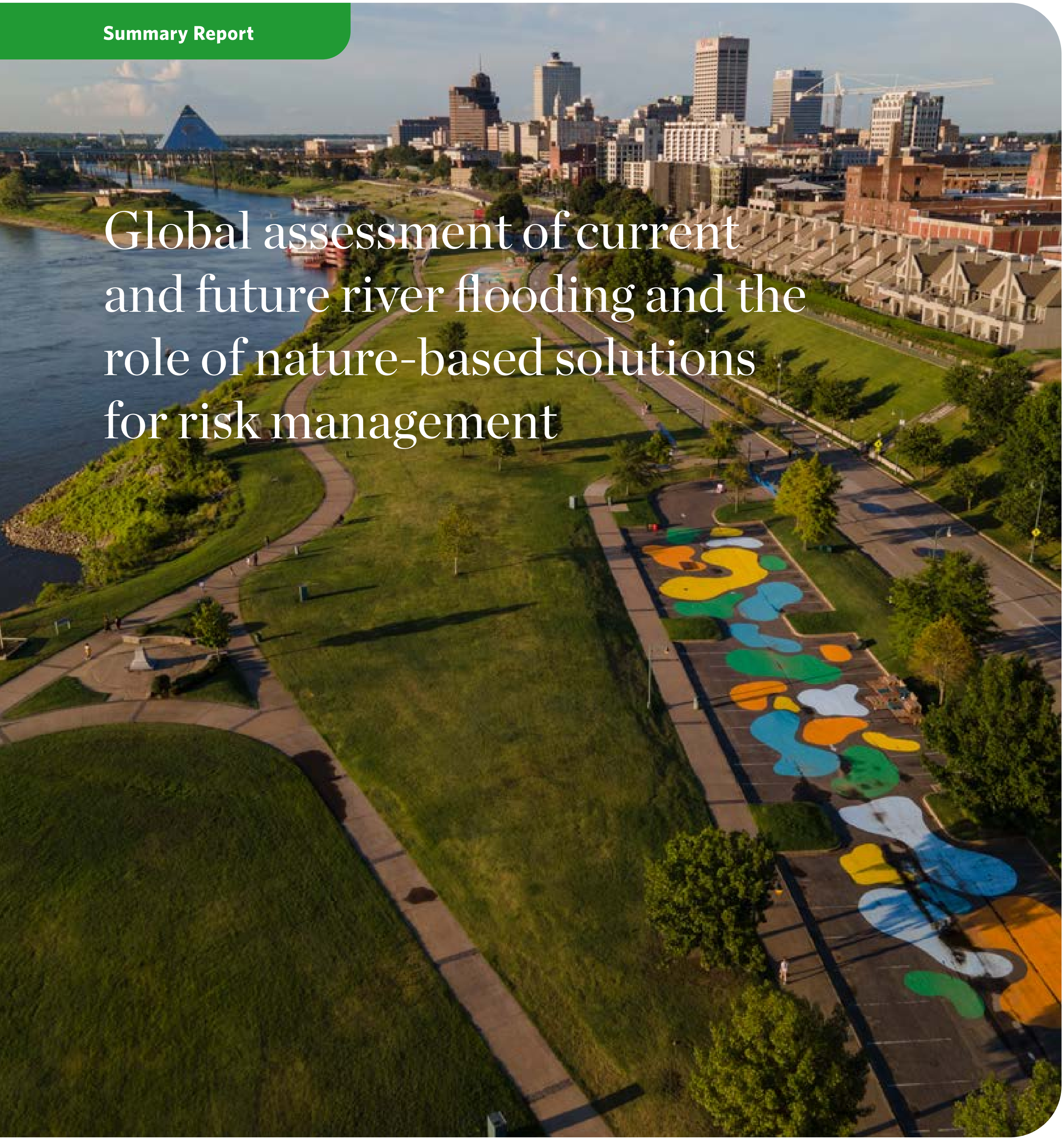
Summary Report

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



The Nature Conservancy Europe
Ruhr Universität Bochum RUB
McGill
Uni Kassel Versität Center for Environmental Systems Research
Bündnis Entwicklung Hilft
Gemeinsam für Menschen in Not.

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

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Pg 12 & 13: Flood affected community in Gaibandha district. © CBM / Gonzalo Bell
Pg 15: Managing rice fields for conservation within the Consumnes River basin. © Erika Nortemann / TNC
Pg 16: An aerial view of the Mississippi River Levee near Mound City, Arkansas. © Rory Doyle / TNC

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This is the 3rd out of a series of three BMU-funded cooperative reports from The Nature Conservancy and Bündnis Entwicklung Hilft. Previous cooperation reports discussed The Global Value of Mangroves for Risk Reduction and Fisheries at Risk – Vulnerability of Fisheries to Climate Change.

Urgent adaptation planning needs

Climate change is altering the magnitude and frequency of riverine flooding. Annual flooding has more than doubled in the last 40 years. Floods are 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). Current investment in flood risk management remains insufficient to meet the current and future needs to significantly reduce loss of life, livelihoods and property caused by river flooding (Kellett & Caravani 2013). The need for increased investment in climate adaptation measures for riverine flood risk is 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.

To better inform adaptation planning, this report provides a global analysis of current exposure and risk associated with riverine flooding as well as future flood conditions towards the end of this century. This report presents findings for 100-year flood events, as this magnitude of flood is often used as the design standard for flood management infrastructure such as levees. The report also presents findings for floods with a return period of 10 years (10-year floods), which is 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.

The report also presents solutions which could help countries and communities cope with the identified changing river flood hazards. The report highlights 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. Beyond addressing flood hazard and exposure, NbS can contribute to reducing societal vulnerabilities, which is vital for holistic disaster risk reduction.

Study Approach

To provide insights on the current state of flooding as it relates to human life, the study maps current inundation areas and the corresponding human settlement areas and agriculture (cropland) exposed to this flooding. Data on population and croplands were spatially overlaid with the mapped inundation areas in a Geographic Information System to estimate the total population and cropland area exposed to flooding at a country and river sub-basin scale.

To highlight how vulnerability impacts overall risk, the study presents the FloodRiskIndex. The index follows the concept of the WorldRiskIndex and is aggregated through the combination of flood exposure (people exposed to present hazard) and vulnerability (22 vulnerability indicators covering susceptibility, lack of adaptation and lack of coping capacities) (Bündnis Entwicklung Hilft 2011; Bündnis Entwicklung Hilft / IFHV 2020). The index shows today's disaster risk for 181 countries worldwide as a consequence of river flooding.

Future flood conditions are modeled by comparing the current period of record (1961-2010) with projections for the second half of the century (2050-2099). The focus is on large, infrequent floods with an estimated return period of 100 years and on more routine, less severe floods with an estimated return period of 10 years. The industry standard, WaterGAP3, was used to model future possible changes in flood size and frequency for each type of flood event (10-year and 100-year floods) under a medium-high climate emissions scenario (Representative Concentration Pathways 6.0).

Key Findings

Current flood conditions: Exposure of people and croplands to flooding and overall risk ranking

+ Globally, 2 billion people live in freshwater flood inundation zones, representing roughly 25% of the current global population. The exposure of people to river flooding is highly heterogeneous across countries, but Europe, South- and Southeast Asia have the highest level of exposure.
+ 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%).
+ The FloodRiskIndex highlights risk hotspots in South Asia and Central Africa.

Eighteen countries have 25% or more of their population at risk from floods. Regions in Europe, South- and Southeast Asia have especially high concentrations of people exposed to river flooding (see Figure 1 & Table 1). In South- and Southeast Asia, this is likely a result of large population numbers within lowland rice growing areas and large river deltas. South- and Southeast Asia are also hotspots for current exposure of croplands to flooding (see Figure 2). 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. Twenty-six countries have 25% or more of their croplands within inundation areas (excluding croplands within 25 km of the coast).

Accounting for vulnerability and exposure, the FloodRiskIndex identifies hotspots of risk in Southern Asia and Central Africa (see Figure 3). Countries with high exposure, but relatively low vulnerability, for example the United States of America, 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. There is a strong need therefore to increase resilience and promote sustainable adaptation practices within existing human settlements and croplands to protect exposed people and assets against the impacts of climate change.

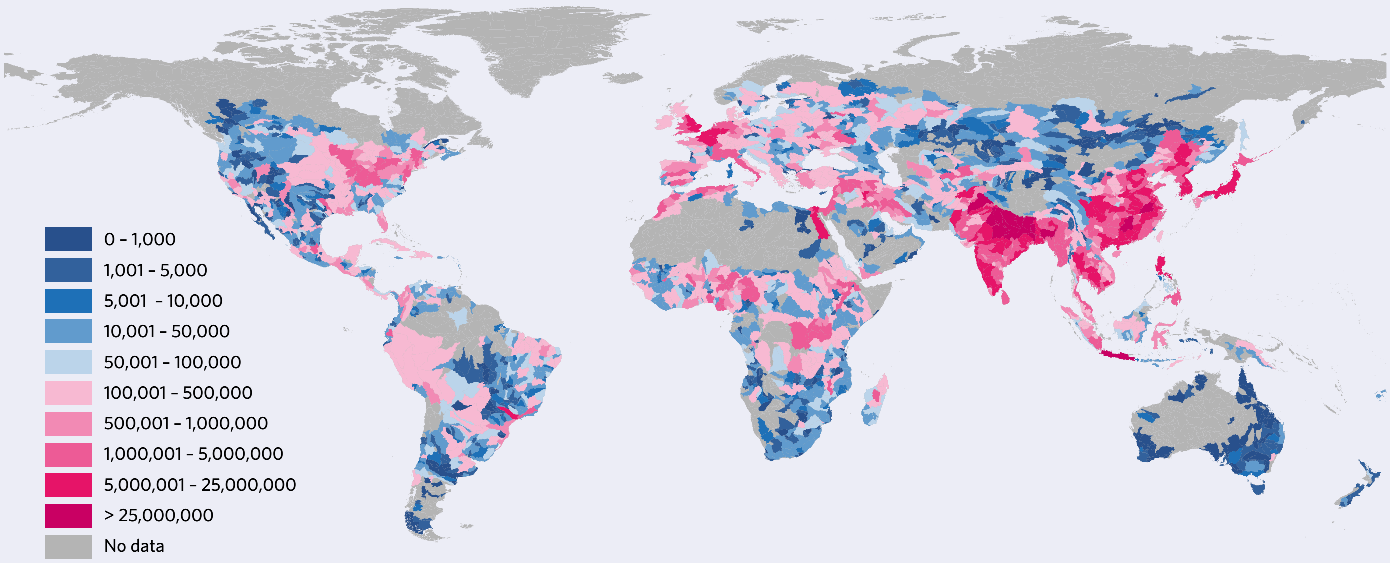

Figure 1: Current exposure of people: Population in inundation areas at sub-basin scale

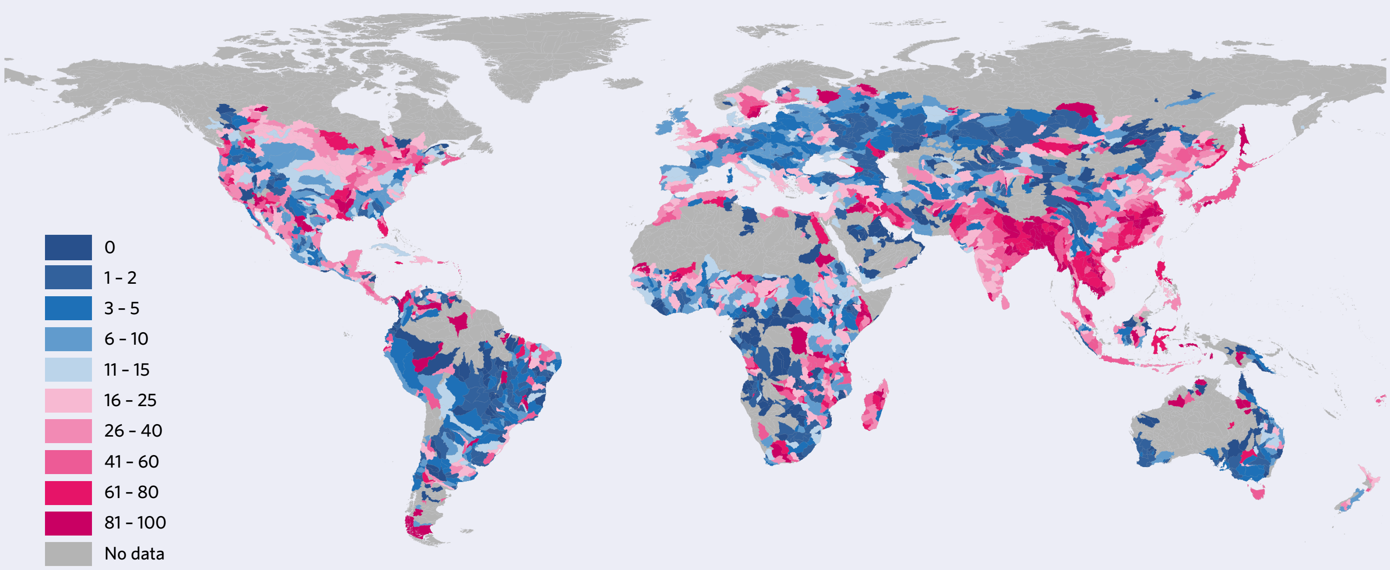

Figure 2: Current exposure of croplands: Croplands in inundation areas at sub-basin scale

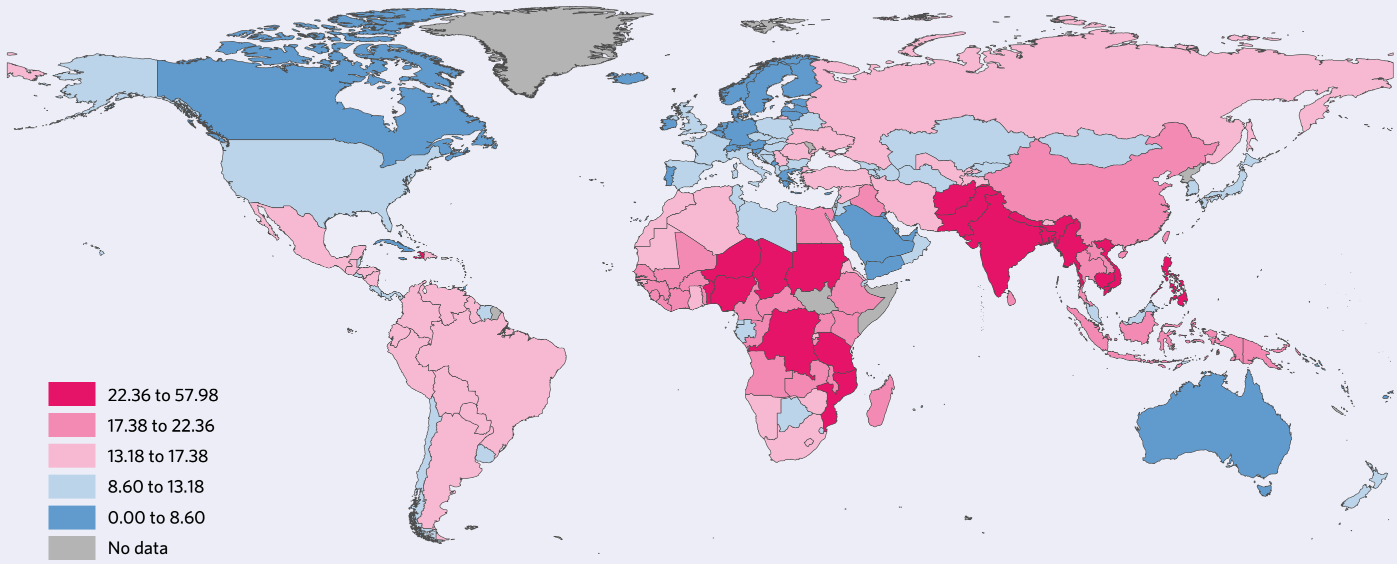

Figure 3: FloodRiskIndex

Top 15 countries most exposed and at risk to riverine flooding					
Countries with the greatest current exposure				**Countries with greatest current flood risk**	
People in inundation areas (millions)		**Croplands in inundation areas (thousands km^2)**		**FloodRiskIndex (0–100)**	
India	663.4	India	880.5	Bangladesh	57.98
China	498.1	China	415.8	Cambodia	49.64
Bangladesh	121.8	United States of America	325.3	India	29.04
Pakistan	78.2	Thailand	140.1	Nigeria	27.3
Indonesia	49.3	Canada	102	Vietnam	27.02
United States of America	49	Pakistan	83.7	Chad	26.71
Vietnam	45.5	Bangladesh	65.6	Democratic Republic of Congo	26.49
Thailand	35.4	Myanmar	63.3	Benin	25.7
Egypt	28.2	Nigeria	52.6	Sudan	25.67
Nigeria	26.5	Russian Federation	39.9	Mozambique	25.51
Iraq	21.8	Argentina	39.1	Haiti	24.9
Brazil	21.2	Cambodia	38.3	Niger	23.62
Japan	21.1	Ukraine	31.8	United Republic of Tanzania	23.57
France	19.7	Chad	29.1	Myanmar	23.1
Myanmar	19.2	Vietnam	28.3	Pakistan	23.01

Table 1: Top 15 countries most exposed and at risk to riverine flooding

Future flood hazard: Changing magnitude and frequency of floods

+ Through climate change, 100-year floods are predicted to become more frequent and larger in many parts of the world, exacerbating the need for accelerated action on climate mitigation and adaptation worldwide. South- and Southeast Asia and Sub-Saharan Africa are identified as hotspots for the greatest contiguous increase in severity of future flood conditions.

Changing conditions for 100-year floods

Areas in Southeast Asia, South Asia, Oceania, and Sub-Saharan Africa have the greatest likely increase in future extreme flood hazard (100-year floods). Sixty-four countries are projected to experience very strong increases in the magnitude (≥15%) of current 100-year floods for over 50% of their river area by the end of this century (see Figure 4). Sixty-eight countries will experience a strong increase in the frequency of current 100-year floods (30% or greater decrease in recurrence interval) for over 50% of their river areas by the end of the century (see Figure 5 & Table 2).

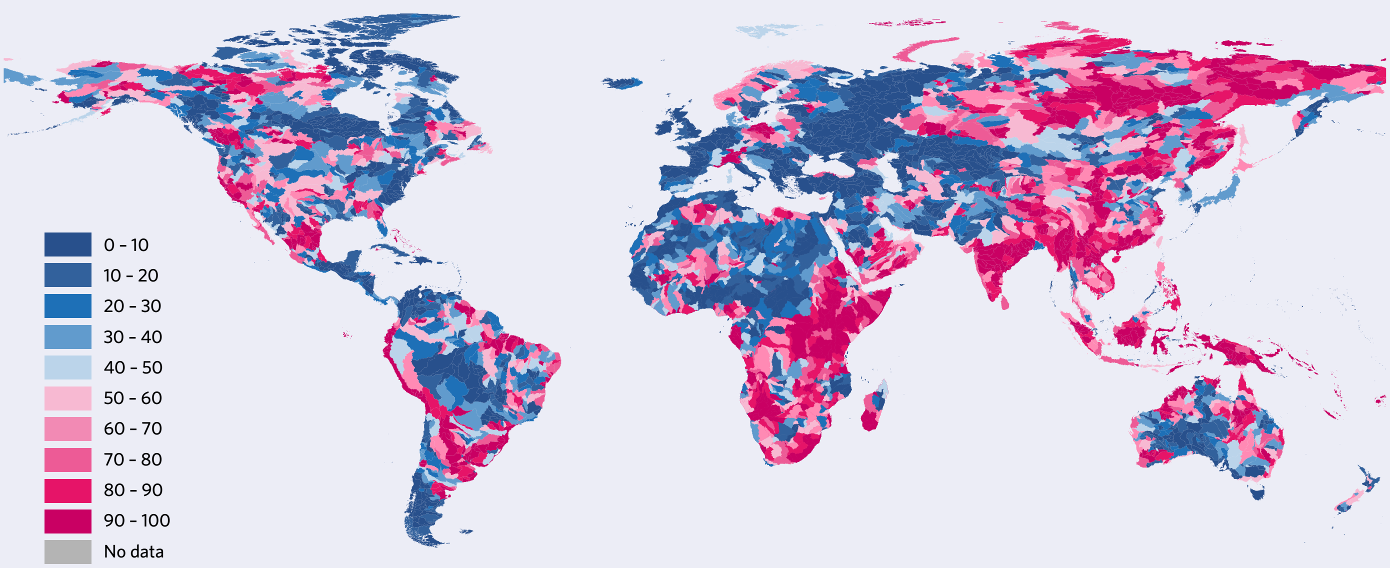

Figure 4: Increase in 100-year flood magnitude: Percent of river sub-basin areas with ≥15% increase in median magnitude of 100-year floods by end of 21st century

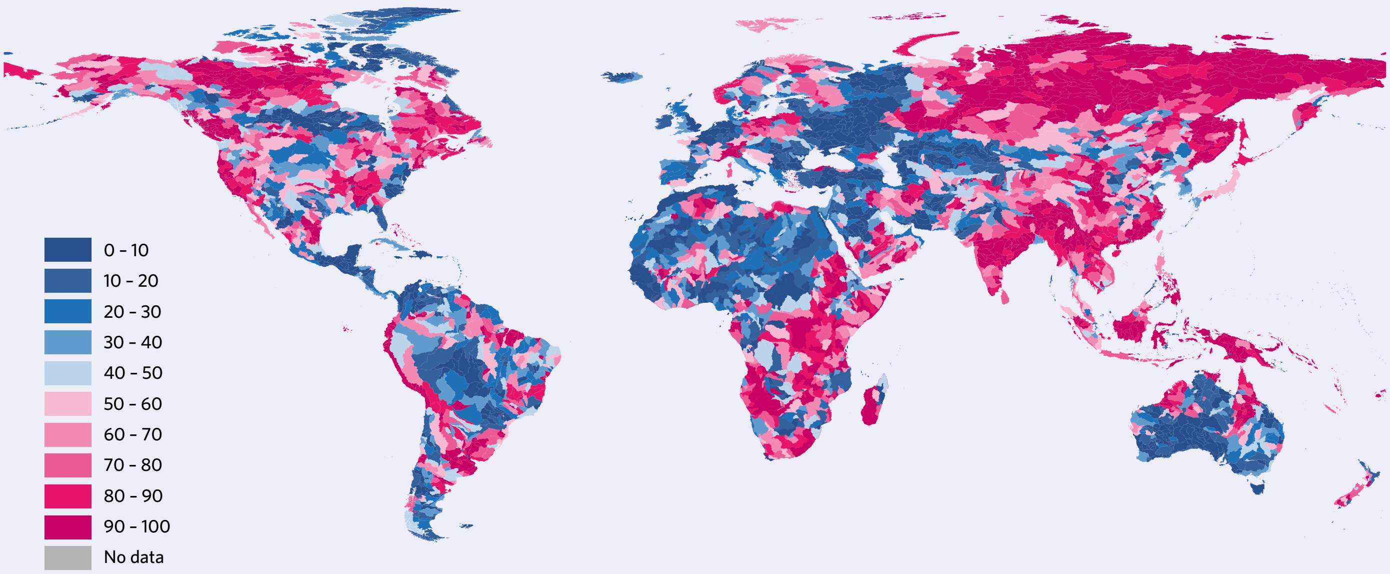

Figure 5: Increase in 100-year flood frequency: Percent of river sub-basin areas with ≥30% decrease in median recurrence interval of 100-year floods by end of 21st century

Changing conditions for 10-year floods

Despite being less catastrophic than 100-year floods in terms of single event losses, changes in 10-year flood frequency and magnitude can have significant negative impacts on food security and the ecological health of river ecosystems. Over time, 10-year floods can also contribute to long-term problems such as erosion, which can result in significant cumulative economic impacts.

Fifty-seven countries have more than half of their river areas predicted to experience 15% or greater increases in magnitude for 10-year floods by the end of the century. Many countries in Southeast Asia, Oceania and East Africa will experience 15% or greater increases in magnitude for nearly their entire river systems. Fifty-eight countries will have more than half of their river areas see a significant increase in the frequency of 10-year floods (decrease in recurrence interval by 30% or more) (see Table 2).

Top 15 Countries with greatest future changes in flood hazard							
Countries with the greatest changing flood hazard							
Percent of river area with ≥ 15% increase in magnitude for 100-year floods		**Percent of river area with ≥ 30% decrease in recurrence interval for 100-year flood (increase in frequency)**		**Percent of river area with ≥ 15% increase in magnitude for 10-year floods**		**Percent of river area with ≥ 30% decrease in recurrence interval for 10-year floods (increase in frequency)**	
East Timor	100%	Bhutan	100%	Bhutan	100%	Bhutan	100%
Bhutan	100%	East Timor	100%	East Timor	100%	Liberia	99%
Kenya	92%	Rwanda	98%	Papua New Guinea	99%	Burundi	99%
Papua New Guinea	91%	Ecuador	94%	Rwanda	97%	Papua New Guinea	98%
Ecuador	91%	Papua New Guinea	85%	Somalia	96%	Rwanda	98%
Rwanda	91%	Indonesia	84%	Zimbabwe	95%	Philippines	97%
Myanmar	89%	Myanmar	83%	Kenya	95%	East Timor	95%
Indonesia	89%	Uganda	82%	Philippines	94%	Ecuador	94%
Lao People's Democratic Republic	88%	North Korea	82%	Indonesia	93%	Cambodia	93%
United Republic of Tanzania	87%	Uruguay	79%	Myanmar	93%	Zimbabwe	92%
Somalia	87%	Lao People's Democratic Republic	79%	Liberia	92%	Lao People's Democratic Republic	91%
Uganda	86%	Philippines	78%	Ecuador	92%	Kenya	90%
Vietnam	86%	Eritrea	77%	Ethiopia	91%	Uganda	90%
Guyana	86%	United Republic of Tanzania	77%	Eritrea	90%	Myanmar	89%
Uruguay	86%	Vietnam	75%	Lao People's Democratic Republic	90%	Vietnam	87%

Table 2: Top 15 Countries with greatest future changes in flood hazard

The Way Forward

Key recommendations to address current and changing flood conditions identified in this study in a holistic and sustainable manner 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. Cutting emissions is the most secure and complete way to reduce future climate hazards. While mitigating greenhouse gas emissions to limit global warming can mitigate some of the adverse changes predicted in future flood hazard conditions, it cannot prevent all future flooding (IPCC 2014). In addition to strong climate change mitigation, countries and communities need to develop and invest more in adaptation strategies for flood risk reduction which consider today's and expected future flood conditions.

Account for adverse interdependencies between socioeconomic developments and flood risk: Socioeconomic trends in combination with the patterns of climate change will greatly shape future flood exposure and flood risk. Increasing populations and economic development have the potential to lead to large increases in the exposure of populations and economic assets to flooding (Winsemius et al. 2016). 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, already characterized by high riverine flood risk, as shown in the FloodRiskIndex, and therefore could experience significant flood-related challenges in the future as these multiple factors come together. Long-term flood risk management planning should therefore be integrated with socioeconomic development planning to 1) plan for development and actions which keep people and economic assets out of the most flood prone areas, 2) implement sustainable measures to reduce flood exposure where human-flood conflict is unavoidable, and 3) promote a fair distribution of resources to reduce vulnerability across society.

Account for future flood conditions in current disaster management and risk planning: Understanding the future anticipated changes in frequency and magnitude of floods can guide the development of urgently needed adaptation planning. Flood management infrastructure is typically designed to withstand flood events at the current magnitude and return period of a 100-year flood. In areas where the magnitude and/or frequency of 100-year floods will significantly increase in the future, existing flood management infrastructure (if any is in place) will be overwhelmed more regularly. This means higher infrastructure maintenance costs and more frequent and more extensive loss of life and property and disruption to business and development. Regions facing increasing frequency and magnitude of 100-year floods (e.g. Sub-Saharan Africa, South Asia and Southeast Asia) must modernize current flood management infrastructure (if any) and flood risk management plans to account for the scale and regularity of future extreme flood events (100-year floods) in order to mitigate losses and damages.

Build capacity for implementing nature-based solutions: Nature-based solutions offer a means to manage flood risk which can provide significant risk reduction and resilience gains and meet the multidimensional social, economic and environmental needs of communities. 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. However, engineered interventions, rather than NbS, remain the current standard approach for flood mitigation strategies in most cases. To achieve a shift towards more sustainable and holistic 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. See Box 1 for a case study example of how an NbS project can be designed to meet multiple purposes.

Promote long-term, sustained nature-based solution programs at a landscape scale rather than isolated projects: Despite mounting evidence in support of NbS, investment in NbS for flood risk management remains below 1% of the total global investment in water resources management infrastructure (WWAP 2018). The primary barriers include: 1) conflicting priorities for land use planning (decisions are primarily driven by economic interests; uncertainty around flooding hinders willingness to invest in mitigation infrastructure), 2) limited capacity for implementing NbS (benefits of NbS are difficult to quantify; 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; Hartmann et al. 2019; Li et al. 2017). To achieve the scale, capacity and institutional support necessary to overcome these barriers, 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 are implemented at scale, can the socioeconomic and ecological benefits be fully captured. For NbS programs to be successful, it is important that they 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; de Bruijn et al. 2015). See Box 2 for an example of a successful NbS program applied at a landscape scale.

BOX 1: 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.

Located along the Brahmaputra River, the district of Gaibandha in northern Bangladesh is particularly prone to river flooding caused by seasonal monsoon rainfalls. 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. 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. 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.

BOX 2: 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 has provided funding in support of 36 projects across Washington state since its founding. This includes measures such as moving levees to increase flood conveyance, restoring riparian areas, 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 kilometers 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 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 further leveraged over $55M from other sources to support the projects implemented.

3) Interagency collaboration and technical assistance: The governmental and non-governmental organizations which manage the program provide significant hands-on support to the local governments who are responsible for developing projects. This 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.

4) Authentic stakeholder engagement: The Floodplains by Design program has a strong facilitated stakeholder engagement process to ensure that relevant stakeholders and the public 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.

These key design elements shown in the Floodplains by Design program have been critical in enabling the successful implementation of a large number of projects across a vast area to achieve large scale, coordinated flood risk reduction benefits which will be maintained and supported by communities, governments and NGOs long into the future.

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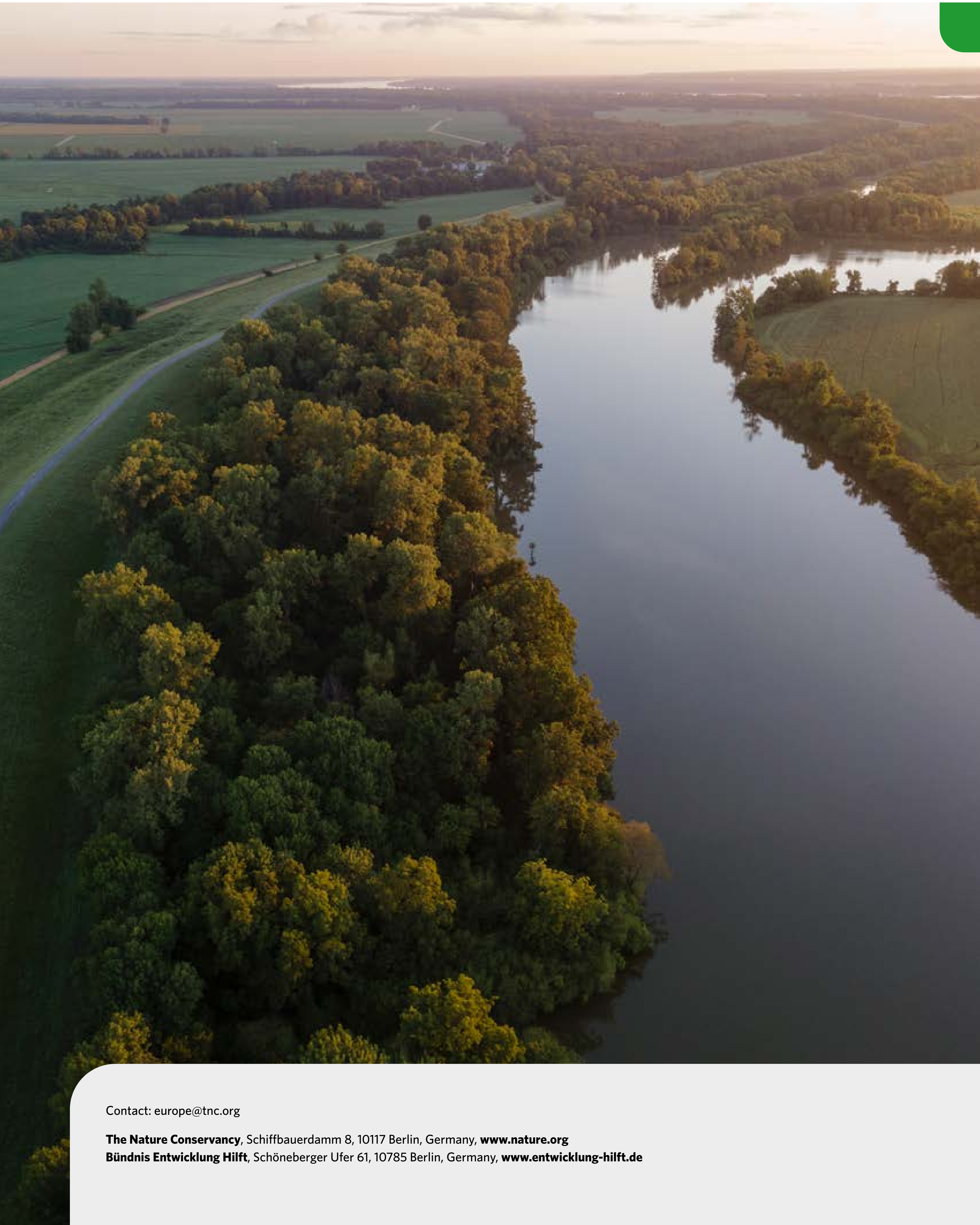

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