Technical Report

Global assessment of current and future river flooding and the role of nature-based solutions for risk management

The Nature Conservancy Europe

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Global assessment of current and future river flooding and the role of nature-based solutions for risk management

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Acronyms List

CBM	Christoffel-Blindenmission Christian Blind Mission e.V.
CDD	Center for Disability in Development
GCMs	Global Climate Models
GDP	Gross Domestic Product
GIEMS-D15	Global Inundation Extent from Multi-Satellites – Downscaled 15 arcseconds
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
MODIS	Moderate Resolution Imaging Spectroradiometer
NbS	Nature-based Solutions
RCP	Representative Concentration Pathway
WaterGAP3	Water Global Assessment and Prognosis Model
UNESCO	United Nations Educational, Scientific and Cultural Organization

Executive Summary

Climate change is altering the magnitude and frequency of riverine flooding and there is a growing urgency for countries and communities to mitigate and adapt to these potentially adverse impacts. This report provides a global analysis of the current exposure of people and croplands to floods, the changing nature of floods towards the end of the 21st century, as well as current flood risk. This analysis focuses specifically on the flood conditions and flood risk associated with rivers. The findings of this global analysis highlight how nature-based solutions (NbS) for flood risk management can be employed as multi-purpose solutions to mitigate the current and predicted future impacts of flooding shown in this study. Beyond addressing flood hazard and exposure, NbS can also contribute to reducing societal vulnerabilities, which is vital for holistic disaster risk reduction approaches.

Key Findings and Recommendations:

+ Globally, **2 billion people live in freshwater flood inundation zones**, representing roughly 25% of the current global population. South and Southeast Asia have the highest level of flood exposure of people.

+ Around **23% of the world's croplands are within inundation areas**. Three of the top five food producing countries have significant cropland areas within inundation zones, including India (45%), China (31%), and the United States of America (23%).

+ Many of the areas with the predicted greatest increase in magnitude and frequency of flooding are those currently most exposed to severe flood hazards. **South Asia, Southeast Asia and Sub-Saharan Africa are identified as hotspots for increasing severity of future flood conditions**. Central Europe and the western coasts of North and South America are also anticipated to experience dramatic changes in flood frequency and magnitude in the future.

+ Bangladesh, Cambodia and India are the three countries with the highest current riverine flood risk worldwide. **Regional hotspots of current risk are located in South Asia and Central Africa**. The high riverine flood risk in South Asia primarily stems from a high flood exposure while the hotspot of risk in Central Africa is closely linked to high vulnerability.

+ One-hundred-and-four countries are predicted to experience current 100-year floods at least twice as frequently by the end of the 21st century (see Appendix for details). Where no investment is made in new flood mitigation infrastructure, **flood risk management budgets and planning should be adjusted to account for current flood mitigation infrastructure being overrun much more frequently** in identified areas where 100-year flood frequency is expected to increase.

+ Sixty-six countries are predicted to experience increases of 25% or more in the magnitude of their current 100-year floods by 2100 (see Appendix for details). Where flood magnitude is expected to increase significantly (e.g. Sub-Saharan Africa, South Asia and Southeast Asia), existing **flood management infrastructure (grey-green solutions) and climate adaptation planning should be updated to meet future expected 100-year flood magnitudes**.

+ Nature-based solutions (NbS) can play a key role in addressing the multidimensional societal needs and risks associated with changing flood conditions. However, engineered interventions, rather than NbS, are currently the standard approach for structural flood mitigation strategies. To achieve a shift towards more sustainable and holistic management, the flood risk management sector needs **capacity building support for implementing nature-based solutions to complement traditional grey solutions**.
+ There is a **need for more sustained, medium to long-term programs dedicated to implementing nature-based solutions for flood risk management**, rather than scattered, individual projects. Beyond pure flood risk reduction, programs should be multi-purpose in design and should explicitly meet the needs of communities in which projects are implemented. Only through a long-term, programmatic approach can NbS be implemented and maintained at a scale which delivers meaningful flood risk management benefits and where the co-benefits of NbS are realized.

1. Introduction

Context

Climate change is altering the magnitude and frequency of riverine flooding. With impacts already being seen today, there is a growing urgency for countries and communities to adapt to these changes and develop and implement flood risk reduction strategies. Annual flooding has more than doubled in the last 40 years (UNDRR & CRED 2020). Floods are also the most common type of natural hazard, accounting for 44% of all disaster events from 2000 to 2019 and affecting 1.6 billion people worldwide (UNDRR & CRED 2020).

The economic cost of the damages from these floods has correspondingly increased in the two recent decades (OECD 2016). However, despite the increase in the number of flood events and damages, the number of fatalities associated with these events has declined. This trend is generally attributed to greater disaster risk reduction at the global and country scales, including the development and deployment of early warning systems and disaster response planning (Tanoue et al. 2016). The lives saved from flood risk reduction programs in recent years is a strong supporting rationale for increasing investment in climate change adaptation. Numerous reports suggest, however, that current investment in flood risk management remains insufficient to meet the current and future needs for climate change adaptation to significantly reduce loss of life, livelihoods and property caused by river flooding (Kellett & Caravani 2013).

The economic and human impacts of floods are furthermore unequally distributed across countries when the economic status and socioeconomic vulnerability of countries are taken into account. While the frequency of flood events is relatively evenly distributed across countries with different income levels, lower income countries have a disproportionate loss of life compared with higher income countries. Conversely, and not unexpectedly, financial losses are larger in high income countries as they have more assets at risk. Despite the higher absolute values of economic losses in high income countries, economic disruptions in lower income countries can account for a greater percentage of overall economic activity and have longer lasting impacts on the long-term economic growth of a country (Berlemann & Wenzel 2018).

Risk associated with flooding, therefore, is not solely determined by size or frequency of floods. Risk is widely recognized as the combination of the likelihood of a hazard occurring, and the expected adverse consequences of this occurrence for assets and people at risk (UNDRR & CRED 2020). This notion of risk is reflected in this report, where riverine flood risk is understood as the interaction between the likelihood of flooding, the physical exposure of people and assets to flooding, as well as their vulnerability towards flood hazards: Risk = Hazard x Exposure x Vulnerability (IPCC 2014). Since risk is a multidimensional and dynamic phenomenon, it can be considered in a number of contexts, including social, economic, and ecological.

Problem statement

The need for increased investment in the development and implementation of climate adaptation measures for riverine flood risk is broadly recognized at the conceptual level. However, the information needed to understand the nature of these risks and to inform the development of climate adaptation policies and programs remains limited.

General trends in these elements of risk are understood, such as the tendency of a rapidly growing human population to settle disproportionately close to waterways (high exposure of settlements) or the high dependency of agriculture on specific hydrological conditions (high vulnerability to changes) (Kummu et al. 2011; Dryden et al. 2021). However, the finer details of risk, including the changes to magnitude and frequency of flood events and the vulnerability of people are key to understanding how future flood conditions will affect lives and livelihoods. For example, the global population is expected to reach 10 billion people towards the end of this century; understanding and planning where people settle will have a major impact on flood risk. Understanding these trends in greater detail and how they affect risk for lives and livelihoods can help inform the scale and type of adaptation needed.

Similarly, food production is at risk. Agriculture, and particularly croplands, are often located in the rich soils of river floodplains. In fact, agriculture is often highly dependent upon specific hydrological conditions, with some crops (e.g. rice) being dependent on predictable annual inundation. Changes to this flooding in scale or frequency can in turn have negative impacts on food production. In fact, extreme flood events are listed as the most damaging natural hazards to crops, causing 65% of reported damages (FAO 2018). More routine (less extreme) flood events can also result in long-term damage to croplands, causing both erosion of valuable soils, and deposition of sand, silts and associated contaminants onto croplands. With global food demand expected to increase by 50% by 2050, and even larger increases expected in currently food-insecure regions, there is growing urgency to better understand the dynamics of flood risk in order to effectively prepare for and adapt to these changes (GCoA 2019).

Aim of study

Better understanding the nature of changing flood conditions is vital to informing adaptation plans to meet these challenges and thereby promote a sustainable and just future. This report provides a global analysis of today's flood conditions and flood risk levels as well as future flood conditions towards the end of this century. This analysis focuses specifically on the flood conditions and risk associated with rivers. It complements previous studies of river flooding and the extensive existing literature on risks associated with the increasing frequency and severity of coastal storms and sea level rise.

Results are reported at the country and basin scales to provide a geographically-specific overview of today's conditions and expected changes. To inform climate change adaptation needs, changing flood conditions are placed in the context of socioeconomic development trends. The report also presents solutions which could help countries and communities cope with the identified changes in river flood hazards. The results inform a discussion of NbS to flood risk management and how these approaches can be designed to address multiple purposes across a range of contexts. These NbS are explored in the context of reducing risks from river flooding, protecting and restoring freshwater biodiversity, and protecting socioeconomic systems.

2. Methods

This assessment of current and future flood conditions is grounded in the IPCC's framework of risk. River flood risk is understood as the possibility of adverse effects from flooding. It derives from the interaction of social and environmental conditions and can be calculated as a function of **1) hazard**, **2) exposure** of people and economic assets and activities to the hazard, and **3) vulnerability** of people and economic assets to negative consequences from the hazard.

The analysis is designed to provide insight into how flood conditions and associated risk factors will change in the future as a result of climate change. The analysis involves three components:

1) **Current exposure** of people and croplands to floods is assessed using the number of people and the area of croplands within current flood inundation areas **(current hazard)** as metrics.

2) **Future change in hazard** posed by changes to key flood metrics as a result of climate change – in this case the frequency and magnitude of two types of floods – is assessed. The focus is on large, infrequent floods with an estimated return period of 100 years (average occurrence probability of 1% in any given year) and on more frequent, less severe floods with an estimated return period of 10 years (average occurrence probability of 10% in any given year). Flood magnitude is measured in terms of water volumes. Flood frequency is measured in terms of recurrence interval: the statistical time between flood events. The greater the recurrence interval, the less frequent a flood occurs, and vice versa.

3) To contextualize the results on exposure and changing hazards in terms of overall **risk**, current exposure and hazard data are combined with **vulnerability** data to create a FloodRiskIndex. Indicators from the WorldRiskIndex are used to comprehensively assess the combined hazard, exposure, and vulnerability of countries to indicate current flood risk levels.

The methodologies of the individual analysis components are described in more detail below.

2.1 Current Exposure to Riverine Floods

Current flood exposure is assessed based on three components, following similar approaches as outlined in Dryden et al. (2021):

a. Inundation area: A dataset of current areas of inundation is used to represent exposure to floodwater areas.

b. Population: A spatially explicit global population dataset is used to identify the number of people who reside within flood inundation areas.

c. Croplands: A global land-cover dataset is used to identify croplands exposed to flooding. Croplands are used as a proxy for agriculture because these areas are generally more sensitive to flood damages than other agriculture areas, such as rangelands used for grazing livestock.

Inundation areas: This study provides an estimate of the spatial extent of human use and appropriation of floodplains and inundated areas in terms of human settlements and agriculture. The study used the GIEMS-D15 database (Fluet-Chouinard et al. 2015) at 15 arc-seconds resolution (~500 m at the equator) to identify inundation areas. Importantly, GIEMS-D15 represents natural and artificial inundated surfaces, including rice paddies and lake-related inundation areas, in addition to riverine areas. Thus, the term *inundation areas* is used in this report, rather than *floodplains* that are connected to rivers. The analysis is limited to freshwater inundation areas only, so inundation areas within 25 km of marine coastlines were excluded as these areas may experience inundation from both inland and ocean sources. All results reported as percentages indicate the population or area within strictly inland inundation areas (ie. further than 25 km from the coast) as a percentage of the total (including coastal) population or area.

The results are presented visually in map form with the data shown at the scale of uniformly-sized river sub-basins (with average areas of approximately 15,000 km^2), using the HydroBASINS level 5 subdivisions (Lehner & Grill, 2013). Accompanying tables show the data at a country scale for the top 15 countries. The same format for presenting results is used throughout the report. Tables showing the top 15 countries for each result category exclude countries with less than 1,000 km^2 area of analysis, which can be affected by data artefacts and outliers. The full list of countries is presented in the Appendix.

Current population exposed: To characterize the number of people at risk from floods, WorldPop (2018) is used to provide global population data at 3 arc-second resolution (~90 m at the equator) for the year 2015. WorldPop uses population estimates from the most recent and highest resolution census data available and supplements these by estimations with satellite imagery and household surveys where census data are incomplete or outdated. The dataset is used to determine the current population distribution at high spatial resolution. The WorldPop dataset was spatially overlaid with the mapped inundation areas in a Geographic Information System (GIS) to estimate the total population exposed to flooding at a country and river sub-basin scale. To assess urban population exposure, the Global Human Settlement Layer database was used, which provides global spatial layers of human population and settlement patterns for multiple time periods (Florczyk et al. 2019). We used the 1-km resolution GHS-SMOD layer (Pesaresi et al. 2019) for the year 2015 to delineate urban areas.

Current croplands exposed: The extent of cropland exposed to flooding was assessed using the Collection 6 MODIS Land Cover Type Product for the year 2015 (following Friedl & Sulla-Menashe 2019). This product provides global maps of land cover at 15 arc-second resolution and detailed land cover layers for different land use types. Croplands in these land cover layers were filtered using the FAO Land Cover Classification System legend. Three types of land use were considered in the assessment of cropland cover. The class "Cropland" (>60% cultivated) was considered as 100% cropland cover, while the two classes "Forest/Cropland Mosaic" (40–60% cultivated) and "Natural Herbaceous/Cropland Mosaic" (40-60% cultivated) were considered as 50% cropland cover. To analyze current exposure of croplands to flood hazards, these data layers were overlaid with the mapped inundation areas in a GIS.

2.2 Expected Future Changes in Riverine Flood Hazard

Future changes in riverine flood hazard are modeled by comparing the current period of record (1961-2010) with projections for the second half of the century (2050-2099). These two periods were used to quantify changes to the following riverine flood indicators:

1. Change in 100-year flood frequency
2. Change in 100-year flood magnitude
3. Change in 10-year flood frequency
4. Change in 10-year flood magnitude

Focusing on both frequency and magnitude of floods improves the characterization and understanding of changing riverine flood conditions in the wake of climate change. Flood frequency and magnitude statistics are not interchangeable as the relationship between flood frequency and flood magnitude is highly non-linear. A small increase in magnitude generally results in a large change of frequency. For example, a 25% increase in magnitude can result in a 75% decrease in median recurrence interval, meaning a four times higher frequency.

A 100-year flood was used as the primary metric of change as this magnitude of flood is typically used to characterize a catastrophic flood for land use planning purposes. A 100-year flood is often used as the design standard for flood management infrastructure such as levees. In the context of climate change, a projected increase in magnitude of the 100-year flood may indicate that existing flood protection works may become overwhelmed more frequently in the future and that possible future 100-year flood magnitudes should be used now when making flood risk management decisions.

The change in frequency for 100-year floods provides valuable insight because the more often damaging floods occur, the more often costs of damages are incurred. Therefore, data on changes in both recurrence period and magnitude of 100-year floods will provide important insights on future adaptation needs.

Floods with a return period of 10 years (10-year floods) help characterize more frequently occurring flood events. Such floods are commonly less catastrophic but can contribute to longer-term issues such as erosion, resulting in significant cumulative economic impacts. Statistical 10-year floods are also relevant from an ecological and food security perspective, as these floods can play a key role in distributing nutrients to agricultural areas and in supporting freshwater species dispersal across landscapes.

Modeling methods

The analysis of future global flood conditions is based on time series of daily river discharge as simulated by the global water model WaterGAP3 (Eisner 2016). The model operates on a 5 arc-minute spatial resolution in daily time steps and has been shown to be an effective tool for representing specific flow events for different maximum flow magnitudes (Schneider et al. 2011; Schneider et al. 2017; Eisner 2016).

WaterGAP3 was driven with results from two global circulation models (GCM) for the period 1961-2099 based on the assumption of greenhouse gas emissions defined in the Representative Concentration Pathway (RCP) 6.0 (IPSL-CM5A-LR and GFDL-ESM2M models). The RCP 6.0 is a medium-high climate emissions scenario which represents some climate action, but insufficient reduction of carbon emissions to meet the goals defined in the Paris Agreement to limit global warming to well below 2°C (UNFCCC 2015). Data for the statistical flood model was derived from a 50-year time series of gridded daily river discharge simulated by WaterGAP3 for current climate conditions (1961-2010) and future climate conditions (2050-2099) from the two GCMs.

The selection of the GCMs was guided mainly by the patterns of changes in precipitation projected by the various GCMs available and the requirement that the results should cover the largest range in the projected changes of flood frequency. It should be noted, however, that it is not guaranteed that the results cover the full range of projected changes in flood frequency at any location. Many global climate change models use a larger number of GCMs to compare results under different scenarios. However, given the data-rich nature of river flood modeling and the global scale of this work, only two models with a large range of future conditions were used for reasons of computational efficiency.

The **change in flood magnitude** was estimated by comparing the magnitude of each flood type's discharge volume (i.e. 100-year and 10-year floods) under current conditions and under future climate conditions. **Change in flood frequency** was estimated by calculating how much more or less frequent the current 10- and 100-year floods would be during the second half of the 21st century, expressed as a change in the recurrence intervals of these floods from present-day conditions.

To derive the change in discharge magnitude and flood frequency, a statistical distribution function which allows the extrapolation of the frequency distribution was fitted to a series of annual maximum daily discharge values of a 50-year period. For distribution functions, a Pearson Type III distribution (Gamma distribution) was run, which is commonly applied for flood frequency analysis (Lehner et al. 2006; Milly et al. 2002; Muzik 2002; Roy et al. 2001) and suggested by organizations as a standard method for statistical flood analysis (US-ACWD 1982; USGS 1981; DVWK 1979; DVWK 1999). Depending on the data sample's skewness a Log-Pearson-III-distribution was used for correction.

2.3 Current Riverine Flood Risk

To provide insight into countries' overall risk to river floods, the current riverine flood risk is expressed in the form of the **FloodRiskIndex**. The index is aggregated through the combination (multiplication) of flood exposure and vulnerability. The index unifies flood hazard with exposure in one variable. The index shows today's disaster risk for 181 countries worldwide as a consequence of river flooding and societal vulnerability, on a scale from 0 (min) to 100 (max).

The **flood exposure** is based on a combination of the absolute and relative population per country annually affected by river flooding. The combination of absolute and relative population numbers accounts for significant differences in population size between countries and facilitates accurate country comparisons. Absolute numbers of the exposed population per country were transformed using the natural logarithm. The logarithmic numbers of exposed population per country were then normalized based on a min-max normalization. The same normalization was applied for the relative numbers of exposed population per country.

The relative and absolute values were then averaged (arithmetic average) and multiplied by 100 to obtain single flood exposure values between 0 and 100 for every country. Data on physical exposure to river flooding is retrieved from the PREVIEW Global Risk Data Platform of the United Nations Environment Programme (2019) with population data from the Oak Ridge National Laboratory (2019).

The **vulnerability** component of the FloodRiskIndex is based on the vulnerability concept used for the WorldRiskIndex (Bündnis Entwicklung Hilft 2011). The vulnerability component consists of three sub-dimensions: susceptibility, lack of adaptation and lack of coping capacities. Each dimension consists of a variety of indicators to best reflect countries' vulnerability towards natural hazards. A total of 22 vulnerability indicators from well-established and publicly accessible data sources such as the World Bank, World Health Organization and UNESCO are used (Bündnis Entwicklung Hilft / IFHV 2020).

3. Results

3.1 Current Flood Conditions

Current exposure of people

Globally, 2 billion people live in freshwater flood inundation zones. This represents roughly 25% of the current global population. This ranges from over 660 million people in India to less than 5 thousand people in countries such as Kuwait. Seventy-one countries have over 1 million people exposed to freshwater floods. Eighteen countries have 25% or more of their population exposed to floods, with Bangladesh, Cambodia and Iraq having the highest levels of their population exposed to floods, with 80%, 77% and 57% exposed, respectively. Regionally, South and Southeast Asia have the greatest level of exposure of population to flood hazards (see Figure 1).

In many countries, a significant number of people residing in urban areas are particularly exposed to flooding. China (330M), India (220M), Bangladesh (54M) and the United States of America (37M) have the most people in urban areas exposed to floods. Three countries have over 70% of their urban population within inundation areas, with 15 countries having more than 40% of their urban population in inundation zones. See Table 1 for further country-level details.

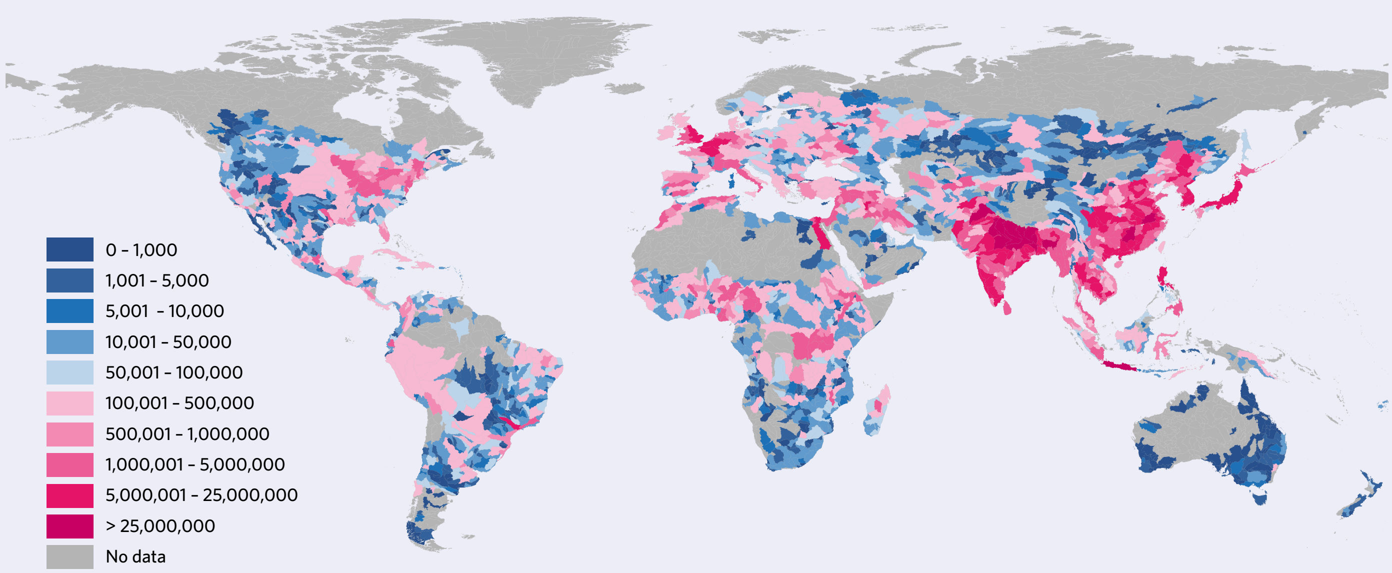


Figure 1: Current exposure of people: Population in inundation areas at sub-basin scale

Top 15 countries by population exposure				
Country	**People in inundation zones (millions)**	**People in inundation zones (relative)**	**People in urban inundation zones (millions)**	**People in urban inundation zones (relative)**
India	663.4	51%	221.3	33%
China	498.1	36%	329.4	66%
Bangladesh	121.8	80%	54.3	45%
Pakistan	78.2	38%	34.2	44%
Indonesia	49.3	19%	34.9	71%
United States of America	49	15%	36.8	75%
Vietnam	45.5	49%	30.1	66%
Thailand	35.4	51%	15.5	44%
Egypt	28.2	33%	25.5	90%
Nigeria	26.5	14%	11.8	44%
Iraq	21.8	57%	8.6	39%
Brazil	21.2	10%	16.4	78%
Japan	21.1	16%	18	86%
France	19.7	30%	16.1	82%
Myanmar	19.2	38%	6.5	34%

Table 1: Top 15 countries by population exposure to current flood hazards

Current exposure of croplands:

Around 23% of the world's croplands are within inundation areas. Twenty-six countries have 25% or more of their croplands within inundation areas (excluding croplands within 25 km of the coast). Three of the top five food producing countries have significant cropland areas within inland inundation zones, including India (45%), China (31%), and the United States of America (23%).

Thirty-one countries have 10,000 or more km^2 (1 million hectares) of croplands within inland inundation areas, with five countries – India, China, United States of America, Thailand, and Canada – having over 100,000 km^2 of croplands within flood prone areas (see Table 2). Regionally, South and Southeast Asia have the highest exposure of croplands to flood hazards (see Figure 2).

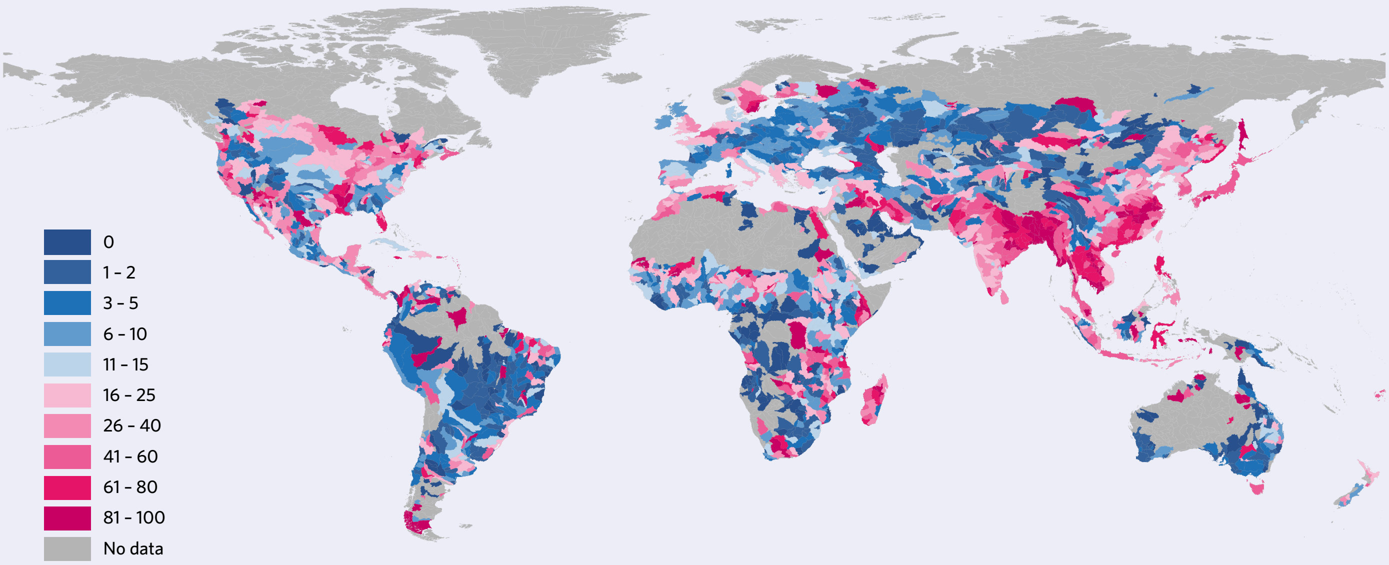


Figure 2: Current exposure of croplands: Croplands in inundation areas at sub-basin scale

Top 15 countries by cropland exposure		
Country	**Croplands in inundation zones (thousands km²)**	**Croplands in inundation zones (relative)**
India	880.5	45%
China	415.8	31%
United States of America	325.3	23%
Thailand	140.1	67%
Canada	102	21%
Pakistan	83.7	47%
Bangladesh	65.6	84%
Myanmar	63.3	46%
Nigeria	52.6	15%
Russian Federation	39.9	4%
Argentina	39.1	11%
Cambodia	38.3	78%
Ukraine	31.8	8%
Chad	29.1	28%
Vietnam	28.3	49%

Table 2: Top 15 countries by cropland exposure to current flood hazards

3.2 Future Flood Hazard

Change in future flood magnitude for 100-year floods

Sixty-six countries are projected to experience increases in the magnitude of current 100-year floods by 25% or more in the second half of this century. Countries that are projected to see the greatest increase in the size of the 100-year floods include Oman (254%), Fiji (106%) and Somalia (99%).

Sixty-four countries are estimated to have 50% or more of their river area experience magnitude increases greater than 15% for 100-year floods (see further details in the Appendix). The top 15 countries which will experience a significant increase in flood magnitude (>15%) for 100-year floods over most of their river areas are shown in Table 3. Figure 3 shows river sub-basins where flood magnitude will increase by more than 15% by the end of the 21st century. As this is an area-based reading, this map only shows the percentage of basin area which will experience *increasing* flood magnitude, so as not to distort findings by null averages in basins where there are both increases and decreases in flood magnitude. Figure 4 shows where individual river networks within larger basins will experience both increases and decreases in magnitude for 100-year floods. While areas with large increases in magnitude occur in almost every continent, South Asia, Southeast Asia, and Sub-Saharan Africa are identified as hotspots for increasing 100-year flood magnitude.

Moderate declines in magnitude of 100-year floods (15% or more), in turn, occur only in a relatively small percent of river areas. Eighty-nine countries will see only 10% or less of their river areas have a decline of 15% or more in the magnitude of 100-year floods. The median decline in 100-year flood magnitudes across countries is 11%. While this seems minimal, relatively small changes in magnitude can lead to large changes in frequency. Countries with the largest percent of their river areas experiencing 15% or greater declines in 100-year flood magnitudes include Belgium (98%), the Netherlands (93%) and Guinea-Bissau (80%). Further country-level details on river areas impacted by declining 100-year flood magnitude are shown in Table 4.

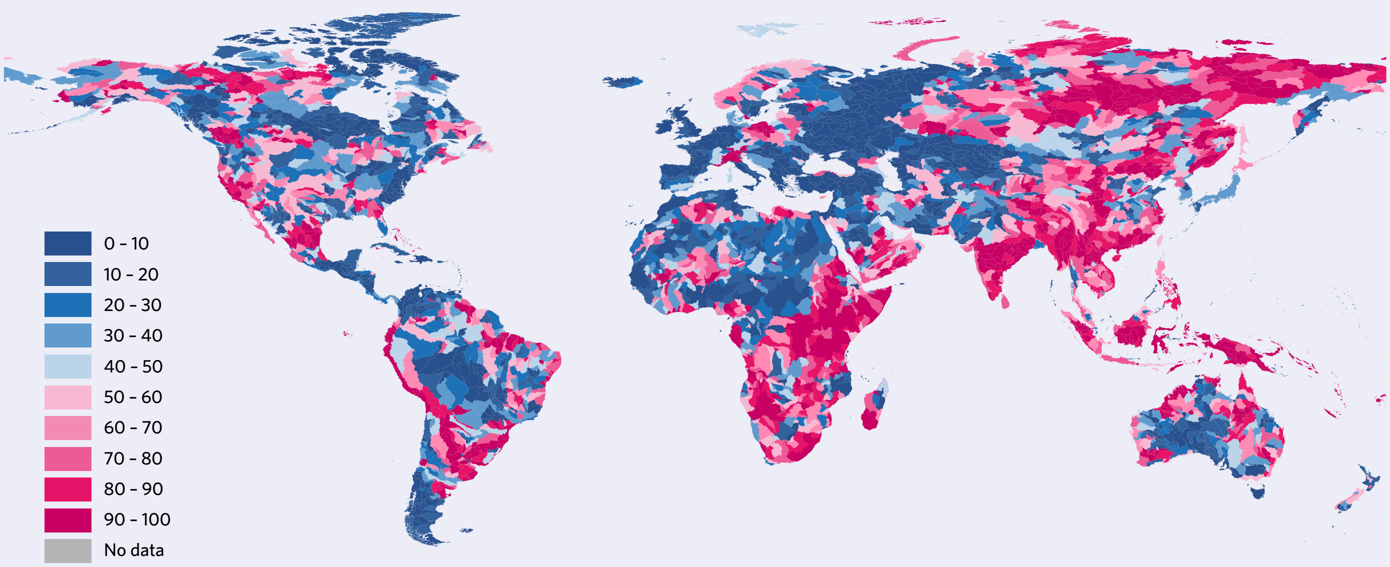
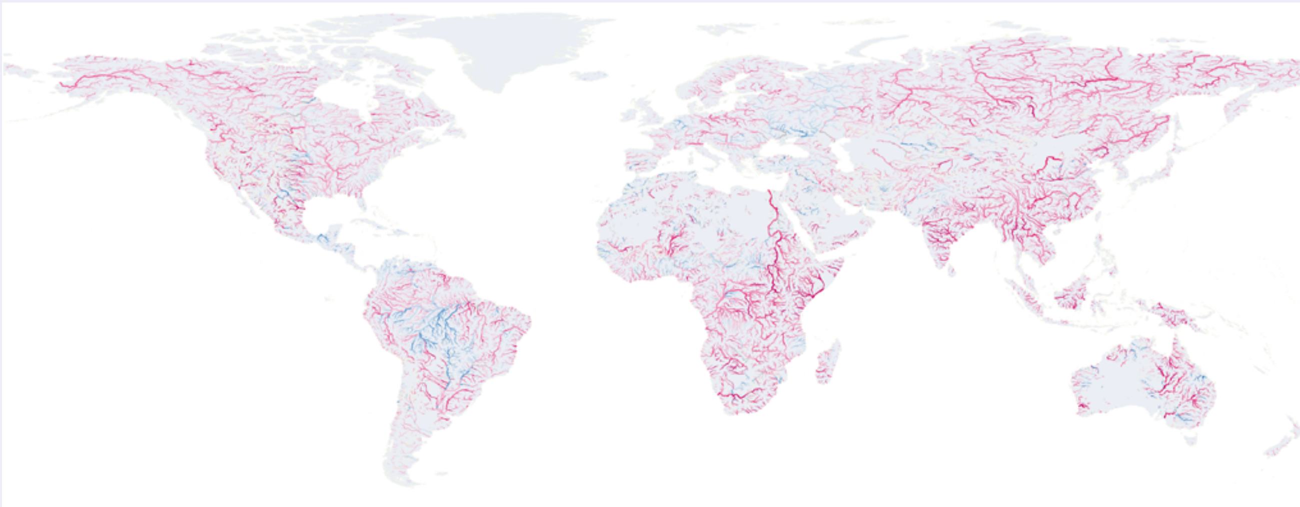


Figure 3: Increase in 100-year flood magnitude: Percent of river sub-basin areas with ≥15% increase in median magnitude of 100-year floods by end of 21st century



Change in 100-year flood magnitude, 2050–2099 vs. 1961–2010 (%)

Figure 4: Change in flood magnitude for 100-year floods in river networks by end of 21st century

Top 15 countries by increase in 100-year flood magnitude		
Country	**Area with >15% increase in magnitude (%)**	**Median increase in magnitude (%)**
East Timor	100%	88%
Bhutan	100%	40%
Kenya	92%	80%
Papua New Guinea	91%	75%
Ecuador	91%	49%
Rwanda	91%	41%
Myanmar	89%	46%
Indonesia	89%	60%
Lao People's Democratic Republic	88%	44%
United Republic of Tanzania	87%	60%
Somalia	87%	99%
Uganda	86%	85%
Vietnam	86%	41%
Guyana	86%	48%
Uruguay	86%	28%

Table 3: Top 15 countries by strong increase in 100-year flood magnitude

Top 15 countries by decrease in 100-year flood magnitude		
Country	**Area with >15% decrease in magnitude (%)**	**Median decrease in magnitude (%)**
Belgium	98%	23%
Netherlands	93%	22%
Guinea-Bissau	80%	29%
The Gambia	77%	21%
El Salvador	74%	24%
Tunisia	65%	25%
Benin	64%	24%
Senegal	61%	27%
Morocco	60%	23%
Guatemala	55%	20%
Dominican Republic	54%	21%
Honduras	49%	21%
Togo	47%	22%
Jordan	47%	23%
Ukraine	43%	20%

Table 4: Top 15 countries by strong decrease in 100-year flood magnitude

Change in future flood magnitude for 10-year floods

Fifty-seven countries have more than half of their river areas predicted to have 15% or greater increases in magnitude for current 10-year floods. These include East Timor (100%), Bhutan (100%), and Papua New Guinea (99%) (see Table 5). The median increase in magnitude for 10-year floods across all countries is 15%. Some countries, such as Oman (100%), Somalia (100%) and Uganda (100%), will have stronger changes and are predicted to have their 10-year floods double in size. Figure 5 shows river sub-basins where 10-year floods will experience increases in magnitude by more than 15% by the end of the 21st century. As with 100-year floods, South Asia, Southeast Asia, and Sub-Saharan Africa are identified as hotspots of concentrated areas of greatest change in flood magnitude for 10-year floods.

Forty-five countries are predicted to have no river area with moderate (15% or greater) decrease in magnitude for 10-year floods. This outcome is a result of the overall small declines in 10-year flood magnitude. The median decrease in 10-year floods among countries is only 9%. Only 12 countries have more than half of their river areas predicted to have 10-year floods decrease by more than 15%. Those that have the most area with decreased magnitude are El Salvador (78%), Guatemala (76%) and Morocco (74%) (see Table 6).

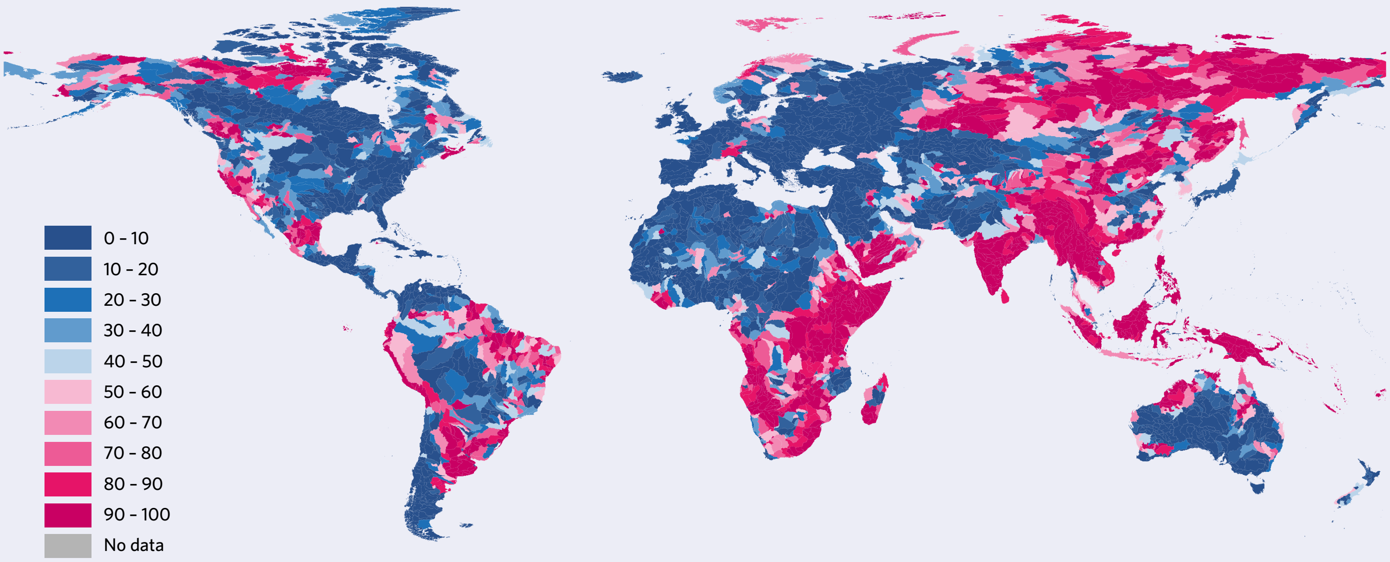


Figure 5: Increase in 10-year flood magnitude: Percent of river sub-basin areas with ≥15% increase in median magnitude of 10-year floods by end of 21st century

Top 15 countries by increase in 10-year flood magnitude		
Country	**Area with >15% increase in magnitude (%)**	**Median increase in magnitude (%)**
Bhutan	100%	44%
East Timor	100%	47%
Papua New Guinea	99%	52%
Rwanda	97%	50%
Somalia	96%	104%
Zimbabwe	95%	36%
Kenya	95%	94%
Philippines	94%	41%
Indonesia	93%	51%
Myanmar	93%	39%
Liberia	92%	19%
Ecuador	92%	33%
Ethiopia	91%	57%
Eritrea	90%	52%
Lao People's Democratic Republic	90%	40%

Table 5: Top 15 countries by increasing 10-year flood magnitude

Top 15 countries by decrease in 10-year flood magnitude		
Country	**Area with >15% decrease in magnitude (%)**	**Median decrease in magnitude (%)**
El Salvador	78%	22%
Guatemala	76%	26%
Morocco	74%	24%
Tunisia	70%	24%
Dominican Republic	69%	25%
Jordan	61%	21%
Western Sahara	54%	28%
Ukraine	48%	19%
Honduras	46%	22%
Cuba	44%	17%
Turkey	42%	15%
Israel	41%	14%
Algeria	40%	23%
Guinea-Bissau	38%	14%
Australia	38%	20%

Table 6: Top 15 countries by decreasing 10-year flood magnitude

Change in future flood frequency for 100-year floods

Sixty-one countries are predicted to experience a significant increase in the frequency of current 100-year floods (as expressed by a decrease in the recurrence interval by 30% or more) for over 50% of their river areas (see Figure 6). A 30% or greater decrease in the recurrence interval means floods of current 100-year flood magnitudes will occur every 70 years or less, instead of every 100 years. The countries which will experience this change across the greatest portion of their river areas include Bhutan (100%), East Timor (100%), Rwanda (98%) and Ecuador (94%). Table 7 shows the top 15 countries with the largest portion of total river area experiencing 30% or greater decreases in recurrence interval for 100-year floods.

One-hundred-and-four countries are predicted to experience current 100-year floods twice as frequently. That is, what is today a 100-year flood will be a 50-year – or even more frequent – flood, in the future. Among these, countries with the greatest decrease in flood recurrence interval (and thereby the greatest increase in flood frequency) are Indonesia (85%), Uganda (82%), and Egypt (79%).

Sixty-eight countries are predicted to have 50% or more of their river areas see a significant decrease in the frequency of 100-year floods (as expressed by an increase in recurrence interval by 30% or more). The countries with the greatest portion of their river areas anticipated to experience this decrease in the frequency of current 100-year flood magnitude events include Belgium (100%), The Gambia (96%) and Guatemala (91%). Table 8 shows the top 15 countries with the largest portion of total river area experiencing 30% or greater increase in the recurrence interval of 100-year floods. Whereas Figure 6 shows the percentage of river basin area which will experience strong increases in flood frequency, Figure 7 shows the variation in increasing and decreasing recurrence intervals of river flooding within individual river networks. South Asia, Southeast Asia, and North Asia are identified as the primary hotspots for flood frequency change in 100-year floods. However, the western coasts of North and South America, as well as parts of the eastern United States and Central Europe will also experience high increases in 100-year flood frequency.

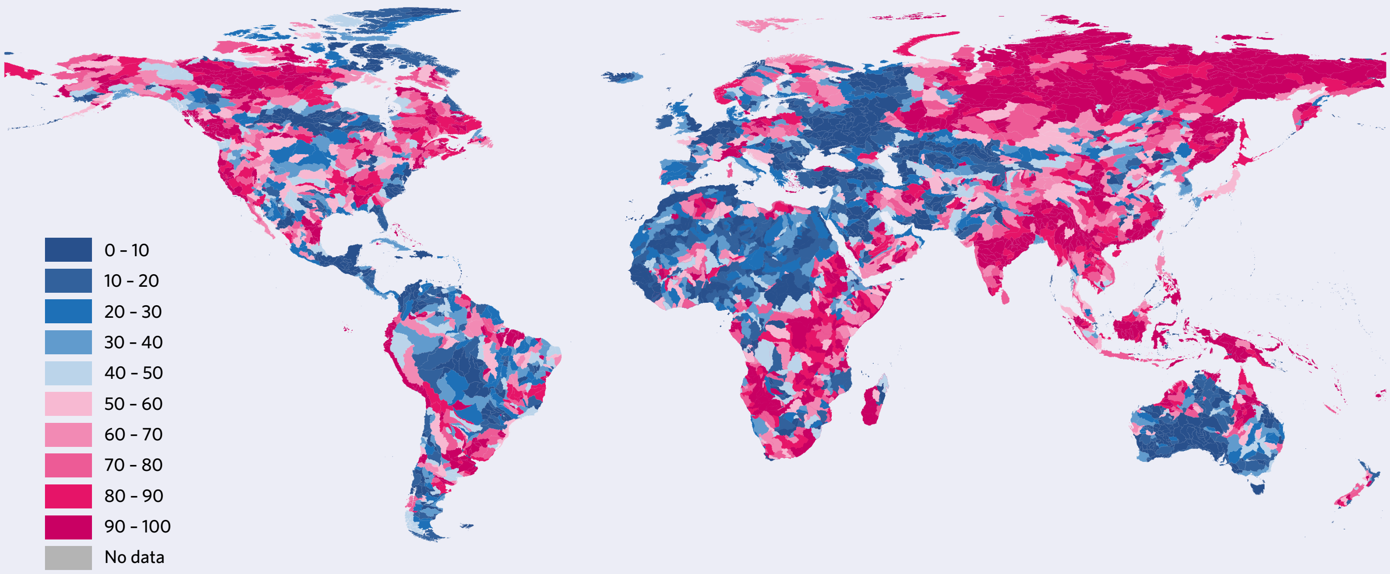


Figure 6: Increase in 100-year flood frequency: Percent of river sub-basin areas with ≥30% decrease in median recurrence interval of 100-year floods by end of 21st century

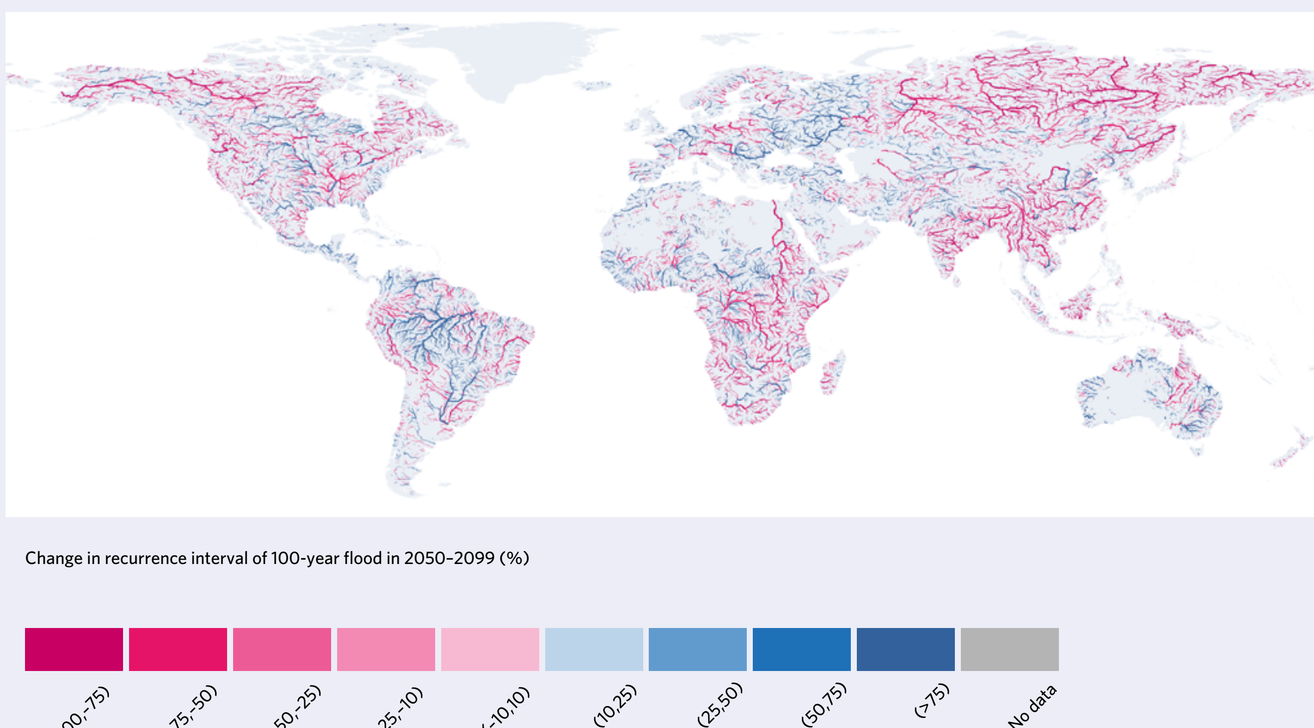


Figure 7: Change in median recurrence interval of 100-year floods for river networks by end of 21st century

Top 15 countries by increase in 100-year flood frequency		
Country	**Area with >30% decrease in recurrence interval (%)**	**Median decrease in recurrence interval (%)**
Bhutan	100%	76%
East Timor	100%	86%
Rwanda	98%	67%
Ecuador	94%	79%
Papua New Guinea	85%	84%
Indonesia	84%	85%
Myanmar	83%	77%
Uganda	82%	82%
North Korea	82%	69%
Uruguay	79%	70%
Lao People's Democratic Republic	79%	65%
Philippines	78%	71%
Eritrea	77%	68%
United Republic of Tanzania	77%	71%
Vietnam	75%	74%

Table 7: Top 15 countries by increasing 100-year flood frequency

Top 15 countries by decrease in 100-year flood frequency		
Country	**Area with >30% increase in recurrence interval (%)**	**Median increase in recurrence interval (%)**
Belgium	100%	> 500%
Netherlands	100%	> 500%
The Gambia	96%	> 500%
Senegal	92%	> 500%
Guatemala	91%	201%
Armenia	89%	> 500%
Sierra Leone	88%	> 500%
Guinea-Bissau	86%	> 500%
Estonia	85%	> 500%
Azerbaijan	84%	419%
Guinea	84%	> 500%
Costa Rica	82%	> 500%
Dominican Republic	82%	> 500%
Morocco	81%	> 500%
Latvia	81%	> 500%

Table 8: Top 15 countries by decreasing 100-year flood frequency

Change in future flood frequency for 10-year floods

The trend for 10-year floods shows less extreme changes than the trend for 100-year floods. Only 58 countries are predicted to have more than half of their river areas see a significant increase in the frequency of 10-year floods (expressed as a decrease in recurrence interval by 30% or more), as seen in Figure 8. The countries with the most river area experiencing this significant increase in frequency of current 10-year flood magnitude events include Bhutan (100%), Burundi (99%) and Papua New Guinea (98%). See further country-level results in Table 9. Thirty-four countries are predicted to have the current 10-year flood occur twice as frequently.

Conversely, fifty-four countries are predicted to see more than half their river areas experience a significant decrease in the frequency of current 10-year floods (30% or more increase in recurrence interval). The countries with the most river area experiencing declining frequency of these floods include the Netherlands (99%), Guatemala (98%) and The Gambia (96%) (see Table 10). Seventy-two countries will see a very high decrease in flood frequency, with median increases in recurrence intervals increasing more than 50%.

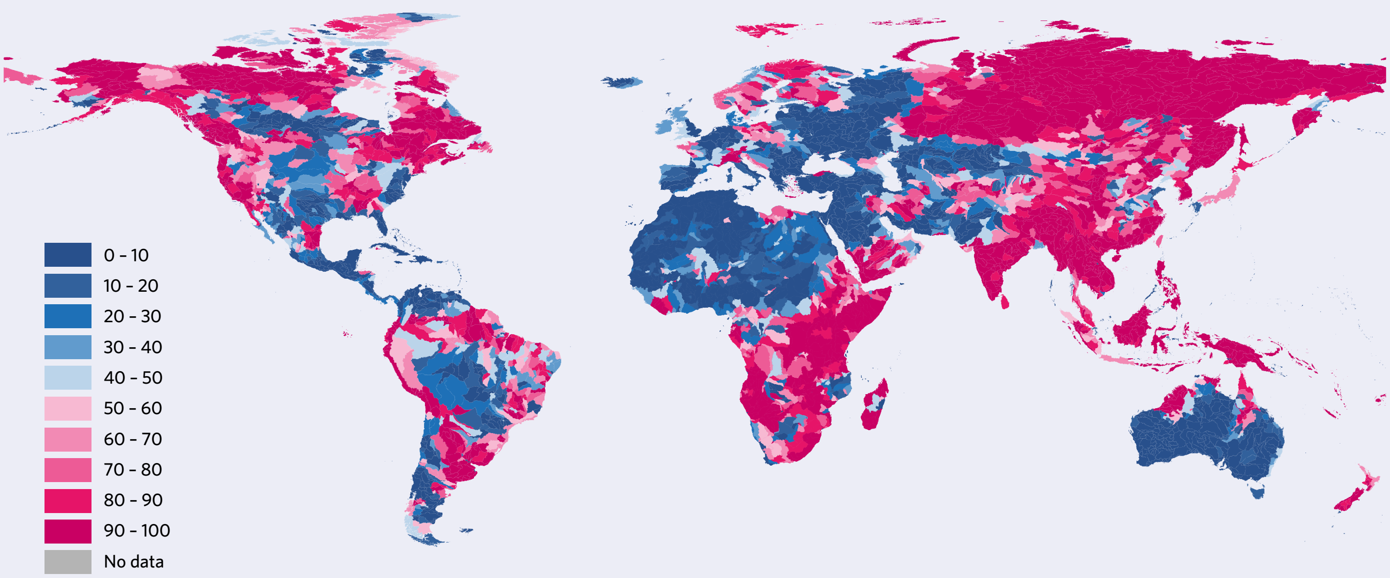


Figure 8: Increase in 10-year flood frequency: Percent of river sub-basin areas with ≥30% decrease in median recurrence interval of 10-year floods by end of 21st century

Top 15 countries by increase in 10-year flood frequency		
Country	**Area with >30% decrease in recurrence interval (%)**	**Median decrease in recurrence interval (%)**
Bhutan	100%	60%
Liberia	99%	50%
Burundi	99%	40%
Papua New Guinea	98%	70%
Rwanda	98%	55%
Philippines	97%	60%
East Timor	95%	50%
Ecuador	94%	55%
Cambodia	93%	50%
Zimbabwe	92%	45%
Lao People's Democratic Republic	91%	55%
Kenya	90%	55%
Uganda	90%	70%
Myanmar	89%	55%
Vietnam	87%	45%

Table 9: Top 15 countries by increase in 10-year flood frequency

Top 15 countries by decrease in 10-year flood frequency		
Country	**Area with >30% increase in recurrence interval (%)**	**Median increase in recurrence interval (%)**
Netherlands	99%	193%
Guatemala	98%	115%
The Gambia	96%	110%
Belgium	94%	255%
North Macedonia	92%	85%
Dominican Republic	90%	200%
Latvia	89%	125%
Tunisia	88%	85%
Morocco	87%	165%
Guinea-Bissau	87%	500%
El Salvador	86%	70%
Israel	85%	75%
Senegal	85%	95%
Estonia	83%	270%
Jordan	82%	85%

Table 10: Top 15 countries by decrease in 10-year flood frequency

3.3 Current Flood Risk

According to the FloodRiskIndex, Bangladesh, Cambodia, India, Nigeria and Vietnam are the five countries with the highest riverine flood risk worldwide. Hotspots of risk are located in South Asia and Central Africa. The high riverine flood risk in South Asia primarily stems from a high flood exposure while the hotspot of risk in Central Africa is closely linked to high vulnerability. This distinction highlights that risk rankings go beyond the flood hazard exposure and are equally driven by societal vulnerability. Countries with high exposure, but relatively low vulnerability, for example the United States of America or the Russian Federation, do not rank highly for flood risk. Conversely, countries such as the Central African Republic with high vulnerability are often at greater risk to much lower levels of exposure than less vulnerable countries and therefore rank higher on the index. The full set of results of the FloodRiskIndex can be seen in figure 9. Table 11 shows a breakdown of the data by country for the top 15 countries. The risk values can range from 0 (min) to 100 (max). The full breakdown of data by country can be seen in the Appendix.

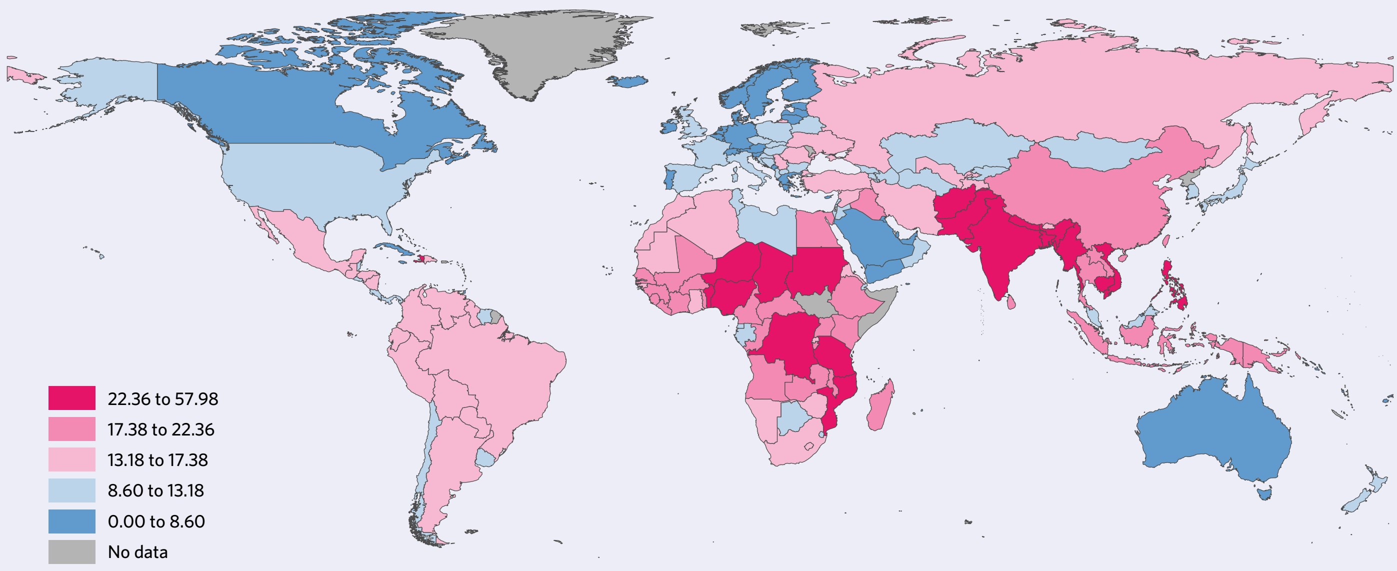


Figure 9: FloodRiskIndex

Top 15 countries in the FloodRiskIndex			
Country	**FloodRiskIndex**	**Flood Exposure**	**Vulnerability**
Bangladesh	57.98	100	57.98
Cambodia	49.64	84.39	58.82
India	29.04	54.86	52.94
Nigeria	27.3	41.02	66.56
Vietnam	27.02	57.78	46.76
Chad	26.71	35.46	75.32
Democratic Republic of Congo	26.49	35.66	74.28
Benin	25.7	39.25	65.48
Sudan	25.67	39.86	64.39
Mozambique	25.51	36.99	68.97
Haiti	24.9	36.5	68.23
Niger	23.62	32.85	71.9
United Republic of Tanzania	23.57	36.86	63.95
Myanmar	23.1	41.7	55.39
Pakistan	23.01	40.44	56.89

Table 11: Top 15 countries by current flood risk

4. Discussion and Recommendations

4.1 Limitations

Before discussing the implications of the presented analysis findings, potential limitations of this study are described to facilitate an accurate understanding and interpretation of the results.

The accuracy of the estimates of **current flood exposure**, based on population and cropland area within inundation areas, is dependent on spatial resolution and data quality, as these results are based on spatially explicit overlays of the current human settlement and croplands data within current inundation areas. For assessing current inundation areas in this study, only flooding occurring more than 25 km inland from the marine coastline was considered, as the GIEMS-D15 model used does not properly distinguish riverine from coastal inundation (Fluet-Chouinard et al. 2015). Therefore, riverine flooding in coastal regions was partly excluded in the analysis of global riverine flood exposure. This buffer of 25 km along marine coastlines might understate and/or otherwise distort the findings for small coastal nations. However, the largely global and regional insights of this report are considered robust, despite this cutoff.

The population data used to assess current flood exposure in today's inundation areas is potentially distorted in rural areas, as small settlements with a spatial extent smaller than 100 m are not accurately detected due to limited spatial resolution. Census population counts were distributed to all respective cells in a region, leading to overly homogenous and not entirely spatially accurate representations of population distributions within sparsely populated regions. However, these distribution errors have little impact on urban population distributions and only slightly distort rural findings. Similar limitations in terms of spatial resolution are perceived for the cropland cover, leading to a limited representation of small farming parcels along tropical latitudes (Dryden et al. 2021).

For the estimation of **future change in flood hazard**, flood modeling at the global scale delivers reliable, yet imprecise results. Identifying specific future flood management and adaptation needs in any given river reach or location requires detailed analysis of projected changes in the context of specific locations. This can only be achieved with simulation models using detailed information on local characteristics such as terrain and land use. A global scale hydrological model, such as WaterGAP3, is not designed to provide a level of site-specific detail. Uncertainty in WaterGAP3 also arises from uncertainties in climate modeling. The presented results on future flood hazards therefore provide insight on the relative scale and direction of change in riverine flood frequency and magnitude, rather than precise analyses of specific future flood conditions. These results can be used for identifying regions where riverine flood hazards are expected to change the most and where the need for adaptation is most acute. To account somewhat for the limited precision in modeling changes in flood hazard in this study, median values of the outputs are reported. Full ranges of output values are shown in the Appendix.

The assessment of **current riverine flood risk**, based on the FloodRiskIndex, has potential limiting factors within the two components: flood exposure and vulnerability. For some countries, zero flood exposure was observed, where one would expect a certain amount of population exposed to annual river flooding. This misrepresentation derives from the underlying data source and the model used to characterize riverine flood hazard conditions. Where no flood events were observed throughout the observation period, no population was exposed. One example is Norway, where no flood exposure was found in the data. Nevertheless, the FloodRiskIndex is largely perceived to be capable of depicting current riverine flood risk levels at the country scale for country comparisons.

As stated before, the vulnerability composite in the analysis of the FloodRiskIndex was adopted from the WorldRiskIndex and reflects general vulnerability of countries towards natural hazards. A more flood specific approach towards vulnerability might be more desirable; however, since the used data on flooding already reflects a certain degree of vulnerability to flooding itself (e.g. nature-based, technical and other constructed solutions that mitigate the severity of flooding) a more general vulnerability approach is suitable for the desired purpose of this study.

4.2 Discussion

The results presented in this report provide insight on the potential current and future climate change-induced impacts of riverine flooding on social, economic and ecologic systems. The study results are intended to be useful to inform countries' and communities' action for flood risk management and climate adaptation against riverine flooding. The current exposure of people and croplands to flooding, the relative future changes in flood hazard, and the current overall flood risk provide a framing of the challenges ahead and can be used to help inform the types, pace and scale of mitigation and adaptation measures required.

Current flood exposure

The assessment of current flood exposure of people and croplands shows that **a significant share of the current global population (~25%) lives in inland flood inundation areas, while 23% of total croplands are located within inundation areas**. This exposure is substantial and reflects high concentrations of human settlement in inland inundation areas, considering that the analyzed inundation areas comprise only 11% of the total land surface areas (Dryden et al. 2021). The exposure of people to river flooding is highly heterogeneous across countries. Regions in North America, South Asia and Southeast Asia are especially exposed to potential river flooding in terms of people. In hese regions, and East Asia, exposure is particularly high for urban populations. In South Asia and Southeast Asia, population exposure is likely affected by large numbers of people living within lowland rice growing areas and large river deltas, which are included in the inundation zones.

In terms of croplands within inundation areas, South Asia and Southeast Asia are also hotspots for current flood exposure. While flood water is important for certain crops to flourish, floods can also be highly damaging to croplands and can lead to erosion of soils and can threaten food security. Three of the top five food producing countries have significant areas within inundation zones, including India (45%), China (31%), and the United States of America (23%). There is a strong need to incorporate flood resiliency and promote adaptation practices within existing croplands to both protect and improve food security in a sustainable manner consistent with global efforts to tackle the twin crises of climate change and biodiversity loss.

Changes to future flood hazard

The analysis of changes to flood hazard shows that future 100-year floods will become more frequent and more extreme in many parts of the world. Areas in Southeast Asia, South Asia, Oceania, and Sub-Saharan Africa have the greatest likely increase in future flood hazards. These results are similar to those of other global studies of freshwater flooding (Alfieri et al. 2017; Winsemius et al. 2016; Arnell & Gosling 2014). Furthermore, every continent has its own areas of significantly changing future flood conditions, including the west coasts of South America and North America, parts of Western Asia, Central Europe and extensive areas of North Asia.

Many of the **areas with the greatest increasing change in flooding are also the areas currently most exposed** to severe flood hazards. This trend is likely a result of prevailing weather patterns and landform features such as river deltas and other low-lying areas. Other areas with large changes include more arid regions like Western Asia and parts of Africa where any change in frequency or magnitude can result in large statistical changes.

Changes to the magnitude and frequency of 10-year floods follow similar geographic trends to those of 100-year floods. These floods are less catastrophic but more frequent, and contribute to long-term problems such as erosion, which can result in significant cumulative economic impacts. Small floods and seasonal high waters are also integrally tied to the ecological health of river ecosystems and to the productivity of flood-dependent agricultural systems, such as rice.

Current flood risk

The FloodRiskIndex highlights the role of vulnerability when assessing overall riverine flood risk, based on the combination of flood exposure and societal vulnerability. Countries with **high flood exposure, but relatively low vulnerability** (e.g., the United States of America) **do not rank highly for overall flood risk** even though they have areas of high flood exposure. Conversely, **countries with high vulnerability** (such as the Central African Republic) **are often at greater risk** to much lower levels of exposure. Given the complex interaction of socioeconomic indicators which influence vulnerability, the FloodRiskIndex is limited to today's flood risk, based on current flood exposure levels and current vulnerability of societies. While future flood risk is not assessed explicitly in this study, major socioeconomic trends can be used to contextualize the picture of current flood risk provided by the FloodRiskIndex against future flood conditions through the modeled changes in flood frequency and magnitude.

Findings in the context of socioeconomic development patterns

Socioeconomic trends in combination with the patterns of climate change will greatly shape future flood exposure and flood risk. The results of this study on current flood exposure of people and croplands, future changes in the flood hazard as well as today's overall flood risk can be partially contextualized for future flood risk by discussing the role of two major trends: population growth and GDP growth. Increasing populations and economic development have the potential to lead to large increases in the exposure of populations and economic assets to flooding (Jongman et al. 2012; Winsemius et al. 2016). Areas expected to have the largest increase in population and GDP coincide with the areas identified in this study as likely facing significantly increased flood hazard conditions (Dottori 2018; Jongman et al. 2012; Winsemius et al. 2016; Hirabayashi et al. 2013). Southeast Asia and Sub-Saharan Africa rank among the areas of greatest future increases in flood frequency and magnitude as well as increases for future population growth and GDP. These regions are also already characterized by high riverine flood risk, as shown in the FloodRisk-Index, and therefore could experience significant flood-related challenges in the future as these multiple factors come together.

The economic disruption caused by floods can often be more significant and long-lasting in more vulnerable countries of the Global South than in wealthier economies of the Global North (Berlemann & Wenzel 2018). Given the trends of increasing population growth and GDP growth, the modeled increasing magnitude and frequency of flood hazards, and the current vulnerability, future exposure and risk could be dramatically exacerbated in these regions if development planning does not account for changing flood patterns. It is also important to note that while areas with high GDP will typically have more assets exposed, they will also be more able to invest more in flood risk management measures, such as early warning systems, flood management infrastructure, and disaster response plans (Jongman et al. 2015). While socioeconomic development typically reduces a country's vulnerability and thereby its risk to flooding, the question of how fairly this development is distributed within a country and where and how communities and developments are planned in relation to inundation areas will be key in determining future flood risk.

All three aspects of current and future flood risk – hazard, exposure and vulnerability can be addressed by the development and deployment of climate adaptation and flood risk management strategies and programs (UNISDR 2015). These strategies include a wide range of possible activities to reduce the exposure, hazards and the vulnerability of countries and communities, including plans and actions which keep people and economic assets out of the most flood prone areas.

The imperative for climate action and adaptation

In light of the changing socioeconomic development patterns and the predicted climate impacts on flood frequency and flood magnitude, the imperative for urgent climate action and adaptation is rapidly mounting. Understanding the future anticipated changes in frequency and magnitude of floods can guide the development of adaptation planning to meet changing riverine flood conditions in the face of climate change.

Changes in frequency and magnitude for 100-year floods are important in considering how often current flood protection infrastructure will be overrun in the future and can provide insights on the future extent of losses and damages due to flooding. The increases in 100-year flood magnitude and frequency presented in this study will lead to more frequent and greater potential loss of life, property, and disruption to business and development for many regions of the world. 100-year floods are typically used as the design standard in constructing flood management infrastructure. This means flood management infrastructure is typically designed to withstand flood events at the current magnitude of a 100-year flood. In areas where the magnitude of 100-year floods will significantly increase in the future, existing flood management infrastructure (if any is in place) will be overwhelmed by these larger floods in the future. In addition, flood events at the current scale of 100-year floods will also occur much more frequently in the future for many regions around the world. This means more frequent and more extensive loss of life and property and disruption to business and development. This study highlights Southeast Asia and Sub-Saharan Africa in particular as facing these threats and shows that 66 countries worldwide are expected to have increases of 25% or more in the median magnitude of their 100-year floods by 2100 (see Appendix for details). Similarly, the results on increases in 100-year flood frequency highlight Southeast Asia and Sub-Saharan Africa as being particularly prone to these changes. These results show that 104 countries are expected to see current 100-year floods occurring at least twice as frequently by the end of this century. This means, much of the current flood management infrastructure (where present) will be strained twice as frequently and will likely therefore have much greater risk of failure and associated maintenance costs. In all cases where the magnitude and/or frequency of 100-year flooding increases, countries must account for these larger flood discharge volumes in extreme events when planning the development of their flood management infrastructure and plans. Considering these changes will be essential in determining the scale of infrastructure and planning needed for effective adaptation.

Alongside increases in flood frequency and magnitude for 100-year floods, changes in 10-year flood occurrence and magnitude are also harmful for exposed assets. Not only do increases in magnitude and frequency of these more flood events amount to a long-term increase in costs through gradual impacts such as erosion, but both increases and decreases in current 10-year flooding can have significant immediate impacts on ecosystems and water-dependent practices which rely on the current scale and regularity of these floods. For example, croplands in many parts of the world rely on a relatively predictable hydrological cycle with regular minor to moderate flood events in order to prosper (IPCC 2018). Ecosystems also have evolved to rely on current scale and regularity of minor to moderate flood events in distributing nutrients throughout a river basin and in driving species dispersal and supporting biodiversity (Naiman and Décamps 1997). However, through climate change and land use change, freshwater biodiversity has declined more than any other species group in recent years (WWF 2020). Both the tendency of humans to disproportionately live near rivers and to utilize grey infrastructure such as dams and levees to manage flood risks contribute to these declines (Death et al. 2015). Future climatic impacts which result in long-term decreases or increases in hydrological flow volumes and regularity would further weaken these already stressed ecosystems and the biodiversity they support. In areas of decreasing or increasing flood frequency and magnitude for both 10-year and 100-year floods, communities are likely to face crises in food production (and potentially food security) and biodiversity loss.

Mitigating greenhouse gas emissions to limit global warming to well below 2°C, as defined in the Paris Agreement (UNFCCC 2015), can mitigate some of the adverse changes predicted in future flood hazard conditions. However, no matter how successful countries are in reducing greenhouse gas emissions, climate change and the associated impact on river hydrologic conditions, including floods, will continue to occur. As a result, there will still be a likely increase in loss and damages from riverine flooding. As discussed above, this is both a result of changes to flood regimes and changes in socioeconomic development patterns. Therefore, in addition to strong climate mitigation action, countries and communities need to develop and invest more in adaptation strategies for flood risk reduction which consider today's and expected future conditions of flood hazard, exposure of people and assets and societal vulnerability to these hazards. As flood risk management programs and projects are designed, approaches are required which support continued socioeconomic development by reducing societal vulnerabilities, while also restoring environmental conditions to minimize adverse compounding impacts on flood hazard conditions. This can include both the restoration of natural areas offering water retention services (NbS) and development planning and actions which keep people and economic assets out of the most flood prone areas.

Nature-based solutions as a multi-purpose solution for flood risk management

The use of Nature-based Solutions (NbS) as a means to manage flood risk offers a multi-purpose approach to address the linked crises of climate change and biodiversity loss and their associated socioeconomic impacts. NbS are defined in this study, according to the IUCN (2016) definition, as all "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". Flood management and ecosystem restoration and conservation are highly compatible, as freshwater ecosystems such as floodplain areas and wetlands act as natural sponges to capture and retain excess water volumes during flood events and then slowly release this water during drought events. They are furthermore areas of high freshwater biodiversity. Nevertheless, these habitats are being lost at an alarming rate (Davidson 2014). The loss and degradation of these freshwater habitats has both reduced the natural hydrological flow regulation services which these ecosystems provide and been a primary driver of freshwater biodiversity loss. As flood management authorities look to develop flood risk management plans, careful consideration should be given to approaches which restore and maintain these natural freshwater systems and the biodiversity they support. Flood management designed using NbS can both restore biodiversity and reduce the severity of flood events by absorbing some of the predicted increased magnitudes in water volume.

The promotion of NbS to mitigate riverine flood risk is not new. The value of NbS is broadly recognized and consistently included in international policy and business discourses and reports, for example, in the IPCC (2019) the IPBES (2019) and the World Bank (2017). In addition, many countries have included NbS into national plans, including national adaptation plans, disaster risk management, development, and drought relief policies (Lo 2016). Despite this solid foundation of support and evidence, investment in NbS for flood risk management remains below 1% of the total global investment in water resources management infrastructure (WWAP 2018). This is consistent with the underspending on disaster risk reduction overall, with funding for disaster risk reduction accounting for 0.4% of all funding spent on international aid (Kellett & Caravani 2013). The barriers to greater investment in NbS are also well documented in the literature. The primary barriers include: 1) conflicting priorities for land use planning (decisions are primarily driven by economic interests; and uncertainty around flooding hinders willingness to invest in mitigation infrastructure), 2) limited capacity for implementing NbS (benefits of NbS are difficult to quantify; and the flood management sector is dominated by traditional engineering expertise), and 3) limited available funding for NbS (high transaction costs and few incentives for engaging stakeholders; little public funding dedicated to support NbS) (Seddon et al. 2020; GCoA 2019; Flitcroft et al. 2019; Hartmann et al. 2019; Darwall et al. 2018; Li et al. 2017).

With these barriers in mind and the diversity of geographies and contexts identified in the study as being impacted by flood hazards, NbS need to be designed and implemented at scale, with sufficient financial, institutional, and technical support. First, it is important to note that NbS do not replace the need for traditional flood management infrastructure, but rather complement this grey infrastructure to create an integrated approach whereby flood management retains and restores some natural hydrological processes within a broader, multi-objective flood risk reduction approach (Hartmann et al. 2019). Secondly, to achieve the scale, capacity and institutional support necessary to overcome the identified barriers and achieve meaningful flood mitigation as well as ecological and social benefits from NbS, planning needs to transition from the current dominant practice of implementing standalone NbS projects to a more programmatic practice of developing long-term, jointed NbS projects at a landscape scale. Only when NbS is implemented at scale, can the socioeconomic and ecological benefits be fully captured. For programmatic approaches to NbS to be successful, it is important that programs include the following key elements: 1) an explicit focus on achieving multiple objectives, 2) a dedicated source of long-term funding, 3) inclusive design for coordination across agency jurisdictions and responsibilities, and 4) early, active and meaningful engagement of stakeholders in the river basin (Ecology 2019; Chan et al. 2018; Xiang et al. 2019; He et al. 2019; de Bruijn et al. 2015). Three of the best known cases of this successful programmatic approach to NbS for flood risk management are Room for the River in the Netherlands, Sponge Cities in China, and Floodplains by Design in the USA. See Box 1 for further insight on the Floodplains by Design program in the USA and see Box 2 for a case study example of how an individual NbS project can be designed to meet multiple purposes.

BOX 1: CASE STUDY

Transitioning from NbS Projects to NbS Programs: Floodplains by Design

In the United States of America, flooding caused more than $2 billion in damages in the state of Washington since 1980. The Floodplains by Design program was launched in 2012 to address this challenge and remains ongoing today. The Floodplains by Design program has provided funding in support of 36 projects across Washington state since 2012. The Floodplains by Design program includes measures such as moving levees to increase flood conveyance, restoring riparian areas, replacing culverts, protecting farms, improving drainage systems and restoring ecological functions of freshwater ecosystems. Collectively, these projects have removed 700 homes from high-risk floodplain areas, reconnected 1,000 hectares of floodplains to rivers, restored 40 km of riverine habitat, and protected 200 hectares of agricultural land. Each of the projects implemented has been coordinated as part of a larger program for managing flood risks and was developed specifically with large scale results and outcomes in mind.

The Floodplains by Design program demonstrates the identified four key elements for successful programmatic management of flood risks through NbS:

1) **Multi-objective projects**
   The Floodplains by Design program in Washington State was developed explicitly as a multi-purpose program. The stated goal of the program is to reduce flood risks and promote floodplain ecosystem recovery while maintaining or improving agricultural production, water quality, and open space/recreation. The funding guidelines require that all projects reduce flood risk to communities and have a significant ecological restoration component (Ecology 2015).

2) **Dedicated funding**
   In Washington state, the state legislature appropriated $116M for the Floodplains by Design program over the period from 2013 to 2019. These state funds leveraged over $55M from other sources to support the projects implemented (Ecology 2015).

3) **Interagency collaboration and technical assistance**
   The governmental and non-governmental organizations which manage the Floodplains by Design program provide significant hands-on support to the local governments who are responsible for developing projects. This support includes training, technical support and facilitation support. These efforts have been considered essential to allow the local county governments with limited in-house expertise on NbS to successfully design NbS projects and undertake this work.

4) **Authentic stakeholder engagement**
   The Floodplains by Design program has a strong facilitated stakeholder engagement process to ensure that relevant stakeholders and the public more broadly are all involved in project siting and design. This allows for the active participation of stakeholders in problem solving and project development. The broad participation by parties with different interests helps overcome the traditional siloed project approaches and builds strong support for the final proposed projects.

The Floodplains by Design program embodies these key elements of inclusive design, dedicated resourcing, multi-purpose frameworks, and interdisciplinary and interagency collaboration. These key design elements have been critical in enabling the program to successfully implement a large number of projects across a vast amount of land in Washington State to achieve large scale, coordinated flood risk reduction benefits which will be maintained and supported by communities, governments and NGOs long into the future.

BOX 2: CASE STUDY

Inclusive Flood Risk Reduction in Northern Bangladesh

According to the FloodRiskIndex, Bangladesh is the country with the highest riverine flood risk worldwide. The high risk primarily stems from an extremely high flood exposure due to the country's geographic location along the Ganges Delta. There are more than 230 rivers and tributaries across Bangladesh. The very high exposure is paired with a high socioeconomic vulnerability from limited coping and adaptive capacities. In recent years the flood risk has very frequently materialized in large-scale flooding, affecting millions of people throughout the country and causing significant adverse impacts on people's livelihoods.

Located along the Brahmaputra River, the district of Gaibandha in northern Bangladesh is particularly prone to river flooding caused by seasonal monsoon rainfalls. In the wake of flooding in August 2020, more than 250,000 people were affected in the district. Seasonal flooding frequently results in the loss of lives and livelihoods, disruption of critical infrastructure services, hampered education, human displacements and regional outbreaks of waterborne diseases. Even though the environmental conditions are not favorable for agriculture, small-scale farming is the predominant income source in Gaibandha, providing livelihoods for the regional population. Alongside the flood hazard, the region is also prone to river erosion due to clay and sandy soils along the riverbanks.

CBM Christoffel-Blindenmission Christian Blind Mission e.V. – one of the members of Bündnis Entwicklung Hilft – is actively engaged in strengthening flood resilience in Gaibandha. In 2016, the Center for Disability in Development (CDD) and CBM pioneered a flood risk reduction project in the northern part of the district along the riverbanks of the Teesta River – a tributary of the Brahmaputra River. Together with the local community, CDD and CBM developed a flood risk reduction initiative, which resulted in a multi-purpose and disability-inclusive flood resilient village for ten local families.

With the support of CDD and CBM, the village's plot was raised by around two meters – one meter above the expected maximum flood height of the nearby Teesta River. Soil was piled up to encircle the land where the new village was determined to be located. Once the surface was encircled and

filled with soil from the riverbanks, the ten families reconstructed their houses and barns for their cattle on top of the elevated land. Strategic parts of the village are stabilized with a combination of locally native deep-rooted fruit trees and bushes to prevent the erosion of the elevated surface during flooding, winds or heavy rainfall. Slopes planted with flood-resistant, deep-rooted turf along the edges enhance the stability of the elevated village. The use of these native deep-rooted natural systems ensure low maintenance of the elevated platform. The NbS also benefit the environment: unlike grey infrastructure, NbS for flood risk reduction do not disrupt the river's ecology and natural course.

The village also has sufficient space for family-organized vegetable gardens, which provide for seasonal harvests. The entire elevated village is designed inclusively to allow easy access and participation for children, elderlies, pregnant women and people with disabilities. Ramps to access the village, as well as wheelchair-friendly water and sanitation facilities within the village, ensure physical accessibility. The village is also equipped with a solar panel to cover the absence of electricity during flood events. Several pipes accelerate the drainage and runoff of wastewater.

This pioneer flood resilient village significantly reduces the exposure and vulnerability of the benefiting families against flooding and erosion. In addition to reducing flood risk, the village project has several co-benefits: the built vegetable gardens and the fruit trees ensure the families' food security and provide valuable income sources since the village inhabitants started to sell their homegrown products on local markets. The elevated land contributed to reducing the loss of livestock and crop failure and therefore increased the resilience of people's livelihoods. The joint ownership as well as the inclusive aspects of the village have strengthened the social cohesion between the families and have led to an increase of cultural community activities. The villagers are also willing to provide shelter for other communities during flood events.

This project shows how NbS can provide several co-benefits beyond cost-effective and sustainable flood risk reduction, such as increased income opportunities and food security. Similar projects have already been initiated in other flood-prone areas in Bangladesh. An expansion of the pilot project along the Teesta River is possible.

4.3 Recommendations

This study presents today's and expected future flood conditions in terms of flood hazard, exposure and vulnerability. The results of this study make a strong case for urgent climate action and adaptation efforts to meet current and future flood risk. The study highlights how NbS can play a key role in addressing these flood risks and changing flood conditions holistically and sustainably. Furthermore, the study suggests best practice principles for implementing NbS programs to successfully meet the multidimensional needs of society and the risks associated with flooding discussed in this report. Key recommendations to move towards this approach and address current and changing flood hazard, exposure and vulnerability conditions and trends identified in this study are listed below.

Ensure strong climate action to limit global warming to 1.5°C: As this study shows, climate change is expected to significantly impact changes in riverine flood hazards. Alongside socioeconomic changes influencing exposure and vulnerability, climate-induced changes in riverine flood hazards can significantly increase future flood risk levels with adverse impacts for millions of people around the globe.

Prioritize hotspots of risk under current and future conditions: Areas across the globe, in particular South Asia, Southeast Asia and Sub-Saharan Africa were identified as regions of high flood risk, both in terms of today's risk levels as well as under changing future flood hazard conditions and socioeconomic developments linked to societal vulnerability. To mitigate current and future disaster risk, identified hotspot regions of flood risk need to be prioritized for flood risk management and adaptation and account for expected changes in future hazards, exposure and vulnerability.

Account for future flood conditions in current disaster management and risk planning: The magnitude and frequency of flooding is expected to change significantly in many regions throughout the 21st century. Already today, such changes need to be consistently considered in the planning phase of flood risk management and adaptation programs to ensure long-term efficacy. Where flood magnitude is expected to increase significantly (e.g. Sub-Saharan Africa, South Asia and Southeast Asia), flood risk reduction and adaptation measures should be geared towards future expected extreme flood event magnitudes and frequencies (100-year floods). In areas where existing flood risk management infrastructure exists, flood risk management budgets and practice should also be adjusted to modernize infrastructure to prevent it from being overrun much more frequently as the magnitude of frequency of extreme (100-year) flood events increases.

Build capacity for implementing nature-based solutions: Nature-based solutions can complement traditional grey infrastructure solutions to significantly reduce flood risk and meet the multidimensional social, economic and environmental needs of communities. However, engineered interventions (grey solutions), rather than NbS, remain the current standard approach for flood mitigation strategies. To achieve a shift towards more sustainable, holistic, and cost-effective management of flood risk, existing guidance documents and frameworks need to be revised to integrate NbS and a broader range of expertise beyond traditional engineering knowledge.

Transition nature-based solution planning and practice from isolated project implementation to a long-term, sustained programmatic approach: There is a need for more sustained, medium to long-term programs dedicated to implementing NbS for flood risk management at scale, rather than scattered, individual projects. Only through a long-term, programmatic approach can NbS be implemented and maintained at a scale which delivers meaningful flood risk management benefits and where the co-benefits of NbS are realized.

Unlock sustained, long-term funding for nature-based solution programs: To enable a successful programmatic NbS for flood risk management approach, dedicated long-term funding is required. Short-term funding instead is likely to result in more scattered individual adaptation projects with stronger focus on short-term priorities. Currently, there is a general lack of funding to implement nature-based disaster risk reduction programs with multiple benefits and purposes. Public funding sources could be a strong source to support NbS programs; however, these should be specifically designed to be cross-sectoral and multi-purpose.

Strengthen inclusive approaches driven by local ownership: Inclusive coordination across agency jurisdictions and responsibilities is needed. The most successful NbS programs have developed methods to engage all relevant stakeholders, especially local communities in river basins, in the processes of planning, implementing and maintaining flood risk management and adaptation programs. This can allow for better consideration of community needs, which generates long-term support and maximizes the capture of co-benefits and ensures long-term positive impact of these programs.

Prioritize long-term benefits over short-term priorities in land use planning and flood management: As of today, economic interests and economic outcomes drive most land use and flood risk management decisions. Investing in flood protection and risk mitigation is undervalued when location and occurrence of hazards are uncertain. Spending on mitigation is minimal compared to spending on recovering and rebuilding after major floods. Similarly, land development activities often fail to adequately integrate considerations for flood risk reduction or natural ecosystem health in their planning. Better monetary quantification of the benefits of improved environmental conditions and risk reduction measures can likely improve sustainable decision-making in land use planning and flood risk management practice.

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Appendix

Overview study findings for all countries

Country	Increase in 100-year Flood Frequency (%)				Increase in 100-year Flood Magnitude (%)				Increase in 10-year Flood Frequency (%)				Increase in 10-year Flood Magnitude (%)				Current Population Exposed		Current Croplands Exposed		Current Flood Risk
	Area with >30% decrease in recurrence interval (%)	Decrease in recurrence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			Area with >30% decrease in recurrence interval (%)	Decrease in recur-rence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			People in inundation zones (total)	People in inundation zones (relative)	Croplands in inundation zones (km²)	Croplands in inundation zones (relative)	FloodRiskIndex
		Median	95%-Quantile	5%-Quantile		Median increase in magnitude (%)	5%-Quantile	95%-Quantile		Median	95%-Quantile	5%-Quantile		Median	5%-Quantile	95%-Quantile					
Afghanistan	23%	44%	82%	5%	22%	13%	2%	47%	19%	25%	60%	5%	13%	9%	1%	27%	3.402.900	13%	1.942	10%	22.63
Albania	22%	43%	68%	10%	3%	7%	2%	16%	4%	10%	33%	5%	0%	1%	0%	6%	232.600	8%	246	9%	10.79
Algeria	34%	51%	81%	11%	40%	40%	5%	347%	5%	20%	90%	5%	9%	16%	1%	> 500%	6.245.500	16%	13.459	23%	15.12
Angola	54%	71%	87%	16%	63%	30%	4%	87%	62%	50%	60%	10%	71%	26%	4%	64%	660.300	3%	67	2%	19.75
Antigua and Barbuda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Argentina	50%	58%	82%	12%	58%	29%	3%	108%	50%	40%	55%	10%	54%	28%	3%	66%	4.772.600	11%	39.196	11%	13.74
Armenia	3%	36%	59%	12%	1%	3%	0%	15%	0%	8%	23%	5%	0%	2%	1%	5%	127.800	5%	134	4%	10.22
Australia	27%	54%	87%	7%	44%	42%	3%	251%	12%	30%	65%	5%	24%	20%	2%	93%	336.100	2%	8.166	3%	7.3
Austria	48%	74%	89%	15%	41%	21%	1%	53%	49%	40%	60%	10%	27%	12%	1%	25%	516.800	6%	555	4%	7.47
Azerbaijan	3%	20%	65%	5%	4%	7%	1%	27%	1%	13%	40%	5%	3%	2%	0%	36%	237.200	2%	727	3%	11.68
Bahamas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Bahrain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.42
Bangladesh	69%	66%	84%	19%	74%	30%	8%	64%	72%	50%	65%	10%	77%	29%	4%	46%	121.841.700	80%	65.693	84%	57.98
Barbados	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Belarus	39%	53%	82%	11%	35%	21%	2%	55%	6%	15%	70%	5%	3%	4%	0%	21%	1.191.500	13%	5.121	9%	10.72
Belgium	-	-	-	-	-	-	-	-	-	-	-	-	0%	0%	0%	0%	4.666.400	42%	3.761	33%	6.95
Belize	-	-	-	-	0%	2%	1%	2%	-	-	-	-	-	-	-	-	8.400	2%	4	7%	11.37
Benin	3%	27%	48%	6%	0%	3%	1%	10%	2%	20%	33%	5%	1%	6%	1%	17%	531.800	5%	1.410	3%	25.7
Bhutan	100%	76%	81%	65%	100%	40%	22%	56%	100%	60%	65%	50%	100%	44%	22%	74%	68.500	9%	2	2%	14.98
Bolivarian Republic of Venezuela	24%	50%	84%	9%	30%	24%	2%	102%	16%	25%	50%	10%	17%	12%	1%	39%	1.757.500	6%	1.262	14%	16.83
Bosnia and Herzegovina	60%	53%	79%	15%	54%	18%	3%	33%	44%	30%	50%	10%	4%	8%	1%	15%	89.900	3%	401	7%	11.9
Botswana	45%	67%	89%	13%	60%	45%	5%	136%	46%	35%	60%	10%	65%	32%	4%	83%	79.700	4%	5	19%	11.45
Brazil	32%	59%	88%	9%	36%	24%	2%	94%	33%	35%	70%	10%	41%	20%	3%	76%	21.221.500	10%	13.410	4%	16.52
Brunei Darussalam	63%	44%	59%	20%	25%	8%	3%	17%	100%	50%	50%	50%	100%	22%	19%	26%	400	-	-	-	3.15
Bulgaria	6%	41%	60%	3%	9%	10%	1%	27%	0%	10%	14%	5%	0%	5%	0%	14%	154.500	2%	795	2%	10.55
Burkina Faso	49%	44%	69%	8%	52%	28%	4%	122%	2%	20%	40%	5%	3%	7%	1%	29%	2.653.000	14%	2.319	12%	19.39

Country	Increase in 100-year Flood Frequency (%)				Increase in 100-year Flood Magnitude (%)				Increase in 10-year Flood Frequency (%)				Increase in 10-year Flood Magnitude (%)				Current Population Exposed		Current Croplands Exposed		Current Flood Risk
	Area with >30% decrease in recurrence interval (%)	Decrease in recurrence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			Area with >30% decrease in recurrence interval (%)	Decrease in recurrence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			People in inundation zones (total)	People in inundation zones (relative)	Croplands in inundation zones (km²)	Croplands in inundation zones (relative)	FloodRiskIndex
		Median	95%-Quantile	5%-Quantile		Median increase in magnitude (%)	5%-Quantile	95%-Quantile		Median	95%-Quantile	5%-Quantile		Median	5%-Quantile	95%-Quantile					
Burundi	51%	42%	72%	25%	61%	21%	6%	55%	99%	40%	55%	30%	75%	20%	8%	49%	1.017.200	10%	944	10%	19.07
Cambodia	67%	62%	85%	14%	73%	29%	4%	72%	93%	50%	60%	30%	89%	31%	14%	55%	12.262.000	77%	38.393	78%	49.64
Cameroon	39%	60%	94%	10%	43%	27%	2%	90%	28%	40%	80%	5%	30%	15%	1%	56%	2.598.100	11%	16.382	26%	22.33
Canada	55%	65%	91%	11%	36%	14%	2%	47%	56%	45%	75%	10%	29%	11%	1%	33%	10.285.000	29%	102.074	21%	7.57
Cape Verde	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Central African Republic	25%	54%	88%	8%	14%	12%	2%	43%	19%	25%	60%	5%	9%	6%	1%	22%	179.800	4%	146	15%	20.03
Chad	14%	36%	94%	4%	21%	20%	1%	370%	9%	40%	90%	10%	14%	13%	1%	378%	3.352.000	24%	29.134	28%	26.71
Chile	36%	52%	84%	5%	28%	13%	1%	47%	20%	30%	70%	5%	16%	9%	0%	50%	778.800	4%	317	5%	11.23
China	60%	65%	89%	15%	64%	30%	4%	147%	60%	40%	70%	10%	65%	24%	4%	90%	498.132.200	36%	415.879	31%	19.87
Colombia	32%	47%	85%	7%	31%	18%	2%	64%	36%	35%	60%	10%	29%	14%	3%	33%	3.002.400	5%	298	7%	16.57
Comoros	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Costa Rica	4%	25%	71%	6%	7%	12%	1%	30%	3%	10%	46%	5%	2%	3%	0%	22%	200.000	4%	52	10%	8.61
Cote d'Ivoire	36%	62%	89%	22%	56%	27%	5%	69%	35%	35%	60%	10%	49%	17%	4%	37%	798.100	3%	288	7%	19.26
Croatia	30%	41%	75%	5%	22%	8%	1%	25%	15%	25%	40%	10%	1%	5%	1%	10%	127.900	3%	818	9%	9.04
Cuba	23%	32%	69%	3%	16%	9%	1%	44%	3%	20%	38%	5%	2%	6%	0%	27%	270.600	2%	1.614	7%	8.08
Cyprus	–	–	–	–	67%	17%	8%	32%	–	–	–	–	0%	1%	1%	1%	2.600	0%	1	0%	4.61
Czech Republic	52%	51%	78%	15%	37%	16%	3%	44%	23%	30%	50%	5%	5%	8%	1%	17%	194.500	2%	283	1%	8.74
Democratic Republic of the Congo	60%	69%	93%	14%	67%	37%	5%	158%	65%	45%	70%	10%	72%	30%	5%	93%	7.326.200	8%	127	13%	26.49
Denmark	33%	54%	65%	10%	58%	36%	2%	77%	4%	20%	38%	5%	33%	16%	4%	30%	58.900	1%	342	1%	5.19
Djibouti	2%	13%	54%	11%	56%	23%	11%	40%	12%	20%	35%	5%	95%	31%	18%	47%	7.100	1%	–	-	11.58
Dominica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Dominican Republic	8%	50%	67%	12%	7%	15%	3%	72%	1%	10%	44%	6%	1%	4%	3%	46%	252.400	2%	387	13%	16.02
East Timor	100%	86%	88%	66%	100%	88%	37%	123%	95%	50%	60%	30%	100%	47%	25%	57%	92.600	8%	–	-	11.99
Ecuador	94%	79%	90%	55%	91%	49%	13%	118%	94%	55%	67%	30%	92%	33%	14%	62%	1.362.700	9%	1.459	25%	14.11
Egypt	23%	79%	99%	17%	23%	63%	4%	> 500%	20%	70%	90%	10%	14%	55%	3%	> 500%	28.297.200	33%	12.084	42%	18.15
El Salvador	4%	24%	52%	7%	4%	8%	4%	22%	0%	20%	20%	20%	2%	16%	16%	16%	205.200	3%	171	7%	12.03
Equatorial Guinea	73%	89%	94%	3%	85%	46%	13%	85%	62%	60%	70%	25%	58%	21%	8%	43%	34.700	3%	–	0%	11.74
Eritrea	77%	68%	90%	36%	84%	62%	10%	200%	58%	35%	60%	15%	90%	52%	22%	124%	662.600	17%	317	10%	15.13
Estonia	6%	36%	54%	11%	3%	6%	0%	16%	5%	25%	70%	9%	3%	7%	1%	16%	86.800	7%	305	7%	6.51
Ethiopia	57%	63%	92%	13%	79%	48%	7%	149%	74%	45%	70%	15%	91%	57%	13%	153%	9.274.100	10%	15.884	10%	22.09
Federated States of Micronesia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Fiji	100%	91%	93%	87%	100%	106%	81%	133%	100%	70%	75%	70%	100%	66%	58%	74%	10.100	–	7	0%	0

Country	Increase in 100-year Flood Frequency (%)				Increase in 100-year Flood Magnitude (%)				Increase in 10-year Flood Frequency (%)				Increase in 10-year Flood Magnitude (%)				Current Population Exposed		Current Croplands Exposed		Current Flood Risk
	Area with >30% decrease in recurrence interval (%)	Decrease in recurrence intervall (%): Median	95%-Quantile	5%-Quantile	Area with >15% increase in magnitude (%)	Median increase in magnitude (%)	Increase in flood magnitude (%): 5%-Quantile	95%-Quantile	Area with >30% decrease in recurrence interval (%)	Decrease in recur-rence intervall (%): Median	95%-Quantile	5%-Quantile	Area with >15% increase in magnitude (%)	Increase in flood magnitude (%): Median	5%-Quantile	95%-Quantile	People in inundation zones (total)	People in inundation zones (relative)	Croplands in inundation zones (km^2)	Croplands in inundation zones (relative)	FloodRiskIndex
Finland	52%	62%	91%	10%	41%	15%	2%	50%	60%	45%	70%	10%	31%	12%	1%	27%	960.200	18%	57	19%	0
France	27%	45%	80%	8%	13%	9%	1%	30%	17%	20%	55%	5%	6%	5%	1%	17%	19.751.500	30%	27.660	13%	9.38
French Guiana	24%	41%	75%	7%	31%	17%	3%	51%	64%	35%	55%	15%	62%	19%	5%	45%	11.900	4%	-	-	-
Gabon	56%	68%	94%	10%	69%	24%	3%	72%	54%	40%	70%	10%	53%	17%	3%	40%	105.800	4%	1	4%	12.97
Gambia, The	-	-	-	-	2%	18%	7%	29%	-	-	-	-	-	-	-	-	209.800	10%	714	16%	14.23
Georgia	22%	39%	61%	4%	7%	4%	1%	23%	7%	20%	40%	5%	1%	4%	0%	13%	142.100	4%	80	3%	11.44
Germany	26%	68%	90%	6%	26%	15%	2%	63%	21%	40%	60%	5%	15%	8%	1%	27%	14.524.200	18%	15.101	11%	8.29
Ghana	28%	56%	86%	11%	31%	40%	3%	132%	7%	20%	40%	10%	8%	8%	0%	29%	1.680.200	6%	1.662	6%	17.37
Greece	12%	31%	60%	6%	2%	6%	0%	16%	0%	10%	33%	5%	0%	1%	0%	7%	267.400	2%	2.802	10%	7.63
Grenada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Guatemala	1%	12%	38%	4%	2%	5%	1%	26%	-	-	-	-	-	-	-	-	1.019.800	6%	243	5%	16.19
Guinea	6%	33%	79%	5%	24%	12%	1%	37%	26%	35%	50%	5%	31%	11%	2%	24%	206.200	2%	324	3%	18.07
Guinea-Bissau	-	-	-	-	0%	3%	3%	3%	-	-	-	-	0%	2%	0%	3%	123.700	7%	5	6%	15.99
Guyana	59%	52%	82%	16%	86%	48%	10%	101%	60%	40%	60%	5%	77%	27%	8%	45%	33.800	5%	3	-	15.19
Haiti	6%	43%	53%	33%	3%	18%	11%	25%	0%	15%	15%	15%	0%	6%	6%	6%	247.400	2%	543	7%	24.9
Honduras	14%	36%	66%	13%	13%	12%	2%	44%	10%	20%	40%	5%	11%	12%	2%	24%	467.100	5%	316	16%	16.5
Hungary	13%	54%	65%	7%	3%	5%	1%	19%	3%	25%	35%	5%	0%	3%	0%	10%	399.900	4%	4.567	8%	10.58
Iceland	15%	77%	87%	39%	10%	20%	0%	58%	12%	40%	50%	10%	5%	9%	1%	27%	900	-	-	0%	0
India	70%	75%	93%	23%	69%	53%	5%	179%	67%	50%	70%	15%	69%	39%	4%	128%	663.445.900	51%	880.563	45%	29.04
Indonesia	84%	85%	95%	32%	89%	60%	12%	137%	84%	65%	80%	20%	93%	51%	16%	87%	49.311.900	19%	16.981	20%	21.48
Iraq	28%	59%	83%	8%	30%	22%	1%	140%	14%	25%	45%	5%	17%	13%	1%	89%	21.863.400	57%	18.534	39%	18.15
Ireland	12%	55%	79%	13%	3%	9%	1%	18%	21%	25%	60%	5%	0%	4%	1%	13%	155.600	3%	133	3%	7.07
Islamic Republic of Iran	37%	47%	78%	8%	33%	16%	2%	59%	25%	25%	50%	5%	25%	12%	1%	33%	9.893.700	13%	15.280	21%	15.96
Israel	11%	30%	55%	2%	4%	11%	0%	22%	0%	10%	10%	10%	-	-	-	-	743.400	9%	744	15%	9.41
Italy	51%	73%	87%	8%	45%	20%	2%	42%	42%	50%	60%	10%	32%	16%	1%	23%	4.749.100	8%	14.153	13%	10.35
Jamaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.200	1%	4	1%	0
Japan	48%	52%	81%	9%	42%	16%	2%	54%	45%	30%	59%	5%	22%	10%	2%	28%	21.127.800	16%	9.494	31%	8.65
Jordan	11%	35%	71%	4%	16%	16%	1%	113%	1%	13%	40%	5%	1%	4%	0%	74%	648.700	10%	569	24%	9.53
Kazakhstan	30%	60%	84%	8%	23%	16%	1%	65%	27%	40%	70%	5%	23%	16%	1%	77%	846.400	5%	1.893	1%	12.01
Kenya	66%	66%	95%	18%	92%	80%	21%	279%	90%	55%	80%	25%	95%	94%	25%	251%	2.496.000	5%	2.610	10%	20.96
Kiribati	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Kosovo	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	27.600	1%	28	1%	-
Kuwait	7%	16%	61%	1%	15%	9%	1%	80%	0%	13%	20%	5%	5%	5%	1%	36%	1.800	0%	-	0%	6.25
Kyrgyzstan	18%	54%	80%	12%	7%	9%	1%	25%	17%	30%	55%	5%	3%	5%	0%	17%	154.800	3%	74	1%	12.41
Lao People's Democratic Republic	79%	65%	89%	15%	88%	44%	9%	100%	91%	55%	70%	25%	90%	40%	12%	67%	3.028.500	44%	2.749	65%	20.73

Country	Increase in 100-year Flood Frequency (%)				Increase in 100-year Flood Magnitude (%)				Increase in 10-year Flood Frequency (%)				Increase in 10-year Flood Magnitude (%)				Current Population Exposed		Current Croplands Exposed		Current Flood Risk
	Area with >30% decrease in recurrence interval (%)	Decrease in recurrence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			Area with >30% decrease in recurrence interval (%)	Decrease in recur-rence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			People in inundation zones (total)	People in inundation zones (relative)	Croplands in inundation zones (km²)	Croplands in inundation zones (relative)	FloodRiskIndex
		Median	95%-Quantile	5%-Quantile		Median increase in magnitude (%)	5%-Quantile	95%-Quantile		Median	95%-Quantile	5%-Quantile		Median	5%-Quantile	95%-Quantile					
Latvia	7%	35%	57%	3%	14%	13%	1%	27%	1%	10%	30%	5%	1%	7%	1%	24%	161.900	7%	388	4%	8.58
Lebanon	18%	29%	63%	11%	7%	4%	0%	21%	–	–	–	–	–	–	–	–	126.300	2%	293	12%	10.89
Lesotho	97%	79%	86%	73%	97%	43%	30%	69%	97%	50%	55%	40%	95%	25%	20%	35%	21.400	1%	4	1%	14.29
Liberia	38%	58%	80%	10%	42%	15%	1%	59%	99%	50%	60%	38%	92%	19%	13%	29%	73.500	2%	1	1%	17.42
Libyan Arab Jamahiriya	28%	55%	92%	10%	30%	37%	3%	> 500%	16%	30%	90%	5%	16%	20%	2%	> 500%	128.500	2%	769	7%	11.9
Liechtenstein	100%	71%	71%	70%	100%	24%	24%	25%	100%	55%	55%	55%	100%	20%	19%	20%	11.900	32%	0	68%	–
Lithuania	74%	48%	74%	11%	80%	24%	5%	60%	2%	10%	30%	5%	0%	4%	1%	11%	202.300	7%	426	2%	8.19
Luxembourg	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4.800	1%	1	0%	5.28
Madagascar	70%	74%	91%	18%	65%	44%	4%	152%	73%	40%	65%	10%	62%	23%	3%	67%	3.630.500	15%	1.529	39%	22.21
Malawi	46%	72%	88%	8%	45%	21%	3%	77%	41%	40%	70%	5%	46%	15%	3%	46%	2.894.600	18%	5.706	22%	20.57
Malaysia	64%	70%	91%	11%	64%	24%	5%	88%	86%	50%	70%	20%	87%	26%	9%	68%	1.742.800	6%	244	5%	12.53
Maldives	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Mali	43%	53%	80%	8%	52%	41%	3%	364%	12%	20%	50%	5%	23%	14%	1%	100%	4.679.700	25%	4.211	21%	21.67
Malta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Mauritania	16%	51%	92%	5%	29%	39%	4%	412%	5%	20%	50%	5%	15%	20%	1%	159%	298.500	8%	40	50%	14.36
Mauritius	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Mexico	38%	60%	86%	10%	50%	48%	4%	224%	22%	30%	60%	5%	44%	25%	2%	90%	10.269.000	8%	14.203	11%	15.2
Mongolia	45%	51%	81%	9%	44%	18%	2%	97%	39%	30%	55%	5%	41%	15%	2%	51%	82.200	3%	49	11%	10.87
Montenegro	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	91.700	15%	4	36%	8.59
Morocco	10%	51%	83%	8%	10%	18%	1%	122%	2%	30%	40%	10%	3%	23%	2%	32%	4.281.000	13%	13.290	18%	15.45
Mozambique	37%	58%	84%	8%	40%	25%	2%	86%	40%	35%	60%	10%	47%	19%	2%	51%	1.419.800	5%	1.874	24%	25.51
Myanmar	83%	77%	89%	23%	89%	46%	11%	165%	89%	55%	70%	20%	93%	39%	14%	77%	19.205.000	38%	63.285	46%	23.1
Namibia	71%	81%	92%	22%	76%	58%	8%	176%	75%	50%	70%	10%	84%	51%	5%	129%	225.800	10%	50	6%	13.44
Nepal	69%	67%	87%	15%	62%	35%	1%	123%	82%	50%	60%	20%	60%	23%	5%	66%	10.287.600	33%	9.650	46%	22.87
Netherlands	–	–	–	–	–	–	–	–	0%	10%	10%	10%	0%	2%	2%	2%	4.173.500	25%	2.324	23%	8.57
New Caledonia	75%	54%	82%	15%	100%	53%	31%	69%	83%	40%	65%	28%	100%	43%	36%	59%	–	–	–	–	–
New Zealand	54%	58%	86%	17%	35%	13%	2%	28%	69%	40%	65%	15%	21%	11%	4%	21%	158.100	4%	71	4%	9.13
Nicaragua	10%	30%	73%	8%	8%	9%	2%	40%	3%	20%	45%	5%	5%	11%	2%	25%	965.900	16%	1.088	28%	14.28
Niger	31%	54%	91%	8%	48%	52%	4%	500%	14%	20%	70%	5%	27%	18%	1%	370%	2.592.300	13%	2.429	5%	23.62
Nigeria	15%	39%	90%	4%	23%	23%	1%	111%	6%	20%	60%	5%	7%	9%	1%	36%	26.597.900	14%	52.630	15%	27.3
North Korea	82%	69%	83%	43%	79%	29%	8%	53%	69%	30%	45%	20%	30%	13%	5%	21%	4.498.200	19%	3.733	11%	–
North Macedonia	3%	28%	46%	6%	0%	2%	0%	6%	0%	10%	10%	10%	0%	2%	2%	2%	151.800	7%	718	24%	10.72
Norway	51%	65%	89%	19%	62%	20%	3%	39%	47%	45%	75%	10%	38%	14%	3%	29%	172.200	3%	158	9%	0
Oman	62%	68%	89%	11%	67%	254%	4%	> 500%	36%	28%	50%	5%	58%	104%	4%	>500%	34.300	1%	0	0%	9.11
Pakistan	41%	42%	76%	7%	39%	18%	2%	95%	12%	20%	50%	5%	15%	10%	1%	26%	78.229.000	38%	83.748	47%	23.01
Palestina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.474.600	29%	378	21%	–
Panama	41%	72%	84%	15%	46%	29%	2%	127%	25%	30%	43%	20%	21%	13%	2%	28%	108.000	3%	14	4%	9.38

Country	Increase in 100-year Flood Frequency (%)				Increase in 100-year Flood Magnitude (%)				Increase in 10-year Flood Frequency (%)				Increase in 10-year Flood Magnitude (%)				Current Population Exposed		Current Croplands Exposed		Current Flood Risk
	Area with >30% decrease in recurrence interval (%)	Decrease in recurrence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			Area with >30% decrease in recurrence interval (%)	Decrease in recur-rence intervall (%)			Area with >15% increase in magnitude (%)	Increase in flood magnitude (%)			People in inundation zones (total)	People in inundation zones (relative)	Croplands in inundation zones (km^2)	Croplands in inundation zones (relative)	FloodRiskIndex
		Median	95%-Quantile	5%-Quantile		Median increase in magnitude (%)	5%-Quantile	95%-Quantile		Median	95%-Quantile	5%-Quantile		Median	5%-Quantile	95%-Quantile					
Papua New Guinea	85%	84%	95%	31%	91%	75%	13%	151%	98%	70%	75%	50%	99%	52%	29%	82%	391.400	5%	20	2%	17.49
Paraguay	39%	66%	90%	17%	49%	72%	4%	> 500%	22%	35%	70%	8%	36%	41%	2%	411%	611.700	9%	909	4%	15.28
Peru	52%	76%	90%	16%	54%	29%	4%	72%	54%	55%	70%	10%	52%	25%	3%	59%	1.505.600	5%	1.493	13%	14.68
Philippines	78%	71%	93%	31%	80%	45%	10%	107%	97%	60%	70%	40%	94%	41%	16%	93%	11.562.000	12%	9.528	28%	22.64
Plurinational State of Bolivia	40%	64%	86%	19%	44%	36%	5%	172%	27%	35%	65%	10%	34%	22%	2%	76%	566.900	5%	2.020	9%	17.11
Poland	67%	69%	88%	13%	76%	35%	5%	85%	43%	30%	60%	5%	30%	13%	2%	33%	1.997.400	5%	6.199	4%	11.06
Portugal	33%	51%	78%	13%	15%	9%	1%	25%	10%	20%	30%	5%	0%	7%	1%	13%	259.600	3%	960	7%	7.75
Puerto Rico	10%	16%	70%	9%	10%	7%	4%	27%	10%	50%	50%	50%	10%	2%	0%	27%	44.300	1%	3	0.5%	–
Qatar	77%	61%	74%	32%	94%	52%	36%	104%	12%	20%	35%	9%	88%	37%	25%	67%	100	0%	–	–	7.4
Republic of Congo	22%	62%	89%	3%	29%	15%	1%	47%	27%	30%	60%	5%	31%	12%	2%	33%	776.900	22%	2	2%	17.85
Republic of Korea	10%	34%	64%	4%	11%	6%	0%	23%	68%	35%	45%	10%	49%	15%	7%	25%	11.897.000	24%	4.393	24%	10.01
Republic of Moldova	4%	24%	58%	14%	7%	11%	3%	23%	5%	30%	36%	20%	0%	6%	1%	8%	200.300	5%	1.025	4%	11.79
Romania	9%	40%	87%	3%	9%	9%	1%	35%	2%	10%	50%	5%	0%	5%	0%	13%	870.800	4%	6.597	6%	13.46
Russian Federation	69%	74%	92%	21%	54%	21%	4%	57%	74%	60%	80%	20%	57%	20%	5%	45%	14.417.500	10%	39.934	4%	14.36
Rwanda	98%	67%	82%	38%	91%	41%	9%	90%	98%	55%	70%	45%	97%	50%	32%	106%	1.260.800	11%	755	9%	17.32
Saint Lucia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Saint Vincent and the Grenadines	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Samoa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Sao Tome and Principe	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Saudi Arabia	43%	66%	89%	15%	52%	57%	6%	> 500%	36%	30%	60%	10%	47%	49%	5%	785%	590.100	2%	70	2%	6.79
Senegal	4%	65%	92%	19%	5%	14%	2%	209%	4%	40%	50%	20%	3%	6%	1%	36%	1.455.400	10%	2.077	9%	18.23
Serbia	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	142.200	2%	1.720	6%	13.81
Seychelles	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Sierra Leone	3%	30%	59%	8%	37%	16%	4%	28%	49%	35%	50%	15%	71%	17%	5%	25%	425.300	7%	521	18%	18.7
Singapore	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–		0
Slovakia	35%	63%	74%	11%	24%	7%	1%	30%	20%	25%	40%	9%	3%	7%	1%	15%	158.800	3%	970	6%	9.81
Slovenia	11%	24%	46%	11%	0%	4%	1%	9%	4%	15%	33%	5%	0%	3%	0%	7%	51.700	2%	26	2%	7.59
Solomon Islands	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Somalia	71%	75%	92%	23%	87%	99%	15%	> 500%	86%	50%	70%	20%	96%	104%	27%	520%	725.700	7%	306	48%	–
South Africa	58%	67%	88%	15%	69%	51%	7%	250%	53%	40%	60%	10%	70%	39%	6%	105%	973.500	2%	1.546	2%	14.74
South Sudan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1.370.300	12%	3.325	17%	–
Spain	20%	40%	77%	5%	16%	10%	1%	45%	3%	20%	40%	5%	1%	5%	0%	14%	6.693.800	14%	21.094	16%	10.23

Country	Increase in 100-year Flood Frequency (%)				Increase in 100-year Flood Magnitude (%)				Increase in 10-year Flood Frequency (%)				Increase in 10-year Flood Magnitude (%)				Current Population Exposed		Current Croplands Exposed		Current Flood Risk
		Decrease in recurrence intervall (%)					Increase in flood magnitude (%)			Decrease in recurrence intervall (%)					Increase in flood magnitude (%)						
	Area with >30% decrease in recurrence interval (%)	Median	95%-Quantile	5%-Quantile	Area with >15% increase in magnitude (%)	Median increase in magnitude (%)	5%-Quantile	95%-Quantile	Area with >30% decrease in recurrence interval (%)	Median	95%-Quantile	5%-Quantile	Area with >15% increase in magnitude (%)	Median	5%-Quantile	95%-Quantile	People in inundation zones (total)	People in inundation zones (relative)	Croplands in inundation zones (km²)	Croplands in inundation zones (relative)	FloodRiskIndex
Sri Lanka	72%	67%	88%	24%	76%	37%	8%	92%	63%	40%	70%	25%	88%	34%	18%	64%	2.264.800	11%	1.421	22%	17.65
Sudan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5.779.400	16%	13.134	19%	25.67
Suriname	22%	45%	85%	5%	43%	21%	4%	88%	64%	40%	55%	12%	70%	25%	3%	42%	32.200	6%	–	–	11.35
Svalbard and Jan Mayen	58%	59%	87%	11%	39%	12%	2%	29%	76%	50%	75%	20%	73%	20%	7%	37%	–	–	–	–	–
Swaziland	16%	38%	90%	10%	80%	43%	2%	110%	71%	45%	65%	15%	95%	47%	20%	105%	9.300	1%	54	8%	11.52
Sweden	38%	61%	91%	10%	32%	14%	1%	45%	47%	40%	70%	5%	23%	11%	1%	29%	1.478.900	15%	3.519	25%	6.28
Switzerland	50%	68%	83%	9%	50%	20%	2%	35%	55%	45%	60%	5%	32%	12%	2%	22%	850.400	10%	255	9%	7.26
Syrian Arab Republic	19%	36%	65%	9%	19%	13%	2%	48%	1%	5%	40%	5%	1%	3%	0%	14%	3.783.300	16%	9.834	25%	17
Taiwan	61%	63%	76%	5%	57%	35%	3%	61%	60%	45%	55%	5%	55%	22%	1%	36%	274.800	1%	198	4%	–
Tajikistan	55%	68%	87%	20%	45%	16%	3%	42%	68%	45%	70%	10%	39%	14%	2%	35%	508.900	6%	326	4%	14.62
Thailand	56%	51%	81%	9%	62%	32%	4%	116%	86%	50%	65%	20%	87%	38%	9%	94%	35.470.000	51%	140.127	67%	20.08
Togo	4%	30%	50%	7%	6%	12%	1%	37%	0%	5%	5%	5%	0%	1%	0%	4%	284.800	4%	442	11%	18.86
Tonga	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Trinidad and Tobago	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
Tunisia	4%	21%	61%	8%	4%	10%	2%	115%	0%	20%	20%	10%	1%	6%	1%	25%	948.400	9%	3.763	15%	10.6
Turkey	12%	42%	76%	5%	6%	8%	1%	29%	3%	25%	50%	5%	1%	6%	0%	17%	4.321.600	6%	19.586	9%	14.01
Turkmenistan	38%	57%	83%	10%	41%	22%	2%	105%	26%	30%	55%	5%	35%	19%	2%	47%	556.200	6%	1.088	7%	12.67
Uganda	82%	82%	99%	48%	86%	85%	26%	> 500%	90%	70%	90%	50%	89%	100%	53%	>500%	4.278.000	12%	6.401	10%	20.11
Ukraine	16%	51%	79%	8%	12%	12%	1%	41%	6%	25%	45%	5%	2%	9%	1%	17%	7.025.700	16%	31.827	8%	14.24
United Arab Emirates	25%	40%	93%	6%	75%	100%	27%	> 500%	36%	20%	51%	5%	62%	30%	6%	340%	10.500	0%	–	-	6.97
United Kingdom	16%	40%	82%	4%	5%	6%	0%	19%	17%	20%	60%	5%	1%	3%	0%	13%	10.357.500	16%	8.371	14%	9.09
United Republic of Tanzania	77%	71%	88%	21%	87%	60%	10%	183%	85%	50%	65%	20%	88%	53%	11%	106%	4.493.700	9%	4.066	22%	23.57
United States of America	49%	60%	89%	11%	43%	18%	2%	92%	37%	35%	70%	5%	26%	12%	2%	44%	49.026.900	15%	325.355	23%	11.4
Uruguay	79%	70%	83%	24%	86%	28%	9%	52%	73%	35%	52%	10%	74%	21%	12%	31%	50.400	2%	248	5%	10.17
Uzbekistan	27%	50%	84%	9%	32%	16%	2%	122%	22%	30%	55%	5%	30%	16%	2%	70%	5.072.700	16%	7.510	16%	15.61
Vanuatu																		–		–	0
Vietnam	75%	74%	88%	23%	86%	41%	12%	115%	87%	45%	60%	24%	84%	29%	8%	50%	45.599.500	49%	28.350	49%	27.02
Western Sahara	23%	49%	89%	5%	30%	76%	4%	> 500%	2%	15%	50%	5%	10%	18%	1%	79%	6.100	1%	–	-	–
Yemen	61%	56%	86%	10%	70%	66%	6%	> 500%	72%	40%	60%	15%	89%	60%	26%	>500%	1.064.100	4%	321	10%	0
Zambia	68%	71%	89%	15%	65%	31%	5%	72%	74%	50%	65%	10%	75%	26%	3%	58%	1.244.200	8%	519	12%	17.99
Zimbabwe	72%	65%	87%	14%	80%	36%	6%	92%	92%	45%	60%	25%	95%	36%	17%	69%	219.100	2%	793	4%	15.63

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