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Global Evidence since 1985

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Abstract

As countries rapidly urbanize, settlements are expanding into hazardous flood zones. This study provides a global analysis of spatial urbanization patterns and the evolution of flood exposure between 1985 and 2015. Using high-resolution annual data, it shows that settlements across the world grew by 85 percent to over 1.28 million square kilometers. In the same period, settlements exposed to the highest flood hazard level increased by 122 percent. In many regions, risky growth is outpacing safe growth, particularly in East Asia, where high-risk settlements have expanded 60 percent faster than safe ones. Developing countries are driving the recent growth of flood exposure: 36,500 square kilometers of settlements were built in the world's highest-risk zones since 1985–82 percent of which are in low- and middle-income countries. In comparison, recent growth in high-income countries has been relatively slow and safe. These results document a divergence in countries' exposure to flood hazards. Rather than adapting their exposure to climatic hazards, many countries are actively increasing their exposure.

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Rapid Urban Growth in Flood Zones: Global Evidence since 1985

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1. Introduction

Disaster losses are rising, and evidence is mounting that climate change is driving up the probability of extreme natural shocks[1,2,3,4]. Yet, it has also proven politically expedient to invoke climate change as an exogenous force that supposedly places disasters beyond the influence of local planners and authorities[5,6]. However, locally determined patterns of urbanization and spatial development are key factors to people's exposure and vulnerability to climatic shocks[7]. In this study we show that since 1985 human settlements around the world – from rural villages to large cities – have expanded continuously and rapidly into present flood zones. Globally, settlement growth in high-risk zones is outpacing growth in safe zones by a large margin. This provides systematic evidence that rather than adapting to increasingly frequent climatic shocks, countries around the world are actively increasing their exposure to flood hazards.

Around the world, urban populations are growing rapidly, as people from agricultural peripheral regions move into cities searching for economic opportunities. As a consequence, cities continue to grow, in terms of population and spatial footprint. Urbanization and economic development have traditionally gone hand in hand as cities enable agglomeration economies[8]; for instance, they enable matchmaking between employers and job seekers, sellers and buyers, and capital and projects; support expensive productivity-enhancing infrastructure such as public transport systems; and favor the circulation of ideas[9,10].

However, on the downside, rapid urban growth can cause congestion effects; for instance, by increasing exposure to natural hazards and pressure on public services and infrastructure. This is particularly relevant in developing countries, which often lack the capacity for comprehensive urban planning and implementation, and the financial resources to invest in transport and protection infrastructure. These challenges are often compounded by fast demographic growth and internal migration, which can mean that risk-informed urban and infrastructure planning cannot keep pace. Moreover, as safe spaces are increasingly occupied, the resulting land scarcity can drive new developments disproportionately into previously avoided areas such as riverbeds, flood plains, or wetlands (figure 1).

This study offers a systematic and global analysis of spatial urbanization patterns and their evolving exposure to flood hazards. It leverages the 2019 high resolution global flood hazard layers by Fathom and the World Settlement Footprint Evolution (WSF-Evo) data set, developed by the German Aerospace Center (DLR) in 2021, which offers high-precision measurements of yearly settlement extents from 1985 to 2015 at 30 by 30 meters spatial resolution and with global coverage (figure 2)[11]. These data allow us to track the speed and shape of urban expansion in large cities through to small rural settlements and estimate flood exposure with high precision, and therefore understand what share of countries' built-up land is exposed to high flood hazards and how this evolves over time. We show that settlements across the world grew by 85 percent between 1985 and 2015, from 693,000 to over 1.28 million square kilometers. In the same period, settlements exposed to the highest flood hazard level increased by 122 percent – thus highlighting that in many places, risky growth is outpacing safe growth.

Figure 1. River-side settlement expansion

(a) Quảng Nam, Vietnam, 2002 (left) and 2021 (right)

Cap-Haïtien, Haiti, 2010 (left) and 2021 (right)

Source: Google Earth

2. Existing evidence

When safe spaces are already occupied, new developments can disproportionately occur in previously avoided areas such as riverbeds, flood plains, or wetlands. When making locational decisions, households and businesses often trade off job accessibility and market potential with disaster risks, and settling in flood-prone areas can become a rational choice[12,13]. Behavioral biases, market failures, and information constraints can also exacerbate excessive risk taking[14,15,16], while inefficient land markets[17] can allow safe land to sit idle while risky areas are developed. Risk levels in urban development depend on geography, socioeconomic trends, and institutional and regulatory factors, such as planning restrictions.

Case study evidence illustrates these mechanisms. For example, in India, low-income households move to Mumbai from rural peripheral regions, searching for economic opportunities. The high density of settlements and land price differentials in the city force new arrivals into previously avoided areas, such as high-risk flood zones near riverbeds, and informal settlements grow without planning or public infrastructure[18]. Similarly, in Vietnam, a flood risk assessment for Ho Chi Minh City finds that informal poor settlements are systematically exposed to higher flood risks than the rest of the city[19], while evidence from the United States documents how, in recent decades, new construction on the Atlantic coast avoided flood-prone areas in sparse locations but took place in the 'least-bad' flood-prone areas in dense locations[20]. New Orleans, first established on higher lands, expanded into lower-lying flood plains as the port's growing role spurred economic activity[21].

The case of Vietnam illustrates the scale and dynamics of evolving flood exposure. Almost one-third of Vietnam's coastline is occupied by towns and built-up settlements, and its 28 coastal provinces are home to 46.6 million people[22]. With the safest and most productive locations already occupied, new developments are increasingly forced onto hazardous land and previously avoided areas that are further from regional hubs or more exposed to natural hazards. Risks are exacerbated when urban planning fails to prioritize densification of safe areas to avoid expanding into risky zones. Evidence from satellite-based nightlight imagery has confirmed that areas in Vietnam with high urban and economic growth face significantly higher flood risk than low-growth areas[22]. About 27 percent of areas with low urban and economic growth are estimated to be exposed to a 100-year flood, compared to some 50 percent of high-growth areas.

Despite the rising interplay between rapid urbanization trends and flood disasters, these risks are mostly documented in anecdotal evidence and case studies. Previous global flood risk assessments provide only limited evidence of the long-term evolution of global settlement expansion and flood exposure.

The lack of high-resolution flood hazard maps and annual settlement footprint data has been a key factor preventing systematic analysis of flood exposure trends over time. Although satellite imagery is now widely used to understand the spatial patterns of urban development across the world, most data sets only cover the most recent years. The Global Human Settlements Layers were seminal as they produced global urban footprints for four discrete time steps—1975, 1990, 2000, and 2014[23]; yet inaccuracies and large time gaps between observations limit the insights into the rapid dynamics of urbanization patterns.[24] Global settlement footprint data sets with high spatiotemporal resolution have become available recently, but have thus far not been used in global flood hazard assessments[25,26].

By using global historical inventories of recorded flood events, such as EM-DAT, studies have estimated exposure indicators at the country level[27]. Yet, the lack of data on the spatial distribution and coincidence of flood hazards and populations means that continuously evolving urban shapes cannot be taken into account accurately, thus making flood exposure difficult to compare over time[27,28,29]. Another study based on satellite data from 2000 to 2018 documents increasing flood exposure, but omits at-risk populations who were unaffected during the study period and events that were not detected by satellite observations[29].

Due to data limitations, past studies also focus on certain types of flood, rather than assessing the combined risks from all flood types (that is, fluvial, pluvial and coastal flooding)[30,31,32,33,34]. Others assess risks for a subset of countries only, falling short of full global coverage[35,36]. Similarly, studies that use relatively coarse spatial resolution flood hazard data tend to inaccurately represent major fluvial floodplains. They do not capture pluvial flood hazards and flooding along secondary rivers, drastically underestimating exposure [35,37,38]. One study using coarse flood data projected that the global number of flood-exposed people will reach 1.3 billion by 2050[3937] but a more recent high-resolution study showed that this threshold has already been exceeded by at least 39% in 2020[39]. This illustrates the importance of using high-resolution data to capture the highly localized nature of flood hazards and people's tendency to avoid settling in the most hazardous locations[355].

This study contributes to the literature in several ways: First, by considering flood exposure trends with annual frequency, we demonstrate the value of annual monitoring of evolving flood exposure. The study documents significant variation in year-on-year growth rates, thus highlighting the need for spatial planners to be highly responsive. Second, it explicitly distinguishes the growth dynamics of safe versus flood-exposed spatial development. This allows us to document a divergence in flood exposure – regions that are either increasing or decreasing their flood exposure as they urbanize over time. Third, rather than focusing on a certain flood hazard type, we combine different flood types (fluvial, pluvial, coastal floods) and assess overall flood exposure. Fourth, by using global data sets, we document trends with complete global coverage and within one consistent methodology. Finally, while past studies (both global and country-specific) have documented a general increase in flood exposure, this study corroborates and expands these findings based on data with high spatio-temporal resolution.

3. Data and methods

3.1. Global flood hazard and settlement data

Flood hazard data

To obtain complete estimates of urban exposure to flood hazards, this study considers the three most common flood types:

- *Fluvial flooding:* when intense or excessive precipitation or snow melt causes rivers to overflow
- *Pluvial flooding:* when surface water builds up beyond the absorptive capacity of soil, due to extended precipitation and insufficient drainage
- *Coastal flooding:* due to tidal or storm surges, or sea level rise.

Country-level pluvial and fluvial flood data are based on the 2019 global Fathom flood hazard data set[40,41]. These provide gridded information on flood extents and depths at a 3-arcsecond resolution (equivalent to 90 meters at the equator), simulating 5, 20, 50, 100, 250, and 500-year flood events, and are available for all countries. The maps are based on the DEM MERIT elevation model that corrects for multiple errors, including absolute bias, stripe noise, speckle noise, and tree and building height biases[42]. We consider flooding with a 100-year return period.

For coastal flood hazards, we use a global coastal flood map with 3-arcsecond resolution, generated using the LISFLOOD-FP hydrological model[43], with DEM MERIT as an input[42]. Coastal flood simulations are forced by extreme sea level scenarios derived from reanalyzing waves (using the WAVEWATCH-III mode[44]) and storm surges (using the DFLOW-FM model[31]), combined with tidal information[45,46]. As with fluvial and pluvial floods, we consider 100-year events.

Global flood maps do not incorporate the effects of artificial flood protection structures like dikes. This data limitation is pervasive in the literature, as there is no complete global inventory of flood defenses. Ongoing initiatives, such as the FLOPROS database, could eventually fulfill this need, but are still falling short of comprehensive coverage[47]. The use of undefended flood maps is likely to result in overestimating exposure in locations where flood protection systems defend against 100-year floods (or higher). Case studies and World Bank country risk assessments suggest that the vast majority of flood-exposed people in LICs and LMICs have no protection from a 100-year flood. Many LICs lack even basic drainage systems to manage light flooding. It is likely that only HICs and some UMICs offer such flood protection standards to a significant share of their populations; however, frequent flood disasters in these countries also demonstrate that coverage is far from complete.

This study considers a 1-in-100 year return flood intensity to reflect relatively rare and intense disasters. However, the concept of return periods is easily misunderstood and the probability underestimated. A 1-in-100 year flood has, on average, a 1 percent probability of occurrence in any given year, which translates to a 10 percent probability in a decade, or 50 percent in a lifetime (68 years). These are significant probabilities that lie well within government planning horizons. For comparison, the Dutch flood protection system protects against events up to 1-in-10,000 years. Further, these probabilities apply independently to any given river basin or microclimate (and we consider hundreds of thousands of locations for this study). This means that, globally, hundreds of 1-in-100 year flood events happen every year.

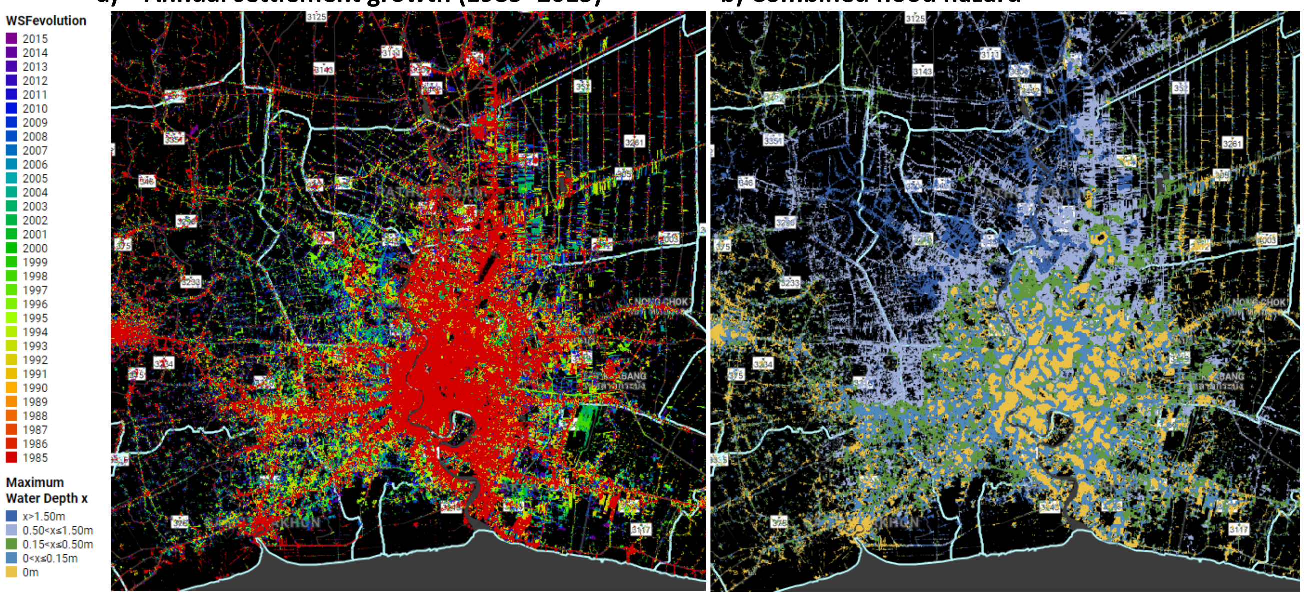
Global settlement footprint data since 1985

Considering the rapid urbanization patterns observed in the recent past, annual high-resolution settlement footprint data are crucial for monitoring the evolution of people's exposure to natural hazards. In this study, we use the WSF-Evo data set developed by DLR[11,48], which enables us to track the flood exposure of new urban development in cities and small rural settlements alike (figure 2). WSF-Evo outlines the global settlement extent from 1985 to 2015 on a yearly basis at about 30x30-meter resolution based on archived Landsat imagery[49]. For each year, we gather all available Landsat-5 and -7 scenes acquired over the given area of interest and extract key statistics—temporal mean, standard deviation, minimum, maximum—for different spectral indices after performing cloud and cloud-shadow masking. Among others, these include: the normalized difference built-up index (NDBI), normalized difference vegetation index (NDVI), and modified normalized difference water index (MNDWI). Temporal features prove generally robust if computed over at least 7 clear cloud-/cloud-shadow-free observations. Accordingly, if this constraint is not satisfied for a given pixel in the target year, we enlarge the time frame backwards (at 1-year steps) until the condition is met.

The 2015 edition of WSF-Evo, generated by jointly exploiting both optical (Landsat-8) and radar (Sentinel-1) multitemporal satellite imagery, outlines the global settlement extent at 10x10-meter resolution.[50] Starting backwards from 2015 (using the WSF2015 as a reference), we iteratively extract settlement and non-settlement training samples for the given target year *t* by applying morphological filtering to the settlement mask derived for the year *t*+1, excluding potentially mislabeled samples by adaptively thresholding the temporal mean NDBI, MNDWI and NDVI. Based on the assumption that settlement growth occurred over time, we also disregard all pixels categorized as non-settlement in the WSF2015 from the analysis.

Figure 2. Settlement growth and flood exposure in Bangkok, Thailand, 1985–2015

a) Annual settlement growth (1985–2015) **b) Combined flood hazard**



Source: authors based on WSF-Evo and Fathom Global datasets

Administrative boundaries

Our definition of national and subnational boundaries follows the standard World Bank global administrative map. Overall, this study covers 225 countries and territories, which are disaggregated into 3,307 subnational units. Our country groupings are also in line with World Bank definitions of geographical regions and income groups.

3.2. Step-wise computation of settlement exposure

Overlaying annual urbanization and flood hazard data

This study estimates the share of the world's urbanized land that is exposed to high flood hazard levels, and assesses how this exposure is evolving over time. Using high-resolution global data sets for flood hazards and settlement extents allows us to conduct this analysis for 225 countries and territories, disaggregated into 3,307 subnational units. This represents all the world population, except those living in disputed territories. The results presented here are derived through a computational workflow that processes large quantities of spatial data, which we can simplify into the following analytical steps:

- **Step 1.** We identify built-up areas using the WSF-Evo data set, which categorizes each 30 by 30-meter resolution pixel as settlement or non-settlement on a yearly basis from 1985 to 2015.

- **Step 2.** We assign each settlement pixel to one of the five considered flood hazard categories defined in line with risk to lives and livelihoods (table 1). We repeat this step for all the world's settlements and each year.
- **Step 3.** On a yearly basis, we compute the total settlement area per flood hazard category for each subnational administrative unit (such as state or province) and calculate its share relative to the corresponding overall settlement area. To address possible limitations of settlement over/under-estimation due to poor Landsat-5 data availability before 2000 in some parts of the world, we apply SPM (see above). To obtain wider trends, we further aggregate exposure estimates to national and regional levels and compute the long-term trends of settlement exposure to flood hazards.

Table 1. Flood hazard categorization applied in this study

Category	Hazard class	Flood depth (meters)	Description
0	None	0	Unaffected during a 1-in-100 year flood
1	Low	0 – 0.15	No significant risk to life or economic activity
2	Moderate	0.15 – 0.5	Disruptions to livelihoods and economic activity; some risk to life for select populations, especially vulnerable groups such as children and disabled people (including through water-borne diseases)
3	High	0.5 – 1.5	A significant share of the affected population is expected to face risk to life, especially if flood waters have a current; major disruptions to livelihoods
4	Very high	Over 1.5	Most affected people could face substantial risk to life and severe and prolonged disruptions to livelihoods

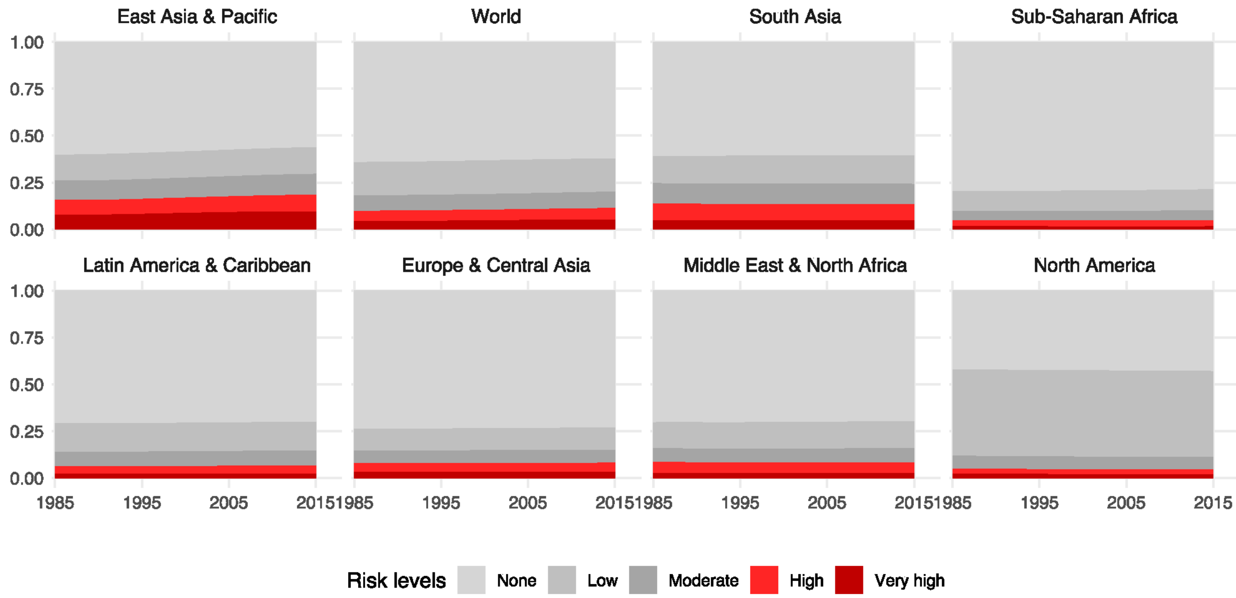
4. Results

4.1. Substantial flood hazard exposure in all regions

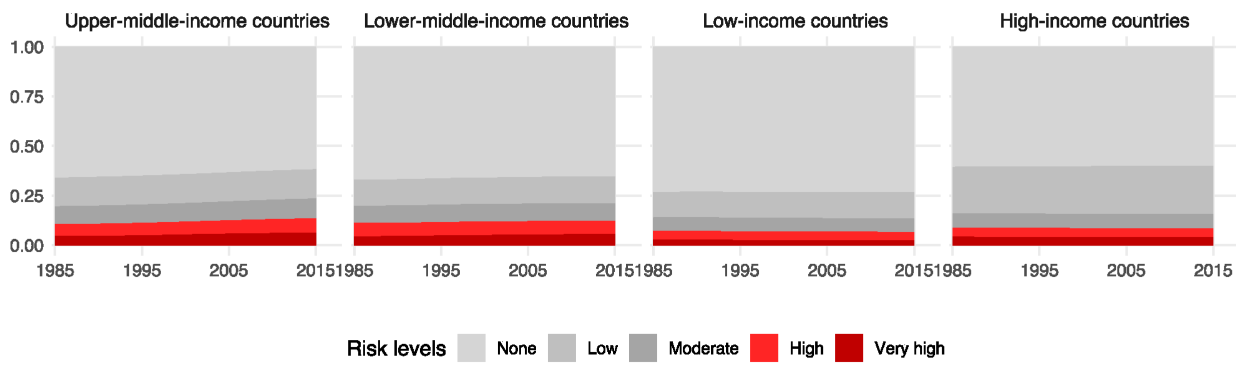
Estimates from this study show that in 2015, at least 11.3 percent of all built-up areas globally face high or very high flood hazards; i.e. inundation depths of at least 50 cm during 1-in-100 year flood events (figure 3). Exposure is lowest in Sub-Saharan Africa (4.6 percent) and North America (4.5 percent), and highest in the East Asia and Pacific region (18.4 percent). These figures confirm that flood exposure levels are substantial across all global regions and income groups. While the normalized shares of exposed settlements (Figure 3) illustrate the relative proportions of safe and at-risk settlements over time, they hide that total settlement extents have expanded significantly in the considered period. This is assessed further in the following.

Figure 3. Share of settlements by flood hazard level

a) By region, settlement extent, normalized



b) By income group, settlement extent, normalized



4.2. Around the world urbanization is more rapid in flood-prone areas

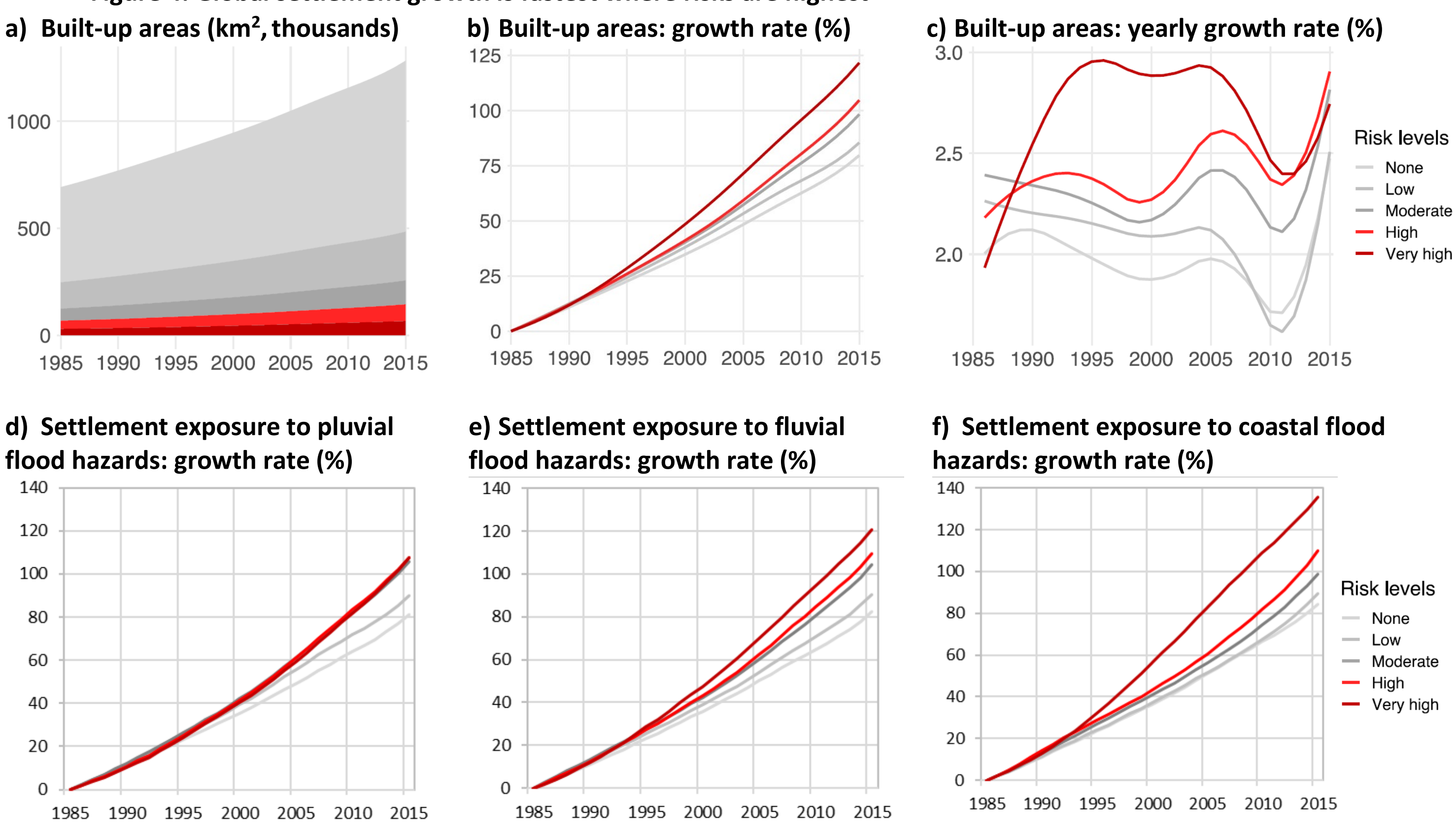
Between 1985 and 2015, the world's built-up settlements grew by 85 percent, from 693,000 to over 1.28 million square kilometers. This confirms growth rates from related studies focused on urban expansion.[51] At the same time, the share of settlements in safe areas dropped by 1.9 percentage points and the share in higher-risk categories increased (table 2). In 2015, 20 percent of all settlement areas were in zones with medium or higher flood risk, up from 17.9 percent in 1985. The share in the highest-risk category has grown most—from 4.3 to 5.2 percent. Of the land that has been built up since 1985, more than 36,500 square kilometers faces inundation depths of over 1.5 meters during severe flood events, and 76,443 square kilometers are exposed to inundation over 0.5 meters.

Table 2. Changing flood exposure in the world's built-up areas

	Share (%) of global settlements facing… *(inundation depth during 100 year flood)*					Extent of global settlement *(km², millions)*
	…no risk *(0 m)*	…low risk *(< 0.15 m)*	…medium risk *(< 0.5 m)*	…high risk *(< 1.5 m)*	…very high risk *(> 1.5 m)*	
1985	64.2	17.8	8.1	5.5	4.3	0.69
2015	62.3	17.8	8.7	6.1	5.2	1.28
Change	-1.9	0	0.6	0.6	0.9	0.59

Our results show that settlement expansion in high-risk flood zones outpaces growth in safe areas. While the world's overall settlement extent has increased by 85.4 percent in the considered time period, settlements with at least moderate flood hazard exposure have grown by 105.8 percent, and those exposed to the highest flood hazard level by 121.6 percent (figure 4b). Year-on-year growth confirms that since the early 1990s, settlement growth in the highest-risk category has increased by almost 3 percent a year, consistently outpacing safe growth (figure 4c). A temporary slowdown in settlement expansion is discernable in 2007–2010, coinciding with the global financial crisis and recession. Flood-exposed settlement growth is outpacing safe growth regardless of which flood type is considered, though exposure to coastal floods is growing most rapidly (figures 4d, e, f).

Figure 4. Global settlement growth is fastest where risks are highest



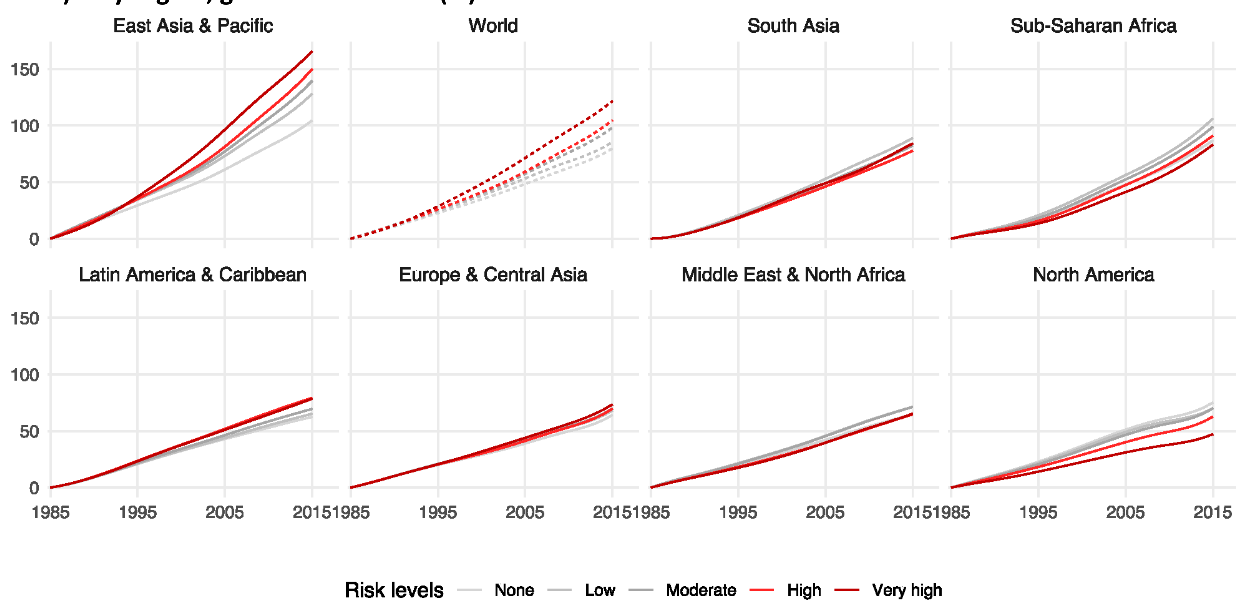
4.3. East Asia has the highest regional increase in exposure

While global trends offer a high-level perspective on urbanization and flood exposure, regional dynamics display stark differences. East Asia & Pacific stands out as the region with the highest urban growth rate and the largest proportion of settlements in the highest flood risk category (inundation depth over 1.5 meters). Between 1985 and 2015, "no risk" settlements expanded by just over 100 percent, while "very high risk" settlements expanded by over 160 percent (figure 5). In other regions, urban expansion has been slower. In Sub-Saharan Africa and South Asia, settlement growth is close to 100 percent, while in Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, and North America it is around 60 percent.

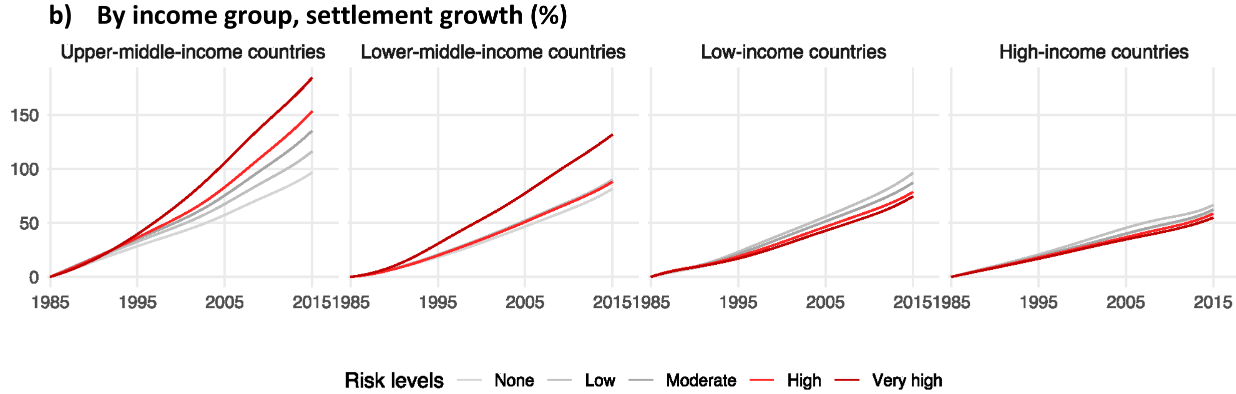
Risky growth is outpacing safe growth in Latin America and the Caribbean, Europe and Central Asia, and East Asia & Pacific, whereas in Sub-Saharan Africa, North America, and Middle East and North Africa, the opposite is true (figure 5). In North America, safe settlements expanded by 75 percent, compared to 49 percent in the highest-risk zones. However, even in these regions, settlements in (very) high-risk flood zones have continued to expand, exposing an ever-growing number of people and assets to flood hazards.

Figure 5. Settlement growth by hazard level

a) By region, growth since 1985 (%)



b) By income group, settlement growth (%)

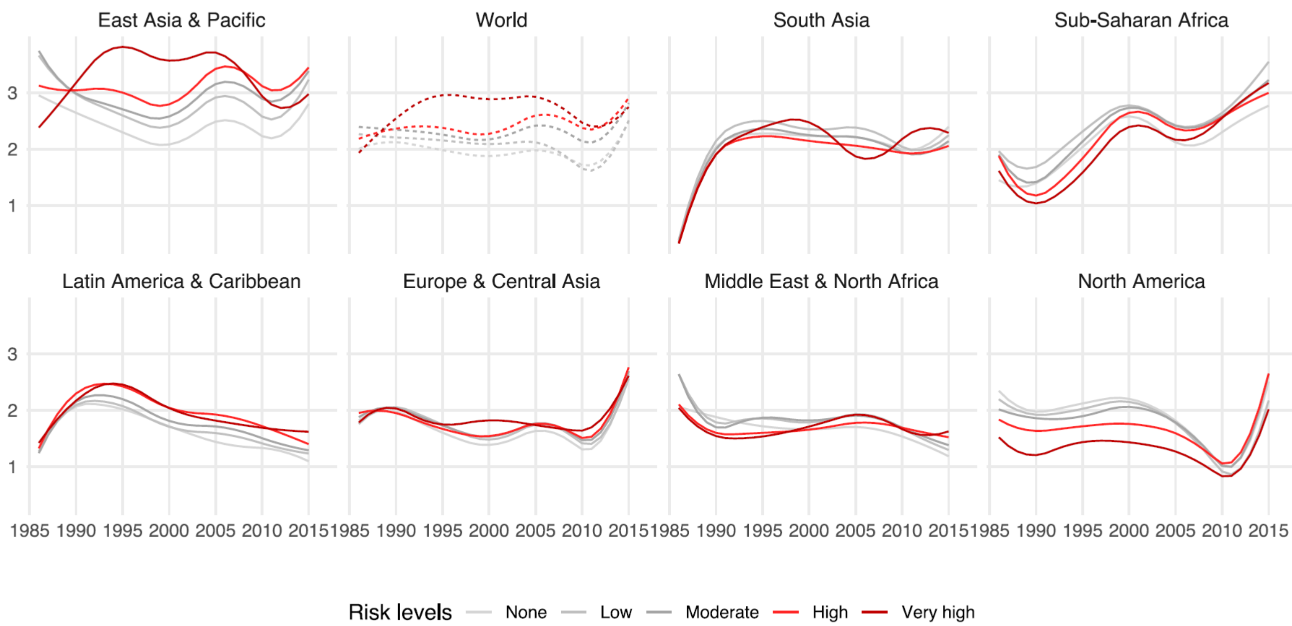


Note: Charts are sorted from fastest to slowest high risk growth.

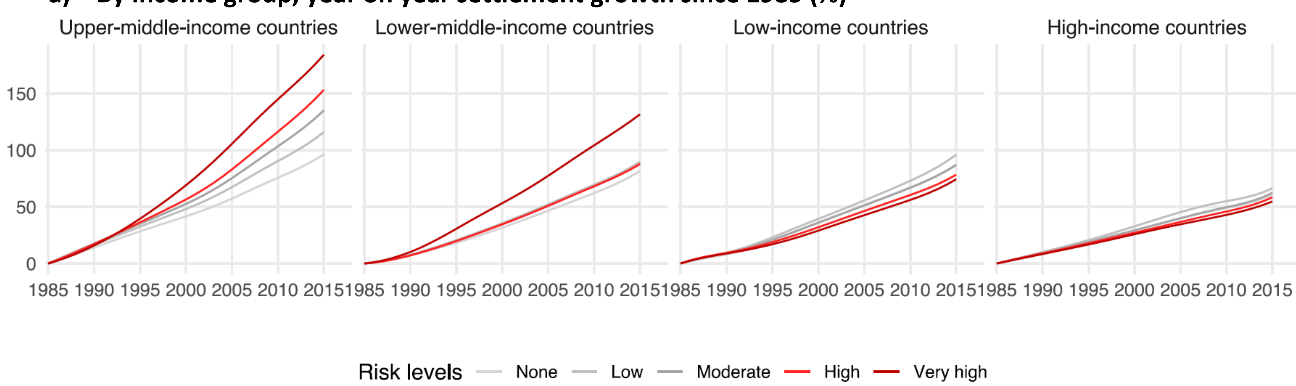
Regionally disaggregated year-on-year growth rates show that settlement expansion is neither steady nor linear. Rather, it fluctuates, apparently driven by a range of factors, including economic fundamentals (Figure 6). In East Asia & Pacific, yearly growth rates have been consistently high at around 2.5 percent; high-risk expansion is particularly high between the early 1990s and 2010, at almost 4 percent. South Asia, Europe and Central Asia, Middle East and North Africa, and North America have maintained relatively steady settlement expansion of around 1.5 to 2 percent for most of the observed period. Latin America & Caribbean is the only region in which settlement growth is continuously decelerating, dropping from around 2 to 1 percent. Meanwhile, in Sub-Saharan Africa, urban growth rates have accelerated continuously, reaching 3 percent in 2014 to match the East Asia & Pacific rates.

Figure 6. Year on year settlement growth (%)

a) By region, year on year settlement growth since 1985 (%)



a) By income group, year on year settlement growth since 1985 (%)



4.4. Middle-income countries display rapid and risky growth

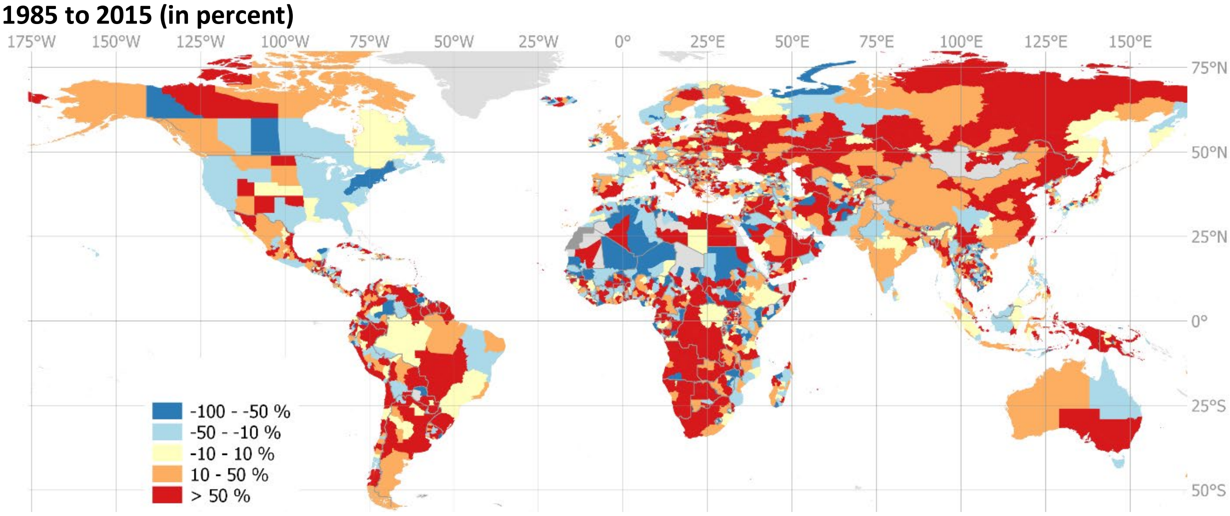
Disaggregating results by country income groupings offers a clearer overview of urbanization and flood risk patterns at different levels of economic development (figure 5). Globally, about 36,500 square kilometers of settlements have been built in the highest-risk zones since 1985. Our results show that only

1.1 percent of these are in low-income countries (LICs); 20.5 percent are in lower-middle-income countries (LMICs); 60.8 percent are in upper-middle-income countries (UMICs); and 17.6 percent are in high-income countries (HICs). Specifically:

- **MICs** have seen the fastest urban growth since 1985, hosting 72 percent of the world's 144,632 square kilometers of built-up areas in high-risk flood zones in 2015. On average, growth in high-risk flood zones is outpacing growth in safe zones by large margins (figure 5b). In **LMICs**, settlement in the highest-risk areas has expanded by 132 percent since 1985, compared to 86 percent of overall settlement expansion. With rapid economic and demographic growth taking place in many of these countries, expanding settlements in high-risk areas locks flood risks into new developments and urban forms, as well as future losses and the need for mounting flood protection investments. **UMICs** have a higher proportion of settlements in the highest-risk areas than any other group. Since 1985, these have grown by 184 percent—nearly twice the rate of safe settlements (96 percent).
- Compared to countries in other income groups, **LICs** have seen moderate settlement growth since 1985. The difference in growth in safe (87 percent) and high or very high-risk areas (77 percent) is less pronounced than in MICs. Notably, on average, settlement growth in high-risk areas has not outpaced safe growth.
- With the slowest urban expansion rate, settlement areas in **HICs** have grown by about 62 percent. This lower growth rate can be linked to comparably slow economic and population growth rates, though many HICs experienced periods of rapid urban expansion before 1985. As in LICs, on average, urban growth in safe areas has been faster than in high-risk ones (figure 5b).

Overall, these results suggest a divergence in countries' exposure to flood hazards. While safe growth dominates in some countries, others are actively increasing their relative exposure to flood hazards. Sub-nationally disaggregated results show that this divergence is also occurring within countries across all regions (Figure 7).

Figure 7. Safe vs risky growth: Relative difference between settlement growth in safe and high risk areas 1985 to 2015 (in percent)



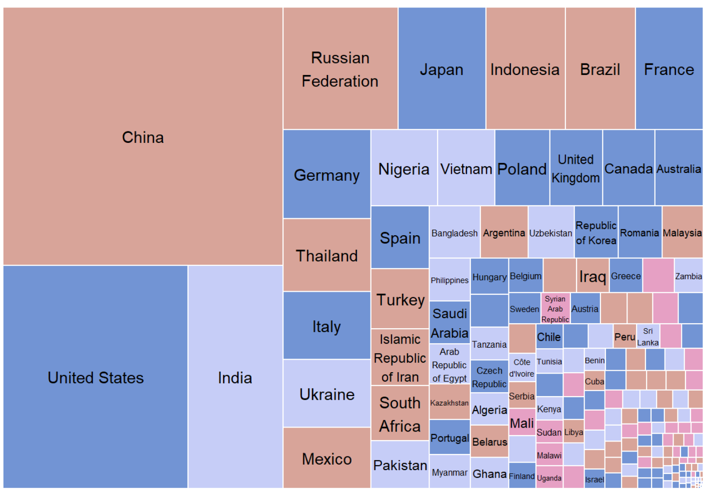
Note: In red areas, the share of flood exposed settlements is increasing – i.e. settlements in high risk flood zones have expanded at least 50 percent more than settlements in safe areas. In blue areas, flood exposure is decreasing.

4.5. Rapid settlement growth in China contributes to global trends, but exposure is also high in high-income countries

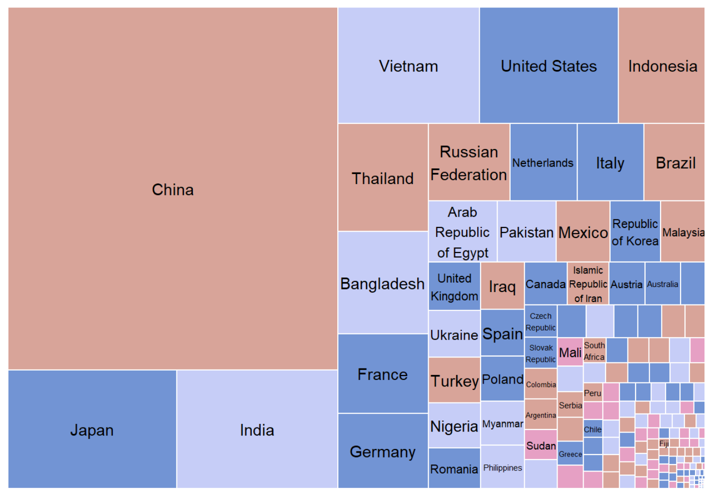
The substantial increase in flood exposure in UMICs is driven by settlement expansion in China. Our estimates show that, between 1985 and 2015, built-up areas in China increased by 165 percent and people's exposure to flood risks also increased, with settlements in the highest flood hazard category growing by 223 percent. Country-specific studies have already documented this trend, with Fang et al. finding a rapid increase in flood exposure, especially around major metropolitan areas in the North-East and coastal regions[52], and Ying et al. finding that climate change may further exacerbate these flood hazards[53].

Figure 8. Proportional representation of settlement extent

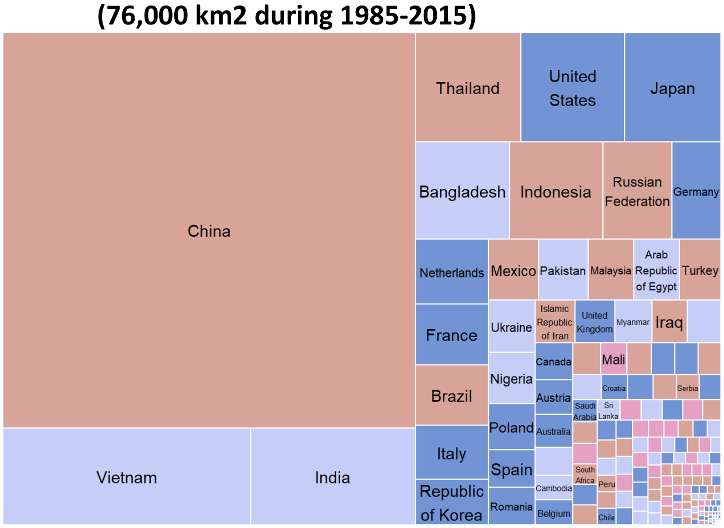
a) Global settlement (1.3 million km^2 in 2015)



b) Settlement extent in high risk flood areas (144,600 km^2 in 2015)



c) New settlement extent in high risk flood areas (76,000 km2 during 1985-2015)



Low income
Lower middle income
Upper middle income
High income

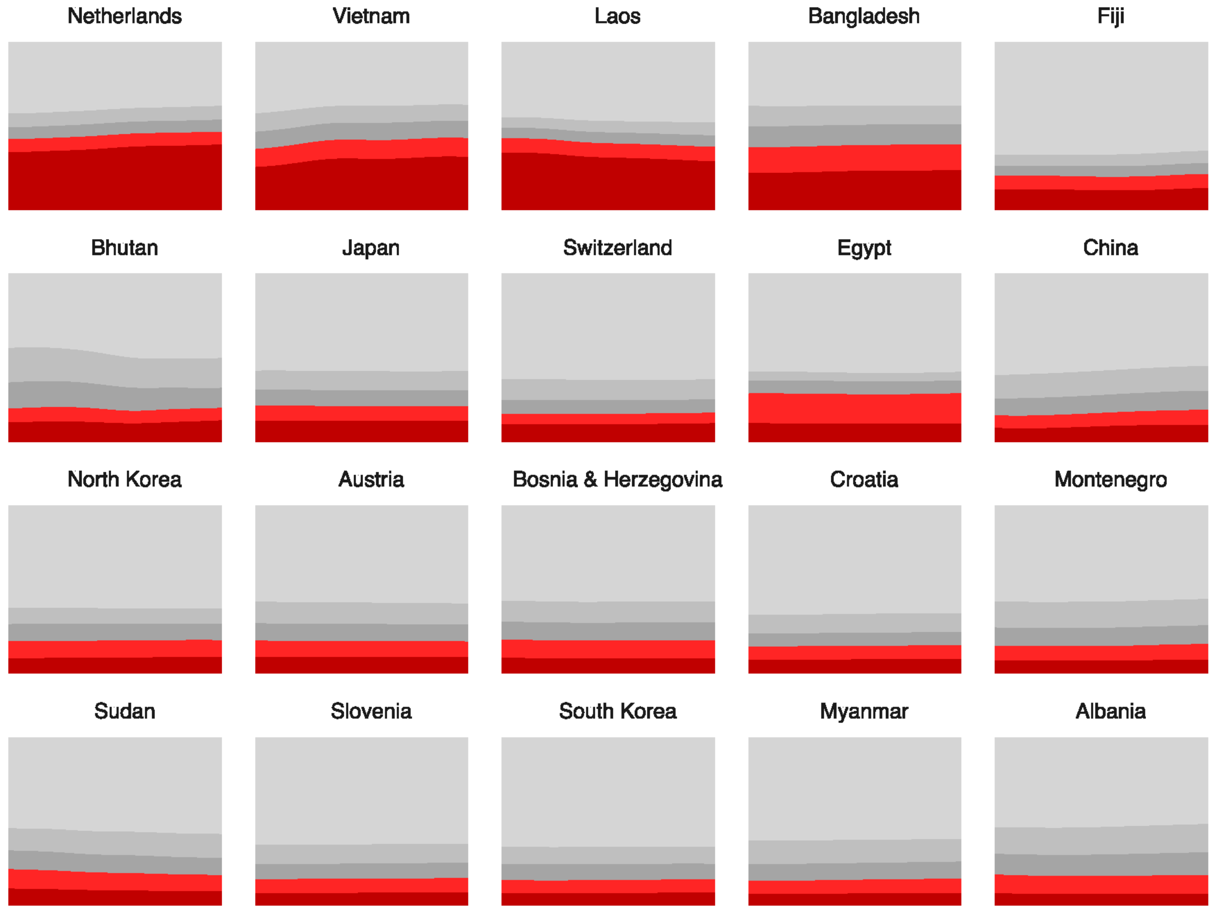
With larger settlement areas than any other country (figure 8a), China contributes significantly to the trends observed for both MICs and East Asia & Pacific. With 46 percent of the world's 76,400 square kilometers of new high-risk settlements within its borders, China is the largest contributor to the global expansion of high-risk settlement. Vietnam and Bangladesh also stand out as LMICs with large settlement areas exposed to the highest flood hazard category (figure 8b).

Several HICs have large settlement areas in high-risk flood zones (figure 8b). While they have seen relatively slow and safe growth in the past 30 years, many HICs, including Japan, the United States, and the Netherlands, already had a significant number of at-risk settlements in 1985 and have invested heavily in protecting them. In the latter, sea dikes protect against up to 1-in-10,000-year storm surges. Nevertheless, even in HICs, many settlements are not protected from the 1-in-100-year flood hazards considered in this study. Recent flooding disasters—in the United States, United Kingdom, Belgium, Germany, and other countries—illustrate that flood hazards continue to pose substantial risks to lives, livelihoods, and assets.

4.6. Some European and Asian countries face disproportionately high exposure

Considering the share of high-risk settlements relative to overall settlements can help us identify smaller countries that face disproportionately high exposure. In three-quarters of all countries, 4 percent or less of overall settlements are estimated to be high-risk, but in several countries, exposure shares are significantly higher. Figure 9 presents the top 20 countries in terms of flood-exposed settlement shares. In the Netherlands, over 35 percent of all settlements are in high-risk zones in terms of hydrology and elevation, though these risks are mitigated through advanced (but not infallible) protection infrastructure. The same is not true in most developing countries, such as the Lao People’s Democratic Republic (34 percent) and Vietnam (25.4 percent), where many settlements are highly exposed without strong protection systems. Flood exposure is particularly high for countries where settlements concentrate along river valleys and basins (for example, Bhutan, the Arab Republic of Egypt, and Bangladesh), and coastal areas (such as Fiji and Vietnam).

Figure 9. Top 20 countries in terms of settlement area by flood hazard level



Note: Countries are ranked by share of 'very high' risk; showing the evolution of share from 1985 to 2015. Countries with populations under 100,000 are omitted.

5. Robustness of estimates

Sensitivity of results to inundation depth thresholds

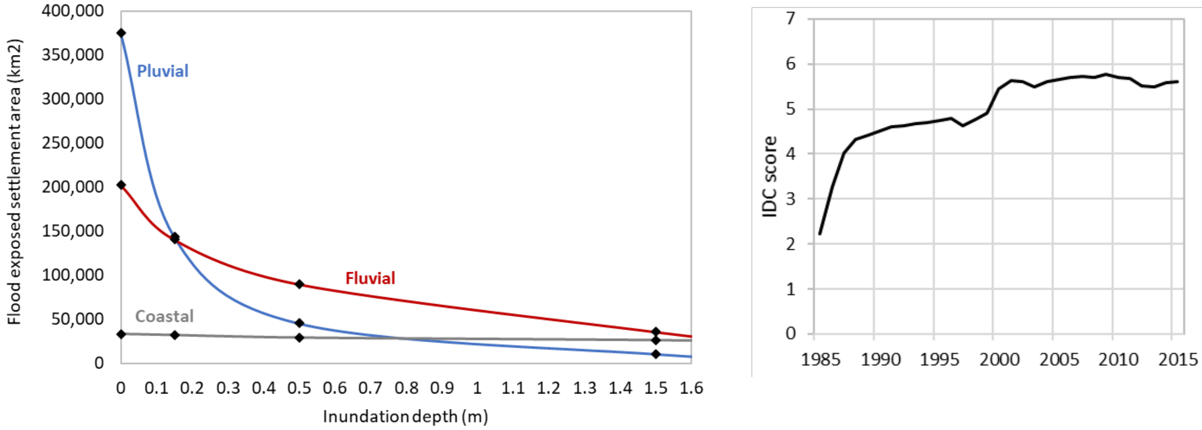
The absolute settlement flood exposure estimates in this study are sensitive to the choice of inundation depth thresholds (table 1). Results presented in this study focus in particular on inundation depths over 0.5 meter, thus highlighting areas with high impact floods. However, there is evidence that flood depths of just 0.15 meter can already cause significant disruptions to economic activity and livelihoods.[30] A sensitivity analysis conducted for this study shows how reducing the depth threshold changes the total exposed settlement area (Figure 10a). In line with past studies, we find that pluvial floods are more sensitive to the choice of threshold, and especially so at low inundation depths.

In relative terms, this study shows that flood-exposed settlement growth is faster than safe growth. Figure 4 has shown that this finding is robust to considering combined flood hazards, or pluvial, fluvial and coastal floods individually. Year-on-year growth rates (Figure 4) demonstrate that this trend is also consistent across time. In short, the relative speed of settlement growth in high-risk and safe areas is robust across flood types, time and inundation depth thresholds.

Figure 10. Sensitivity and robustness of estimates

a) Flood exposed settlement area for different inundation depth thresholds

b) Input data consistency (IDC) score



Input data consistency of WSF-Evo

To assess the accuracy of the data set, we conduct an extensive validation exercise by crowdsourcing photointerpretation of high-resolution airborne and satellite historical imagery, with the support of Google. For this purpose, we define a statistically robust and transparent protocol: For 1990, 1995, 2000, 2005, 2010 and 2015, we label about 200,000 30x30-meter reference cells distributed over 100 sites around the world, summing up to about 1.2 million validation samples overall. Results confirm that WSF-Evo displays high levels of accuracy relative to other global settlement layers – in particular GHSL, GISA, GAIA, and GAUD – thus suggesting that WSF-Evo is well suited for tracking settlement trends in both urban and rural areas.

Availability of Landsat-5/7 imagery considerably varies across the world and over time. Independently from the implemented approach, this may result in inaccuracy of settlement outlines where we collect few or no scenes. Accordingly, to measure the goodness of the Landsat imagery, we generate an Input Data Consistency (IDC) Score, where 6 = very good; 5 = good; 4 = fair; 3 = moderate; 2 = low; and 1 = very low. The IDC Score is defined as:

$$IDC\ Score = 7 - \min\{[(8 - \min\{\#clearObs, 7\}) \cdot \min\{6, (\#timeFrame)\}], 6\}$$

where $\#clearObs$ represents the number of available clear observations per pixel and $\#timeFrame$ the corresponding time frame in number of years. Figure 10b displays the IDC score for the global data set.

To overcome possible drawbacks from settlement over/under-estimation due to limited Landsat data availability before 2000, we apply Shape Prescriptive Modeling (SPM)[54] to the temporal settlement extent profile computed for each subnational unit. SPM allows the model choice and its mathematical form to be driven by an understanding of the underlying process—for example, exhibiting a monotonically decreasing trend or requiring the curve to pass through a given data point. By transforming prior knowledge into a constraint in the modeling function, SPM avoids overfitting. The more we know about a physical phenomenon, the more accurate the functional form will be. In our analysis, we implement SPM to model the settlement extent using least square cubic splines, which offer high flexibility in building a curve. Specifically, the method enables us to: i) force monotone increasing, as the WSF-Evo has been generated assuming settlement growth; and ii) perform a weighted minimization based on the average IDC Score, which increases trust in the items corresponding to years with higher data availability. Overall, we use SPM to model the temporal profile of the settlement of each subnational unit for the five hazard classes and four flood hazards (i.e. pluvial, fluvial, coastal, and combined), summing up to more than 66,000 curves.

Relative accuracy of WSF-Evo (Kappa coefficients)

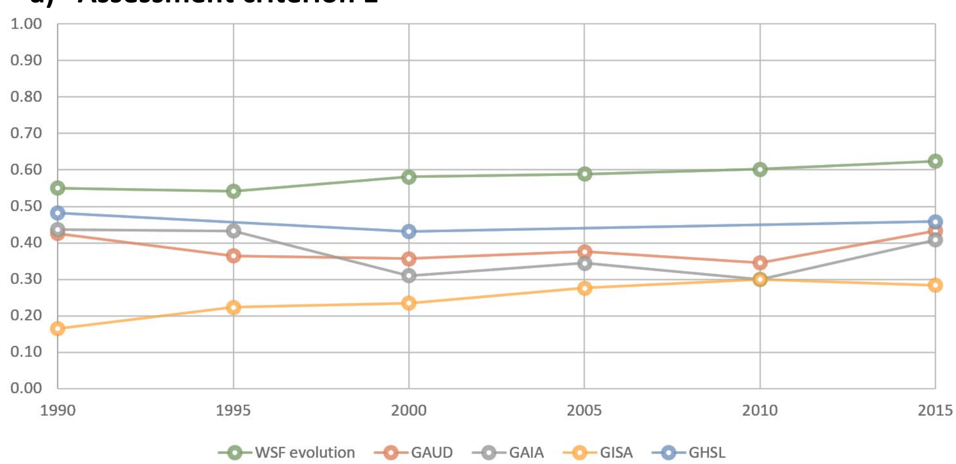
Figure 11. presents the kappa coefficients for the WSF-evolution data set used in this study, as well as the key comparator layers GAUD, GAIA, GISA and GHSL. For the purpose of comparison, we define settlements as the combination of buildings and building lots. We define blocks of 3-by-3 grid cells as the spatial assessment unit, thus yielding units of 9 cells with 30-by-30 meter size each. For 1990, 1995, 2000, 2005, 2010 and 2015, we label about 200,000 30x30-meter reference cells distributed over 100 sites around the world, summing up to about 1.2 million validation samples overall. We then evaluate the kappa coefficient for three separate assessment criteria:

1. **Criterion 1:** For each cell, positive agreement occurs only for matching labels between the classification and the reference;
2. **Criterion 2:** For each block, a majority rule is applied over the entire 3-by-3 block of both the classification and the reference; if the final labels match, then the agreement is positive;
3. **Criterion 3:** Each block is labeled as *settlement only*, if it contains at least one cell marked as settlement; if the final labels match, then the agreement is positive.

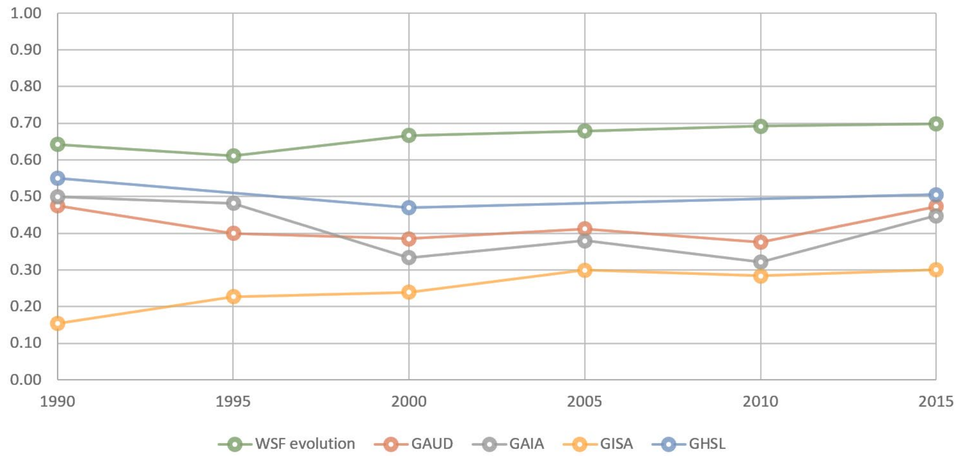
Kappa coefficients for WSF-Evo are consistently higher than comparator layers across all years and all three assessment criteria. For assessment criteria 1 and 2, kappa coefficients for WSF-Evo increase over time. For Criterion 3, WSF-Evo exhibits a steady Kappa of 0.8 on average. This means that wherever the WSF-Evo settlement data is positive, there is a high likelihood that within the reference block there is a pixel belonging to the settlement class. This suggests that WSF-Evo is well suited for detecting built-up areas not only in urban regions, but also in less densely settled rural regions.

Figure 11. Kappa coefficients for WSF-Evo and comparator layers

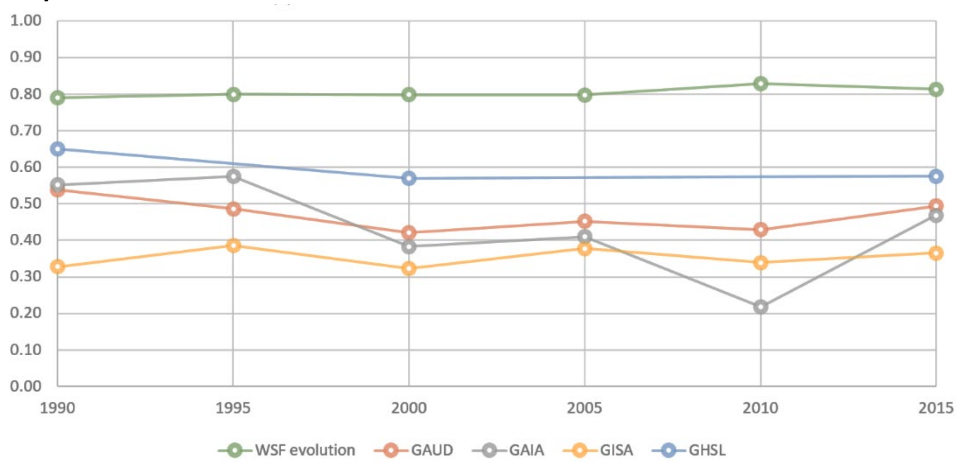
a) Assessment criterion 1



b) Assessment criterion 2



c) Assessment criterion 3



6. Discussion

Intensifying natural hazards due to climate change are forcing countries to step up action on adaptation. Yet, tracking countries' success in adapting to evolving climate risks has proven difficult.[55] Besides the changing climate, people's exposure to climate hazards is also driven by spatial development choices. Demographic and economic growth is accompanied by migration from rural to urban areas, resulting in new neighborhoods and industrial zones springing up, expanding cities, towns, and settlements – often in areas with heightened risk.

The results presented in this study document a divergence in countries' exposure to flood hazards. Rather than adapting their exposure to climatic hazards, many countries are actively increasing their exposure. While growth is shown to be relatively safe in HICs, risky growth is especially rapid in MICs. Driven by their rapidly growing economies and urban centers, settlement growth in high-risk zones is outpacing growth in safe areas. Without risk-informed spatial planning, LICs risk following the same trajectory of high-risk growth.

Globally, this study shows that overall settlements expanded by 85 percent between 1985 and 2015 on average, while those exposed to the highest flood hazard level increased by 122 percent. These differences suggest the influence of a host of underlying causes for the increasing flood exposure of urbanization, including geographic and climatic features, socioeconomic trends, planning practices, and institutions.

These findings carry concrete implications for urban planners and policy makers. In areas, where flood exposure is already high, investments in disaster preparedness and protection are crucial to mitigate losses; for instance, through early warning systems, evacuation protocols, insurance, social protection, and retrofitting of infrastructure. In areas, where flood exposure is still low but increasing rapidly, revision of land use and urbanization plans will be essential, along with reviewing and reforming risk-informed building codes and infrastructure masterplans. While land scarcity and geographic constraints may mean that settling in flood zones cannot always be avoided, this necessitates careful planning of flood protection systems and disaster preparedness measures to enable resilient socio-economic development.

In an age of increasing disaster losses due to flood events, effective flood risk mitigation efforts must be based on a robust understanding of the different contributing factors to flood risk. These can include intensifying hazards (for instance, due to climate change), increasing exposure to hazards (due to expanding at-risk settlements), and rising vulnerability to shocks (for instance, due to inadequate building standards or social protection systems). This study shows with high geographic granularity that rising exposure is key to understanding the global rise in flood disaster losses.

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Economy-level summary statistics

This table provides an economy-level breakdown of results. Results show total built-up areas, i.e. settlement extent (SE). Safe SE refers to areas that are not estimated to experience any flooding during a 1-in-100 year flood event. High risk (or very high) SE denotes areas that are estimated to experience inundation depths over 0.5 meters (or 1.5 meters) during a 1-in-100 year flood event.

	Total SE			**Safe SE**			**High risk SE**			**Very high risk SE**		
	1985 *(km^2)*	**2015** *(km^2)*	**Change** *(%)*	**1985** *(km^2)*	**2015** *(km^2)*	**Change** *(km^2)*	**1985** *(km^2)*	**2015** *(km^2)*	**Change** *(%)*	**1985** *(km^2)*	**2015** *(km^2)*	**Change** *(%)*
World	**692,629.5**	**1,284,036.0**	**85.4**	**445,001.8**	**799,493.3**	**79.7**	**68,188.8**	**144,631.7**	**112.1**	**29,999.2**	**66,477.0**	**121.6**
China	100,806.6	270,440.2	168.3	61,190.2	148,952.5	143.4	15,708.7	50,693.3	222.7	8,142.7	26,561.6	226.2
United States	90,361.7	155,721.3	72.3	36,571.5	64,527.7	76.4	4,412.8	6,847.3	55.2	2,026.4	2,963.4	46.2
India	43,901.1	80,726.0	83.9	28,195.3	51,973.4	84.3	4,744.7	8,183.0	72.5	1,401.5	2,330.3	66.3
Russia	29,108.3	53,714.5	84.5	23,687.9	42,954.0	81.3	1,267.4	2,714.2	114.2	445.7	970.0	117.7
Japan	29,532.2	41,020.1	38.9	17,114.1	23,848.0	39.3	6,266.9	8,551.0	36.4	3,661.1	4,938.6	34.9
Indonesia	22,117.9	37,149.1	68.0	12,777.0	21,536.3	68.6	2,495.1	4,466.8	79.0	719.0	1,375.9	91.4
Brazil	19,086.4	32,750.4	71.6	15,865.2	26,979.9	70.1	1,170.7	2,125.2	81.5	513.1	913.9	78.1
France	19,859.8	31,061.5	56.4	14,758.9	23,347.5	58.2	2,116.5	3,069.3	45.0	1,068.7	1,540.7	44.2
Germany	19,694.6	29,890.3	51.8	14,199.7	21,578.2	52.0	1,883.4	2,925.6	55.3	751.8	1,225.6	63.0
Thailand	12,256.3	24,488.4	99.8	7,184.6	13,215.8	83.9	1,711.4	4,205.5	145.7	552.6	1,310.0	137.1
Italy	15,486.0	22,907.1	47.9	9,995.7	14,381.4	43.9	1,374.4	2,225.8	61.9	506.9	839.6	65.6
Ukraine	13,014.2	22,695.5	74.4	10,935.3	18,749.2	71.5	516.4	1,046.0	102.6	181.9	385.7	112.0
Mexico	12,001.6	20,591.8	71.6	7,272.7	12,332.8	69.6	758.2	1,417.8	87.0	204.3	380.5	86.3
Nigeria	9,401.2	19,321.1	105.5	7,235.8	14,772.0	104.2	499.7	1,020.3	104.2	134.0	278.4	107.7
Vietnam	5,251.4	16,617.8	216.4	2,241.2	6,239.1	178.4	1,895.4	7,077.9	273.4	1,332.5	5,189.9	289.5
Poland	8,154.2	15,924.4	95.3	6,462.5	12,410.4	92.0	385.4	853.1	121.3	79.0	185.6	134.9
UK	10,522.4	15,222.0	44.7	8,648.3	12,412.5	43.5	720.2	1,081.2	50.1	275.6	421.9	53.1
Canada	9,223.9	15,132.8	64.1	5,369.5	8,948.2	66.7	490.7	791.2	61.2	186.0	294.5	58.4
Australia	9,227.6	14,132.4	53.2	7,615.8	11,500.4	51.0	396.9	664.8	67.5	133.8	221.2	65.3
Spain	8,396.7	13,960.7	66.3	6,540.3	10,705.7	63.7	494.6	876.9	77.3	189.5	334.0	76.3
Turkey	6,884.9	13,408.1	94.7	4,569.0	8,702.1	90.5	474.3	1,021.2	115.3	142.4	294.0	106.5
Iran	7,258.2	12,657.9	74.4	4,187.1	7,265.7	73.5	405.9	773.5	90.6	147.8	276.2	86.9
South Africa	7,619.6	12,279.3	61.2	6,428.2	10,297.8	60.2	135.4	246.0	81.7	35.7	74.5	108.8
Pakistan	5,936.9	10,567.3	78.0	3,245.8	5,728.8	76.5	894.6	1,548.1	73.1	131.2	247.8	88.9
Bangladesh	5,362.0	10,217.4	90.6	2,051.0	3,878.1	89.1	1,994.3	3,985.1	99.8	1,173.4	2,392.2	103.9
Argentina	6,209.5	9,441.9	52.1	3,879.3	5,749.4	48.2	234.9	429.9	83.0	37.6	72.3	92.1
Uzbekistan	5,719.1	9,292.7	62.5	3,671.8	5,860.2	59.6	249.0	403.6	62.1	44.7	73.3	63.9
Korea, Rep.	4,112.0	8,777.8	113.5	2,685.1	5,754.3	114.3	598.6	1,311.7	119.1	285.1	623.0	118.5
Romania	5,147.9	8,711.8	69.2	3,367.2	5,650.5	67.8	522.4	900.7	72.4	129.9	226.0	74.0
Malaysia	4,340.4	8,286.8	90.9	2,684.4	5,147.5	91.8	644.1	1,247.9	93.7	257.8	497.4	93.0
Philippines	4,355.9	6,717.7	54.2	2,333.4	3,590.7	53.9	510.6	818.6	60.3	124.5	200.4	61.0
Saudi Arabia	3,536.0	6,708.7	89.7	2,916.9	5,449.2	86.8	114.9	231.8	101.8	26.4	53.8	103.5
Egypt	4,198.1	6,278.3	49.6	2,459.7	3,677.0	49.5	1,196.8	1,798.9	50.3	452.2	673.1	48.8

Kazakhstan	3,293.4	5,584.6	69.6	2,237.5	3,694.9	65.1	163.3	323.5	98.1	23.2	52.4	125.8
Portugal	3,171.4	5,325.1	67.9	2,780.8	4,633.9	66.6	96.1	175.5	82.7	38.0	70.3	85.1
Myanmar	3,413.2	5,280.3	54.7	2,112.2	3,208.2	51.9	486.8	826.1	69.7	217.4	369.9	70.2
Hungary	3,826.3	5,244.9	37.1	2,791.5	3,771.9	35.1	217.8	336.8	54.7	43.5	73.4	68.7
Tanzania	2,248.6	4,779.2	112.5	1,799.5	3,738.0	107.7	57.2	127.2	122.4	11.8	25.4	114.8
Czech Rep.	3,105.9	4,764.6	53.4	2,240.6	3,445.7	53.8	289.3	451.5	56.1	97.3	152.8	57.0
Algeria	2,734.3	4,711.7	72.3	2,118.1	3,682.1	73.8	104.7	168.5	61.0	24.5	40.1	63.8
Netherlands	2,845.8	4,706.8	65.4	1,196.9	1,767.1	47.6	1,226.5	2,243.1	82.9	1,002.7	1,869.6	86.5
Belarus	2,634.8	4,678.2	77.6	2,358.9	4,123.0	74.8	44.6	99.2	122.3	9.3	21.2	128.7
Ghana	2,462.2	4,540.4	84.4	2,064.5	3,781.3	83.2	101.7	193.7	90.5	30.6	61.7	102.0
Taiwan, China	2,934.5	4,463.6	52.1	1,619.5	2,296.8	41.8	408.5	670.8	64.2	163.6	276.6	69.0
Belgium	2,676.1	4,438.3	65.8	1,927.4	3,191.1	65.6	306.1	506.4	65.4	169.5	286.2	68.9
Venezuela	2,883.3	4,353.3	51.0	1,830.3	2,696.8	47.3	196.4	322.3	64.1	59.8	96.9	62.1
Iraq	2,604.1	4,329.0	66.2	1,406.9	2,311.0	64.3	570.5	899.1	57.6	150.3	251.7	67.4
Greece	2,803.7	4,289.9	53.0	1,852.0	2,743.2	48.1	156.0	264.2	69.4	27.6	48.9	77.3
Congo, Dem. Rep.	2,664.1	4,135.3	55.2	2,307.4	3,523.8	52.7	108.6	196.3	80.7	62.8	115.1	83.3
Zambia	1,619.5	3,816.3	135.6	1,303.9	2,947.2	126.0	21.9	72.4	230.9	6.2	22.6	266.5
Sweden	2,487.1	3,815.9	53.4	2,065.9	3,179.2	53.9	129.2	189.3	46.6	46.7	67.9	45.4
Syria	2,360.7	3,551.0	50.4	1,739.8	2,566.1	47.5	88.1	148.6	68.7	18.3	34.3	87.7
Austria	1,976.5	3,541.9	79.2	1,134.6	2,077.9	83.1	382.0	666.2	74.4	186.8	332.0	77.7
Bulgaria	2,305.5	3,199.5	38.8	1,520.4	2,113.1	39.0	187.4	268.6	43.3	50.6	76.6	51.3
Colombia	2,019.3	3,061.1	51.6	1,228.8	1,800.9	46.6	263.7	432.5	64.0	117.7	197.1	67.4
Mozambique	1,079.7	3,049.5	182.4	932.1	2,582.9	177.1	38.8	97.2	150.3	11.1	27.4	147.0
Denmark	1,912.5	3,028.1	58.3	1,621.6	2,532.2	56.2	77.5	142.6	84.0	28.2	55.0	95.0
Azerbaijan	1,590.9	3,009.5	89.2	973.8	1,791.4	84.0	93.8	159.8	70.5	15.8	26.2	66.3
Côte d'Ivoire	1,619.4	2,894.9	78.8	1,416.6	2,526.9	78.4	61.9	112.7	82.0	27.9	49.1	76.1
Serbia	1,747.1	2,786.8	59.5	1,179.3	1,852.4	57.1	159.7	281.9	76.5	48.0	89.6	86.8
Mali	972.6	2,754.6	183.2	492.7	1,445.3	193.3	129.0	313.3	142.9	43.1	99.1	129.8
Morocco	1,605.5	2,739.1	70.6	1,161.2	1,951.7	68.1	62.8	108.0	72.0	15.5	27.0	74.4
Finland	1,459.7	2,664.7	82.6	1,245.1	2,264.7	81.9	64.2	112.4	75.1	21.3	36.2	70.3
Chile	1,482.3	2,616.0	76.5	861.4	1,549.4	79.9	79.1	144.8	83.1	20.1	38.7	92.3
Tunisia	1,442.6	2,555.2	77.1	1,105.9	1,950.7	76.4	47.4	79.7	68.0	9.6	15.9	65.9
Slovak Rep.	1,733.5	2,443.3	40.9	944.4	1,328.9	40.7	307.0	445.1	45.0	87.2	131.6	51.0
Kenya	1,499.0	2,438.7	62.7	1,266.2	2,012.7	59.0	41.6	76.8	84.5	12.5	22.2	77.7
Sudan	1,561.9	2,396.3	53.4	849.8	1,385.5	63.0	331.7	425.5	28.3	150.8	191.0	26.7
Malawi	1,366.6	2,376.4	73.9	1,155.6	1,968.6	70.3	25.0	50.4	101.4	5.6	12.2	116.9
Uganda	1,094.6	2,355.5	115.2	1,023.6	2,168.0	111.8	15.7	39.3	150.9	4.6	11.5	149.6
Switzerland	1,439.0	2,354.9	63.6	905.1	1,484.4	64.0	237.3	402.5	69.6	145.6	254.4	74.7
Cameroon	1,651.3	2,354.8	42.6	1,372.2	1,916.3	39.7	79.3	126.3	59.3	27.7	44.5	60.7
Peru	1,508.6	2,184.2	44.8	1,168.7	1,624.9	39.0	90.4	158.1	74.8	47.2	84.0	78.2

Sri Lanka	1,244.7	2,169.4	74.3	910.6	1,586.8	74.3	120.2	218.9	82.1	54.9	103.5	88.7
Ethiopia	963.3	2,038.5	111.6	784.0	1,666.7	112.6	32.4	69.0	113.1	9.5	21.0	121.2
Croatia	1,230.7	2,033.6	65.2	802.9	1,310.2	63.2	194.7	336.5	72.8	94.9	172.5	81.7
Cambodia	544.1	1,927.2	254.2	303.6	1,124.7	270.5	84.4	286.6	239.5	32.9	115.5	250.9
Tajikistan	1,160.3	1,917.2	65.2	591.8	981.0	65.8	81.2	136.3	67.7	25.3	44.6	76.6
New Zealand	1,463.9	1,852.6	26.6	1,006.2	1,266.3	25.8	110.6	141.1	27.5	32.4	41.6	28.6
Libya	1,142.9	1,843.1	61.3	897.1	1,437.2	60.2	51.0	84.9	66.4	12.3	22.5	82.7
Moldova	1,327.8	1,830.0	37.8	1,126.4	1,546.3	37.3	56.8	85.8	51.1	17.3	27.5	58.8
Burkina Faso	607.3	1,804.5	197.1	406.0	1,183.3	191.4	14.4	43.1	198.7	0.8	3.1	287.9
Benin	779.8	1,798.8	130.7	605.1	1,399.9	131.3	17.8	42.7	140.0	3.8	9.3	144.7
UAE	694.8	1,765.6	154.1	559.9	1,405.6	151.0	31.4	121.4	286.6	6.7	34.4	412.7
Ecuador	1,040.1	1,672.5	60.8	679.8	1,028.5	51.3	113.0	229.8	103.4	39.6	80.2	102.5
Ireland	770.6	1,663.1	115.8	610.7	1,311.0	114.7	44.9	98.8	120.2	16.2	34.2	111.5
Angola	1,072.3	1,649.7	53.8	936.9	1,415.8	51.1	21.1	43.6	106.3	3.5	9.3	165.9
Madagascar	936.7	1,630.4	74.1	732.2	1,279.9	74.8	84.3	140.9	67.2	41.7	67.9	63.0
Cuba	1,152.4	1,574.9	36.7	845.9	1,135.4	34.2	42.8	64.7	51.1	14.6	21.3	45.8
Lithuania	922.3	1,571.6	70.4	797.4	1,349.3	69.2	26.3	46.4	76.2	8.2	13.8	69.0
Guinea	752.9	1,569.8	108.5	642.2	1,299.4	102.3	31.1	76.1	144.5	11.4	28.4	150.5
Kyrgyz Rep.	826.8	1,561.4	88.9	403.0	760.6	88.7	41.9	84.0	100.6	11.7	25.9	120.8
Turkmenistan	1,063.6	1,560.5	46.7	623.0	905.8	45.4	147.9	221.8	50.0	20.7	32.7	57.9
Israel	1,029.5	1,536.7	49.3	908.1	1,316.1	44.9	17.1	32.8	91.3	2.4	5.1	109.8
Norway	807.7	1,520.7	88.3	655.3	1,261.5	92.5	67.4	109.2	62.0	43.4	68.3	57.3
Botswana	697.2	1,488.4	113.5	510.8	1,069.4	109.4	22.2	46.8	110.9	2.7	7.5	175.9
Georgia	948.2	1,415.2	49.3	560.5	830.4	48.2	80.9	121.5	50.2	30.0	43.3	44.3
Guatemala	980.4	1,394.2	42.2	750.8	1,025.0	36.5	53.7	86.5	61.0	22.2	34.3	54.4
North Korea	765.5	1,302.3	70.1	467.4	803.2	71.8	144.4	255.3	76.7	66.6	124.3	86.6
Afghanistan	723.5	1,228.0	69.7	401.7	669.7	66.7	44.1	78.6	78.1	10.0	21.0	109.3
Bolivia	671.9	1,217.0	81.1	395.3	682.1	72.5	38.0	73.6	93.6	8.7	19.3	121.7
Senegal	621.4	1,205.7	94.0	447.7	852.2	90.3	37.9	70.7	86.3	13.8	21.1	52.7
Puerto Rico (U.S.)	850.1	1,174.8	38.2	640.3	892.5	39.4	44.6	60.1	34.8	11.3	16.1	41.9
Lebanon	793.6	1,137.6	43.4	681.1	958.0	40.6	20.2	32.1	59.5	5.8	9.4	61.9
Nepal	512.9	1,084.9	111.5	286.6	586.9	104.8	45.9	106.2	131.1	8.8	25.2	186.1
Dominican Rep.	548.4	1,080.8	97.1	368.3	723.3	96.4	25.6	53.3	108.5	5.6	12.2	118.7
Laos	380.1	1,041.8	174.1	170.7	501.7	193.8	161.7	389.2	140.7	129.1	299.4	131.9
Zimbabwe	666.4	1,033.9	55.1	580.8	882.1	51.9	12.6	22.9	82.0	4.8	8.1	69.0
Jordan	789.8	1,001.1	26.8	711.3	891.9	25.4	11.7	15.0	27.4	3.2	3.8	17.0
Bosnia and Herzegovina	426.6	979.2	129.6	242.4	560.8	131.3	85.3	191.1	124.0	39.0	85.8	120.2
Oman	763.1	947.3	24.1	590.0	745.2	26.3	17.7	21.3	20.4	2.2	2.6	18.5
Paraguay	471.3	941.9	99.8	409.9	808.7	97.3	8.1	22.9	181.8	2.8	9.1	228.4
Yemen	532.9	852.8	60.0	406.6	658.7	62.0	12.6	21.1	67.7	1.6	2.9	81.1

Armenia	574.6	827.7	44.0	355.3	503.8	41.8	40.3	60.4	49.8	12.7	18.7	47.3
Slovenia	468.1	756.7	61.7	299.7	481.3	60.6	71.6	120.8	68.7	33.2	55.4	66.8
Honduras	429.7	747.5	74.0	254.7	429.8	68.7	34.2	62.6	83.0	8.9	14.9	66.9
Costa Rica	443.5	743.4	67.6	301.6	493.5	63.6	29.9	53.4	78.6	9.1	16.3	78.6
Latvia	479.0	735.5	53.5	373.1	567.9	52.2	49.6	77.5	56.4	22.2	36.8	65.5
Uruguay	479.1	723.0	50.9	420.0	627.0	49.3	7.8	14.7	87.6	2.3	4.2	83.1
Albania	338.2	707.2	109.1	182.0	367.0	101.7	60.6	125.6	107.2	23.1	46.5	101.6
West Bank and Gaza	590.7	707.0	19.7	548.5	652.0	18.9	6.5	8.5	31.4	1.7	2.1	23.6
Togo	417.5	685.3	64.1	347.9	568.7	63.4	9.5	17.2	81.0	1.6	3.4	116.8
Sierra Leone	331.6	678.0	104.4	269.7	549.1	103.6	24.9	49.8	100.0	12.2	24.2	97.7
Cyprus	369.4	613.5	66.1	267.6	441.8	65.1	10.3	19.1	84.9	1.9	4.0	107.8
Jamaica	373.8	597.9	60.0	263.4	433.9	64.8	17.4	27.5	57.9	5.1	8.6	67.9
Rwanda	326.5	585.5	79.3	282.6	517.5	83.1	9.7	15.3	57.0	3.2	5.2	62.4
Panama	328.7	569.1	73.1	263.5	446.3	69.4	16.0	32.9	105.7	4.7	10.4	119.4
Kuwait	452.0	560.1	23.9	378.7	444.9	17.5	19.7	33.8	72.0	5.6	8.2	46.2
El Salvador	335.9	555.3	65.3	220.1	358.6	62.9	20.9	35.3	69.1	6.6	10.7	62.4
Liberia	295.4	552.2	86.9	194.7	384.8	97.6	34.0	59.9	76.1	8.2	16.9	107.0
Central African Rep.	324.1	529.1	63.3	262.6	421.8	60.6	25.3	40.6	60.8	18.1	27.7	52.7
Chad	329.0	526.0	59.8	137.0	225.7	64.8	85.8	135.9	58.3	18.2	27.8	52.8
Estonia	336.0	523.5	55.8	297.3	455.0	53.0	5.2	10.6	104.9	0.8	2.0	152.7
Haiti	291.0	517.1	77.7	145.6	258.9	77.8	22.4	38.4	71.3	2.8	5.3	89.3
North Macedonia	349.7	517.1	47.9	175.4	250.1	42.6	45.3	71.8	58.5	12.9	22.7	76.0
Niger	244.4	495.4	102.7	156.0	332.5	113.2	32.5	57.6	77.3	11.2	19.0	70.8
Nicaragua	292.8	475.5	62.4	194.5	309.0	58.9	12.6	23.3	84.7	3.7	6.9	85.2
Congo, Rep.	373.8	473.4	26.6	309.3	382.6	23.7	19.0	28.8	51.2	9.1	14.6	59.8
Kosovo	196.0	455.7	132.6	121.0	277.4	129.1	17.5	39.3	124.5	5.3	11.3	112.9
Trinidad and Tobago	366.5	435.5	18.8	223.1	264.7	18.7	21.8	27.6	26.5	2.8	3.5	22.0
Qatar	169.6	434.9	156.4	169.3	430.1	154.0	0.1	3.2	2209.5	0.0	1.2	15616.6
Gabon	294.7	387.3	31.4	226.8	291.2	28.4	20.9	30.3	45.1	11.8	16.4	39.3
Burundi	191.3	334.5	74.9	143.7	256.3	78.4	9.8	16.3	66.9	2.8	4.8	72.3
Singapore	279.1	329.6	18.1	197.6	236.3	19.6	13.7	16.2	17.6	1.9	2.5	34.7
Somalia	150.4	318.4	111.6	99.3	201.2	102.7	17.5	33.5	91.7	3.7	6.7	82.3
Gambia, The	152.7	300.5	96.9	115.6	223.9	93.7	3.4	6.5	94.4	1.2	1.6	37.7
Namibia	160.9	283.5	76.2	115.0	196.0	70.5	8.6	19.6	128.9	1.5	4.4	194.1
Mongolia	127.7	265.7	108.1	82.0	176.2	114.8	3.8	10.1	166.5	0.1	0.3	113.4
Brunei Darussalam	159.1	253.4	59.3	106.8	166.8	56.1	13.3	26.9	101.7	2.7	5.6	110.7
Mauritania	49.3	245.0	397.0	33.0	186.5	464.4	6.0	16.5	176.0	2.5	4.9	92.5
Suriname	145.8	228.5	56.8	57.9	90.6	56.5	20.2	34.5	70.7	2.5	4.3	76.9
Guadalupe	152.7	227.5	48.9	128.6	192.1	49.4	5.6	8.0	41.7	1.4	2.1	52.6

Guyana	197.1	223.1	13.2	89.4	101.6	13.6	27.0	31.1	15.0	4.7	6.0	27.5
Réunion (Fr.)	60.4	208.0	244.2	60.4	208.0	244.2	0.0	0.0	n.a.	0.0	0.0	n.a.
Luxembourg	120.8	206.6	71.0	92.0	161.5	75.6	12.8	19.7	53.1	6.7	10.2	51.3
Guinea-Bissau	104.4	206.0	97.4	98.5	191.3	94.2	0.3	1.2	258.8	0.1	0.3	409.0
South Sudan	72.2	203.9	182.3	50.3	137.5	173.3	6.5	24.4	274.1	2.1	9.2	333.9
Martinique (Fr.)	137.8	199.3	44.6	122.0	176.9	45.0	5.2	7.4	43.3	1.5	2.2	51.3
Hong Kong SAR, China	105.4	195.9	85.8	76.2	128.9	69.0	14.7	36.0	144.5	8.7	23.4	167.7
Fiji	91.9	189.3	105.9	62.0	123.1	98.5	18.6	40.1	114.9	11.1	24.1	116.0
Bahrain	111.5	183.8	64.8	105.2	166.2	58.0	0.3	1.6	521.2	0.0	0.1	21915.8
Equatorial Guinea	78.8	181.1	129.9	59.3	122.3	106.4	6.0	16.4	175.1	2.5	5.8	129.7
Montenegro	94.6	176.3	86.5	54.1	98.2	81.5	15.4	30.5	98.0	7.2	14.1	96.2
Papua New Guinea	133.1	172.1	29.2	96.9	120.2	24.0	6.8	11.4	66.1	2.4	4.3	75.4
Mauritius	109.8	158.1	43.9	71.1	99.8	40.4	3.4	5.4	60.2	0.5	1.0	95.0
Lesotho	82.4	151.9	84.3	71.9	134.9	87.5	2.4	3.7	53.9	1.1	1.6	39.5
Bahamas, The	46.3	118.1	155.3	26.9	71.0	164.0	1.9	7.3	275.6	0.5	2.5	412.6
Barbados	95.6	114.7	20.0	78.4	93.5	19.3	1.0	1.3	31.2	0.2	0.2	24.5
Eswatini	48.4	105.6	118.3	45.2	97.5	115.9	1.2	2.5	105.6	0.6	1.2	84.2
Malta	87.4	101.9	16.6	81.1	94.0	16.0	1.2	1.5	19.5	0.2	0.3	25.8
Eritrea	45.6	99.9	119.0	39.1	84.5	116.5	0.5	1.5	187.4	0.0	0.3	566.3
Iceland	52.5	99.6	89.6	41.8	76.1	81.9	5.4	10.5	93.4	3.5	6.4	84.9
New Caledonia (Fr.)	71.5	89.6	25.3	56.8	70.8	24.6	4.8	5.9	22.8	1.8	2.1	16.9
Guam (U.S.)	83.4	89.4	7.3	64.7	69.8	8.0	5.1	5.3	4.2	2.7	2.8	3.4
Azores Islands (Por.)	74.0	85.1	14.9	74.0	85.1	14.9	0.0	0.0	n.a.	0.0	0.0	n.a.
Belize	37.9	82.9	119.1	28.6	62.3	117.8	1.7	3.8	126.6	0.2	0.6	179.5
Madeira Islands (Por.)	56.5	78.7	39.2	50.9	70.6	38.7	1.0	1.5	53.8	0.2	0.4	78.8
Timor-Leste	46.1	69.8	51.4	20.0	30.7	53.5	6.7	9.3	38.8	1.2	1.7	39.6
Comoros	61.4	68.3	11.3	27.6	31.8	15.0	1.5	1.6	10.9	0.2	0.2	9.6
French Guiana (Fr.)	54.3	68.2	25.5	40.1	48.5	21.0	4.5	7.4	64.0	1.7	3.5	108.1
Virgin Islands (U.S.)	52.1	65.9	26.5	42.5	54.4	27.9	0.5	0.6	27.1	0.1	0.1	25.1
Curaçao (Neth.)	17.0	55.9	228.8	6.3	21.6	241.8	0.0	0.1	375.3	0.0	0.0	n.a.
Saint Lucia	29.2	52.8	81.3	25.2	45.4	80.4	1.1	2.3	108.4	0.3	0.7	175.3
Aruba (Neth.)	40.0	49.4	23.4	32.1	39.7	23.7	0.5	0.7	22.2	0.1	0.1	59.6
Cabo Verde	27.8	44.7	60.6	24.2	39.2	62.2	0.6	0.9	33.5	0.1	0.1	29.7
Djibouti	8.5	41.0	382.5	7.6	36.2	375.3	0.1	0.7	627.6	0.0	0.1	472.7
Cayman Islands (U.K.)	20.2	37.8	87.0	12.1	24.0	98.8	2.5	4.0	58.5	0.7	0.9	33.7

Saint Vincent & Grenadines	27.1	32.3	19.3	19.2	22.9	19.4	1.9	2.3	19.9	0.6	0.8	20.6
Jersey (U.K.)	18.7	30.4	62.0	15.6	25.8	65.7	1.6	2.0	30.8	1.0	1.4	37.3
Solomon Islands	25.4	28.3	11.5	19.2	20.9	8.7	2.3	2.7	18.2	1.2	1.4	18.1
Grenada	19.8	26.5	33.9	16.9	22.5	33.0	0.7	1.0	38.5	0.2	0.3	41.2
Maldives	25.0	25.7	2.8	23.5	24.1	2.5	0.1	0.1	0.0	0.0	0.0	0.0
Antigua and Barbuda	19.6	25.0	27.4	16.2	20.4	25.7	0.7	1.1	42.9	0.2	0.4	53.4
Vanuatu	19.4	24.8	27.7	15.9	20.1	26.4	1.0	1.3	26.3	0.4	0.5	21.1
Isle of Man (U.K.)	13.3	24.1	80.8	11.2	19.7	76.5	1.1	1.8	60.5	0.7	1.0	52.3
Guernsey (U.K.)	18.0	24.1	33.5	13.0	17.7	36.1	3.2	3.9	22.5	2.5	3.1	21.3
Dominica	12.6	19.5	55.6	9.7	15.2	56.6	0.4	0.9	104.0	0.1	0.3	109.8
Saint Kitts and Nevis	13.9	18.7	35.0	9.2	12.8	38.5	0.1	0.1	24.7	0.0	0.0	n.a.
Bhutan	5.0	15.1	200.2	2.2	7.6	238.9	1.0	3.0	207.8	0.6	1.9	232.4
Sint Maarten (Neth.)	12.2	13.8	13.3	10.0	11.3	13.1	0.7	0.8	12.6	0.2	0.2	12.9
Liechtenstein	7.1	13.5	91.1	3.5	6.8	92.2	2.5	4.8	91.2	1.6	3.4	115.6
Saint-Martin (Fr.)	10.2	12.6	23.0	6.8	8.6	25.8	1.1	1.2	13.7	0.1	0.2	17.0
British Virgin Islands (U.K.)	8.6	11.5	34.4	7.4	10.0	34.9	0.0	0.0	143.9	0.0	0.0	n.a.
Mayotte (Fr.)	10.6	11.3	7.3	10.5	11.3	7.2	0.0	0.1	28.5	0.0	0.0	16.7
San Marino	8.2	11.2	36.6	7.3	9.9	35.9	0.5	0.7	40.2	0.2	0.2	39.0
Anguilla (U.K.)	8.1	9.6	17.7	7.4	8.6	17.5	0.3	0.3	14.3	0.1	0.1	14.7
Macau, China	5.8	8.6	48.6	5.7	7.9	39.7	0.0	0.4	1106.3	0.0	0.3	n.a.
Bonaire (Neth.)	2.0	7.2	260.1	1.1	4.6	309.6	0.1	0.2	43.0	0.0	0.0	56.9
Andorra	1.4	4.6	233.8	0.8	2.1	179.2	0.4	1.7	315.5	0.3	1.3	281.9
Saint Barthélemy (Fr.)	3.2	3.7	15.6	3.1	3.5	15.3	0.0	0.0	n.a.	0.0	0.0	n.a.
Saint-Pierre-et-Miquelon (Fr.)	2.3	3.0	26.7	1.8	2.3	31.8	0.3	0.3	9.7	0.1	0.1	25.4
Gibraltar (U.K.)	2.3	2.6	10.2	1.7	1.8	5.7	0.0	0.0	n.a.	0.0	0.0	n.a.
Monaco	1.5	1.7	13.8	1.5	1.7	13.9	0.0	0.0	n.a.	0.0	0.0	n.a.
Turks & Caicos Islands (U.K.)	0.4	1.5	255.2	0.4	1.3	240.7	0.0	0.0	366.1	0.0	0.0	n.a.
Sint Eustatius (Neth.)	1.3	1.4	10.0	1.3	1.4	9.6	0.0	0.0	n.a.	0.0	0.0	n.a.
Montserrat (U.K.)	0.8	0.9	22.9	0.7	0.9	22.3	0.0	0.0	n.a.	0.0	0.0	n.a.
Vatican City	0.3	0.4	7.1	0.3	0.4	7.3	0.0	0.0	0.0	0.0	0.0	n.a.
Saba (Neth.)	0.3	0.3	18.9	0.2	0.3	22.3	0.0	0.0	n.a.	0.0	0.0	n.a.