.tif, country_id_raster.tif + mapping CSV, region_id_raster.tif + region_map.pkl, population_housing_baseline.csv
_4_1_GEE_Collect_Heat_IndoorWGBT.ipynb	Computes indoor Wet-Bulb Globe Temperature (95th percentile, hottest month) from NASA GDDP-CMIP6 (5-GCM ensemble) via Google Earth Engine, for 2 emissions scenarios × 9 target years	GEE: NASA/GDDP-CMIP6, MODIS land mask	data_processed/GEE_heat/WBG_T_indoor_hotmonth_{ssp}_{year}.tif (18 files) + QC outputs in validation/
_4_2_GEE_WRI_Aqueduct.ipynb	Computes maximum riverine + coastal flood inundation depth from WRI Aqueduct via GEE, for 2 RCP scenarios × 3 years	GEE: WRI/Aqueduct_Flood_Hazard_Maps/V2, MODIS land mask	data_processed/GEE_flood/flood_inundation_{scenario}_{year}.tif (6 files) + QC outputs
_4_3_Multi-Hazard_data_cleanup.ipynb	Aligns all 4 hazard layers (earthquake, heat, flood, storm) to the master 1 km grid and converts each to binary exposure masks at two severity thresholds	GEM earthquake PGA raster, STORM wind rasters, Notebooks 4.1/4.2 outputs, master grid, WB boundaries	data_processed/hazard_masks/mask_{hazard}*.tif (earthquake ×2, heat ×36, flood ×12, storm ×4), data_processed/country_mask_1km.tif
_5_Cohort_Model___Hazard_Analysis_subnational.ipynb	Core cohort-based housing model: ages/retires/rebuilds housing stock by quality tier (Fragile/Medium/Robust) under BAU vs. Resilient policy, for 6 population scenarios × 9 years; overlays hazard exposure; runs governance-capacity sensitivity; performs greenfield land-expansion analysis; exports GIS rasters and Excel statistics (country + Admin-1 level)	Notebook 1 (SSP_AHS_Projections...gpkg), Notebook 2 (GEM.gpkg), Notebook 3 (housing stock rasters, ID rasters), Notebook 4.3 (hazard masks), WB Admin-1 boundaries, CLASS.xlsx	data_processed/Raster/*.tif (cohort stock/expansion rasters), data_processed/admin1_id_raster.tif + mapping, results/integrated_statistics/housing_quality_results_validated{suffix}.xlsx (+ _subnational), hazard_analysis_results{suffix}.xlsx (+ _subnational, _second_threshold), results/land_analysis/housing_land_requirements*.xlsx
_5_1_Sensitivity_Analysis.ipynb	Consolidates lifespan, governance-capacity, and hazard-threshold sensitivity results from Notebook 5 into summary tables	Notebook 5 outputs (multiple *_validated*, hazard_analysis_results*, housing_land_requirements* files), CLASS.xlsx	results/sensitivity_analysis/sensitivity_analysis_main.xlsx, sensitivity_analysis_annex.xlsx
_6_Visualization_Figures.ipynb	Produces global, regional, and country-level figures (trends, hazard exposure, land expansion, maps)	Notebook 1 gpkg, Notebook 3 mapping CSV, Notebook 5 Excel	results/integrated_figures/*.png (global + country-specific subfolders + maps/)

		outputs, Notebook 5's land-analysis Excel, CLASS.xlsx, WB boundaries	
_6-1_Map_Export_for_GIS_Visualization.ipynb	Builds two GIS-ready single-band rasters for external mapping (ArcGIS)	Notebook 5 rasters (data_processed/Raster/SSP3_*_Expansion.tif, SSP3_2050_{BAU,Resilient}_Stock_FMR.tif)	results/rasters/Map1_Cumulative Construction_2030_2050.tif, Map2_PolicyDividend_FragileReduction.tif
_7_Replacement_cost_analysis.ipynb	Computes replacement cost per capita by quality tier (from GEM), applies to projected construction volumes, expresses cost relative to GDP (with cost-elasticity adjustment)	Notebook 2 (GEM_aggregated_county_level.csv), Notebook 5 (housing_quality_results_validated.xlsx), Notebook 1 (SSP_GDP_PPP_Projections_Wide.csv), CLASS.xlsx	results/cost_analysis/housing_cost_country.xlsx, housing_cost_summary.xlsx
_8_Triple_burden.ipynb	Classifies countries by combining normalized housing-demand pressure, hazard exposure, and fiscal incapacity into a composite "Triple Burden" index and ranking	Notebook 5 (housing_quality_results_validated.xlsx, hazard_analysis_results.xlsx), Notebook 7 output (see Known Issues), WB boundaries	results/triple_burden/triple_burden_composite_index.xlsx, 5 figures (.png/.pdf/.svg)

Folder Structure

Future_housing_needs/

└─ data_raw/

├─ WB_Official_Boundaries/ (Admin 0/1 boundaries, CLASS.xlsx, WDI indicator CSVs)

├─ CORESIDENCE/ (national & subnational household size)

├─ UN_Population_division/ (UN DESA household size/composition)

├─ SSP/ (SSP basic drivers, SSP urbanization)

├─ GEM/ (taxonomy/vulnerability mapping files, ADM1 shapefile, earthquake PGA raster)

- | └─ GHSL/ (population grids)
- | └─ WorldPop/ (SSP-consistent future population grids)
- | └─ STORM/ (tropical cyclone wind speed rasters)
- | └─ data_processed/
- | └─ HH_model/ (Notebook 1: trained model, robustness tests, offsets)
- | └─ HH_projections/ (Notebook 1: AHS + GDP projections, GeoPackage)
- | └─ HH_projections_FE_sensitivity/ (Notebook 1: between-effects sensitivity)
- | └─ GEM/ (Notebook 2: aggregated exposure/cost data)
- | └─ housing_stock/ (Notebook 3: 1km housing-unit rasters)
- | └─ GEE_heat/ (Notebook 4.1: indoor WBGT rasters)
- | └─ GEE_flood/ (Notebook 4.2: flood inundation rasters)
- | └─ hazard_masks/ (Notebook 4.3: binary hazard exposure masks)
- | └─ Raster/ (Notebook 5: cohort stock/expansion rasters)
- | └─ master_grid_template.tif, country_id_raster.tif, country_id_mapping.csv,
- | | region_id_raster.tif, region_map.pkl, admin1_id_raster.tif, admin1_id_mapping.csv,
- | | population_housing_baseline.csv, country_mask_1km.tif
- | └─ results/
- | └─ integrated_statistics/ (Notebook 5: housing quality & hazard analysis Excel outputs; checkpoints/)
- | └─ land_analysis/ (Notebook 5: greenfield land expansion Excel outputs)
- | └─ sensitivity_analysis/ (Notebook 5.1: consolidated sensitivity Excel outputs)
- | └─ integrated_figures/ (Notebook 6: global/regional/country figures; maps/)
- | └─ rasters/ (Notebook 6.1: GIS-ready map rasters)
- | └─ cost_analysis/ (Notebook 7: replacement cost / GDP-share Excel outputs)
- | └─ triple_burden/ (Notebook 8: composite index Excel + figures)

└─ script/

└─ _1_AHS_projection_and_validation.ipynb

└─ _2_GEM_subnational.ipynb

└─ _3_Population___Housing_Stock.ipynb

└─ _4_1_GEE_Collect_Heat_IndoorWGBT.ipynb

└─ _4_2_GEE_WRI_Aqueduct.ipynb

└─ _4_3_Multi-Hazard_data_cleanup.ipynb

└─ _5_Cohort_Model___Hazard_Analysis_subnational.ipynb

└─ _5_1_Sensitivity_Analysis.ipynb

└─ _6_Visualization_Figures.ipynb

└─ _6-1_Map_Export_for_GIS_Visualization.ipynb

└─ _7_Replacement_cost_analysis.ipynb

└─ _8_Triple_burden.ipynb