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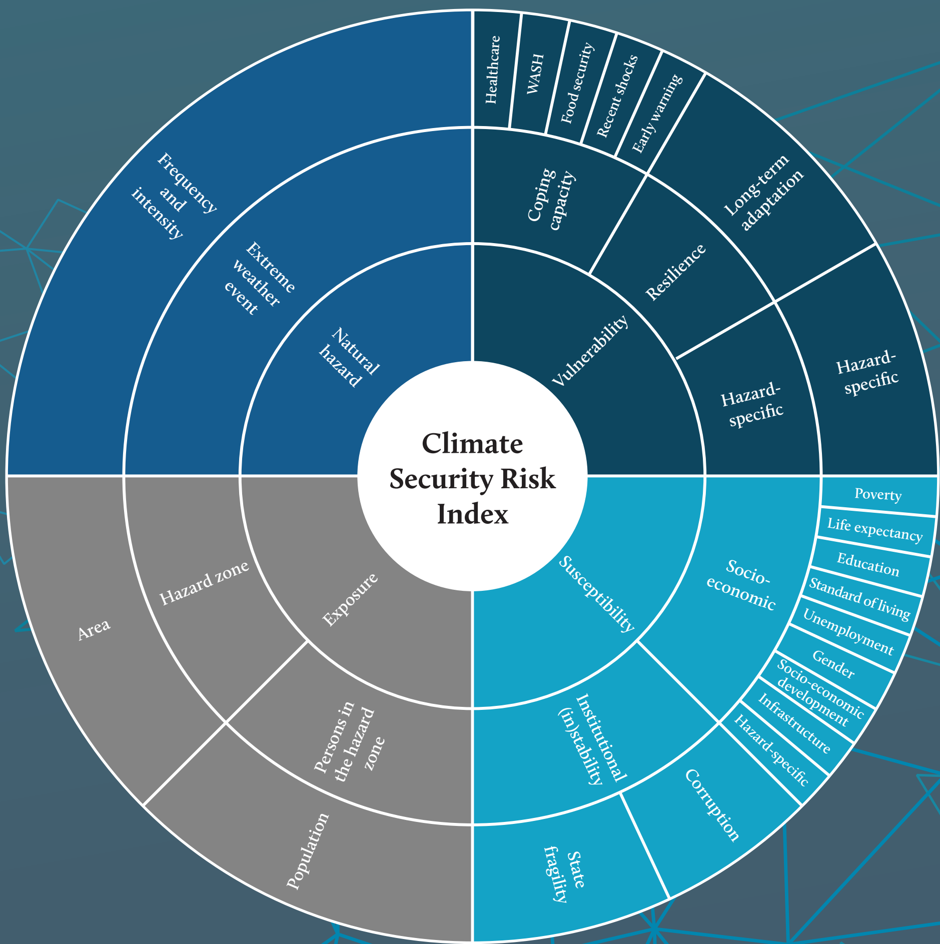
Climate Security Assessment

A Methodology and Assessment of the Nexus between Climate Hazards and Security of Nations and Regions

Femke Remmits, Elisabeth Dick, Michel Rademaker



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HCSS Security
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The International Military Council on Climate and Security (IMCCS) is a group of senior military leaders, security experts, and security institutions across the globe dedicated to anticipating, analyzing, and addressing the security risks of a changing climate. The IMCCS is co-led by:

IMCCS Secretary General
The Honorable Sherri Goodman, Former Deputy Undersecretary of Defense (Environmental Security)
US Department of Defense

IMCCS Chair
General Tom Middendorp (Ret), Former Chief of Defence of the Netherlands

The IMCCS Expert Group consists of IMCCS leaders committed to driving analysis, policy and communications on climate and security, including through the development, publication and endorsement of the World Climate and Security Report, as well as other timely analysis driven by demand signals from the IMCCS. IMCCS Expert Group currently consists of representatives from four institutions:

- The Center for Climate and Security (CCS), an institute of the Council on Strategic Risks (CSR)
- *The Hague* Centre for Strategic Studies (HCSS)
- The Planetary Security Initiative at the Netherlands Institute of International Relations (Clingendael)
- The French Institute for International and Strategic Affairs (IRIS)

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Executive Summary

Climate change and its adverse impacts on the world's environment present increasing security risks to human systems. The rising frequency and strength of extreme weather events, like floods, tropical storms, landslides and, wildfires, are highly likely to increase the occurrence as well as the scope of climate-related disasters. Where extreme weather events interact with human systems, they have the potential to generate widespread mortality, morbidity, and health issues to people present in the hazard zone. Through the destruction of and damage to vital ecosystems, resources, livelihoods of people, infrastructures, and essential services, natural hazards can produce critical adverse consequences, including increased resource scarcity and/or competition, heightened inequality and social tensions, forced displacement and/or migration, and destabilized institutions. Through these mechanisms, natural hazards can pose substantial risks to overall societal stability and security.

Climate security, in this report, implies the relationship between national security and human security and climate change through the direct and indirect security threats posed by climate change-related natural hazards. National security is a fundamental condition to protect human lives and to advance human security, including human rights. Natural hazards include events or trends *directly* influenced by climate change, including coastal and riverine floods, tropical storms (cyclones, hurricanes, typhoons), landslides, droughts, heatwaves, and wildfires. Security threats include those adverse impacts of natural hazards on human societies that spill over into higher-order security risks, including significant natural disasters requiring military responses or natural hazards resulting in threats to critical resources and infrastructure, wide-scale forced displacement, political instability, or intra-state violence and conflict.

Climate change and natural hazards generally do not directly produce intra-state violence or conflict. More often, climate change acts as a threat multiplier by triggering or aggravating existing pressures within societies, including demographic, social, economic, or political strains, that potentially develop as underlying drivers of instability and insecurity. Especially when climate change overburdens the capacity of governments to effectively deal with these accumulating pressures, societies become more vulnerable to social or political instability.

This risk methodology and assessment focuses on the risks to national security generated by climate-related disasters and comprises elements like territorial integrity, ecological security, economic security, physical security, human security and, social and political stability. The methodology supports the combination of multiple indicators and creates a plot based on an X-axis that delineates the hazard on a scale for the *probability* of a climate-related disaster to occur and a Y-axis that delineates the *potential impact* of the specific natural hazard. Such a matrix can be developed to assess climate security risks at different geographical levels: global, regional, and even national levels. The output of this risk assessment methodology is a climate security risk matrix, a tool that helps to identify and evaluate climate-driven risk by assessing the probability and consequences (impact) of potentially hazardous events for countries and regions. Its potential is that it employs well-established data sources and combines them in new ways to give insight into the world's most salient risks regarding climate changes and its consequences for security. Data on discreet events can also be used to produce time series and assess trends in climate-driven risk.

Using the risk assessment methodology aims to inform decision-makers by identifying specific targets to prevent, mitigate, or avert the security impacts of climate-related extreme weather events. Moreover, progress in disaster risk reduction can be measured and the effectiveness of certain strategies assessed.

Introduction

According to projections by the Intergovernmental Panel of Climate Change (IPCC), the earth's temperatures will rise with an average of 1.5˚C between 2030 and 2052.[1] A continued growth in emission rates will result in more extreme temperatures on land, a global mean sea level rise, and an increase in the oceans temperatures. Changes in the global climate are producing substantial effects on natural and human systems around the world. The impacts of climate change are already affecting biodiversity and ecosystems. Moreover, a rise in global temperatures and the mean sea level amplifies the risk of more frequent and severe extreme weather events, including flooding events, tropical storms, heat waves, and droughts.[2]

This climate security methodology and risk assessment are commissioned by the International Military Council on Climate and Security and sponsored by the Government of Luxembourg to assess climate security risk. Climate security is defined as the negative impacts of climate change on national security. These negative impacts can be both direct and indirect and include threats such as conflicts over critical resources, economic damages and destruction of vital infrastructure, loss of territory, environmentally induced migration, international tensions and disputes over resources, and increased instability and (political) radicalization through climate-induced hardship.[3] Such disturbances severely affect human lives and can produce multiple and critical forms of human insecurity.[4]

This risk assessment focuses on the risks to national security generated by climate-related disasters. Considering that natural disasters are generally confined to delineated

1 Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty" (Geneva: Intergovernmental Panel on Climate Change, 2018), 4.

2 Intergovernmental Panel on Climate Change, 7–9; United Nations Climate Security Mechanism, "Briefing Note" (New York: United Nations Climate Security Mechanism, 2020), 1–4.

3 European Commission, "Climate Change and International Security: Paper from the High Representative and the European Commission to the European Council" (Brussels: European Commission, 2008), 5–8; Matt McDonald, "Discourses of Climate Security," *Political Geography* 33 (2013): 42–51; Expert Group of the International Military Council on Climate and Security, "The World Climate and Security Report 2020" (Washington, D.C.: Expert Group of the International Military Council on Climate and Security, 2020), 11–12; The Center for Climate and Security, "Climate Security" (Washington, D.C.: The Center for Climate and Security, 2015).

4 Human Security Unit, "Human Security in Theory and Practice: Application of the Human Security Concept and the United Nations Trust Fund for Human Security" (New York: United Nations Office for the Coordination of Humanitarian Affairs, 2009), 7; Human Security Unit, "Human Security Handbook: An Integrated Approach for the Realization of the Sustainable Development Goals and the Priority Areas of the International Community and the United Nations System" (New York: United Nations Trust Fund for Human Security, 2016), 5.

geographical areas and their impact is largely shaped by environmental, demographic, socioeconomic, and institutional conditions as well as risk management capacities that are determined by national contexts and policies, this climate security risk methodology and assessment will adopt a focus on national security and comprises of elements like territorial integrity, ecological security, economic security, physical security, human security and, social and political stability.

Background

What is climate security?

Climate change and its adverse impacts on the world's environment are posing growing security risks to human systems. More frequent and extreme weather events are highly likely to increase the occurrence and scope of climate-related disasters. When extreme weather events interact with human systems, these can produce widespread mortality, morbidity, and health issues to people present in the hazard zone. Moreover, through the destruction of and damage to vital ecosystems, resources, livelihoods of people, infrastructures, and essential services, natural hazards can generate critical consequences, including increased resource scarcity and/or competition, heightened inequality and social tensions, forced displacement and/or migration, and destabilized institutions.[5] Through these mechanisms, natural hazards pose substantial risks to overall societal stability and national and human security.

The implications of climate-related disasters on overall stability and security are largely indirect, multidimensional – having detrimental impacts on social, economic, political, and environmental aspects varying across geographical and demographic contexts – and changing over time. For example, the impacts of climate-related disasters on crucial and resource-dependent economic sectors, such as agriculture and fishing, can produce profound impacts on food security within communities. In already resource-scarce environments, climate-related disasters could put extra pressure on the livelihoods and well-being of its population. Where governments are not capable or sufficiently motivated to provide their citizens with basic needs – including food, water, energy, health, and security – this will affect the legitimacy of the government in the eyes of the population and potentially trigger social and political instability.[6]

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5 Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 8–10.

6 Expert Group of the International Military Council on Climate and Security, "The World Climate and Security Report 2020," 11.

What is the relationship between climate change and conflict?

The concept of climate security, in this report, refers to the relationship between national security and climate change through the direct and indirect security threats posed by climate change-related natural hazards. National security is a fundamental condition to protect human lives and to advance human security, including human rights. Security threats include those adverse impacts of natural hazards on human societies that spill over into higher-order security risks, including significant natural disasters requiring military responses or natural hazards resulting in threats to critical resources and infrastructure, forced mass-displacement, political instability, or intra-state violence and conflict.[7]

Climate change and its adverse impacts generally do not directly produce intra-state violence or conflict. More often, climate change acts as a threat multiplier by triggering or aggravating existing pressures within societies that potentially become drivers of violence or conflict.[8] Such existing pressures include – among others – continuous population growth, rapid urbanization rates, ethnic or religious tensions, environmental degradation, food, water, and energy availability and quality, health issues, scarce resources, inequality, livelihood insecurity and migration, political polarization, corruption, or weak institutions.[9] Climate change acts as an additional stressor to these pressures that might accumulate and develop as underlying drivers of instability and insecurity. When climate change overburdens the capacity of governments to effectively deal with these pressures, societies become more vulnerable to social or political instability.[10]

Especially in brittle and fragmented countries with developing governance structures, social and political instability could advance as drivers of intra- (or inter)-state violence and conflict. For example, the adverse security impacts of climate change and climate-related disasters can produce fertile environments for terrorist or paramilitary activities. In extremely resource-scarce environments, terrorists or other stakeholders may take control over critical resources such as water reservoirs. This makes it easier for terrorist organizations to recruit among local populations by offering access to those resources or by providing alternative livelihoods or other (financial) rewards in return.[11] Climate-related disasters also have the potential to influence relations between countries and

7 Expert Group of the International Military Council on Climate and Security, 11.

8 United Nations Environment Programme, "Climate Change and Security Risks," United Nations Environment Programme, 2017; United Nations Department of Political and Peacebuilding Affairs, "Addressing the Impact of Climate Change on Peace and Security," Political and Peacebuilding Affairs, 2020.

9 United Nations Environment Programme, "Climate Change and Security: Strengthening Resilience to Climate-Fragility Risks" (New York: United Nations Environment Programme, 2017); Lukas Rüttinger, "Climate-Fragility Risks - The Global Perspective" (Berlin: Adelphi, 2017).

10 United Nations Climate Security Mechanism, "Briefing Note," 5.

11 The White House, "Findings from Select Federal Reports: The National Security Implications of a Changing Climate" (Washington, D.C.: The White House, May 2015), 3.

exacerbate international competition over resources. In drought-prone areas of the Middle East and Africa, water scarcity is already causing deteriorating intra-group relations by generating tensions between national governments and local communities and non-state actors.[12]

How are climate related risks relevant to IMCCS?

Climate-related risks are thus rarely the direct cause of violence and conflict but contribute to these underlying risk factors of instability and insecurity. While a global temperature rise of 1.5-2˚C in the next three decades will produce more frequent and extreme weather events leading to natural disasters, climate change is highly likely to drive these correlated climate security risks as well in the near- and mid-term future. The international security community has a responsibility to prepare for and mitigate the security risks of climate change and its adverse impacts. In many countries, military forces already play an important role as first responders to natural disasters and are key actors in the disaster risk management community. The role of militaries in the context of natural disasters is likely to increase with the growing security risks of such disasters. Moreover, climate change and its adverse impacts could pose risks to military infrastructure, force readiness, military operations to countries worldwide. Considering this context, it is vital to assess the risk of natural disasters leading to enhanced social and political instability or violence and conflict.[13]

This risk assessment focuses on the risks to national security generated by climate-related disasters. Considering that natural disasters are generally confined to delineated geographical areas and their impact is largely shaped by environmental, demographic, socioeconomic, and institutional conditions as well as risk management capacities that are determined by national contexts and policies, this climate security risk methodology and assessment will adopt a focus on national security.

12 Stephen Adaawen et al., "Drought, Migration, and Conflict in Sub-Saharan Africa: What Are the Links and Policy Options?," ed. Everisto Mapedza et al., *Current Directions in Water Scarcity Research*, Drought Challenges, 2 (2019): 15–31; Peter H. Gleick, "Water, Drought, Climate Change, and Conflict in Syria," *Weather, Climate, and Society* 6, no. 3 (2014): 331–40; Tobias Ide, "Climate War in the Middle East? Drought, the Syrian Civil War and the State of Climate-Conflict Research," *Current Climate Change Reports* 4, no. 4 (2018): 347–54; Colin P. Kelley et al., "Climate Change in the Fertile Crescent and Implications of the Recent Syrian Drought," *Proceedings of the National Academy of Sciences* 112, no. 11 (2015): 3241–46.

13 Expert Group of the International Military Council on Climate and Security, "The World Climate and Security Report 2020," 6.

National security implications: climate-related instability and insecurity

National security refers to the protection of the vital interests of the nation and its citizens. Even though countries around the world maintain different conceptualizations of and approaches to national security, these vital interests of countries generally include:[14]

- Territorial security: refers to the territorial sovereignty of nation-states, this can be threatened by military intrusion or occupation, but also by extreme flooding events
- Economic security: this can, for instance, be threatened by a critical disruption in financial transactions caused by a widespread electric or internet breakdown
- Ecological security: this includes critical damage to or destruction of the environment and vital ecosystems as a result of natural processes or human activities, including extreme weather events and contamination
- Physical security: this refers to threats to human lives, including mortality, injury, or disease, caused for instance by military conflict, crime, terrorism, pandemics, or extreme weather events
- Social and political stability: this refers to violations of the rule of law, including political repression and human rights abuses, for instance as a result of disputes and tensions between groups of people

When a country's vital interests are threatened, by extension its national security is at risk.[15] National security is highly interconnected with human security. Disturbances to territorial, economic, ecological, physical and social and political security can pose significant human security threats, including poverty, famine, a lack of access to basic health care, resource depletion, pollution, physical violence, identity-based tensions, political repression, and human rights abuses.[16] Risks to these security dimensions are different than national security threats, as they include risks to people's livelihoods. However, insofar that human insecurity can threaten the legitimacy of ruling authorities, it can impede national security from within. The impacts of climate change on national and human security, therefore, are inextricably linked.[17]

14 Kim R. Holmes, "What Is National Security?" (Washington, D.C.: The Heritage Foundation, 2015), 18–19; National Coordinator for Security and Counterterrorism, "National Security Strategy" (The Hague: Ministry of Justice and Security, 2019), 12, 44.

15 Ministerie van Justitie en Veiligheid, "National Security," Government of the Netherlands (Ministerie van Algemene Zaken, December 1, 2011).

16 Human Security Unit, "Human Security in Theory and Practice: Application of the Human Security Concept and the United Nations Trust Fund for Human Security" (New York: United Nations Office for the Coordination of Humanitarian Affairs, 2009), 7; Human Security Unit, "Human Security Handbook: An Integrated Approach for the Realization of the Sustainable Development Goals and the Priority Areas of the International Community and the United Nations System" (New York: United Nations Trust Fund for Human Security, 2016), 7.

17 Florian Krampe, 2019. Climate Change, Peacebuilding and Sustaining Peace. Stockholm International Peace Research Institute.

Climate change is increasingly defined and approached as a threat to national and human security by international governmental organizations and national governments.[18] In 2007, the UN Security Council - as the responsible UN body for safeguarding international peace and security - discussed the relationship between climate, energy, and security for the first time. Since then, the Security Council has gradually considered the international and regional security implications of climate change in several UN Resolutions and Council debates initiated by its Member States.[19]

While climate change and its adverse impacts (in general) do not produce direct implications to national security, climate change acts as a burden multiplier by overwhelming the capacity of governments to manage existing drivers of instability and insecurity which potentially result in intra- or inter-state violence or conflict.[20] In developing as well as developed economies, climate change, and its adverse impacts are posing heightened challenges to the capacity of governments to provide its population with basic needs and human security. This, coupled with existing pressures within society, climate change, and natural hazards, will put additional burdens on communities and governance institutions around the world. In already fragile or fragmented contexts as well as in developed and stable communities, climate change is putting extra stress on existing demographic, socioeconomic, and/or political dynamics. Depending on the intensity and frequency of climate-related disasters, the degree of vulnerability and susceptibility of a society, climate change stressors could overburden the capacity of governments increasing the risk to instability, violence, and conflict.[21]

The specific **risks** to national security triggered by climate-related disasters analyzed in this climate security risk methodology and assessment include social and political instability and intra-state violence and conflict.

Within nation states, the **drivers** of social and political instability or violence and conflict produced by climate-related disasters include:

- Widespread mortality and morbidity
- Critical environmental degradation, leading to a loss or alteration of vital ecosystems
- Widespread destruction and loss of critical infrastructure and livelihoods
- Critical rates and spread of health issues that overburden the capacity of health services

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18 European Commission, "Climate Change and International Security: Paper from the High Representative and the European Commission to the European Council"; John Comiskey and Michael Larrañaga, "Climate Security: A Pre-Mortem Approach to a Sustainable Global Future," *Homeland Security Affairs* 15, no. 8 (2019): 1–42.

19 Climate Security Expert Network, "Short History of UNSC Engagement on Climate-Related Security Risks," Climate Security Expert Network, September 10, 2015; United Nations Climate Security Mechanism, "Briefing Note," 8.

20 United Nations Environment Programme, "Climate Change and Security Risks"; United Nations Department of Political and Peacebuilding Affairs, "Addressing the Impact of Climate Change on Peace and Security."

21 Expert Group of the International Military Council on Climate and Security, "The World Climate and Security Report 2020," 11–12; The White House, "Findings from Select Federal Reports: The National Security Implications of a Changing Climate," 8.

- Critical cuts in the availability and quality of food, leading to widespread food insecurity
- Critical cuts in the availability and quality of freshwater resources, leading to widespread water insecurity
- Critical cuts in the availability and quality of energy supplies, leading to widespread energy insecurity
- Increased social and economic inequality between people, including gender inequalities and gender-based violence
- Increased competition between people and/or groups of people over scarce and critical resources
- Increased tensions within society, including social, ethnical, cultural, and/or political tensions
- Forced displacement and increased migration from disaster-prone areas to cities, overtaking the pace of infrastructural development within these cities
- Increased pressures on weak governance or increased corruption, overburdening the capacity of the government institutions and/or decreasing the legitimacy of the government
- Increased and heightened political polarization

These drivers of instability, violence, and conflict constitute root causes to human insecurities, including economic, food, health, environmental, personal, community, and political insecurities.[22] The multi-dimensional ways in which climate change and its adverse impacts, including climate-related disasters, produce critical threats to national security underscore the importance and necessity to develop adequate climate security risk assessments. This report presents a methodology to measure the security risks of climate-related disasters. The quantification of climate-related risk allows for a more detailed evaluation and analysis of risk and the data that will be needed for the design of appropriate and advanced risk reduction strategies.

Risk assessments are developed using different methodologies and visualizations. The output of this methodology is a climate security risk matrix, a tool that helps to identify and evaluate climate-driven risk by assessing the probability and consequences (impact) of potentially hazardous events. A climate security risk matrix is a plot based on an X-axis that delineates the hazard on a scale for the *probability* of a climate-related disaster to occur, and a Y-axis that delineates the *potential impact* of the specific natural hazard. Such a matrix can be developed to assess climate security risks at different geographical levels: global, regional, and even national levels.

22 Human Security Unit, "Human Security in Theory and Practice: Application of the Human Security Concept and the United Nations Trust Fund for Human Security" (New York: United Nations Office for the Coordination of Humanitarian Affairs, 2009), 7; Human Security Unit, "Human Security Handbook: An Integrated Approach for the Realization of the Sustainable Development Goals and the Priority Areas of the International Community and the United Nations System" (New York: United Nations Trust Fund for Human Security, 2016), 7..

Scope

Climate change and security risks

This risk assessment exclusively considers climate change-related natural hazards which refer to natural hazards that have been or will be directly influenced and/or aggravated as a consequence of global climate change. This risk assessment adopts this focus due to the projected increase in the frequency and intensity of these natural hazards. This selection of hazards excludes natural events like earthquakes, mass movements, tsunamis, glacier lake outburst floods, or volcanic activity which are geologically occurring phenomena. The future occurrence of the latter type of natural events is not *directly* determined by climate change, although their incidence might be aggravated to some degree by global rising temperatures and sea-level rise or through triggering and cascading effects of other hazards.

In this disaster risk assessment, hazards thus include natural events or trends directly influenced by climate change. These include:

- Flooding: coastal and riverine floods
- Tropical storms: cyclones, hurricanes, typhoons
- Landslides
- Droughts
- Heat waves
- Wildfires.

The criteria for the disaster risks assessed in this report are climate-related disasters whose impact on social, economic, political, and environmental systems can generate such critical security implications that either: require military responses, resulting in threats to critical resources and infrastructure, generate forced mass-displacement, heighten political instability, or intra-state violence and conflict. For instance, in countries of Asia and the Pacific, it is not uncommon that military forces serve as first responders in disaster rescue and relief operations when the extent of losses and damages exceed the ability or disrupt the functioning of local support services.[23] In drought-

23 Deon Canyon, Benjamin Ryan, and Frederick Burkle, "Military Provision of Humanitarian Assistance and Disaster Relief in Non-Conflict Crises," *Journal of Homeland Security and Emergency Management*, 2017; Elizabeth Ferris, "Future Directions in Civil-military Responses to Natural Disasters" (Washington, D.C.: Brookings Institution, 2012).

prone countries of the Horn of Africa, recent drought periods have already been linked to regional instability and episodes of conflict between pastoralist communities.[24] Recent research has related the onset of the violence leading up to the Syrian civil war in 2011 – among other variables – to the intense drought period between 2006-2010. This drought period increased social susceptibility and generated competition over resources and employment in an already complex and brittle political context.[25]

24 Adaawen et al., "Chapter 2 - Drought, Migration, and Conflict in Sub-Saharan Africa."
25 Ide, "Climate War in the Middle East?"; Marwa Daoudy, "The Climate-Security Nexus with Marwa Daoudy," Center for Strategic and International Studies, June 1, 2020.

Used terms and definitions

A number of key variables underlie our risk assessment methodology and the broader design of the Climate Security Risk Matrix. Based on extensive research into the disaster risk management literature and existing risk assessment methodologies, the following components were identified: risk, natural hazard, probability, vulnerability, coping capacity, resilience, potential impact, susceptibility, and exposure. Existing risk assessment methodologies have used varying definitions of these concepts. For that reason, we explain the terms and definitions used in this chapter. To arrive at our own conceptualization, and ultimately a measurement, of the key components associated with climate security risk, we have reviewed and analyzed academic and climate-related literature on said concepts (see Appendix 1: Review of the literature).

Climate change

Climate change is understood – in line with the definition presented by the IPCC – as "an alteration in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer".[26]

Risk

Risk refers to the potential adverse impacts of natural physical events or trends on the human and natural environment, causing critical loss, damage, or adverse effects to exposed elements of value. Risk is measured as a function of the probability of a natural hazard to occur and the potential adverse impacts this hazard could cause within a society.[27] A natural hazard (the event) and exposed elements must simultaneously be present in one location to give rise to risk. Natural hazards can also take the shape of slow-onset events, or environmental degradation processes, including rising sea levels, salinization or desertification.[28]

26 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*, ed. Christopher B. Field et al. (Cambridge: Cambridge University Press, 2012), 29.

27 Intergovernmental Panel on Climate Change, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (New York: Cambridge University Press, 2014), 1772.

28 Platform on Disaster Displacement, "Key Definitions – Disaster Displacement," Platform on Disaster Displacement, 2021.

Disaster Risk

When hazardous physical events interact with vulnerable and susceptible contexts and generate widespread humanitarian, environmental or, economic impacts that result in severe alterations of the normal functioning of a community or society, such an event can be defined as a disaster.[29] Data on discreet events can also be used to produce time series and assess trends in climate-driven risk, including slow-onset disasters.

Natural physical events do not give rise to disasters by itself. Disasters occur when a natural physical event interacts with exposed people, ecosystems, resources, economies, infrastructure, and institutions (for the definition of exposure see *Used terms and definitions*).[30] The susceptibility of these elements to be negatively affected is the consequence of human design and behavior, which is why "natural disaster" is often argued to be a misleading concept. If there are no people or valuable assets located in areas where natural hazards could arise – i.e. if there is no exposure of susceptible elements –, then the impact of a natural physical event in that location would not be considered a disaster. Likewise, if societies are capable to effectively deal with the occurrence of a natural event, there would also be no disaster risk. For instance, if a country experiences frequent flooding events but has sufficient and effective flood protection infrastructure in place so that these floods do not or only rarely exceed or break through these defenses and interact with exposed elements, then there would also be no (or a limited) risk for a natural disaster to arise. Hence, natural disasters are in fact "un-natural" and dependent on human-related factors.[31]

Developing effective disaster risk management strategies, therefore, require a critical assessment of characteristics of the human environment, human behavior, and other human-produced factors that influence the impact of natural physical phenomena on people and societies.[32]

Risk Assessment

Assessments of (disaster) risk involve identifying possible risks and analyzing their potential impact to be able to effectively respond and adapt to the most significant threats and to seize opportunities of preventing or mitigating future risk. In risk analysis, the risk is commonly defined and measured as a function of two main elements: probability and (potential) impact or consequences.

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29 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 31.

30 Intergovernmental Panel on Climate Change, 32.

31 Jörg Birkmann, "Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions," in *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies* (Tokyo: UNU-Press, 2006), 10.

32 Birkmann, 10.

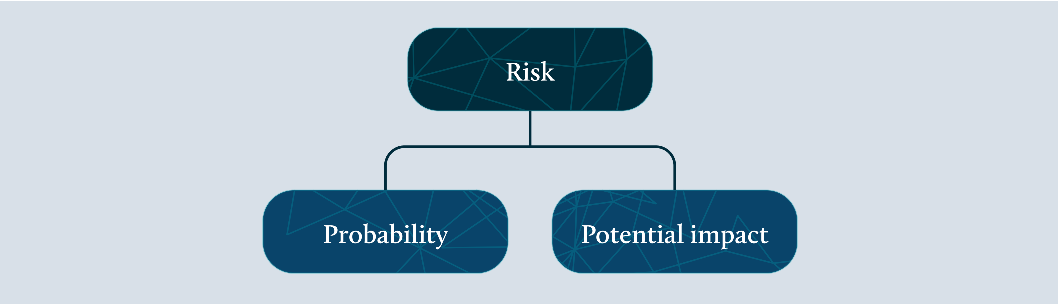

Figure 1. Risk as a function of probability and potential impact

Probability

Probability refers to the likelihood of a (natural) disaster to occur. The probability of a country to experience a natural disaster is determined by the conjunction and interaction of a natural hazard (the threat) alongside a country's vulnerability to be affected by this threat. The vulnerability influences whether a natural hazard will transform into a natural disaster.[33] If protection mechanisms and infrastructure of a country to a specific natural hazard are sufficient and effective, this country is not very vulnerable to this hazard and the probability of a natural disaster to develop will be significantly lower. For instance, if a country is regularly subjected to landslides and as a result develops adequate and effective coping mechanisms to them, then the vulnerability of that country to this hazard will decrease as will the probability of disaster risk. Likewise, if a coastal country experiences frequent coastal flooding but has established adequate and successful defense infrastructures against a coastal flood, then this country is not vulnerable to coastal flood risk.

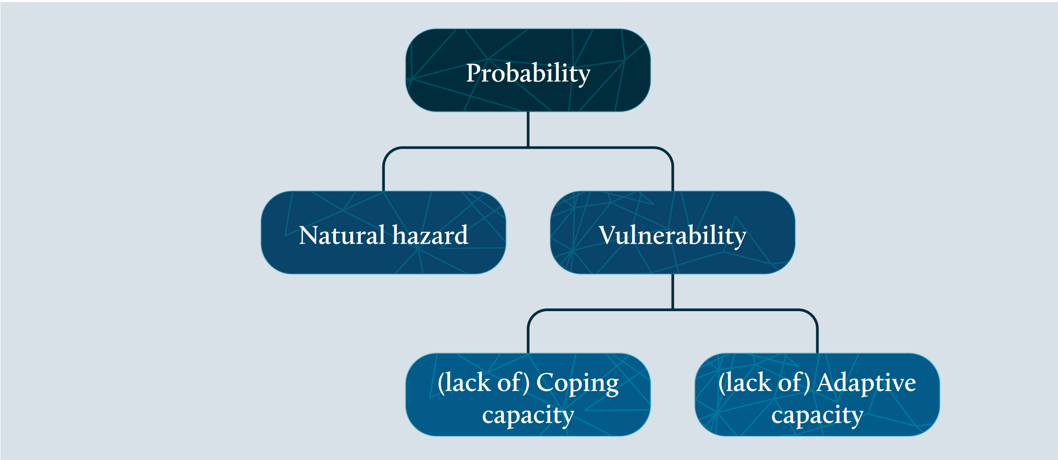

Figure 2. The conceptual framework of probability

33 Bündnis Entwicklung Hilft; United Nations University - EHS, "Press Release - WorldRiskReport 2015: Food Insecurity Increases the Risk of Disaster" (Berlin: Bündnis Entwicklung Hilft; United Nations University - EHS, 2015), 1.

Natural Hazard

The concept of 'natural hazard' refers to the possible future occurrence of a natural physical phenomenon that may produce adverse effects on exposed and susceptible elements.[34] In this risk methodology, the term natural hazard refers to climate change-related physical events or trends. For a definition of natural hazards, we consulted the Emergency Events Database (EM-DAT) which provides clear definitions, criteria, and a classification of types of (natural) hazards.[35]

Although the specific impacts of climate change vary greatly across geographically locations, it is projected that climate change will increase both the frequency as well as the intensity of natural hazards, like tropical storms, flooding, landslides, droughts, and wildfires, in many regions of the world in the coming decades.[36] Such extreme climate events, in vulnerable contexts, have the potential to inflict damage and loss to human lives, human wellbeing, the environment, and socioeconomic conditions. In addition to such discreet events, climate-driven risk include slow-onset disasters relating to environmental degradation processes, including rising sea levels, salinization or desertification.[37] Such processes are highly complex phenomena, yet data on discreet events can be used to produce time series and assess trends in climate-driven risk, including slow-onset disasters.

This report includes risk assessments of climate change-related hazards, including:

- **Coastal flooding:** Coastal floods include floods caused by an overflow, overtopping, and breaching of flood defenses such as dikes as well as flattening dunes/producing dune erosion. Land behind such coastal defenses experience flooding and/or damage.[38]
- **River flooding:** River flooding refers to floods caused by an overflow or overtopping of rivers above a minimum flooding threshold or that exceed flood protection standards.[39] Riverine floods may also cause a breaching of flood defenses such as dikes and embankments. Land behind such coastal defenses experience flooding and/or damage.[40]

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34 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 69.
35 Centre for Research on the Epidemiology of Disasters, "General Classification," EM-DAT The International Disaster Database, accessed June 18, 2020.
36 Michael Hagenlocher et al., "Drought Vulnerability and Risk Assessments: State of the Art, Persistent Gaps, and Research Agenda," *Environmental Research Letters* 14, no. 8 (2019): 1.
37 Platform on Disaster Displacement, "Key Definitions – Disaster Displacement," Platform on Disaster Displacement.
38 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 559; Safecoast Project Team, "Coastal Flood Risk and Trends for the Future in the North Sea Region, Synthesis Report" (The Hague: Safecoast, 2008), 24.
39 Lorenzo Alfieri, Francesco Dottori, and Luc Feyen, "JRC PESETA III Project Task 7 - Rivers Floods" (Luxembourg: Publications Office of the European Union, 2018), 5; L. Feyen et al., "Climate Change Impacts and Adaptation in Europe" (Luxembourg: Joint Research Centre of the European Union, 2020), 18.
40 Safecoast Project Team, "Coastal Flood Risk and Trends for the Future in the North Sea Region, Synthesis Report," 24.

- **Tropical storms:** Tropical storms, cyclones, hurricanes, and typhoons, although named in a different way, refer to the same natural hazard. Essentially, these extreme weather events refer to a large scale closed-circulation storm system which combine a low-pressure center, spiral rain bands, and strong winds that rotate counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. Depending on the location and strength of the tropical storm, the storm is referred to as either a tropical cyclone (in the Southern Pacific/Indian Ocean), a hurricane (in the Western Atlantic/Eastern Pacific), or a typhoon (in the Western Pacific).[41]
- **Landslides:** Landslides refer to the downward and outward movement – either sliding, spreading, falling, toppling, flowing (when assisted by water), or a combination thereof – of slope-forming materials, like soil, rock, or debris under the influence of gravity.[42]
- **Droughts:** Droughts can be defined as prolonged periods of abnormally dry weather conditions, causing critical shortages of water that drop below normal levels of soil moisture, groundwater, rivers or lakes.[43] Drought is a relative term as are a natural occurring phenomena that encompass specific spatial and temporal features and can refer to either: meteorological or climatological drought (indicating a lack in precipitation), hydrological drought (referring to groundwater, streamflow, and reservoir), agricultural drought (referring to soil moisture), and socioeconomic drought (referring to the supply and demand of water).[44] A megadrought is an abnormally lengthy and pervasive drought, usually lasting a decade or more.[45]
- **Heat waves:** Heat waves refer to periods (at minimum two-three days) of abnormally hot and dry or hot and humid weather.[46] In urban areas, extremely hot temperatures can heat up buildings, roads, and other infrastructure and increase temperatures with 1 to 5 ˚C degrees in comparison to outlying areas, producing a city-specific hazard termed urban heat island (UHI) effects which further aggravates heat stress.[47]

41 Laurent Cousineau, "Tropical Storm Definition," Climate Change Guide, 2020; Shannon Doocy et al., "The Human Impact of Tropical Cyclones: A Historical Review of Events 1980-2009 and Systematic Literature Review," *PLoS Currents Disasters* 1 (2013): 2; National Hurricane Center and Central Pacific Hurricane Center, "Glossary of NHC Terms," National Hurricane Center and Central Pacific Hurricane Center, accessed September 16, 2020.

42 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 561; United Nations Office for Disaster Risk Reduction, "National Disaster Risk Assessment: Governance System, Methodologies, and Use of Results 2017" (Geneva: United Nations Office for Disaster Risk Reduction, 2017), 21.

43 World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance" (Washington, D.C.: The World Bank, 2019), 6.

44 Jürgen V. Vogt et al., "Drought Risk Assessment and Management: A Conceptual Framework" (Luxembourg: Joint Research Centre of the European Union, 2018), 11.

45 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 559.

46 Center for Climate and Energy Solutions, "Heat Waves and Climate Change," Center for Climate and Energy Solutions, July 18, 2019; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 560.

47 Lei Zhao et al., "Interactions between Urban Heat Islands and Heat Waves," *Environmental Research Letters* 13, no. 3 (2018).

- **Wildfires:** Wildfires refer to widespread and destructive fires driven by weather-related conditions, including high temperatures, dry conditions, and high winds. However, wildfires are often directly ignited due to human activity or lightning events. Wildfires are unplanned, characterized by "rapid fire spread, intense burning, long-range fire spotting and unpredictable shifts", and especially devastating when they arise at the conjunction of wildland and urban areas.[48]

Vulnerability

Vulnerability, in this risk assessment and methodology, refers to a country's propensity to be affected by the specific physical shocks of a natural hazard. Vulnerability is a critical determinant of whether a natural hazard will turn into a natural disaster. Vulnerability to natural hazards is influenced by a country's capacity to manage, mitigate, or avert the incidence and magnitude of physical shocks of a natural event and thereby to mitigate or avert a (natural) disaster.[49] The vulnerability of a country to a specific natural hazard is determined by two components: coping capacity and resilience (or adaptive capacity). When a country exhibits very high levels of coping and adaptive capacity to a specific natural hazard, it is not vulnerable to the occurrence of a natural physical phenomenon and its physical shocks. For instance, if a country is not vulnerable to the impacts of coastal flooding because it has built sufficient dams and dikes, despite this natural hazard frequently occurring, the probability of disaster risk is low. Alternatively, when a country is highly vulnerable to the impacts of coastal flood events because it lacks flood protection infrastructure, the probability to suffer climate security risks is high.

- **Coping capacity** involves the capacity of elements at risk to cope with or recover from the physical shocks of a (natural) disaster in a timely and efficient way, including the protection, rebuilding, or enhancement of its fundamental assets, structures and functions in the short to medium term.[50]
- **Resilience** represents the ability of a system and its component parts – i.e. people, livelihoods, buildings, infrastructure, assets – to adapt to climate security risks and to anticipate potential natural hazards which contributes to the mitigation or even prevention of future disaster risk.[51]

48 European Commission, "Forest Fires: Sparking Firesmart Policies in the EU" (Luxembourg: Publications Office of the European Union, 2018), 6, 10–11; Feyen et al., "Climate Change Impacts and Adaptation in Europe," 18; Sungmin O, Xinyuan Hou, and Rene Orth, "Observational Evidence of Wildfire-Promoting Soil Moisture Anomalies," *Scientific Reports* 10, no. 11008 (2020): 1; World Health Organization, "Wildfires," World Health Organization, 2020.

49 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 70.

50 Intergovernmental Panel on Climate Change, 73.

51 Intergovernmental Panel on Climate Change, 73.

Potential impact

Potential impact refers to the prospective adverse consequences of future climate-related disasters on natural and human systems. Impact generally refers to the (prospective) extent of losses, damages, and adverse effects to people, livelihoods, ecosystems, economies, societies, cultures, institutions, and infrastructure as a result of the interaction of climate-related events with exposed elements that are sensitive and susceptible to that specific event. Impacts are often also referred to as consequences.[52] This risk assessment and methodology measures potential impact as a function of exposure and susceptibility. These potential impacts include adverse consequences which could become or aggravate drivers of instability and insecurity in a given society.

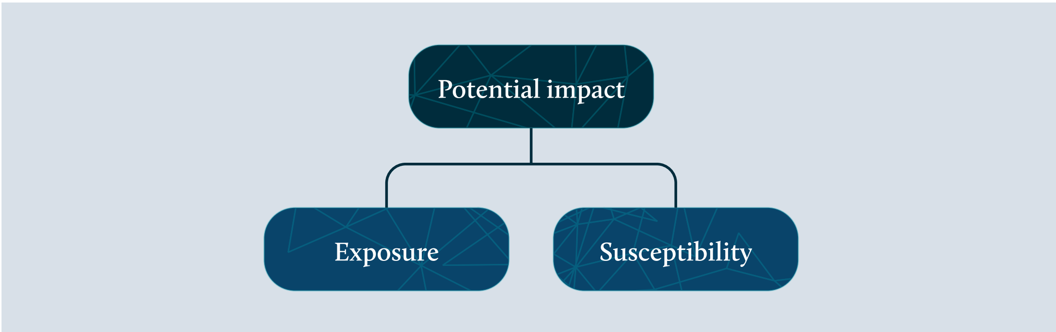

Figure 3. The conceptual framework of potential impact

- **Exposure** refers to the presence of vital elements – including people, ecosystems, resources, livelihoods, infrastructures, and services – in locations that could be adversely affected by the impacts of a potential hazard. The component of exposure essentially involves factors of the environment that influence the extent of the physical impact (to human and natural systems) of a certain climate-related hazard, which also depends on the type and characteristics of the hazard.
- **Susceptibility**, in the context of climate change, refers to the propensity of exposed elements to suffer negative consequences in terms of losses, damages, and adverse effects as a result of the impacts of climate-related hazards. Susceptibility essentially incorporates socially constructed propensity to be negatively affected and is a key component of disaster risk.

52 Intergovernmental Panel on Climate Change, *Climate Change 2014*, 1767.

Security threats

The disaster risks assessed in this report refer to climate-related disasters whose impact on social, economic, political, and environmental systems can generate critical national and human security implications. Security threats include those adverse impacts of natural hazards on human societies that spill over into higher-order security risks, including significant natural disasters requiring military responses or natural hazards resulting in threats to critical resources and infrastructure, forced mass-displacement, political instability, or intra-state violence and conflict.

Conceptual Framework

The way in which various concepts interrelate and interact with each other is illustrated in the conceptual model of climate security (see Figure 4).

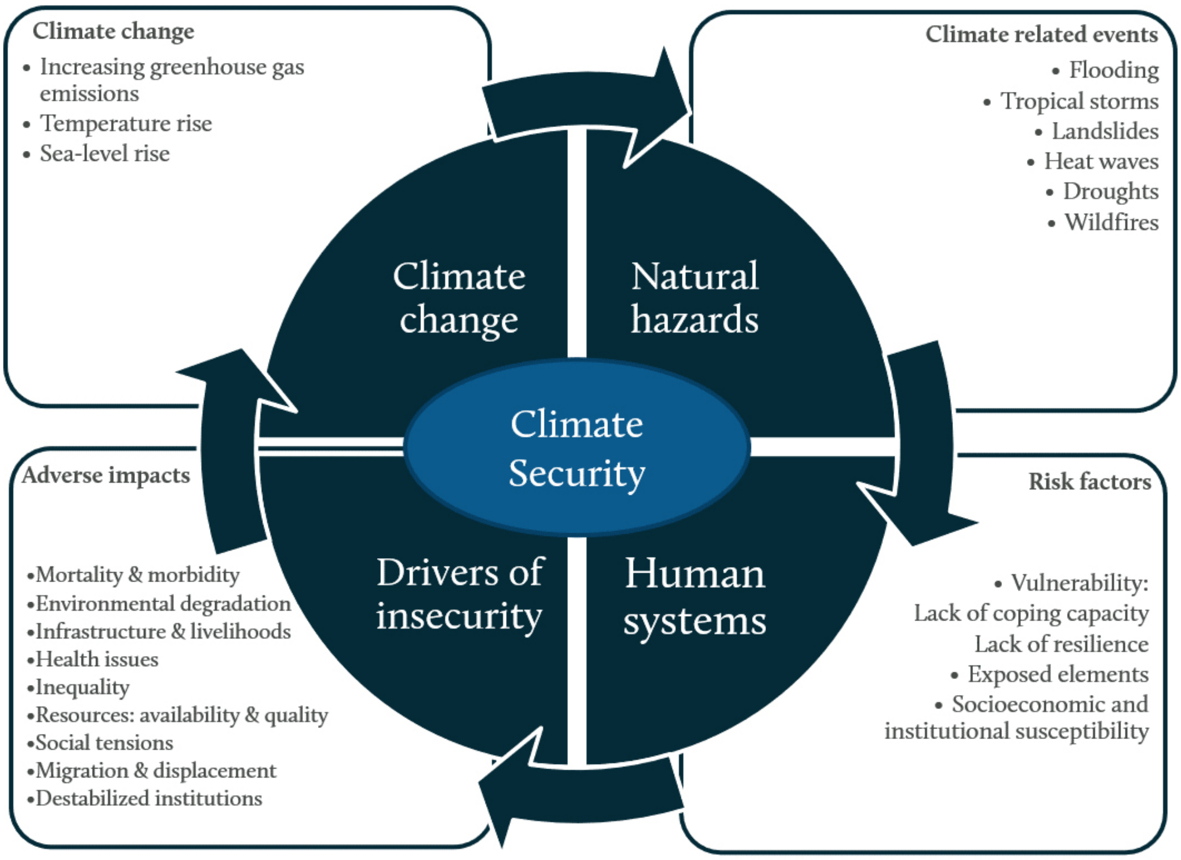

Figure 4. The conceptual framework of climate security

To assess and populate the various components of climate security risk with indicators and data, one requires a more detailed and comprehensive understanding of these drivers of climate security risk.

The drivers of climate-related disaster risks – the factors that influence the impact of such disaster on societies by shaping exposure, susceptibility, and vulnerability (or lack of capacity) – are often related to levels of sustainable development. Factors of sustainable development shape the incidence of natural disasters. Unsustainable development increases the probability to natural disasters through pollution, increased levels of greenhouse gas emissions, environmental degradation, and inadequate land planning. Unsustainable development also increases a society's exposure and susceptibility to natural hazards and consequently aggravate the impact of a natural hazard within a society. Through these mechanisms, climate security risk is shaped by factors of sustainable development.[53]

While sustainable development influences and aggravates climate-related disaster risk, natural disasters also impact levels of sustainable development. Natural hazards can critically damage livelihoods – through death, injury, the destruction of assets, essential resources, or infrastructure – and potentially drive already susceptible populations (further) into poverty. In certain scenarios, the substantial social and economic consequences produced by climate-related disasters might destabilize societies and generate security threats. In this way, natural hazards and sustainable development aggravate one another in a vicious cycle that can accumulate in disasters.[54]

The direct and indirect relationship between climate-related disaster risk and sustainable development has been established and underlined by many international organizations, including the United Nations Development Programme (UNDP), the United Nations Office for Disaster Risk Reduction (UNDRR), and the IPCC. Many of the Sustainable Development Goals (SDGs) of the UN are focused on factors that influence drivers of climate security risk, such as poverty, inequality, employment, infrastructure, or institutions.[55] Both the Hyogo Framework for Action and the Sendai Framework for Disaster Risk Reduction underlined the need to integrate disaster risk reduction and sustainable development, which they consider two interrelated objectives.[56] Identifying and addressing these underlying factors and drivers of disaster risk is essential in order to reduce, mitigate, or even prevent contemporary and future climate security risks.[57] [58]

The Hyogo Framework for Action 2005-2015 emphasized the importance of developing disasters risk and vulnerability indicators to evaluate the adverse effects of disasters on societies and to inform effective disaster risk reduction strategies. According

53 United Nations Development Programme, "Reducing Disaster Risk: A Challenge for Development" (New York: United Nations Development Programme, 2004), 10–11.
54 United Nations Development Programme, 26.
55 United Nations Office for Disaster Risk Reduction, "National Disaster Risk Assessment: Governance System, Methodologies, and Use of Results 2017," 17.
56 Jörn Birkmann, "Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions," 41; United Nations International Strategy for Disaster Reduction, "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters" (Geneva: United Nations International Strategy for Disaster Reduction, 2007); United Nations Office for Disaster Risk Reduction, "Sendai Framework for Disaster Risk Reduction 2015-2030" (Geneva: United Nations Office for Disaster Risk Reduction, 2015).
57 Jörn Birkmann, ed., *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*, Second edition (Tokyo: United Nations University Press, 2013), xxi.
58 Jörn Birkmann, ed., *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*, Second edition (Tokyo: United Nations University Press, 2013), xxi.

to the Framework, this set of indicators needs to be able to assess social, economic, institutional, and environmental conditions that shape the disaster risk of a society in the context of natural hazards. In addition, the Hyogo Framework argues for the need to develop and strengthen national preparedness and resilience to climate change and extreme weather events.[59] Often, countries still primarily focus on their response capacities to natural disasters. An assessment of the social, economic, institutional, and environmental conditions that influence disaster risk will inform policymakers and identify targets for effective disaster risk preparedness and mitigation.[60]

To assess climate security risk, this risk assessment methodology adopts a comprehensive and holistic approach to disaster risk. The methodology incorporates the key themes addressed in the UN Sendai Framework for Disaster Risk Reduction and Sustainable Development Goals (SDGs). The Sendai Framework outlines seven clear targets and four priorities for action during the period 2015-2030 to prevent new and reduce existing disaster risks. The SDGs serve as proxy indicators to measure the underlying drivers of climate security risks. Moreover, the selection of indicators covers – in line with Sendai's predecessor the Hyogo Framework for Action – social, economic, institutional, and environmental factors that influence the impact of natural hazards on societies. Through these specific factors and indicators, the risk assessment methodology of this report aims at informing decision-makers by identifying specific targets to prevent, mitigate, or avert the security impacts of climate-related extreme weather events. Moreover, progress in disaster risk reduction can be measured and the effectiveness of certain strategies assessed.

59 United Nations International Strategy for Disaster Reduction, "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters," 6–7.
60 Jörn Birkmann, *Measuring Vulnerability to Natural Hazards*, xxi.

Risk assessment and matrix methodology

This report adopts a multi-structure assessment of *risk*, including the components natural hazard, vulnerability, lack of coping capacity, lack of resilience (or adaptative capacity), exposure, and susceptibility – in line with the definition of the IPCC as well as many others.[61] This chapter describes the operationalization of the key components of climate security risk through assessment indicators. The first section reflects on the research design of this risk assessment methodology and the second section explains how the results of this assessment are plotted on a risk matrix that maps the climate security risk of countries on a global scale. A more technical description of the approach to assess climate security risk employed by this report is included in the annex of this document (see Appendix 2: Measuring Climate Hazards Risk). The methodological annex also provides a detailed overview and justification of all the indicators used to operationalize the components of risk, including their relevance in the context of climate security.

Research design for the risk assessment

Climate security risk is calculated as a function of probability and potential impact. Probability refers to the likelihood of a (natural) disaster occurring in a country. The probability to disaster risk is shaped by the onset of a natural hazard – a climate-related extreme weather event – and the vulnerability of a country to be affected by the incidence of that specific hazard, determined by its capacity to manage, mitigate, or avert its physical shocks. Potential impact refers to the magnitude of consequences in terms of losses, damages, and negative effects that a natural disaster could generate in a society due to the exposure of susceptible elements to this hazard. Together, the probability of a natural disaster and its potential impact produce climate security risk. It follows that the formula for risk becomes:

$$\text{Risk} = \text{Probability} \times \text{Potential Impact}$$

The probability of a hazard – or the potential future occurrence of a hazard – is determined by the onset of the natural event and the vulnerability of a country to that specific event, caused by a lack in the capacity (coping and adaptive) of a country to avert or mitigate the physical shocks of that natural event.

61 Birkmann, "Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions," 18; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 69–73.

The function of probability is:

$$\text{Probability} = \text{Natural Hazard} \times \text{Vulnerability}$$

In this formula, natural hazard is a function of the occurrence, frequency, and intensity of climate-related natural events.

The vulnerability of a country to be affected by the occurrence of a specific hazard are mitigated through a society's coping and resilience (or adaptive capacities). To make the calculation and scoring of probability – and the score of the individual component indicator vulnerability – more straightforward for communication, in our methodology higher scores indicate poorer circumstances. Thus, high scores for probability indicate a higher likelihood of a natural event to occur as well as an inadequate capacity to manage, mitigate, or avert its physical shocks. Therefore, the scores for coping capacity and resilience are inversed, so that a country's insufficient or inadequate performance in relation to their coping and adaptive capacity results in higher vulnerability and, consequently, higher probability scores. In this way, countries with adequate and effective mechanisms and infrastructures in place to manage, mitigate, or avert the occurrence of natural hazards will score lower in vulnerability. Hence, the probability to be affected by the destructive shocks of a natural hazard will be lower. It follows that the two components' labels are inversed to become: lack of coping capacity and lack of resilience. Now, the higher the score for (lack of) coping capacity or (lack of) resilience will also result in a higher score for probability of a certain hazard to impact given country.[62] Vulnerability is the equation of lack of coping capacities and lack of resilience. While probability is defined by natural hazard and vulnerability.

$$\text{Vulnerability} = \frac{\text{Lack of coping capacities} + \text{Lack of resilience}}{2}$$

And also:

$$\text{Probability} = \sqrt[2]{\text{Natural Hazard} \times \text{Vulnerability}}$$

Which can be converted into the following equation:

$$\text{Probability} = \sqrt[2]{\text{Natural Hazard} \times \frac{\text{Lack of coping capacities} + \text{Lack of resilience}}{2}}$$

The other variable of risk, the potential impact of a climate-related hazard on a society – or the consequences in terms of loss, damage, and adverse effects within a country – are determined by the exposure of susceptible elements. The function of potential impact is the geometric mean of exposure and susceptibility:

$$\text{Potential Impact} = \sqrt[2]{\text{Exposure} \times \text{Susceptibility}}$$

62 Tom De Groeve, Karmen Poljansek, and Luca Vernaccini, "Index for Risk Management - INFORM" (Luxembourg: Publications Office of the European Union, 2015), 18.

The impact score of natural hazards reflects losses, damages, and adverse effects to human lives and vital ecosystems, resources, livelihoods, infrastructures, and institutions. Risk assessment methodologies regularly define the potential impact of climate related disasters as a measurement of demographic or macro-economic data, such as the number of fatalities or economic loss in terms of GDP or damage to buildings. However, the impact of climate-related disasters in terms of, for instance, economic damage does not fall within the scope of the IMCCS's mission. Instead, we aim to capture climate security risks (see Figure 4) in our risk matrix to be able to better inform disaster risk management and climate change adaptation decision-making.

This risk methodology adopts a more integrated and comprehensive understanding of potential losses, damages, and effects of climate related hazards to the human system in a given exposure period through a holistic conceptualization of susceptibility, including environmental (physical and demographic), socioeconomic, and institutional dimensions and indicators.[63]

It follows that total function of climate security risk becomes:

$$\text{Risk} = \sqrt[4]{\text{Natural Hazard} \times \text{Vulnerability} \times \text{Exposure} \times \text{Susceptibility}}$$

The resulting methodological framework provides the main building frame to measure climate security risk. This framework is outlined in Figure 5 below.

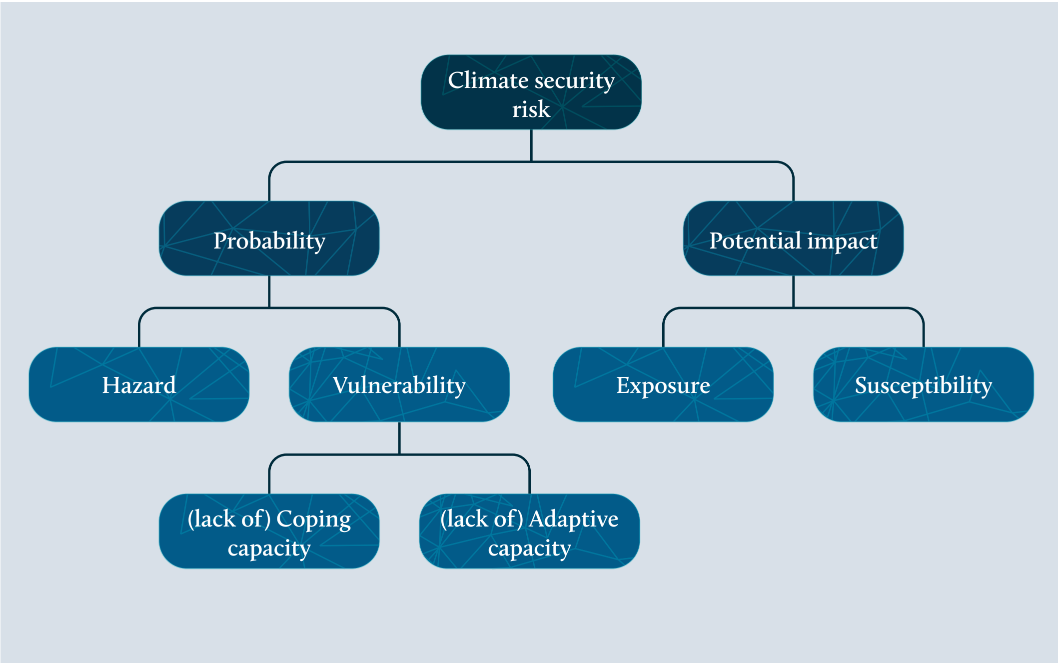

Figure 5. The methodological framework to measure climate security risk

63 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 76–81.

Application into risk matrices

This risk methodology and assessment result in climate security risk scores for countries in relation to the different types of climate-related hazards. The results of this assessment can be visualized on a risk matrix that plots the probability score of a climate-related hazard risk on the X-axis and the potential impact score of this hazard on the Y-axis. A risk matrix is employed to map the risk of a specific hazard on a global level, in which various countries will appear scattered on the plot. This will allow it to analyze and assess the risk of a certain type of hazard across countries on the world level. An example of such a matrix can be found below (see Figure 6).

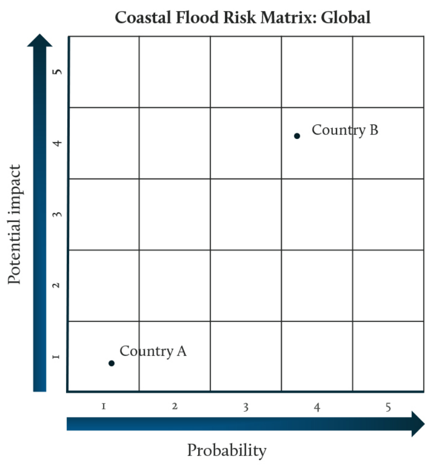

Figure 6. Example of a global coastal flooding risk matrix

When combining the climate security risk scores for all countries in relation to one hazard type in such a matrix, this result in a scatter plot on the global level, with low-risk countries in the left-bottom corner, and high-risk countries in the right-top corner of the matrix. Scatter plots can be employed to evaluate correlational relationships between variables but are also useful graphs for identifying outlier points in the data.

The climate security risk scores of countries on the global level can be mapped out on a world heatmap, visualizing the risk level of countries based on different color dimensions, with darker colors representing higher climate security risk scores.

The disaster risk matrixes of different hazard types can also be combined for one specific geographical entity (a country or region) to compare and analyze the relative level of risk for different types of hazard within the selected geographical entity (see Figure 7).

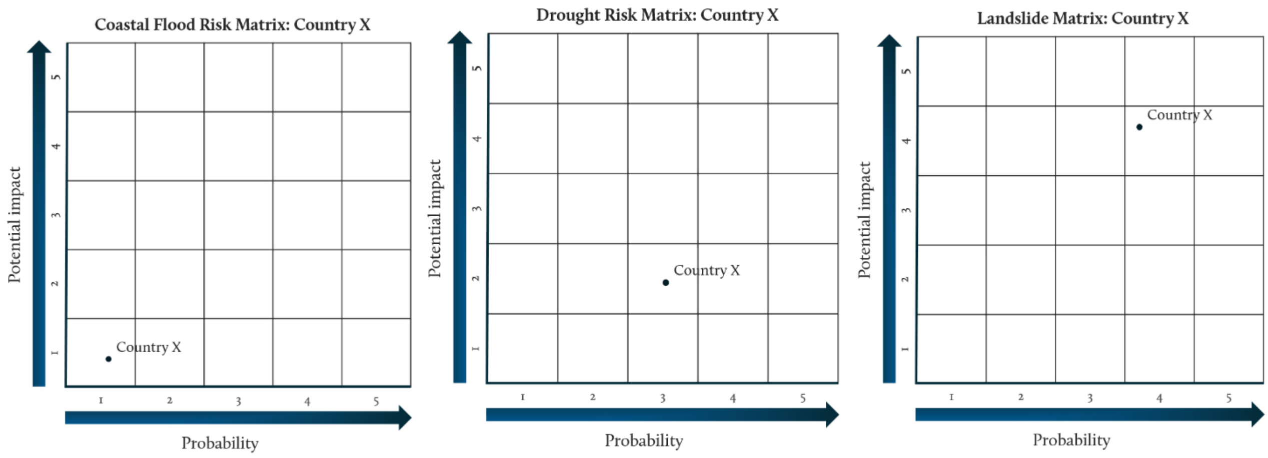

Figure 7. Comparing hazard risks within a single country

This risk assessment does not consider *interstate* violence and conflict generated by climate change and natural disasters, even though instability and conflict within states might demonstrate spill-over effects to neighboring states. The scope of this risk assessment is confined to national security and *intra-state* violence and conflict. There are four main reasons for this. First, disaster risk management is above all the primary responsibility of national governments. Second, the environmental, demographic, socioeconomic, and institutional conditions and factors that potentially influence or produce the risk to instability and intra-state violence and conflict are generally the results of national policies and largely confined to national borders. Third, data and statistics on these factors and conditions are also typically measured and presented on the level of nation states. Fourth, even though instability and insecurity within states is already difficult to foresee, violence or conflict between two or more nation states is more the outcome of unpredictable human behavior and interaction – including complex historical, religious, ideological, economic, and political motives – and are more likely to be constrained by international political and diplomatic agreements and regulatory instruments and organizations.[64]

Considering our definition of climate security in terms of climate change-related impacts on national security, this risk assessment does not consider *interstate* violence and conflict generated by climate change and natural disasters, even though instability and conflict within states might demonstrate spill-over effects to neighboring states.

64 Peter H. Gleick, "Water, Conflict, and Peace," *Open Rivers: Rethinking Water, Place & Community*, no. 11 (2018): 35.

Country Climate Security Risk Analysis

The risk matrices of different hazards and their respective climate security risk allow for both cross-country comparison as well as comparison of the relative climate security risk of various hazard types within a country. This section will elaborate on how these matrices should be interpreted and how their results can be employed for further analysis.

Interpretating the climate security risk scores

The probability and potential impact of a certain hazard in a given country will be represented as a score ranging between 0 and 100. Higher scores indicate worse performance and a higher risk to climate security impacts, with the value of 100 representing the country with the highest probability or likely impact of a certain climate-related hazard. The notion that higher scores indicate worse performance and higher risk is applied to the four components of climate security risk – exposure, susceptibility, coping capacity, and resilience – and their underlying dimensions and indicators.

Risk matrix: Cross-country comparison

The climate security risk scores are plotted on risk matrices that visualize the relative climate security risk of countries in relation to a specific climate-related hazard. The dots that appear on the risk matrix represent the climate security risk scores for individual countries. From the notion that higher scores indicate worse performance and higher risk follows that the further countries appear from the axes of the climate security risk matrices, the worse their performance. The further to the right a country appears on the climate security risk matrix, the higher the potential impact of climate security risk. The more vertically a country appears on the climate security risk matrix, the higher the probability to climate security risk. Countries appearing in the right-top corner of the matrix are the at most risk to climate security impacts. The position of a country on the plot is indicative of the kinds of measures and strategies required to mitigate climate security risk.

Global and regional scatter plots

The world scatter plot of a specific hazard type represents an overview of the relative climate security risk scores of all countries. The value of 100 represents the country with the highest probability or highest likely impact of a certain climate-related hazard. In the case where a country appears on the axes itself – either on the vertical or horizontal axis or on the origin – one or more of the components of climate security risks equals zero. The component to which this most often applies is exposure. A country will score a value of 0 on exposure if that country does not comprise any land area or persons that risk exposure to the adverse impacts of a certain natural hazard. For instance, countries without coasts are not exposed to coastal flooding and, countries without hills or mountain slopes do not experience exposure to landslide events. Hence, these countries will appear on the horizontal axis. As countries without exposure to a certain natural hazard do not hold meaningful results for this climate security risk assessment, these countries are excluded from the scatter plots that visualize the risk analysis. Scatter plots can also be made on the regional level by analyzing clusters of countries. Zooming in on clusters of countries allows for a more in-depth and thorough analysis of the climate security risk of a specific hazard in a more delineated geographical region, including the specific measures and strategies required to manage, mitigate, or avert risk there. Data on discreet hazardous events can also be used to produce time series and assess trends in climate-driven risk.

World heat map

The results of the world scatter plot are visualized in a world heat map for a single hazard type. These maps provide a global geographical overview of locations where certain hazard types are more prone to arise and produce climate security risks. Such a heat map might reveal certain climate-related trends. For instance, comparing the global heat map of tropical storms risk to drought or wildfires risk might indicate a trend of increased humidity in the northern hemisphere in contrast to a trend of intensifying dry conditions in the southern hemisphere.

Risk matrix: In-country analysis

The climate security risk scores can also be plotted on risk matrices that visualize the relative climate security risk of various climate-related hazard types within a single country. On such a plot, the dots that appear on the matrix represent the climate security risk score of various hazard types. The different degrees of probability and the potential impact can be compared across hazards taking the country as the unit of analysis. The interactions and compounding effects of these different hazard types within a single country can be analyzed through additional qualitative research. As on the regional level, data on discreet events can also be used to produce time series and assess trends in climate-driven risk within specific countries, including slow-onset disasters.

Visualizing the results

The climate security risk scores for the different hazard types are visualized below on the global level in scatter plots and heat maps. In the scatter plots, the individual country scores are represented by country codes and categorized per region. The heat maps visualize the relative risk values of countries based on a color scheme in which darker colors indicate higher risk scores.

Coastal flood risk

Figure 8 and Figure 9 below visualize the climate security risk scores of countries in relation to coastal flooding. India represents the country with the highest probability to coastal flooding security risk, which is why it receives the value of 100. Indonesia and Brazil also demonstrate a relatively high coastal flood security risk. The relatively high-risk scores of large countries, such as Brazil, Canada, and Russia can be partially explained by their scores on exposure, which are significantly high resulting from the extremely long coastlines of these countries. The Maldives scores the highest potential impact.

Global plot of coastal flooding risk including country codes

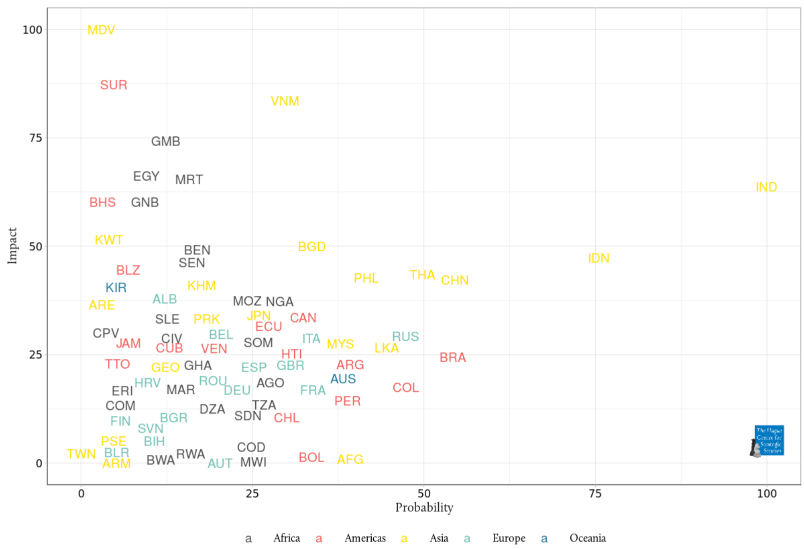

Figure 8. Global plot of coastal flood risk including country codes.

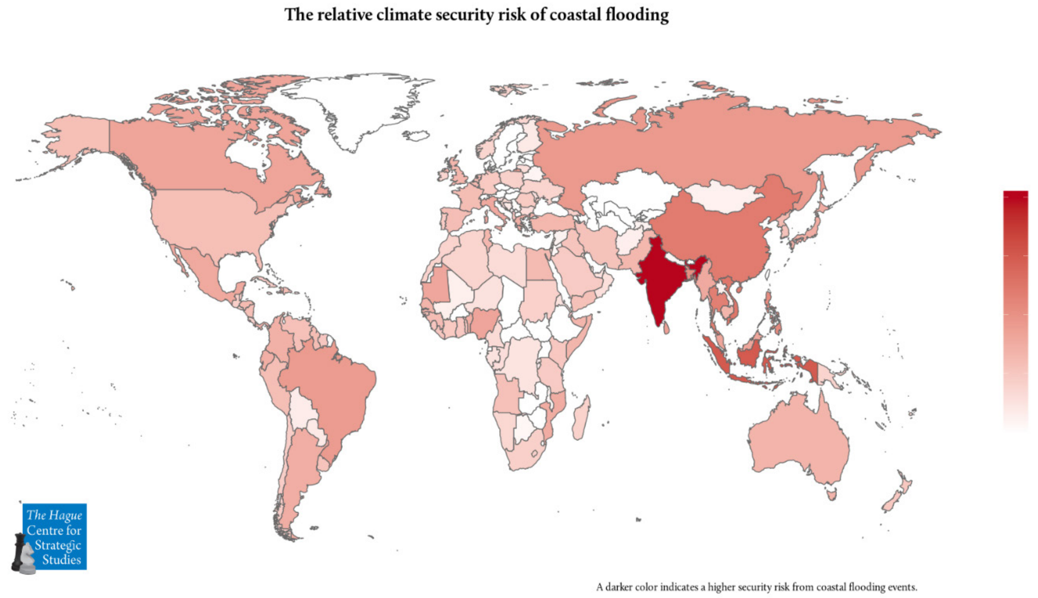

Figure 9. The relative climate security risk of coastal flooding.

Riverine flood risk

Figure 10 and Figure 11 below visualize the climate security risk scores of countries in relation to riverine flooding. Again, India represents the country with the highest probability to riverine flooding security risk. Bangladesh, Brazil, China, Indonesia, Japan, and Russia also score high relatively riverine flooding security risk. The Maldives, once more, scores the highest potential impact, followed by Vietnam.

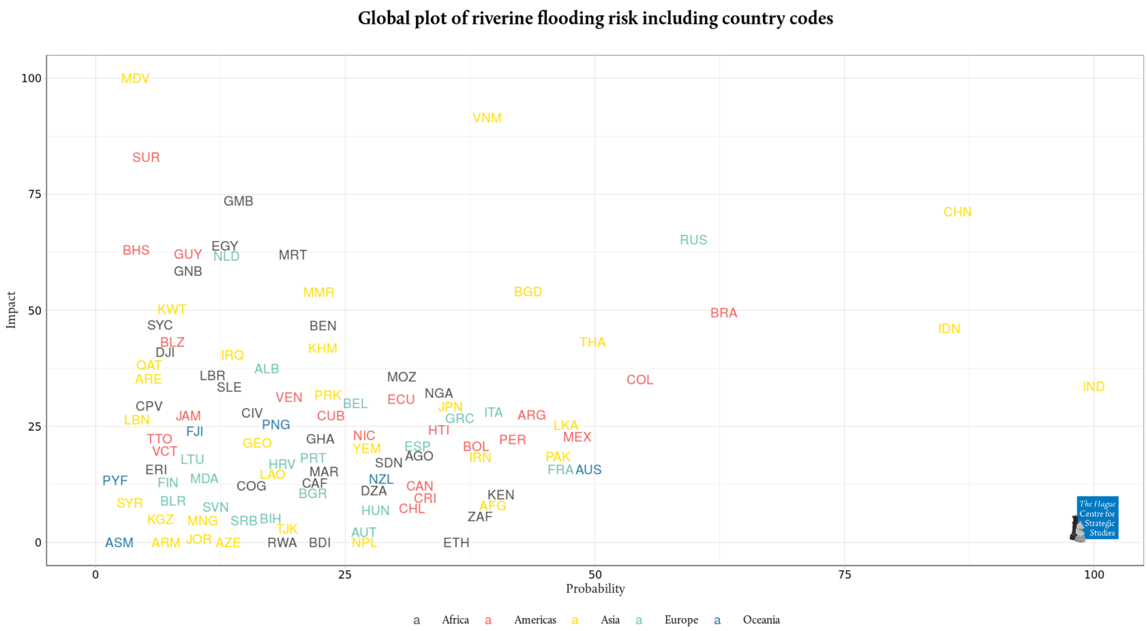

Figure 10. Global plot of riverine flood risk including country codes.

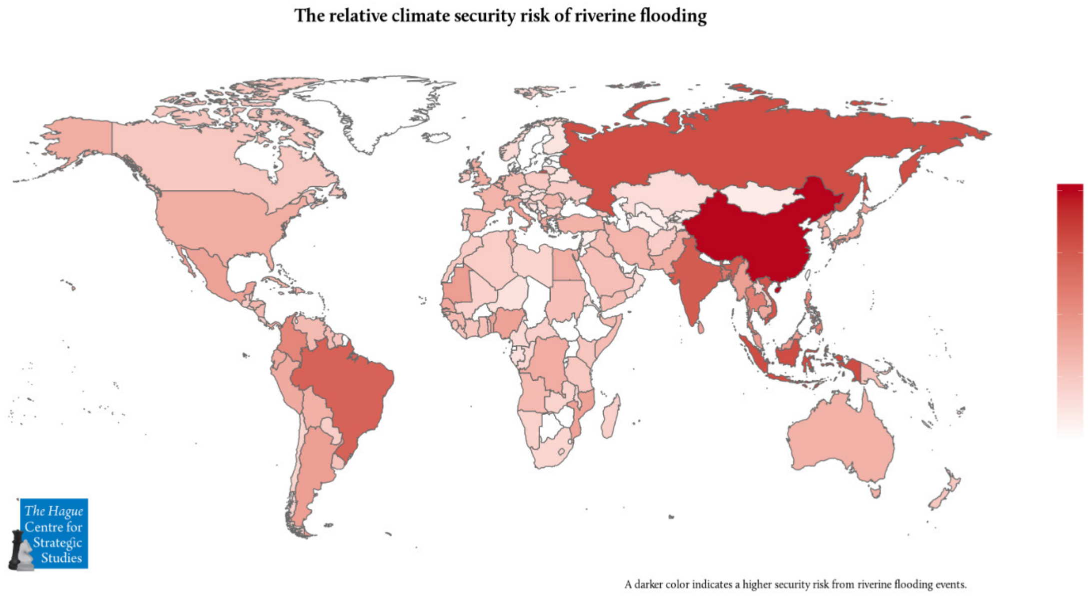

Figure 11. The relative climate security risk of riverine floods.

Tropical storms risk

Figure 12 and Figure 13 below visualize the climate security risk scores of countries with respect to tropical storms. India represents the country with the highest probability of tropical storm security risk, followed by Japan, the Philippines, and Bangladesh. Australia, China, and the United States also show relatively high tropical storm security risk values.

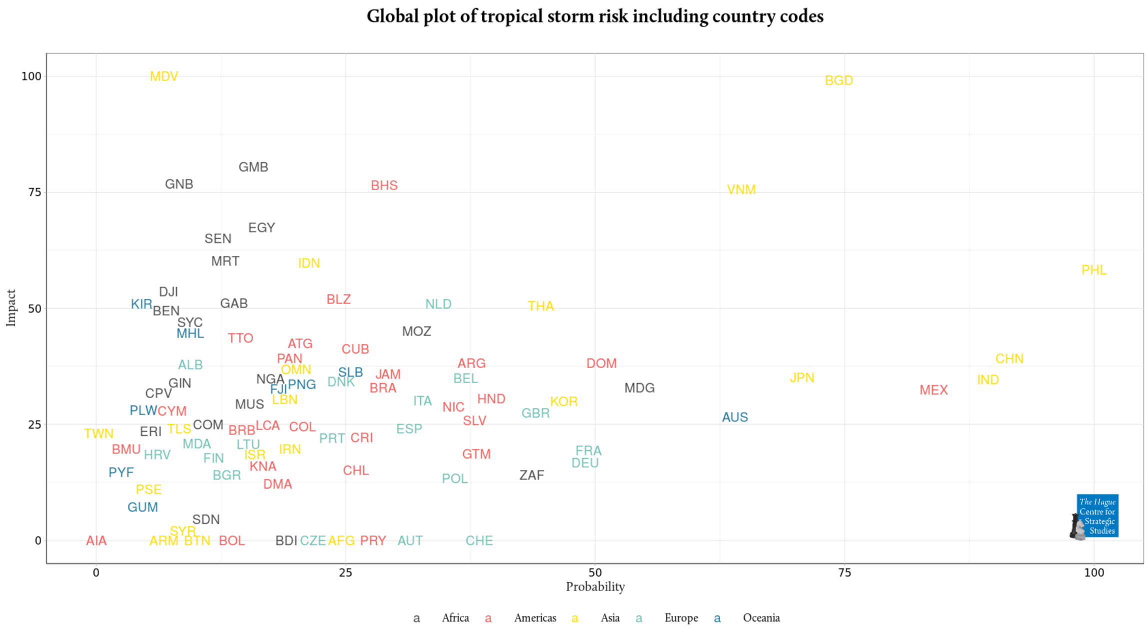

Figure 12. Global plot of tropical storm risk including country codes.

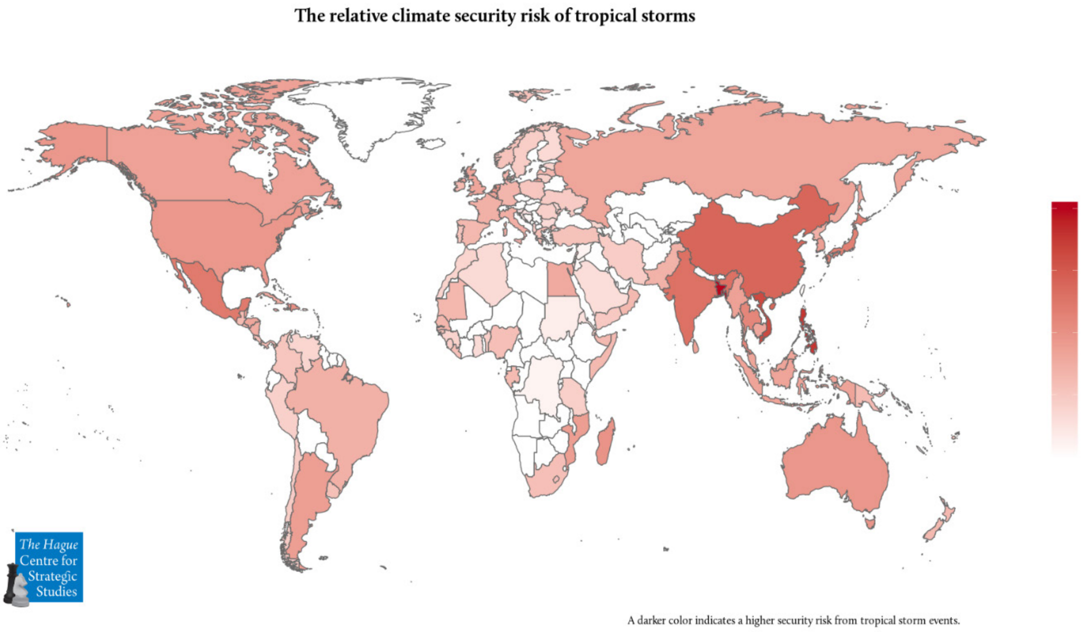

Figure 13. The relative climate security risk of tropical storms.

Landslide risk

Figure 14 and Figure 15 below visualize the climate security risk scores of countries with regards to landslides. China, Indonesia, and India represent the countries with the highest landslide security risk, with Indonesia having the highest probability and China the highest potential impact. Afghanistan, Nepal, Pakistan, and the Philippines also demonstrate relatively high landslide security risk.

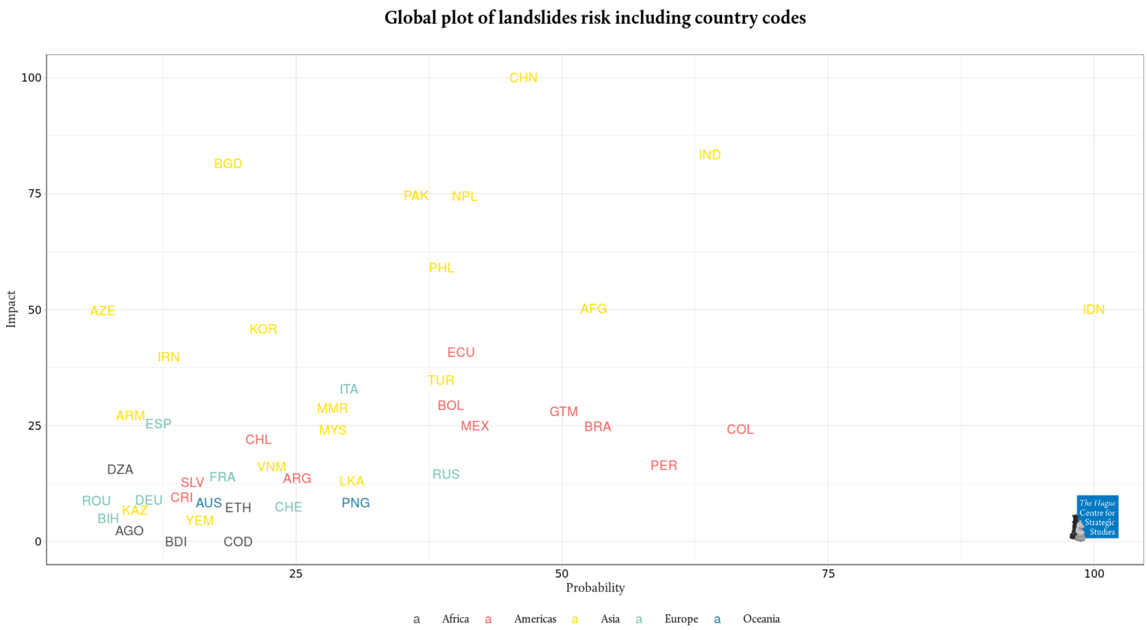

Figure 14. Global plot of landslide risk including country codes.

The relative climate security risk of landslides

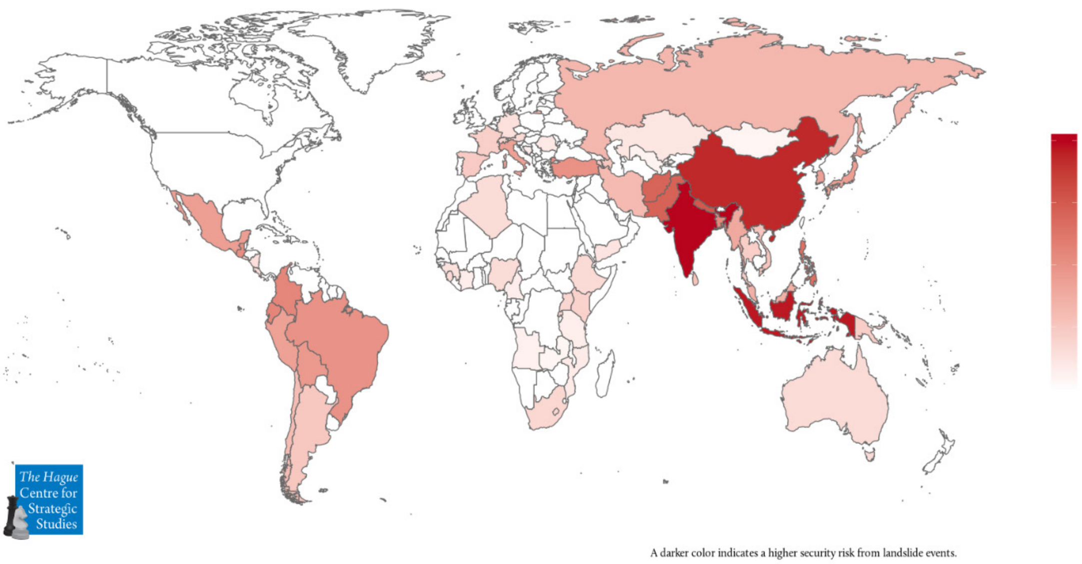

Figure 15. The relative climate security risk of landslides

Drought risk

Figure 16 and Figure 17 below visualize the climate security risk scores of countries in relation to droughts. Bolivia, Brazil, China, Honduras, and India represent the countries with the highest drought security risk. Overall, Central and South American countries score relatively high in relation to this hazard. African countries, like countries of the Sahel region, have not experienced many past drought periods, which is why they do not necessarily demonstrate high drought security risk. Drought events take years, sometimes decades, to develop.

Global plot of drought risk including country codes

Figure 16. Global plot of drought risk including country codes.

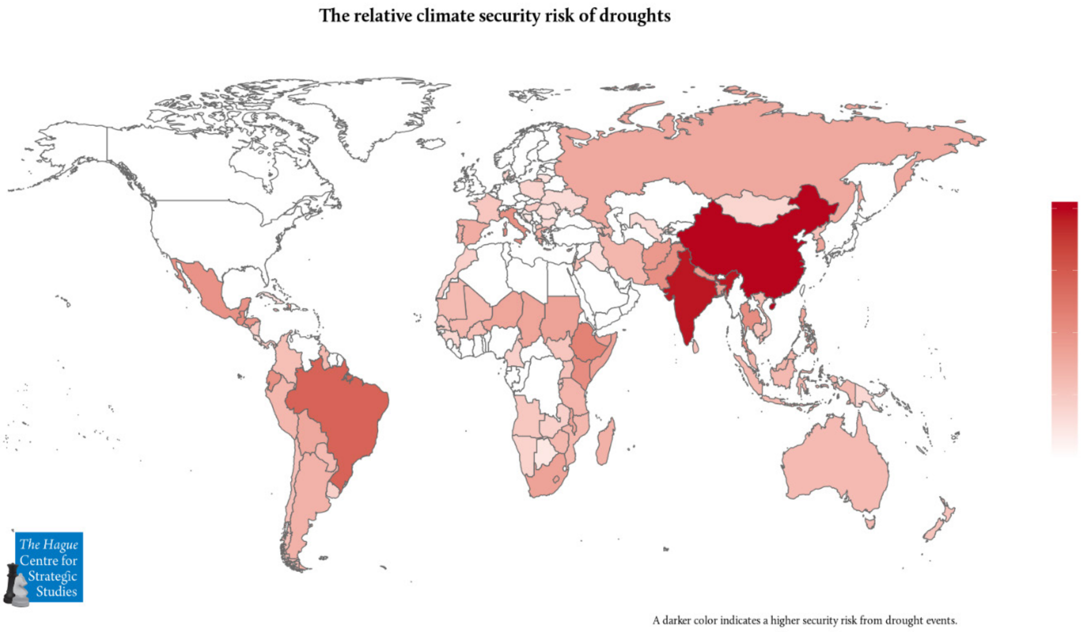

Figure 17. The relative climate security risk of droughts.

Heatwave risk

Figure 18 and Figure 19 below visualize the climate security risk scores of countries in relation to heatwaves. Though India represents the country with the highest probability to heatwave security risk, China is the country where heatwaves would have the greatest impact followed by the US and Russia. Again, large countries show relatively high risk, which can be explained by their large populations and shares of agricultural land, leading to higher exposure, as well as higher values of ambient air pollution which decreases their resilience.

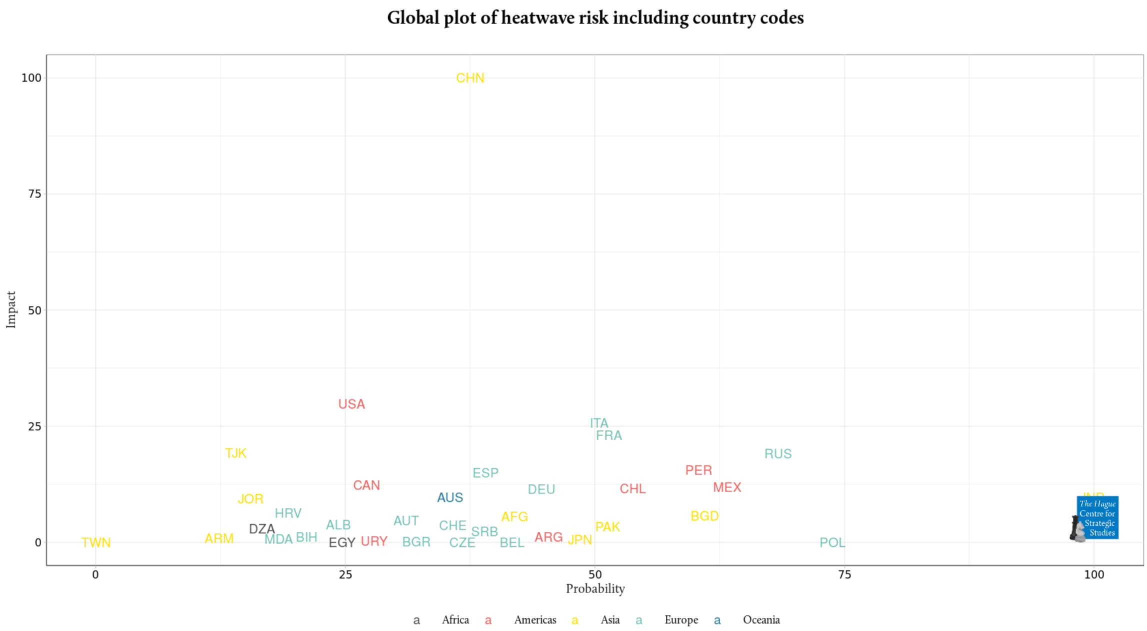

Figure 18. Global plot of heatwave risk including country codes.

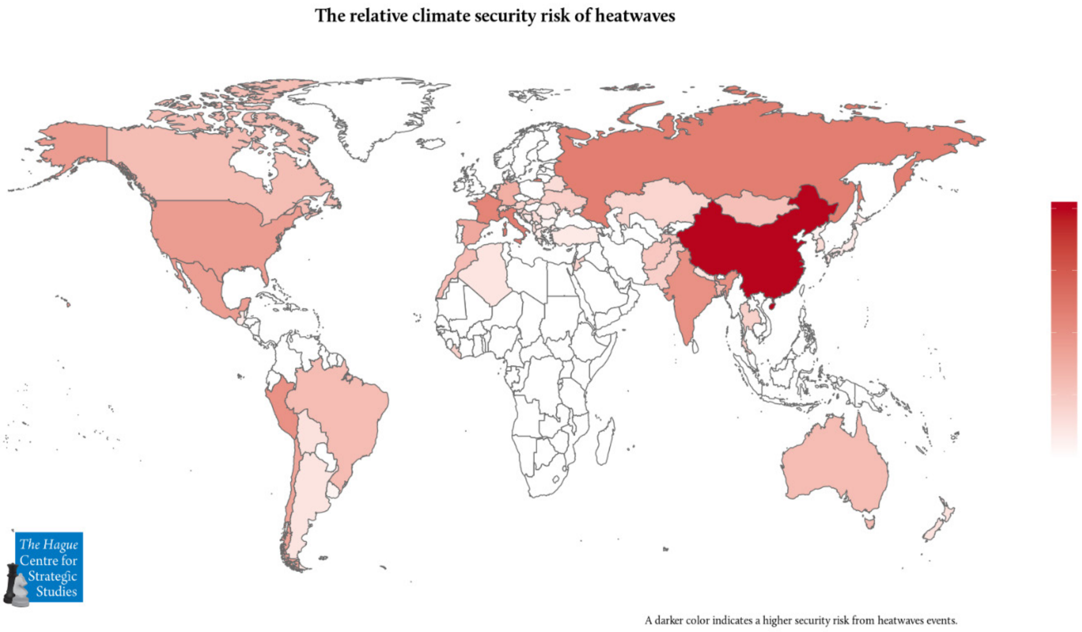

Figure 19. The relative climate security risk of heat waves.

Wildfires risk

Figure 20 and Figure 21 below visualize the climate security risk scores of countries in relation to wildfires. The US represents the country with the highest wildfires' security risk, followed by Australia, Russia, Chile, Spain, and Indonesia.

Figure 20. Global plot of wildfires risk including country codes.

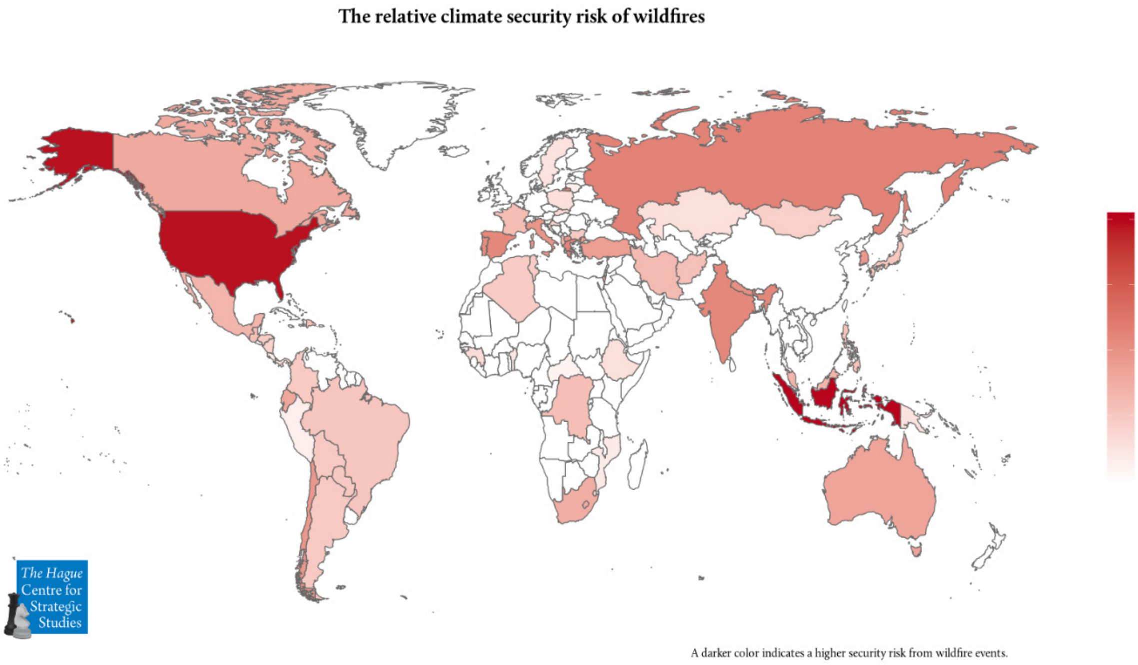

Figure 21. The relative climate security risk of wildfires.

Comparing Country Risk Matrices

Figure 22 to Figure 27 below show the climate security risk matrices for individual countries. These matrices combine the risk scores for different hazard types in the context of a single country, here Australia, China, India, the Netherlands, Russia, and the USA. The climate security risk matrix of Australia indicates that potential climate-related hazards have relatively low to low-medium impact. The probability of wildfires risk is highest, followed by tropical storms.

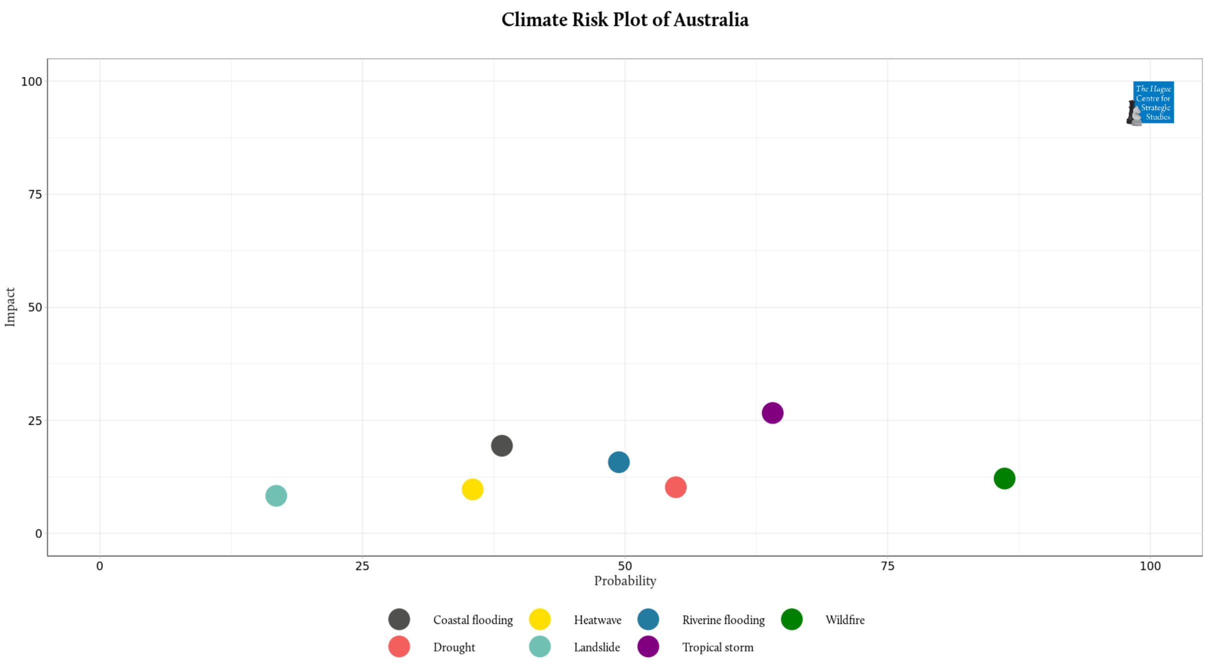

Figure 22. Climate Risk plot of Australia

In the case of China, tropical storms have the highest probability to affect the country. Riverine flooding, however, reveals the highest climate security risk score for China due to the combination of a high probability with a high potential impact score. Although droughts would produce greater adverse consequences in the country, this natural hazard demonstrates a lower probability. China experiences relatively the highest exposure and susceptibility to heatwaves and landslides.

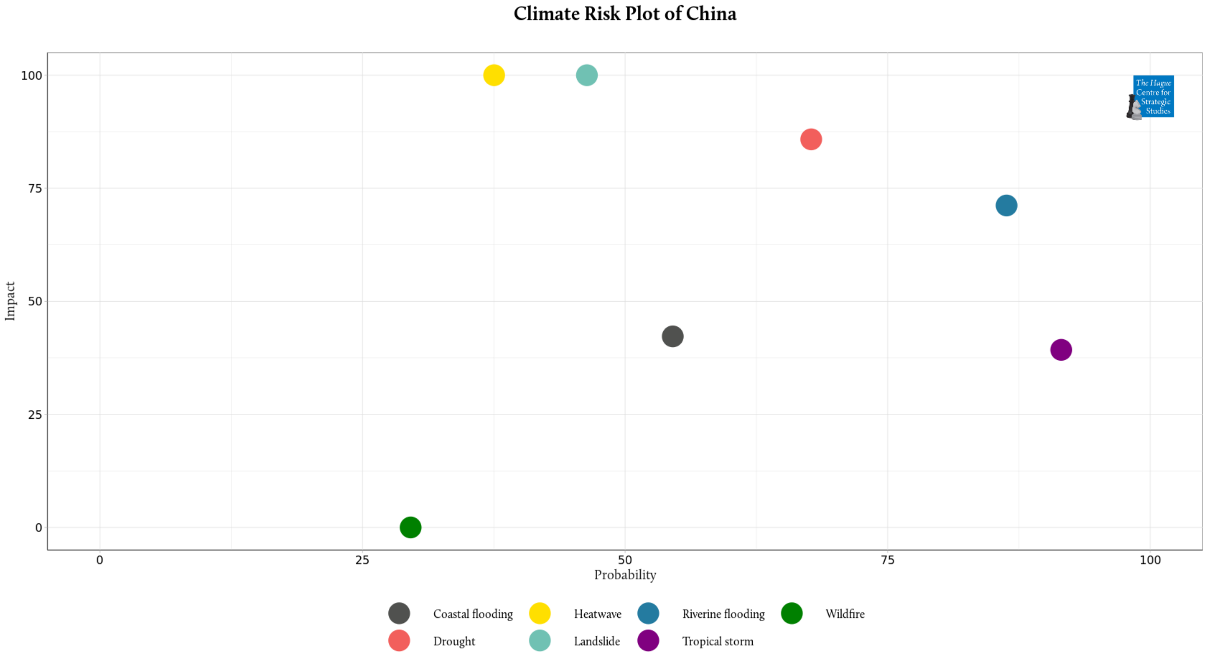

Figure 23. Climate Risk plot of China

India demonstrates the highest relative probability and very high total climate security risk scores in regard to several hazards. In India, coastal flooding, riverine flooding, and heatwaves receive the highest probability scores, with varying levels of potential impact. Though landslides would most adversely affect the country, this hazard demonstrates a lower probability.

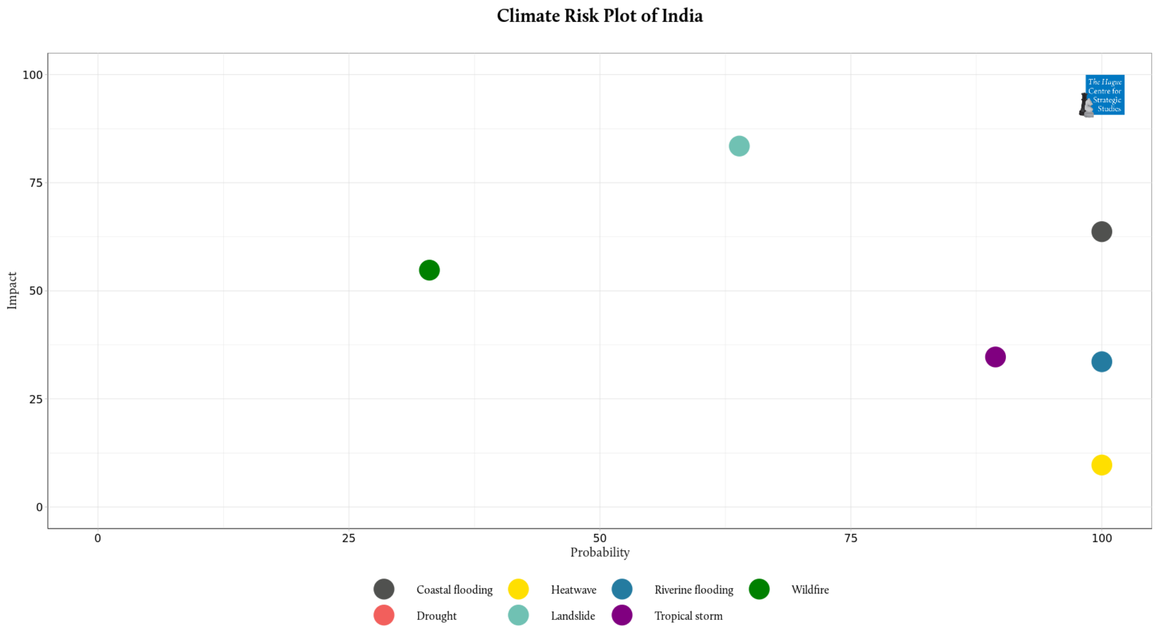

Figure 24. Climate Risk plot of India.

In the Netherlands, the potential impact of coastal and riverine flooding events and tropical storms would be moderately high, likely due to its low elevation. However, there is a low probability that such events would affect the country. Heatwaves and tropical storms demonstrate relatively higher probability to affect the country, though with – respectively – moderate and minimum potential impact.

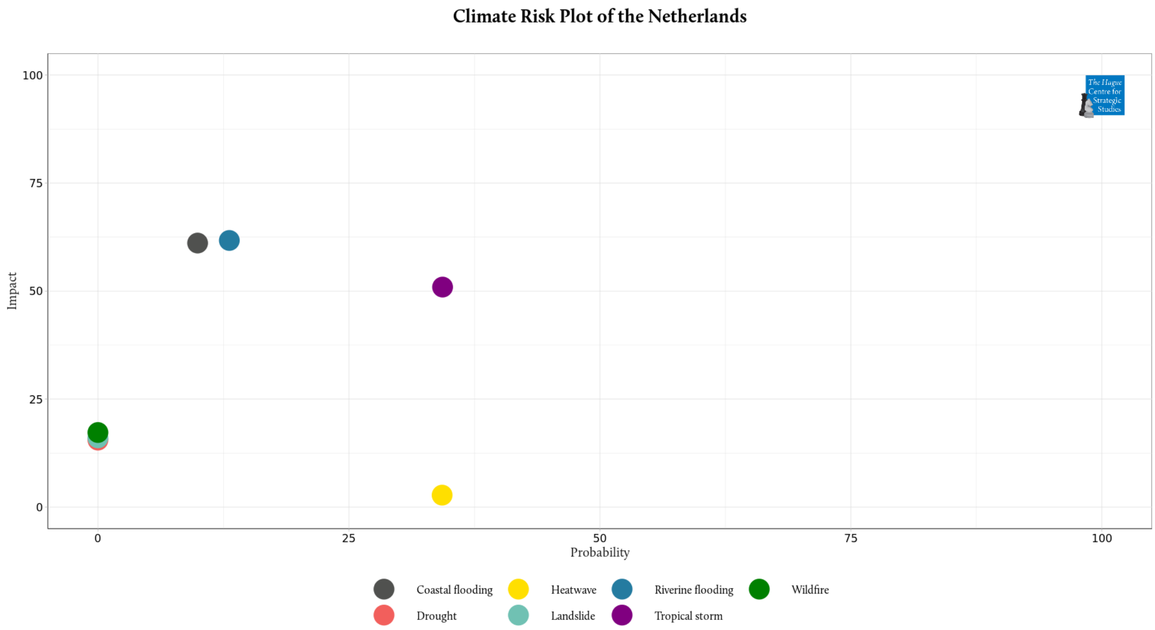

Figure 25. Climate Risk plot of the Netherlands.

Russia experiences probability and potential impact from all types of climate-related hazards. Wildfires and riverine flooding generate the highest climate security risks, followed by heatwaves.

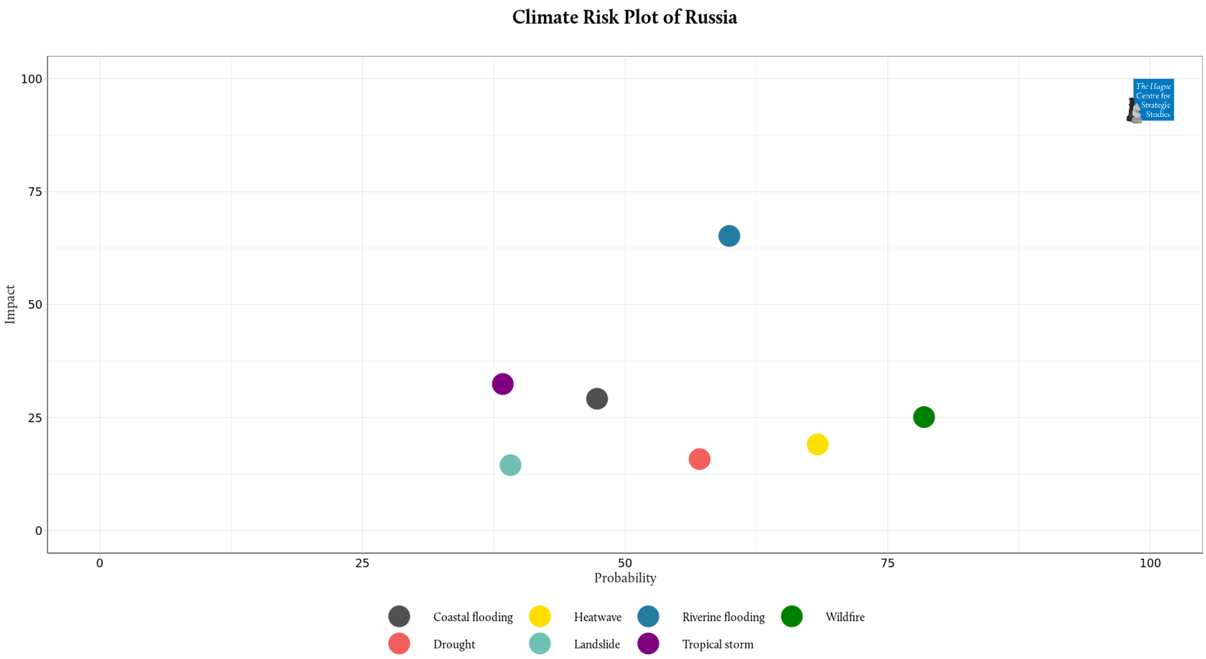

Figure 26. Climate Risk plot of Russia

In the United States, the probability wildfires risk is the highest. The potential impact of this hazard is above-average. Tropical storms also show a relatively high probability to affect the country, though the potential impact of these hazards receives a relatively low score.

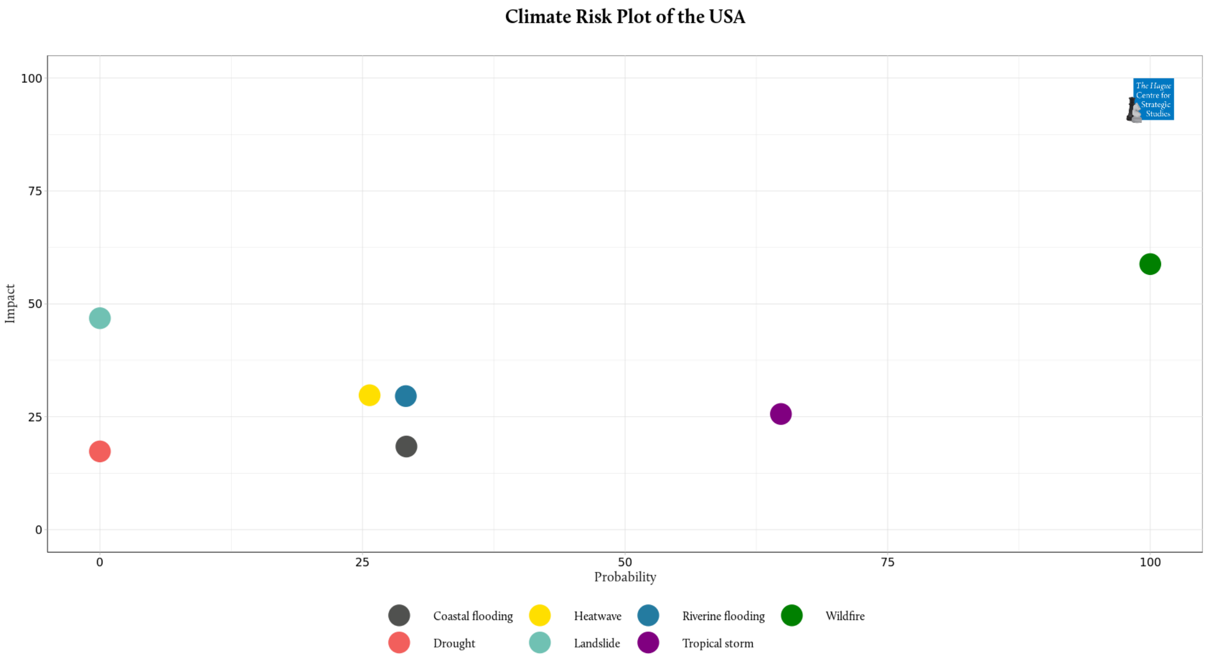

Figure 27. Climate Risk plot of the USA

Limitations

An important aspect of this risk assessment methodology and the resulting climate security risk matrices that should be considered by its users is that the findings always signify simplified representations of complex social and environmental phenomena. Understanding risk, in general, is a complex undertaking and involves the quantification of multi-dimensional factors and dynamics. The function of this risk assessment methodology is to quantify climate security risk to provide actionable and measurable targets for policymakers and security institutions with the aim to manage, mitigate, or avert climate security risks. The composite index of climate security risk is the outcome of carefully selected factors and indicators. Still, the composite index of climate security risk and plots of countries on a matrix convey simplified representations of real conditions and this should be kept in mind. Measures and policies designed and implemented based on these risk scores manage, mitigate, or avert the risks captured by this composite index.

Other limitations primarily concern constraints of the methodology or in the available data. This risk assessment methodology is not – or only partially – able to cover all dimensions and factors of climate security risk. The final analysis of this risk assessment methodology results in climate security risk scores for approximately 140 countries. Primarily smaller countries that do not have sufficient data, either because they did not report certain data or because statistics are dated, are excluded from the final results.

This is problematic especially when these countries are particularly facing challenges from climate-related hazards, such as the Small Island Developing States (SIDS). Some of these limitations can be addressed in future versions of this risk assessment methodology. Others will – to some extent – always be present in risk assessment models of this scope.

Operationalizing real-life contextual factors and dynamics: As is frequently the case with analyzing complex real-life phenomena, operationalizing all contextual factors, dynamics and causal mechanisms is a highly complex undertaking. Certain factors and dynamics of human exposure and susceptibility as well as all factors and dynamics determining the vulnerability to a certain hazard could not (or only partially) be converted into quantifiable data. For instance, important mechanisms to avert or mitigate the adverse impacts of landslides include the design and strength of hill or slope infrastructure. Also critical for averting the risk to many climate-related hazards are early warning technologies. Even though such data might be available, either qualitatively or quantitively, on the national level, global statistics on these factors does not (yet) exist. The indicators included in this risk assessment methodology to measure exposure, susceptibility, and vulnerability are based on available data on the global level for a longer period of time to be able to compare data across countries as well as to analyze trends over time. For some factors of risk, it was possible to select and employ proxy indicators. Also challenging is the operationalization of slow-onset natural hazards, as environmental degradation processes are highly complex to convert into quantifiable data and for these longer time series of data are required. These long time series are not available on global level.

Capturing all dynamics and causal mechanisms of risk: The factors and dimensions of risk addressed and captured in the risk assessment methodology influence climate security risk through different dynamics and causal mechanisms. Across contexts, the relative influence of certain factors and dimensions of risk might differ. For instance, in certain contexts, the dimension of health might be critically important to reduce climate security risk while in other contexts long-term adaptive strategies are more effective. Moreover, the relative significance of certain factors and dimensions might change over time. It was not possible to capture such variations in our global risk assessment model. Moreover, it was not possible to capture the relative influence of the different components of risk to one another. For example, improvements or declines in the coping capacity or resilience of countries might affect the degree of exposure of that country. The current methodology is not (yet) able to quantitively capture such dynamic interactions.

Compounding risks: Many regions of the world are prone to multiple types of climate-related hazards. The interactions and compounding effects of multiple hazard types appearing in combination in certain geographical contexts are not captured in this risk assessment methodology. Assessing interactions and compounding risks requires a semi-quantitative approach, including qualitative research on the interactions between different climate-related hazard types and potential triggering or compounding effects as well as advanced quantitative multi-hazard risk modeling.

Data limitations: Gaps in the data or limited ranges in datasets cannot be completely prevented. On certain dimensions and indicators of climate security risk that are addressed in our assessment, there do not exist datasets or only data that partially cover a certain indicator. For example, global datasets on the availability of adequate healthcare for a country's population are limited. The current health indicator uses two proxy indicators to assess a country's health sector. Gaps in the dataset of hospital beds per 1,000 persons exist for various countries and years, especially for small countries that did not report their statistics. Health care expenditure is added to compensate for these missing data. Still, these two datasets only partially cover the quantity and quality of healthcare. For most datasets, data is derived from 2018, which is commonly the latest available year. Hence, the risk scores are predominantly based on statistics from 2018. For some datasets for which this year was not available, the latest available data was used, with data being no older than 2010. Overall, the selection of datasets to populate the indicators of risk is constantly based on considerations of the accuracy of the analysis, simplicity of the indicators and associated datasets, and availability of the underlying data. Gaps that persist in the data do methodologically not hamper the final results.

The relative weight of indicators: In this risk methodology, the four components of risk are all weighted equally. Within every component, the individual dimensions receive equal weighting and within every dimension also every indicator is weighted equally. Because some components of risk comprise more underlying indicators and datasets than others, individual indicators do not exert equal influence on the overall risk score. For instance, susceptibility includes significantly more fixed indicators than (lack of) resilience. As a result, hazard-specific indicators that supplement this component of risk exert relatively less influence on the overall risk score than the hazard-specific indicator included to assess (lack of) resilience.

Responsiveness of the indicators: The current indicators and datasets used to measure the factors and dynamics of risk are based on statistics that are at least dated from one year ago. Countries implement measures or are subject to societal processes and developments that alter the value of these indicators and underlying data. However, there will always be a delay between the implementation of such measures or altering societal conditions and changes in the data. These delays are due to the time it takes for such changes to materialize and to be reflected in quantitative statistics.

Negative vs. positive impacts: Currently, the risk assessment methodology of this report only considers the negative effects of climate-related hazards in terms of losses, damages, and adverse consequences. However, climate-related hazards might also produce positive effects on societies and populations. For instance, seasonal riverine flooding is employed in irrigation practices by societies around the world. Flood-based farming is common among many communities in Africa and Asia where the use and management of floods yields great agricultural productivity. While most climate-related hazards are most damaging and destructive to human environments, they might also produce certain positive impacts and benefits for natural environments and ecosystems. The same is true for landslides and wildfire events that sometimes contribute to vegetation productivity and biodiversity, thereby improving ecosystems. Still, climate change is changing the frequency and scope of hazards at a rate that natural and human systems are likely not able to adapt to, thereby reducing the potential of these positive causal dynamics.

Changing conditions: Other variables that might influence climate security risk scores concern climate change and human activities that will affect the future occurrence of climate-related hazards. These include environmental degradation processes, such as rising sea levels, salinization, and desertification, that culminate into slow-onset disasters. However, data on such processes is not yet available on the global level. The assessment of the hazard component is based on historical records of hazardous events under past and current climate conditions. Climate change will impact the frequency and intensity of climate-related hazards, but it could also affect the geographical location or scope where hazards arise. For instance, climate change might open new areas of land that become exposed to landslide hazards. Likewise, human activity is also able to either decrease or increase the location, frequency, and intensity of climate-related hazards. Human settlement and building patterns can alter exposure to certain hazards. The buildings of adequate dams and dikes, for example, significantly decreases exposure to flooding. These variables might decrease or increase the future climate security risk.

Predicting future developments: The point made under Changing conditions is that this methodology looks at past and current situations and does not (yet) address future developments. To address and predict future developments, the current methodology could serve as a foundation and further developed into a prediction model. This is a daunting task. At HCSS we are currently studying this in relation to water conditions. Predictive modeling requires an extra discipline that is in place, but that needs time and further development to mature.

Appendix 1: Review of the literature

In general, countries with all levels of development that lack a sufficient level of preparedness for natural events will experience similar impacts produced by a natural disaster: mortality and morbidity, destruction and/or alteration of ecosystems, damages to (critical) infrastructure and housing, disruptions in the quantity and quality of food and water supply, destruction of livelihoods, and adverse impacts on mental health and human well-being.[65]

The scope and severity of adverse impacts that natural hazards could generate are dependent on the characteristics of the hazard, the geographical location in which the hazard develops as well as highly context-specific dynamics, including environmental, physical, socioeconomic, cultural, and/or institutional-related factors.[66] Therefore, it is not feasible nor realistic to build a single methodology to assess the potential impact of natural hazards.

Exposure reflects the physical exposure of elements at risk to the incidence of a specific extreme weather event. There is no disaster risk if there is no exposure of physical elements to a certain hazard – regardless of the intensity of that hazard. Elements exposed to disaster risk could be either persons, ecosystems, livelihoods, assets, and infrastructure situated in the hazard zone.[67] The **hazard zone** can effectively be defined as the geographical area susceptible to the incidence of an extreme weather event and its physical shocks of at least a minimum level of intensity that could produce critical damage or loss, thereby generating a disaster.[68] Exposed persons are persons who are in the hazard zone and risk death or serious injury as a consequence of the impact of an extreme weather event.

The extent of losses and damages and the consequences for overall stability and security are influenced by the **susceptibility** of exposed elements within a country to be negatively affected by the impact of natural hazards. While exposure depends on physical attributes of the human environment, such as population and the size of the so-called hazard zone, susceptibility is shaped by socio-economic, institutional,

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65 Intergovernmental Panel on Climate Change, *Climate Change 2014*, 40.
66 Hagenlocher et al., "Drought Vulnerability and Risk Assessments," 2.
67 Intergovernmental Panel on Climate Change, *Climate Change 2014*, 1765.
68 M. Marin-Ferrer, L. Vernaccini, and K. Poljansek, "Index for Risk Management INFORM Concept and Methodology Report - Version 2017" (Luxembourg: Publications Office of the European Union, 2017), 24.

and environmental factors. Levels of socioeconomic inequality and exposure and institutional instability can influence the extent and kinds of losses and damages in the immediate aftermath of a natural event through various direct and indirect causalities. For instance, natural hazards will have greater impacts on economic sectors with closer links to climate resources and conditions, such as livestock farming, agriculture, fishing, forestry, food production, and certain types of energy production.[69] It follows that in countries for which a large segment of the population or a substantial share of its GDP are dependent on these economic sectors the socioeconomic losses, damages, and consequences will be more significant. Natural hazards will also have much more substantial consequences to more vulnerable groups of the population experiencing human insecurities, including people who live in poverty, who enjoy low levels of employment, and/or who experience significant socioeconomic inequality. The increased insecurities these people experience to sustain their livelihoods critically weakens their capacity to protect themselves and recover from the impact of natural hazards. The impacts of natural hazards to institutions and the provision of vital services will be greater in countries that are already fragile or experience high rates of corruption.[70]

Indirectly, socioeconomic and governance factors also influence the construction and maintenance – and thus indirectly the effectiveness – of infrastructures like buildings, roads, hospitals, dams, dikes, and other critical infrastructure. Socioeconomic and governance factors can affect the adoption of critical monitoring and warning systems as well as the development and implementation of risk management strategies.[71] Such mechanisms and strategies form part of the general coping and adaptive capacity of society in the face of climate change and its adverse impacts, including (more frequent and intense) natural hazards.

While susceptibility refers to the socially constructed propensity to be negatively affected, **vulnerability** is determined and constructed by the physical characteristics of the hazard. Specifically, the level of vulnerability implies a country's propensity to be affected by or the ability to withstand the physical onset of a natural hazard. The degree of vulnerability can critically increase or decrease the magnitude of the hazard's physical shocks. There does not exist one clearly delineated definition or measurement of vulnerability in the literature. Establishing a universal definition of vulnerability is challenging because of the highly multi-dimensional and dynamic nature of vulnerability: its conditions vary across time and geographical contexts in

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69 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 16.

70 Birkmann, *Measuring Vulnerability to Natural Hazards*, 27–32, 224–25; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 70–72; Hagenlocher et al., "Drought Vulnerability and Risk Assessments."

71 Susana Ferreira, Kirk Hamilton, and Jeffrey R. Vincent, *Nature, Socioeconomics and Adaptation to Natural Disasters: New Evidence from Floods*, Policy Research Working Papers (The World Bank, 2011), 2–6.

addition to being scale-dependent (the individual, household, community, regional or national level). Moreover, vulnerability is highly situation specific as it interacts with the physical characteristics and shocks of the natural hazard.[72] Commonly, vulnerability is described as determined by coping capacity and resilience. Sometimes, susceptibility is considered and included as a component of vulnerability as well.[73]

Capacity – both the capacity of a society to cope with as well as to adapt to the adverse impacts of climate change – refers to the positive factors in the human system that have the potential ability to reduce the risk presented by a certain hazard.[74] Capacity, constituted by coping and adaptive capacity, is determined by early warning capacities, spatial planning, social capacity, economic capacity, and disaster management. The disaster risk assessment literature does not always differentiate between "coping" and "adaptive" capacity or resilience. However, whereas "coping capacity" is more often associated with the immediate-term coping structures and mechanisms to disasters, "adaptive capacity" is perceived as affecting the more long-term adaptation to climate change and its related impacts rather than just responding to them.[75] Hence, to better inform disaster risk management and climate change adaptation decision-making, we found it useful to make a distinction between these two components.[76]

Capacity is an important aspect of the relationship between vulnerability and risk. Capacity plays a significant role in reducing the disastrous impact of physical events and is often juxtaposed to vulnerability, as vulnerability is – among other things – the consequence of a shortage in capacity. In this sense, an increase in the capacity of a society to cope with and adapt to climate change and natural hazards implies a decrease in the vulnerability of that society. Contrarily, the higher a vulnerability of a society the weaker its capacity.[77]

Even though the four key components of climate security risk – exposure, susceptibility, coping capacity, and resilience – are generally hazard-specific, there are certain factors of sustainable development that influence a society's vulnerability to, and the impact of, natural hazard regardless of the specific type of hazard.[78] The link between sustainable

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72 Birkmann, "Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions," 12–13.
73 John Day et al., "WorldRiskReport 2019 - Focus: Water Supply" (Berlin: Bündnis Entwicklung Hilft; Ruhr University Bochum, 2019); Marin-Ferrer, Vernaccini, and Poljansek, "Index for Risk Management INFORM Concept and Methodology Report - Version 2017."
74 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 72.
75 Intergovernmental Panel on Climate Change, *Climate Change 2014*, 1758, 1761.
76 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 73.
77 Intergovernmental Panel on Climate Change, 72.
78 Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 70.

development and disaster risk has been emphasized by the UNDP, the IPCC and the Hyogo Framework for Action as well as the Sendai Framework for Disaster Risk Reduction. The Sustainable Development Goals (SDGs) have been recognized and integrated as critical targets in the context of disaster risk reduction.[79] The targets of the SDGs are intended to reduce both a country's susceptibility and vulnerability to disaster risk from every natural hazard across spatial contexts. The SDGs cover a wide range of thematic issues and include socioeconomic, institutional, and environmental targets. Hence, countries' achievements in sustainable development serve as indication of a society's overall susceptibility and vulnerability to climate-related disasters and security risks.

79 Birkmann, "Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions," 41.

Appendix 2: Measuring Climate Hazards Risk

The existing risk assessment literature and the conceptual framework and drivers of climate security provide the foundation for the selection of the various factors, components, dimensions, and indicators to measure climate security risk. In this section, the methodology to assess climate security risk and plot this on a risk matrix will be discussed in more detail. The first section reflects on the criteria for the selection of indicators and the second section explains how these indicators are combined to generate a climate security risk index score which ranks the climate security risk of countries on a five-point scale.

Assessment indicators

To develop a comprehensive risk assessment that will inform effective disaster risk management strategies, this risk assessment methodology employs a holistic approach to the measurement of exposure, susceptibility, coping capacity, and resilience. The overall exposure and susceptibility of societies to critical losses, damages, and consequence in the face of natural hazards and the capacity to avert such impacts will be measured in relation to socioeconomic, institutional, and environmental factors. Moreover, the selection of indicators aims to reflect and incorporate – as a proxy for the underlying drivers of climate security risks – the key themes of sustainable development set out by the UN SDGs. The key themes of the SDGs are fundamental aspects of human security and include: ending poverty and hunger, improving health, education, and water and sanitation, reducing (gender) inequality, enhancing economic growth, innovation and infrastructure, promoting peaceful and inclusive societies including effective, inclusive, and accountable institutions, tackling climate change, increasing sustainable consumption, production and development, and preserving our vital ecosystems.[80]

Through the inclusion of socioeconomic, institutional, and environmental factors of disaster risk and the incorporation of the key themes of the SDGs, the indicator framework includes an assessment of the underlying drivers of climate security risk. This allows the translation of the more abstract components of coping capacity, resilience,

80 United Nations Department of Economic and Social Affairs, "The 17 Goals," United Nations Department of Economic and Social Affairs, 2020.

exposure, and susceptibility into distinguishable, communicable, and actionable targets for policymakers and security officials to mitigate and avert climate security risks. As the SDGs are focused on the root causes of human insecurities, incorporating the key themes of the SDGs in the indicator framework also ensures a human security and people-centered approach to strengthen resilience to climate change and natural hazards.[81]

The selection of quantitative indicators is grounded in extensive literature research and in line with the IPCC's integrated and comprehensive understanding and quantification of risk that includes a multi-dimensional and holistic approach, using socio-economic, institutional, and environmental indicators. In addition, the set of indicators used by other risk matrix methodologies were considered, including the United Nations Environment Programme's Global Risk And Vulnerability Index Trends per Year (GRAVITY), the Inter-American Development Bank's indicators for disaster risk and risk management, the European Commission's Joint Research Centre's INFORM Risk Index, and the WorldRiskReport 2019.[82] While avoiding redundant overlap, the indicators that the Inter-American Development Bank, GRAVITY, INFORM, and the WorldRiskReport employ into their risk assessments were integrated in the indicator framework.

The quantitative indicators to measure the individual components of risk will largely remain stable across different types of hazards, specifically for the larger part of the components susceptibility and (lack of) coping capacity and resilience. A country's susceptibility to adverse impacts and vulnerability to the physical shocks of natural hazards is largely determined by general socioeconomic, institutional, and environmental indicators. Independent of the type of natural hazard, these factors shape and determine the scope of the disaster and climate security risk. However, there are also socioeconomic, institutional, and environmental characteristics of the human environment that interact with the specific physical attributes and shocks of natural hazards. Hence, susceptibility and vulnerability are shaped by and include both general as well as hazard-specific indictors (see Table 1).

Exposure to a natural hazard is much more dependent on the physical attributes and shocks of the natural event. Hence, the quantitative indicators used to measure exposure will require modification to fit the specific characteristics of the concerned hazard (see Table 1). The selection of both hazard-specific indicators to measure probability and

81 Human Security Unit, "Human Security Handbook: An Integrated Approach for the Realization of the Sustainable Development Goals and the Priority Areas of the International Community and the United Nations System" (New York: United Nations Trust Fund for Human Security, 2016), 5.

82 Hy Dao and Pascal Peduzzi, "Global Risk And Vulnerability Index Trends per Year (GRAVITY) - Phase IV: Annex to WVR and Multi Risk Integration" (Geneva: United Nations Development Programme, Bureau of Crisis Prevention & Recovery, 2003); Inter-American Development Bank, "Indicators for Disaster Risk and Risk Management: Program for Latin America and The Caribbean: Trinidad and Tobago" (Washington, D.C.: Inter-American Development Bank, 2010); Marin-Ferrer, Vernaccini, and Poljansek, "Index for Risk Management INFORM Concept and Methodology Report - Version 2017"; Day et al., "WorldRiskReport 2019 - Focus: Water Supply."

impact are based on additional research of hazard-specific risk assessment literature and research methodologies.[83]

In selecting the stable and hazard-specific quantitative assessment indicators, this report intended to keep the indicators straightforward, implementable, transparent, and without redundant overlap, to be able to populate them with high-quality, openly available, and preferably annually updated data from reliable databases on many countries, and to keep them generally consistent with the ambitions for risk reduction and climate change adaptation of the IMCCS consortium.

A detailed description of the stable indicator framework (see Table 1), including the definition, periodicity, and limitations of the datasets can be found below (see Appendix 3: Stable indicator framework).

A climate security risk index score

To arrive at an index score of the various components of climate security risk requires the population of these components with suitable and regularly updated datasets and the normalization of this data into combined scores ranging from 0-100. Again, existing risk assessment methodologies, including the methodology employed by GRAVITY, INFORM, and the WorldRiskReport, are consulted for the approach of this report.[84]

Probability

Assessing the future incidence of a (natural) physical event, or the *probability* of a hazard requires a trend analysis of past extreme weather events. This type of data is often gathered and published by climate hazard maps and databases as well as national and international disaster catalogs. To arrive at an index score for the variable 'natural hazard', the data on the past occurrence and frequency of extreme weather events is gathered and normalized.

The methodology of this report sought to arrive at index scores for the natural hazard that reflects equivalent levels of intensities across the various types of natural hazards. Equivalent levels refer to a comparable level of frequency and severity of the extreme weather event, with similar loss and damage levels.

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83 Abdullah Al Baky, Muktarun Islam, and Supria Paul, "Flood Hazard, Vulnerability and Risk Assessment for Different Land Use Classes Using a Flow Model," *Earth Systems and Environment* 4, no. 1 (2020): 225–44; Birkmann, "Measuring Vulnerability to Promote Disaster-Resilient Societies: Conceptual Frameworks and Definitions"; Birkmann, *Measuring Vulnerability to Natural Hazards*; De Groeve, Poljansek, and Vernaccini, "Index for Risk Management - INFORM"; Hagenlocher et al., "Drought Vulnerability and Risk Assessments"; Safecoast Project Team, "Coastal Flood Risk and Trends for the Future in the North Sea Region, Synthesis Report."

84 Dao and Peduzzi, "Global Risk And Vulnerability Index Trends per Year (GRAVITY) - Phase IV: Annex to WVR and Multi Risk Integration"; Marin-Ferrer, Vernaccini, and Poljansek, "Index for Risk Management INFORM Concept and Methodology Report - Version 2017"; Day et al., "WorldRiskReport 2019 - Focus: Water Supply."

The other variable of probability is the vulnerability of a community to a specific hazard type. Vulnerability is shaped by socioeconomic, institutional, and environmental drivers and factors that determine the propensity to be affected by the physical shocks of a hazard. The degree of vulnerability can critically increase or decrease the magnitude of these physical shocks. To include dynamic changes in risk and to better inform risk management and climate change adaptation decision-making, both coping and adaptive capacity (resilience) are included as components of vulnerability. Coping capacity and resilience are not necessarily opposites of vulnerability. These variables influence one another through dynamic relationships and interactions. For example, communities that are highly vulnerable to specific natural hazards could demonstrate high capacity in certain coping or adaptation areas.[85] Vulnerability – or a lack in coping capacity or resilience – is measured through both general as well as hazard-specific indicators. The general and hazard-specific indicators are combined in index scores for both coping capacity and resilience. Subsequently, the index scores for coping capacity and resilience are inversed to represent a lack in these capacities – which is why "lack of" is placed between brackets – and combined in an overall vulnerability score.

Susceptibility is not considered as a component of vulnerability in this methodology, as this component refers to socio-economic and institutionally constructed variables independent of the onset of a natural event. These socially constructed variables do not directly impact the onset of the hazard and cannot directly mitigate the magnitude of its physical shocks. Hence, susceptibility does not (directly) influence probability and is included as an individual component of potential impact – or negative consequences.

Potential Impact

The potential impact of a natural hazard on a country is – among others – determined by the presence of exposed elements to the adverse effects of this hazard and their susceptibility to the specific hazard's impacts. Hence, the higher the physical exposure, the higher the impact and the higher the susceptibility of exposed elements, also the higher the impact. The measurements of exposure and susceptibility are based on quantitative methods, using assessment indicators and datasets.

The potential impact is measured in relation to socioeconomic, institutional, and environmental factors. Exposure is generally hazard-specific and therefore based on hazard-specific environmental indicators. The assessment of susceptibility is based on both general and hazard-specific socioeconomic and institutional indicators that are combined in an overall susceptibility score.

85 Intergovernmental Panel on Climate Change, 73–74.

Risk

The overall risk score is calculated as a product of these four components (Natural Hazard, Vulnerability, Exposure, Susceptibility). In this formula, the composite score that represents risk is equally sensitive to performance and changes in Natural Hazard (the threat), Vulnerability, Exposure, and Susceptibility. This format allows countries experiencing similar exposure but demonstrating minor disparities in terms of their susceptibility or vulnerability to exhibit different results in terms of overall risk. To incorporate that every component can counterbalance the others, our overall risk score is calculated as the geometric average of these four components.

$$\text{Risk} = \sqrt[4]{\text{Natural Hazard} \times \text{Vulnerability} \times \text{Exposure} \times \text{Susceptibility}}$$

In the equation, the outcome of the calculation – the overall risk to a certain hazard – will equal zero if either one of the four components (Natural Hazard, Vulnerability, Exposure, Susceptibility) scores zero. Conceptually, if a society is highly vulnerable to a specific type of hazard, for example, coastal floods, and essentially demonstrates or possesses no coping capacity or adaptive strategies to deal with the incidence of a flooding event, but there are no inhabitants or essential economic activities located in regions prone to coastal flooding and thus exposed to this hazard, then the overall risk to coastal floods in this society equals zero. Alternatively, if a society that is located in a coastal zone is highly exposed to coastal flooding events – simply due to its geographical location in a flood-prone area – but has developed very resilient and efficient coping and adaptive capabilities and strategies and hence demonstrates an ideal capacity to deal with and recover from such an event (and which thus scores zero on Vulnerability), then the overall risk to coastal flooding in this society is also likely to equal zero.

Scoring risk on a 100-point scale

The probability and potential impact of a certain hazard in a country will be represented as a score ranging between 0 and 100. Higher scores indicate worse performance, with the value of 100 representing the country with the highest probability or likely impact of a certain climate-related hazard. The notion that higher scores indicate worse performance and higher risk is likewise applied to the four components of climate security risk – exposure, susceptibility, coping capacity, and resilience – and their underlying dimensions and indicators. This will allow straightforward interpretation and comparison of a country's overall risk score.

Probability and potential impact, as the variables of climate security risk, and their underlying components and dimensions, are calculated and conveyed as composite scores for every country. Establishing the methodology for analyzing the data, weighing the indicators, and compiling them into composite scores for the different levels of analysis is done through a process of aggregating the data and analyzing its results. In this risk methodology, the four components of risk are all weighted equally. Within every component, the individual dimensions receive equal weighting and within every dimension also every indicator is weighted equally.

Appendix 3: Stable indicator framework

The selection of quantitative indicators to measure Natural Hazard, Vulnerability, Exposure, and Susceptibility that will remain stable for all types of hazards is described in Table 1 below.

This table clearly illustrated the multi-structured conceptualization and measurement of climate security risk. The climate security risk is measured in relation to four components – Natural Hazard, Vulnerability, Exposure, and Susceptibility – that each consist of one or more dimensions that contribute to the component's index score. These dimensions are influenced by indicators that are selectively chosen based on existing risk assessment literature and the underlying drivers of climate security risk. Each indicator is populated by one or more datasets (referred to under 'indicator name'). In addition to the stable indicators and datasets described below, the dimensions of '(lack of) coping capacity', '(lack of) resilience', and 'susceptibility' might be assigned hazard-specific indicators based on the specific characteristics and shocks of the natural hazard. Exposure is always hazard-specific, but for reasons of clarity included as a component in the table below.

A more detailed description of the stable indicators, including the definition, periodicity, and limitations of the datasets is included below structured according to the four components of climate security risk and their respective dimensions.

Component	Dimension	Indicator	Indicator name	Source	Latest data
Natural Hazard	***Extreme weather event***	*Frequency and intensity*	Hazard-specific	-	-
Vulnerability	***(lack of) Coping capacity***	*Early warning**	Mobile cellular subscriptions (per 100 people)	World Bank	2018
			Individuals using the Internet (% of population)	World Bank	2018
			Adult Literacy Rate	UNESCO	2018
			Access to electricity (% of population)	World Bank	2018
		Healthcare	Number of hospital beds (per 1,000 people)	World Bank	2015
			Current health expenditure (% of GDP)	World Bank	2016

Component	Dimension	Indicator	Indicator name	Source	Latest data
Vulnerability *(cont.)*	***(lack of) Coping capacity*** *(cont.)*	*WASH*	People using at least basic sanitation services (% of population)	World Bank	2017
			People using at least basic drinking water services (% of population)	World Bank	2017
		Food security	Prevalence of undernourishment (% of population)	World Bank	2018
			Average dietary energy supply adequacy (percent) (3-year average)	FAO	2018
		Recent shocks	Relative number of people affected by disasters in the last 3 years	Institute for Health Metrics and Evaluation	2017
	(lack of) Resilience	*Long-term adaptation*	Gross insurance premiums (adjusted as % of GDP)	OECD	2018
			Implementation of the Sendai Framework for Disaster Risk Reduction – Progress of Global Targets	UNDRR	2019
Exposure	***Hazard zone***	*Area* (exposed land)	Hazard-specific	-	-
	Persons in the hazard zone	*Population* (population exposed)	Hazard-specific	-	-
Susceptibility	***Socio-economic susceptibility***	*Poverty*	Poverty-population below US$ 1.90 per day PPP	World Bank	2018
		Life expectancy	Life expectancy at birth	World Bank	2018
		Education	School enrollment, primary and secondary (% gross)	World Bank	2017
		Standard of living	GNI per capita (PPP $)	World Bank	2019
		Unemployment	Unemployment, total (% of total labor force)	International Labour Organization	2019
		Gender	Gender Inequality Index	Human Development Reports, UNDP	2019
		Socioeconomic development	Level of Socioeconomic Development	BTI	2019
		Infrastructure	Quality of overall infrastructure	WEF Global Competitiveness Index	2017
	Institutional (in)stability	*Corruption*	Corruption Perception Index	Transparency International	2019
		State fragility	Fragile States Index	The Fund for Peace	2019

Table 1. Overview of the fixed indicator framework

*The dimension of **early warning** will remain stable for all rapid-onset hazards and is therefore included in the fixed indicator framework. However, an early warning does not possess the same capacity to avert or mitigate losses, damages, or consequences in the context of slow-onset events. The impact of rapid-onset events, whose sudden physical collision with natural and human systems cause immediate destruction, mortality, and morbidity in defined geographic locations, can be very effectively averted or reduced through early warning mechanisms. The incidence of slow-onset events, such as droughts, regularly develops over several months or potentially even years. Though slow-onset events indirectly – in conjunction with external pressures – lead to mortality and disease, the direct impacts of drought events on human systems are largely socio-economic. And while hazards like floods and landslides are more spatially bound, droughts generally arise across larger geographical areas. Hence, the capacity to cope with the impacts of slow-onset events, like droughts, in each country are much less determined by early warning capabilities. The dimension of early warning is fixed for rapid-onset events, but hazard-specific for slow-onset natural hazards.

**The indicators Life expectancy, Education, and Standard of Living are the three fundamental dimensions that constitute the UNDP's Human Development Index (HDI). To establish independence from the composite index of the UNDP, this risk assessment methodology operates the separate dimensions of the HDI independently and directly from the original source.

Component: Vulnerability

Vulnerability comprises a country's propensity to be negatively affected by the specific physical shocks of a natural hazard and depends on the overall capacity of a society to manage, mitigate, or avert the incidence and physical shocks of a natural event.

Dimension: (lack of) Coping capacity

Coping capacity involves the capacity of elements at risk to cope with or recover from the impacts of a (natural) disaster in a timely and efficient way, including the protection, rebuilding, or enhancement of its fundamental assets, structures, and functions in the short to medium term.[86] This capacity is influenced by the availability of vital resources and services as well as the ability to employ these to deal with the shocks of natural hazards.[87] This risk assessment methodology measures coping capacity as a function of early warning capabilities, healthcare, water, sanitation, and hygiene (WASH), food security, and recent shocks. The value of "recent shocks" is inverted to become a

86 Intergovernmental Panel on Climate Change, 73.
87 Birkmann, *Measuring Vulnerability to Natural Hazards*, 22.

negative value. The composite score of these indicators represents the coping capacity of a country. This composite score is subsequently inverted to signify a lack of coping capacities to capture vulnerability.

Indicator: Early warning

Early warning capacities can influence the extent of losses, damages, or consequences in the context of rapid-onset events. Specifically, early warning systems (EWS) can significantly decrease vulnerability and enhance response capacities in the face of a natural event.[88] The impact of rapid-onset events generally takes the form of a sudden physical collision with natural and human systems that leads to immediate destruction, mortality, and morbidity in defined geographic locations. These immediate impacts can be effectively averted or reduced through timely and well-communicated warning information that allows individuals exposed to a hazard to undertake action to avoid or reduce their risk, including the timely evacuation of persons and vital resources, assets, and services from the hazard-zone.[89] The availability of timely and accurate warning information depends on the presence of effective EWS and identified institutions that distribute the warning information. Besides, the efficiency of warning mechanisms is largely dependent on and determined by the scope of communication networks to distribute disaster-related information in a timely and effective manner as well as the connectivity of people to these communication networks and their capacity to access and understand this information.

As data on the presence of EWS and institutions are not easily available or quantifiable, data on the accessibility and effectiveness of communication networks required to disseminate disaster-related information and warnings to the public will serve as a proxy for early warning capacities. The datasets used to assess the effectiveness of information dissemination and communication in the context of early warning include; Mobile cellular subscriptions, Individuals using the internet, Adult literacy rate, and Access to electricity.

Details

Indicator name: Mobile cellular subscriptions (per 100 people)
Definition: Mobile cellular telephone subscriptions are subscriptions to a public mobile telephone service that provide access to the public switched telephone network (PSTN).[90]
Description: This indicator comprises the number of postpaid subscriptions and the number of active prepaid accounts (subscriptions that have been used during the last three months). The indicator includes all mobile cellular subscriptions that

88 Birkmann, 125.
89 Birkmann, 125.
90 World Bank Group, "Mobile Cellular Subscriptions (per 100 People)," The World Bank, 2020.

make voice communications possible, including both analog and digital cellular systems and 4G subscriptions. It does not include subscriptions via data cards or USB modems, subscriptions to public mobile data services, private trunked mobile radio, telepoint, radio paging and telemetry services. Mobile communications are particularly important for rural populations. The mobility, simplicity, adaptable deployment, and relatively low and declining manufacturing costs of wireless technologies enable even remote rural populations to be connected and possible to reach by local and national administration and organizations, even with low levels of income and literacy.[91]
Periodicity: Annual
Limitations: Information on subscriptions is widely available for most countries. Yet even though this number provides a general indication of the population's access to the telecommunications network, it does not indicate the exact penetration rate - the percentage of individuals or households with actual access to telecommunications. Also, the quality of this data differs among reporting countries because of variations in national policies regarding the provision and availability of data for operators. Potential differences in the definition and measurement used for mobile cellular telephone subscriptions might also influence cross-country comparison.[92]

Indicator name: Individuals using the internet (% of the population)
Definition: Internet users are individuals who have used the Internet (from any location) in the last 3 months.[93]
Description: This indicator includes internet users that have used the internet via a computer, mobile phone, personal digital assistant, games machine, or digital TV.[94] The digital and information revolution has expanded the range of instruments available to people to communicate and be connected. New information and communications technologies (ICT) offer vast opportunities for progress in all domains of life in developed and developing countries, including opportunities for better health services, improved service delivery, online education.[95]
Periodicity: Annual
Limitations: Information on subscriptions is widely available for most countries. Yet even though this number provides a general indication of the population's access to the telecommunications network, it does not indicate the exact

91 World Bank Group.
92 World Bank Group.
93 World Bank Group, "Individuals Using the Internet (% of Population)," The World Bank, 2020.
94 World Bank Group.
95 World Bank Group.

penetration rate - the percentage of individuals or households with actual access to telecommunications. Especially in developing countries, the data does not give a good idea of by whom and to what purpose ICT is used (e.g. private use, education, business, government).[96]

Indicator name: Adult literacy rate (total, % of people ages 15 and above)

Definition: This indicator measures the percentage of people ages 15 and older who can both read and write with an understanding of a brief simple statement regarding everyday life circumstances or activities.

Description: The literacy rate within a country indicates the level of educational attainment as well as the effectiveness of the education system. This indicator reveals to what extent people can obtain, understand, and use information, including critical information on, for example, the approaching of an extreme weather event, the location of shelters, the health effects of such events, or first aid techniques.[97]

Periodicity: Annual

Limitations: Assessing the actual literacy of a population is difficult. Estimating national literacy rates requires sample or survey measurements under monitored conditions. Commonly, countries base their national estimates on self-reported data. Sometimes countries use educational attainment data as a proxy measurement. However, in this case, often different lengths of school attendance or levels of achievement are applied. The application of different definitions of literacy and methods of data collection are obstacles to cross-country comparison.[98]

Indicator name: Access to electricity (% of the population)

Definition: Access to electricity measures the percentage of the population with access to electricity.[99]

Description: This indicator measures access to electricity services based on electrification data from industry, national surveys, and international sources.[100] Access to electricity is particularly crucial to human development as electricity is essentially indispensable for many basic activities and services, including lighting, heating, refrigeration, and communication as well as many technological appliances. Electricity is crucial for both human development – allowing economic activity and prosperity – as well as for direct coping capacity in the face of natural hazards – facilitating widespread connectivity and early warning capacities.

96 World Bank Group.
97 World Bank Group, "Literacy Rate, Adult Total (% of People Ages 15 and Above)," The World Bank, 2020.
98 World Bank Group.
99 World Bank Group, "Access to Electricity (% of Population)," The World Bank, 2020.
100 World Bank Group.

Periodicity: Annual

Limitations: Information on access to electricity is widely available for most countries. Yet even though this number provides a general indication of the population's access to electricity, it does not say something about the quality and reliability of this power source.

Indicator: Healthcare

The availability and quality of healthcare and medical services is a key factor of the vulnerability of a country and, hence, to disaster risk. Particularly, adequate healthcare determines the immediate coping capacity of a country in relation to natural disasters. According to the World Health Organization, health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".[101] The health impacts of natural disasters can be both direct – leading to widespread mortality and morbidity – and indirect – leading, for example, to waterborne infectious diseases, chronic diseases, disablement, and mental health problems.[102] The availability and quality of healthcare and medical services influence a country's capacity to deal with both these direct and indirect health effects. Natural disasters can also severely disrupt the capacity of healthcare and medical services to respond to the impacts of natural disasters by destroying facilities and paralyzing critical services or by affecting the overall quality of healthcare.[103] The availability and quality of healthcare and medical services are determinants of the health system's coping capacity to deal with these shocks, as they influence its ability to accommodate for the additional demands and pressures that are likely to be placed upon it.

To measure the availability and quality of healthcare and medical services within a country, this risk assessment methodology employs the proxy indicators Number of hospital beds and Current health expenditure as a percentage of total GDP.

Details

Indicator name: Number of hospital beds (per 1,000 people)

Definition: This indicator measures how many hospital beds there are available in a country for every 1,000 persons.[104]

Description: Hospital beds include inpatient beds available in public, private, general, and specialized hospitals and rehabilitation centers. For most countries,

101 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2013 - Focus: Health and Healthcare" (Berlin: Bündnis Entwicklung Hilft; United Nations University - EHS, 2013), 13.
102 Bündnis Entwicklung Hilft; United Nations University - EHS, 12.
103 Hoang Van Minh et al., "Primary Healthcare System Capacities for Responding to Storm and Flood-Related Health Problems: A Case Study from a Rural District in Central Vietnam," *Global Health Action* 7 (2014): 1–11.
104 World Bank Group, "Hospital Beds (per 1,000 People)," The World Bank, 2020.

beds for both acute and chronic care are included.[105] Statistics on the health workforce, such as the number of health workers per 1,000 people, were not widely available or annually updated for most countries.[106]
Periodicity: Annual
Limitations: Statistics on the number of hospital beds does not indicate the general quality of healthcare or the size and competence of the health workforce needed to assist the patients occupying these beds. Moreover, data is not available for a significant number of countries and the latest data is from 2015. The application of different sources and means of monitoring are also obstacles to cross-country comparison of the data.[107]

Indicator name: Current health expenditure (% of GDP)
Definition: This indicator measures the level of current health expenditure expressed as a percentage of GDP. Estimates of current health expenditures include healthcare goods and services consumed during each year.[108]
Description: Levels of and trends in health financing in a country are indicate the resources allocated to the development and maintenance of health facilities, health information systems, or qualified human resources – either in quality or in quantity.
Periodicity: Annual
Limitations: This indicator does not include capital health expenditures such as buildings, machinery, IT and stocks of vaccines for emergencies or outbreaks. These indicators also do not say something about the availability, accessibility, and the actual quality of the healthcare system.

Indicator: Water, Sanitation, and Hygiene (WASH)

The availability and sustainable management of water resources and sanitation are at the core of the UN 2030 agenda for sustainable development.[109] Water is an essential resource for human subsistence, health and well-being, livelihoods, the quality of rural and urban life, and economic prosperity. The availability and quality of safe drinking

105 World Bank Group.
106 World Health Organization, "Density of Community Health Workers (per 1,000 Population)," World Health Organization - The Global Health Observatory, 2020.
107 World Bank Group, "Hospital Beds (per 1,000 People)."
108 World Bank Group, "Current Health Expenditure (% of GDP)," The World Bank, 2020.
109 United Nations Environment Programme, "Progress on Integrated Water Resources Management. Global Baseline for SDG 6 Indicator 6.5.1: Degree of IWRM Implementation" (Nairobi: United Nations Environment Programme, 2018), vi.

water and sanitation critically influence an individual's health and are critical drivers of prosperity and economic development of whole societies. However, water resources are under increasing pressure from human activities and climate change. Climate change is drying up vital water supply systems while unsustainable usage and administration of water resources are decreasing the availability of fresh and clean drinking water and sanitation.[110] Natural disasters directly affect the availability of fresh and clean water for drinking and sanitation purposes. Natural disasters can cause critical damage to or pollute essential water supply systems. This has devastating effects on human lives, health and well-being, water-dependent livelihoods and businesses, and vital ecosystems. Inadequate water supply and sanitation facilities can significantly increase the risk of water- and vector-borne infectious diseases. At the same time, the availability of fresh and clean drinking and sanitation water is vital in the wake of natural disasters in the context of people's nutrition and medical care. Hence, Water, Sanitation and Hygiene (WASH) is a key determinant of the coping capacity of societies to deal with and recover from the impact of such disasters.[111]

Details

Indicator name: People using at least basic sanitation services (% of the population)
Definition: People using at least basic sanitation services refer to people using basic sanitation services as well as those using safely managed sanitation services.
Description: This indicator measures the percentage of people using improved sanitation facilities that they do not have to share with other households and where excreta are safely disposed of and treated offsite. Improved sanitation facilities are defined by the WHO/UNICEF as including "flush/pour flush to piped sewer systems, septic tanks or pit latrines: ventilated improved pit latrines, compositing toilets or pit latrines with slabs."[112]
Periodicity: Annual
Limitations: Often, countries lack sufficient or adequate information on either wastewater treatment or the management of on-site sanitation. National estimates are produced based on information available for the dominant type of sanitation system. If no information is available, it is assumed that 50 percent is safely managed.[113]

110 United Nations Environment Programme, vi–vii.
111 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2013 - Focus: Health and Healthcare," 20–22.
112 World Bank Group, "People Using Safely Managed Sanitation Services (% of Population)," The World Bank, 2020.
113 World Bank Group.

Indicator name: People using at least basic drinking water services (% of population)
Definition: People using at least basic drinking water services refers to people using basic water services as well as people using safely managed water services. Basic drinking water services is defined as drinking water from an improved source, of which collection time does not require more than 30 minutes for a round trip.
Description: This indicator measures the percentage of people of the total population using at least basic water services. This measurement includes both people who use basic water services as well as people who use safely managed water services. Basic drinking water services are defined by the WHO/UNICEF as "drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip." Improved water sources include "piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water."[114]
Periodicity: Annual
Limitations: National estimate are produced when data is available for at least 50 percent of the population.[115]

Indicator: Food security

Food security refers to the physical, social and economic access to sufficient quantities and qualities of food for all people at all times.[116] Access to safe and nutritious food is a fundamental component of human development. Akin to water resources, food is an essential resource for human subsistence, health and well-being, livelihoods, the quality of rural and urban life, and economic prosperity. The prevalence of malnutrition in a country, especially undernourishment, are important indicators for the capacity of people to deal with shocks, including climate change and natural hazards. Indeed, as the WorldRiskReport 2015 has emphasized, the disastrous impacts of natural hazards are significantly reduced when people are well fed. Alternatively, the vulnerability of a country to disasters and the risk of conflict can be severely increased by widespread hunger and food insecurity. Moreover, during natural disasters and episodes of conflicts, food security is highly at risk. Floods and hurricanes, for instance, do not only destroy crops and agricultural land, but they also critically disrupt food supply systems by destroying key transportation networks to crisis regions. The availability and quality of

114 World Bank Group, "People Using at Least Basic Drinking Water Services (% of Population)," The World Bank, 2020.
115 World Bank Group.
116 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2015 - Focus: Food Security" (Berlin: Bündnis Entwicklung Hilft; United Nations University - EHS, 2015), 7.

food in a country influence how well a country can deal with disruptions in the supply chains of food. Like with water, a strong food system is essential for people's survival and health and critically important to avert hunger or a health crisis in the wake of a natural disasters.[117]

To capture the capacity of a society to absorb climate-related shocks to the food system, this risk assessment methodology evaluates the access to and availability of food. Access to food implies that all people in a country can acquire adequate food and do not have to experience hunger. Sufficient availability refers to the extent that a country's production system and market (including food imports) can provide in sufficient food supplies for its population.[118] To measures access and availability of food, Prevalence of undernourishment and Average dietary energy supply adequacy are used as proxy indicators.[119]

Details

Indicator name: Prevalence of undernourishment (% of the population)
Definition: This indicator measures the population below the minimum level of dietary energy consumption (also referred to as the prevalence of undernourishment).
Description: Specifically, the prevalence of undernourishment as a percentage of the total population evaluates the probability that an average individual from the population does not consume a number of calories that is sufficient to fulfill her or his energy requirements for an active and healthy life.[120] The indicator is calculated by comparing "a probability distribution of habitual daily dietary energy consumption with a threshold level called the minimum dietary energy Requirement". Both variables are based on the conditions for an average individual in the reference population.[121] Both the INFORM and GRAVITY indexes use child malnutrition as an indicator to assess the degree of food security in a country. However, this indicator also contains data on child obesity, which is not necessarily relevant to or indicative of levels of food security in the context of coping with the impacts of climate disasters. Also, child malnutrition does not necessarily say something about the levels of food security among the population as a whole.

117 Bündnis Entwicklung Hilft; United Nations University - EHS, 12–30; The Economist Intelligence Unit, "Global Food Security Index 2019: Strengthening Food Systems and the Environment through Innovation and Investment" (London: The Economist Intelligence Unit, 2019), 5, 9–10.

118 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2015 - Focus: Food Security," 7.

119 INDDEX Project, "Data4Diets: Building Blocks for Diet-Related Food Security Analysis" (Boston: Tufts University, 2018), 142–44.

120 Food and Agriculture Organization of the United Nations, "Suite of Food Security Indicators," Food and Agriculture Organization of the United Nations, 2020.

121 Food and Agriculture Organization of the United Nations.

Other indicators that say something about the level of food security among a population are for instance the number of people undernourished (million) or the prevalence of severe food insecurity in the total population (percent) (annual value). However, the absolute number of people undernourished – which estimates the number of people at risk of undernourishment – says less about the general level of development and food security within a country. For example, the United States would have a relatively high number of undernourished people in comparison to, for instance, Ghana or Sudan, simply because the total population of the US is such a great number. Prevalence of undernourishment as a percentage of the total population takes account of differences in population sizes.[122] Although the latter would be an adequate indicator to evaluate the degree of food access and food security among a population, data availability is best for Prevalence of undernourishment.

Periodicity: Annual

Limitations: The Prevalence of undernourishment indicator considers dietary energy intake and therefore by itself is not a sufficient indicator of average levels of nutrient adequacy or dietary quality within a country which could also be indicative of the capacity of the food system to absorb climate-related shocks.[123] To provide a more comprehensive assessment of food security within a country, we also include an assessment of the supply side of food by including the indicator Average dietary energy supply adequacy (percent) (3-year average).

Indicator name: Average dietary energy supply adequacy (percent) (3-year average)

Definition: Average dietary energy supply adequacy expresses the Dietary Energy Supply (DES) as a percentage of the Average Dietary Energy Requirement (ADER).[124]

Description: Average dietary energy supply adequacy is calculated at the national level. This indicator is an estimate of the sum amount of calories from foods available for human consumption in a given country. Each country's average supply of calories for food consumption is normalized by the average dietary energy requirement estimated for its population to provide an index of adequacy of the food supply in terms of calories.[125] Even though this estimate does not say something about the quality and affordability of food, it can be a valuable indicator for determining whether a country's food supply contains sufficient

122 World Bank Group, "Prevalence of Severe Food Insecurity in the Population (%)," The World Bank, 2020.
123 INDDEX Project, "Data4Diets: Building Blocks for Diet-Related Food Security Analysis," 142–44.
124 Food and Agriculture Organization of the United Nations, "Suite of Food Security Indicators."
125 Food and Agriculture Organization of the United Nations.

dietary energy for its population's aggregate needs.[126] This indicator is updated annually for nearly all countries and is a useful indicator to compare nutrition availability across countries and over time. for cross-country comparisons of energy consumption, as well as for analysis of trends over time within a country.[127]

Periodicity: Annual

Limitations: A limitation of this indicator is that it does not reflect actual nutritional consumption but rather nutritional availability. This indicator includes foods that appear on the standardized food balance sheet (FBS) and therefore does not include all potential sources of dietary energy intake or certain foods consumed in only selected cultural contexts (e.g. insects or wild foods). In addition, since the indicator is a national-level estimate, it cannot be disaggregated by age or sex to detect inequalities in dietary energy availability (or consumption) across population groups which would be possible with the individual- or household-level dietary data.[128]

Indicator: Recent shocks

Recent shocks refer to the past occurrence of natural and/or human disasters. Countries and populations recently affected by natural and/or human disasters are commonly still in the recovery and rebuilding phase from financial, material, and institutional losses and damages. Recent shocks make a country more vulnerable to the incidence of future disasters. Disasters can critically set back development processes and reduce the capacity of both their populations, economy and institutions to cope with and absorb future shocks. Hence, recent shocks are incorporated as a variable of coping capacity. The value of recent shocks is inverted to incorporate its negative causal relationship with a country's coping capacity.

The indicator employed as a proxy for recent shocks evaluates only the occurrence of shocks in the last three years. Within this period a country is commonly still recovering from the impact of previous shocks which affects a country's coping capacity in face of future disasters. When a longer period of time passes between two disasters of the same type, a country has the opportunity to recover from past shocks like natural hazards. When a country is fully recovered, past shocks add to the general experience with and knowledge about this disaster type which informs preparedness, protection, and mitigation strategies and mechanisms.

126 INDDEX Project, "Data4Diets: Building Blocks for Diet-Related Food Security Analysis," 47.
127 INDDEX Project, 48.
128 INDDEX Project, 48; Uma Lele et al., "Measuring Food and Nutrition Security: An Independent Technical Assessment and User's Guide for Existing Indicators" (Washington, D.C.: Food Security Information Network, 2016).

Details

Indicator name: Relative number of people affected by disasters in the last 3 years
Definition: The relative number of people affected by disasters in the last 3 years refers to people who have experienced negative impacts of a natural or man-made disaster in the past three years.
Description: The relative number of people affected by disasters in the last 3 years is taken from the EM-DAT international disaster database by selecting: ALL disaster types (natural, technological, complex) for ALL geographical locations/ countries for the period 2017 to 2020. The data on the number of deaths due to disasters of the EM-DAT database includes data on deaths from three disaster groups: natural disasters, technological disasters, and complex disasters that include some major famine conditions for which droughts were not the principal source. Natural disasters are segregated into six sub-groups: Biological, Geophysical, Climatological, Hydrological, Meteorological, and Extra-terrestrial disasters. Disaster events only appear in the EM-DAT database when they meet at least one of the following entry criteria: Deaths: 10 or more people deaths; Affected: 100 or more people affected/injured/ homeless; Declaration/international appeal: Declaration by the country of a state of emergency and/or an appeal for international assistance. Some secondary criteria are also considered when data is missing, such as "Significant Disaster/ Significant damage (i.e. "worst disasters in the decade» and/or " it was the disaster with the heaviest damage for the country").[129]
Periodicity: Annual
Limitations: The human impact due to disasters recorded by EM-DAT does not include adequate data on the socio-economic impact of recorded disasters and does not indicate information concerning the time of recovery from these impacts.

Dimension: (lack of) Resilience

Resilience represents the ability of a system and its component parts – i.e. people, livelihoods, buildings, infrastructure, assets – to adapt to climate security risks and to anticipate future hazards.[130] This ability, also referred to as adaptive capacity, is influenced by socio-economic and infrastructure resilience. Socio-economic resilience influences the ability of a society to access and mobilize resources to anticipate, mitigate, and absorb

129 EM-DAT, "EM-DAT Guidelines: Data Entry, Field Description/Definition," EM-DAT Public, 2020.
130 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 73.

the socio-economic impact of disasters.[131] Resilience of infrastructures is important because of the dependency of societies on critical infrastructures for shelter, food and water supplies, sanitation, energy, health services, transportation, communication, and effective governance.[132] This risk assessment methodology measures resilience as a function of insurance premiums and the implementation of disaster risk management. The composite score of these indicators represents the adaptive capacity or resilience of a country. This composite score is subsequently inverted to signify a lack of resilience to capture vulnerability.

Indicator: Insurance premiums

Market-based insurance industries play an important role in carrying and transferring risk. Specifically, insurances contribute to socioeconomic and financial resilience against the impacts of extreme weather events through the risk financing and risk transfer of serious losses of financial, material, and infrastructural assets for both governments, businesses, and individuals.[133] A market-based insurance industry contributes to a country's resilience to physical risks (economic risks that could arise from direct – e.g. destruction of property and critical infrastructure – and indirect – e.g. business interruption, affected labor force, the interconnectivity of supply chains – impacts); liability risks (encompass the impacts that could arise tomorrow if parties who have suffered loss or damage from the effects of climate change seek compensation from those they hold responsible); and transition risks (financial risks which could result from the process of transition towards a lower-carbon economy in which a reassessment of the value of a large range of assets takes place).[134] There is increasing evidence that countries with widespread market-based insurance coverage recover faster from the financial impacts of extreme events.[135] In addition, the size of the insurance industry could influence investments made in green infrastructure and the scope of green financing in clean technology.[136] In this way, the market-based insurance industry enhances the socio-economic and financial resilience of societies to manage the impacts of disasters while also adding to the adaptation to and mitigation of climate change.

Details

Indicator name: Gross insurance premiums (Total, million US$, adjusted as % of GDP)

131 Intergovernmental Panel on Climate Change, 72.
132 Birkmann, *Measuring Vulnerability to Natural Hazards*, 36.
133 World Bank Group and Organisation for Economic Co-operation and Development, "Fiscal Resilience to Natural Disasters: Lessons from Country Experiences" (Paris: World Bank and OECD Publishing, 2019).
134 The Geneva Association, "Climate Change and the Insurance Industry: Taking Action as Risk Managers and Investors" (Zurich: The Geneva Association, 2018), 10–11.
135 The Geneva Association, 15; World Bank Group and Organisation for Economic Co-operation and Development, "Fiscal Resilience to Natural Disasters: Lessons from Country Experiences."
136 The Geneva Association, "Climate Change and the Insurance Industry: Taking Action as Risk Managers and Investors," 11–12.

Definition: This indicator measures the total insurance premiums in a given country as a percentage of GDP.
Description: The OECD indicator measures the total insurance premiums in a given country in million USD. This favors large countries or countries with large economies. Hence, this indicator is adjusted as a percentage of GDP.
Periodicity: Annual
Limitations: This number provides a general indication of the socio-economic resilience of an economy, it does not indicate the penetration rate - the percentage of individuals or households that have an insurance and to whom – what groups of the population and what economic activities – the transfers of risk apply.

Indicator: Disaster risk management

Disaster Risk Management plays a crucial role in reducing the disaster risk of natural hazards. Specifically, DRM includes the development and implementation of disaster risk reduction policies and strategies in order to prevent, mitigate, and manage the risk of natural disasters. DRM can significantly reduce a country's vulnerability, exposure, and susceptibility to natural hazards and includes activities relating to risk prevention, mitigation, transfer, and preparedness.[137] DRM covers a wide range of strategies and mechanisms, such as development planning, enhanced land-use and urban planning, water and land management, constructing hazard-resilience infrastructure, innovative technologies, widespread awareness-raising, and hazard warning and protection mechanisms.[138] Examples of disaster risk reduction strategies include implementing flood/storm damage reduction measures for buildings, installing reflecting or heatabsorbing infrastructure including buildings, roads and, pavements, making hills landslide proof, producing drought-resilient crops, etc.

Progress on the implementation of the Sendai Framework for Disaster Risk Reduction is used as a proxy indicator to measure DRM. The Sendai Framework focuses on the development and implementation of measures and strategies which address the three dimensions of disaster risk (exposure to hazards, susceptibility and capacity, and hazard characteristics) to prevent the formation of new risk, decrease existing risk and enhance resilience.

137 Federal Ministry for Economic Cooperation and Development, "Disaster Risk Management: Approach and Contributions of German Development Cooperation" (Berlin: Federal Ministry for Economic Cooperation and Development, 2015), 4–14.

138 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 74–76.

Details

Indicator name: Implementation of the Sendai Framework for Disaster Risk Reduction
Definition: This indicator measures the implementation of the Sendai Framework for Disaster Risk Reduction in relation to countries' achievements regarding the framework's seven global targets.
Description: The Sendai Framework delineates seven global targets – with 38 underlying global indicators – to guide, support, and review progress in the country's efforts relating to the development and implementation of disaster risk reduction strategies and mechanisms.[139] The global targets of the Sendai Framework include: 1) Reduce global disaster mortality; 2) Reduce the number of affected people globally; 3) Reduce direct economic loss in regards to GDP; 4) Reduce disaster damage to critical infrastructure and disruption of basic services; 5) Increase the number of countries with national and local disaster risk reduction strategies; 6) Substantially enhance international cooperation to developing countries; 7) Increase the availability of and access to multi-hazard early warning systems. The 38 indicators of the Sendai Framework assess progress and evaluate global trends in the reduction of risk and losses. The scoring and progress of countries in relation to these indicators and global targets reflect achievements in the domains of disaster risk assessment, prevention, mitigation, preparedness, response, recovery, and reconstruction.[140]
Periodicity: Annual
Limitations: A limitation of this indicator is that data is based on countries' self-reporting and might be subject to the incompleteness of reporting and biases in such data. Also, reported progress does not necessarily mean actual progress and there are limitations in terms of consistent availability of reported data for countries over longer time periods.

Component: Exposure

Exposure refers to the presence of elements – including people, ecosystems, resources, livelihoods, infrastructures, and services – in locations that could be adversely affected

139 United Nations Office for Disaster Risk Reduction, "Sendai Framework for Disaster Risk Reduction 2015-2030."
140 United Nations Office for Disaster Risk Reduction, "Measuring Implementation of the Sendai Framework," Sendai Framework for Disaster Risk Reduction Monitor, 2020; United Nations Office for Disaster Risk Reduction, "Sendai Framework for Disaster Risk Reduction 2015-2030."

by the impacts of a potential hazard. The component of exposure essentially involves factors that influence the physical impact (of persons and the environment) to a certain climate-related hazard, which also depends on the type of (natural) hazard. Exposure, in this risk assessment methodology, depends on the size of the hazard zone and the number of people located in this area.

There exist two significant differences in terms of exposure to the impact of a rapid-onset event, like floods, tropical storms, tsunamis and, landslides, and slow-onset events, like droughts. First, in the case of rapid-onset events, people are struck suddenly by the swift and relatively inescapable onset of an extreme weather event. In this scenario, the number of people residing in the hazard zone is generally the number of people exposed to the impact of the extreme weather event. For slow-onset hazards, the number of people affected does not necessarily equal the number of people currently residing in the hazard zone, as people still have the time and opportunity to leave the hazard zone in the face of a projected hazard. Second, droughts can occur anywhere around the world – except for desert regions where the incident does not really have any significance – as opposed to floods or storms that can only transpire in certain regions and along largely well-defined geographical fault lines, like river networks or coastlines. The concentration of rapid-onset events to well-defined geographical areas as opposed to slow-onset events that generally expose larger geographical scales, has implications for the exposure of elements to such events.

Dimension: Hazard zone

Hazard zones comprise the land areas prone to the incidence of a natural event and its physical shocks of at least a minimum intensity level. The demarcation of a hazard zone differs for the specific type of hazard. For flooding events, the area exposed to the impact of a hazard is often defined as the land area where elevation is below 5 meters. For coastal flooding, the exposed land area is also often measured in consideration to the total coastline length. For droughts, the land area exposed is more widespread and typically defined as a measurement of agricultural lands. Data on hazard zones include geographic indicators (e.g. coastline length) or hazard-specific maps.

Dimension: Persons in the hazard zone

In general, there are two approaches to measuring exposure of people. One is to evaluate absolute the exposure by assessing the absolute number of people potentially at risk of being exposed to a hazard, i.e. the absolute number of people residing in the hazard zone. Another approach is to evaluate relative exposure by assessing the relative number of people exposed. The relative number of people exposed is evaluated by calculating the number of people exposed relative to the total population of a country.

This approach favors large and more populated countries.[141] This risk assessment methodology employs the absolute number of people residing in the hazard zone. This approach is adopted because this risk assessment report adopts a national security approach that considers the climate security risks for a country's total population.

For some types of natural hazards, there is no risk when there are no persons (or vital assets) located in the hazard zone. For these hazards, including floods, tropical storms, landslides, and heatwaves, it is generally clear when and how many people are located in the hazard zone. For the calculation of the number of people located in the hazard zone, this risk assessment methodology employs data on population distribution. For droughts and wildfires, the hazard zone is less clearly delineated and less fixed, commonly comprising a whole country. In this case, data on the total population of a country is considered.

Component: Susceptibility

Susceptibility, in the context of climate change, refers to the propensity of exposed elements – persons, livelihoods, and assets – to be adversely affected by the impacts of hazard events. Susceptibility is shaped by socio-economic and institutional indicators, including socio-economic inequality and exposure and institutional (in)stability.

Dimension: Socio-economic inequality and exposure

Certain people and groups of the population are specifically susceptible to the impacts of natural disasters and experience increased risk to, for instance, food and water insecurity, health issues, and the destruction of their livelihoods in the wake of natural hazards. This increased risk is socially and economically constructed.

Various demographic and socio-economic characteristics of the population play an important role in shaping the socio-economic dimension of susceptibility, generated by socio-economic inequality and exposure. These conditions include health and well-being, gender, educational as well as occupational patterns and opportunities.[142] For instance, education increases the capacity of people to diversify livelihood dependencies. Low rates of persons enrolled in primary or secondary education affect this capacity and commonly indicate that people are dependent for their livelihoods on economic activity in the secondary or informal economy. People employed in these sectors are commonly more economically exposed to extreme weather events.

141 Marin-Ferrer, Vernaccini, and Poljansek, "Index for Risk Management INFORM Concept and Methodology Report - Version 2017," 28.

142 Birkmann, *Measuring Vulnerability to Natural Hazards*, 26–28; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 80–83; Aleksandar Ivanov and Vladimir Cvetković, "The Role of Education in Natural Disaster Risk Reduction," 2014, 123.

Moreover, they provide less social and occupational securities. When a large share of the population lives in poverty, is unemployed, or experiences grave inequalities due to their socio-economic circumstances, the impacts of extreme weather events are more gravely felt to the livelihoods and assets of the population while these people commonly also enjoy fewer safety-nets. Critical insecurities to people's livelihoods can produce tensions within society, either between groups of people based on ethnicity, religion, or ideology or directed towards local or national government institutions. Countries with industrialized economies and high levels of socioeconomic development generally experience greater losses and damages – in financial and material terms – in the wake of natural disasters because of the amount and value of resources located in the hazard zone. However, a general high level of socio-economic development among the population decreases inequality and the exposure of these people to experience critical threats to their health and well-being. In societies with low socio-economic development, critical inequalities and threats to health and livelihoods could give rise to climate security risks. Socio-economic development is therefore an important factor in tackling climate security risks. The general level of socio-economic development in a country also influences the extent of financial, material, and institutional resources allocated to disaster risk management strategies and climate change adaptation initiatives. Hence, indirectly, socio-economic exposure also shapes the resilience of a society to climate-related events.

Factors of socio-economic inequality and exposure that influence the socio-economic susceptibility of people include health and well-being, gender, education coverage, and economic status and opportunities. Besides infrastructural development, the exposure of livelihoods and assets to be adversely affected is largely hazard-specific. To represent health and well-being, education coverage, and economic status and opportunities, this risk assessment methodology measures the socio-economic dimension of susceptibility as a function of the following indicators: poverty, health status (proxied through life expectancy at birth), education, the standard of living, unemployment, gender, socioeconomic development, and infrastructure.

Indicator: Poverty

People living in extreme poverty experience struggles with providing themselves or their families with basic needs, including sufficient food and water or access to sanitation, basic infrastructure, healthcare, and education services. Poor people often live in substandard living conditions and are generally more exposed to physical insecurity and extreme weather events.[143] Reducing extreme poverty has been adopted as one

143 World Bank Group, "Poverty and Shared Prosperity 2018: Piecing Togeter the Poverty Puzzle" (Washington, D.C.: The World Bank, 2018), 1.

of the Sustainable Development Goals and the Sendai Framework to reduce human vulnerability to natural hazards and disaster risk.[144]

Poverty is an indicator of economic insecurity. Another possible indicator for economic insecurity is income inequality within an economy. However, in contrast to income inequality, poverty is not exclusively related to income or employment. Living in extreme poverty can have various causes, including unemployment, social exclusion, exposure to diseases, or, other phenomena that halt productivity. Poverty rates are therefore an important indicator of human development and human security. According to the UNDP, poverty hinders people's basic capacity to participate effectively in a society, including active social and political participation.[145] Hence, poverty is an important indicator of economic inequality and social dissatisfaction. Growing inequality is not only an important factor reducing economic growth but also in weakening social structures, increasing social and political tensions and potentially being a driver of unrest and conflict.[146]

Globally, most poor people live in rural areas, making them especially vulnerable to the impacts of climate change on our environment.[147] Rural residents often maintain complex livelihood strategies, such as farming or pastoralism, that depend on seasonal characteristics including rain and cyclical migration. These vulnerable livelihood strategies are extremely susceptible to the impacts of climate change and extreme weather events, like droughts, excessive rain, and soil erosion.[148] When hit by a natural disaster, the rural poor see their livelihoods destroyed, pushing them further into poverty and creating a vicious cycle of vulnerability and exposure to climate change. Often, the rural poor and vulnerable migrate to the city to find housing and employment. Poor people often settle in unsafe housing conditions or disaster-prone areas, including slums. Moreover, poverty is a key driver of people living and working in disaster-prone areas. Moreover, in large urban areas, rapid urbanization rates and the concentration of people affect the adequacy of urban planning and infrastructural development. Poor urban planning and infrastructure, in turn, weaken the capacity of urban clusters of people to manage the impact of natural hazards. These processes generate new patterns of vulnerability and risks to extreme weather events.[149]

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144 United Nations Development Programme, "Reducing Disaster Risk: A Challenge for Development," 26.
145 United Nations Development Programme, "Human Development Report 2019 - Beyond Income, beyond Averages, beyond Today: Inequalities in Human Development in the 21st Century" (New York: United Nations Development Programme, 2019), 73.
146 United Nations, "Sustainable Development Goal 1: No Poverty: Why It Matters" (United Nations, 2016), 2.
147 World Bank Group, "Poverty and Shared Prosperity 2018: Piecing Togeter the Poverty Puzzle," 5.
148 United Nations Development Programme, "Reducing Disaster Risk: A Challenge for Development," 5.
149 United Nations Development Programme, 9; Hessel C Winsemius, "Disaster Risk, Climate Change, and Poverty: Assessing the Global Exposure of Poor People to Floods and Droughts," *Environment and Development Economics* 23 (2018): 330.

Poverty levels are also indicative of the general level of human development within a country. There are various measures that countries can implement to mitigate the impact of extreme weather events, such as early warning systems and defensive infrastructure. However, such measures require financial resources, effective governance processes, and strong social structures.

Details

Indicator name: Poverty-population below US$ 1.90 per day PPP

Definition: Poverty headcount ratio at $1.90 a day measures the share of the population living on less than $1.90 a day at 2011 international prices.[150]

Description: In 2015, the World Bank valued the International Poverty Line (IPL) at $1.90 a day in 2011 purchasing power parity (PPP) US dollars to define and measure extreme global poverty. This specific value was based on the national poverty lines and purchasing patterns and costs of the fifteen poorest countries in the world. The $1.90 IPL reflects the minimum costs of basic living in the world's poorest countries and is intended to indicate the absolute minimum threshold for defining poverty in countries from all levels of development. The objective of the World Bank was to be able to compare poverty across countries. 2011 PPP exchange rates, or 2011 international prices, were therefore introduced to account for the different costs of living and well-being across states. In addition to the $1.90 IPL, the World Bank introduced the $3.20 lower-middle-income and $5.50 upper-middle-income IPLs based on the median poverty lines of, respectively, 32 lower-middle-income countries and 32 upper-middle-income countries. These two additional relative poverty lines allow for country comparisons within developing regions across countries for which the IPL of $1.90 is too low to be of any value. The $3.20 and $5.50 do not replace but supplement the original $1.90 IPL which still serves as the most reliable measurement to perform global cross-country comparisons.[151]

Other options of measuring poverty include national poverty lines. However national poverty lines are not useful for cross-country comparison as these values indicate the minimum level of income deemed adequate in a particular country based on population-weighted subgroup estimates from household surveys.[152]

Periodicity: Annual

150 World Bank Group, "Poverty Headcount Ratio at $1.90 a Day (2011 PPP) (% of Population)," The World Bank, 2020.
151 Francisco Ferreira and Carolina Sánchez-Páramo, "A Richer Array of International Poverty Lines," World Bank Blogs, October 13, 2017; World Bank Group, "Measuring Poverty," The World Bank, April 10, 2020.
152 World Bank Group, "Poverty Headcount Ratio at National Poverty Lines (% of Population)," The World Bank, 2020.

Limitations: Data is gathered from primary household survey data acquired from government statistical institutions and World Bank country departments. Limitations of this dataset mostly pertain the timeliness, frequency, quality, and comparability of household surveys. The availability and quality of data on poverty is sometimes less in small states, in countries with fragile situations, and in low-income countries (and even various middle-income countries).[153]

Indicator: Life expectancy

This risk assessment methodology employs life expectancy at birth as an indicator of health status. In general, people living in countries with a higher national income and health spending and with higher primary education coverage and income per capita tend to have longer life expectancies. In addition, literacy rates and food and safe drinking water availability are important factors. Hence, Life expectancy at birth is not only an indicator of the health status of people, but also of the general level of human development within a country.[154]

Life expectancy at birth as well as the following indicators – school enrollment and GNI per capita – are indicators or proxy indicators of the Human Development Index, included independently. The Human Development Index (HDI) was constructed to emphasize that the development of people and societies should not merely be evaluated in economic terms and that the condition and capabilities of persons serve as the ultimate development criteria. The HDI is developed as a composite index based on three dimensions – health, education, and standard of living – measured through four indicators, including life expectancy at birth, expected years of schooling, mean years of schooling, and GNI per capita. As stated by the UNDP, the HDI simplifies and evaluates only a part of what human development implies. For example, the index does not include some other key elements of human development, including poverty, disparity, and gender inequality.[155] This risk assessment methodology does not include the HDI itself but evaluates the three dimensions of the HDI autonomously. This approach is adopted to be able to evaluate the individual indicators of human development separately. In this way, this methodology allows for the identification of specific targets of disaster and climate security risk reduction for policymakers. Also, including the individual indicators of the HDI separately creates independence from the composite index in terms of data availability and the selection of the underlying datasets. That is, this risk assessment methodology prefers actual School enrollment over the aggregate score of

153 World Bank Group, "Poverty Headcount Ratio at $1.90 a Day (2011 PPP) (% of Population)."
154 Mahfuz Kabir, "Determinants of Life Expectancy in Developing Countries," *The Journal of Developing Areas* 41, no. 2 (2008): 185–204; Organisation for Economic Co-operation and Development, "What Has Driven Life Expectancy Gains in Recent Decades? A Cross-Country Analysis of OECD Member States," in *Health at a Glance 2017: OECD Indicators* (Paris: OECD Publishing, 2017), 31–44.
155 United Nations Development Programme, "Human Development Index (HDI)," United Nations Development Programme - Human Development Reports, 2020.

Expected years of schooling and Mean years of schooling to measure the dimensions of education.

Details

Indicator name: Life expectancy at birth (total, men/women)
Definition: Life expectancy at birth is defined as the average years a newborn child can expect to live in a given country, provided that current death rates stay stable.[156]
Description: Life expectancy at birth is the most used indicator to assess the health status of the population of a given country. This indicator summarizes mortality risks and trends across all age groups. The average life expectancy at birth of people in a country can increase due to a number of factors, including improved living standards, enhanced lifestyles and education, and better access to and quality of health services. The data of these indicators are derived from WHO life tables based on data on child and adult mortality and disaggregated by sex.
Periodicity: Biannual
Limitations: This data is obtained directly from registered deaths and population counts. Where data was not available, census and survey information is used. There are significant problems in assessing the completeness of reporting and biases in such data, and the availability of consistent data sources for countries over time.

Indicator: Education

Education is another dimension of human development that influences the socio-economic inequality and exposure of people and populations to be adversely affected by natural disasters. Education is an important driver for improving health conditions, increasing gender equality, and advancing economic growth and societal stability. Persons that have enjoyed at least primary education have acquired a basic skill level in reading, writing, and mathematics skills that provides them at a minimum with employment prospects in the informal or secondary sector. Persons that have additionally enjoyed secondary education have acquired advanced reading, writing, and mathematics abilities that provide them with skills and qualities that will substantially raise their economic status, decrease poverty, improve social mobility, and enhance gender equality.[157] Secondary education coverage is also important for the development

156 Organisation for Economic Co-operation and Development, "Life Expectancy at Birth," OECD Data, 2020.
157 Harold John Culala and John Angelo De Leon, "Secondary Education for Sustainable Development," in *Quality Education*, by W. Leal Filho (Berlin: Springer, 2020), 1–8.

of more advanced production processes and innovative technologies that contribute to economic development.[158]

Besides being an important indicator of levels of human development and decreasing the socio-economic susceptibility of people to experience grave consequences from natural disasters, education is also an important factor of resilience. That is, education increases the general familiarity and awareness of children in relation to natural hazards. For example, schools often teach children about the onset, characteristics, and risks of extreme weather events. Especially in disaster-prone countries, children are educated on how to best protect themselves and their families from these natural hazards, the knowledge that also spreads on to the family and the community.[159]

Details

Indicator name: School enrollment, primary and secondary (% gross)

Definition: Gross enrollment ratios are "the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown". "Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science, art, and music."[160] Secondary education "completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers."[161]

Description: Gross enrollment ratios are indicative of the capacity of each level of a country's education system. However, a high ratio can also be produced by a substantial number of overage children registered in each grade as a result of repetition or late entry instead of reflecting a successful education system. Net enrollment ratios exclude overage and underage students and thus more accurately reflect the education system's capacity and efficiency.[162]

However, as Primary school enrollment (% gross) has at least sufficient data until 2017/2018, whereas Primary school enrollment (% net) has more gaps in the data for certain countries and certain years, we employed gross ratios.[163]

To assess the degree and level of education in a given country, we will employ the aggregated score of primary and secondary school enrollment (% gross). This will be indicative of the general level of education among the country's population.

158 World Economic Forum, "Methodology - The 12 Pillars of Competitiveness," Global Competitiveness Report 2014-2015, 2020.
159 Ivanov and Cvetković, "The Role of Education in Natural Disaster Risk Reduction."
160 World Bank Group, "School Enrollment, Primary (% Gross)," The World Bank, 2020.
161 World Bank Group, "School Enrollment, Secondary (% Gross)," The World Bank, 2020.
162 World Bank Group, "School Enrollment, Primary (% Gross)."
163 World Bank Group; World Bank Group, "School Enrollment, Primary (% Net)," The World Bank, 2020.

As not all countries that have data on primary school enrollment also contain data on secondary school enrollment, for some countries the gross percentage of primary school enrollment will be multiplied to substitute the lack of data in the gross percentage of secondary school enrollment.

An indicator that is often used to evaluate a country's education system is Mean or Average years of schooling. However, this dataset of the World Bank only contains data until 2010, which is why we measured school attendance through the proxy indicators of primary and secondary school enrollment (% gross).

Periodicity: Annual

Limitations: Enrollment indicators are based on annual school surveys. These registration numbers do not necessarily indicate actual attendance or dropout rates throughout the schoolyear.[164]

Indicator: Standard of living

A standard of living refers to the level of wealth and comfort and the amount and quality of material goods and services available to the population of a given country. Like with poverty, people with a low standard of living experience struggles with providing themselves or their families with basic needs, including sufficient food and water or access to sanitation, basic infrastructure, healthcare, and education services. People who live in substandard living conditions and are generally more exposed to physical insecurity and extreme weather events.[165] The general standard of living is also indicative of the general level of human development within a country and the capacity to implement measures to mitigate the impact of extreme weather events, such as early warning systems and defensive infrastructure. A commonly used indicator to measure the standard of living is the Gross National Income (GNI) per capita indicator.

Details

Indicator name: GNI per capita (PPP $)

Definition: GNI per capita (PPP $) measures the total value added by all resident producers "plus any product taxes (fewer subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad".[166]

Description: GNI is calculated in the national currency of a country and subsequently converted to U.S. dollars at official exchange rates to allow cross-

164 World Bank Group, "School Enrollment, Primary (% Gross)"; World Bank Group, "School Enrollment, Secondary (% Gross)."
165 World Bank Group, "Poverty and Shared Prosperity 2018: Piecing Togeter the Poverty Puzzle," 1.
166 World Bank Group, "GNI per Capita, PPP (Current International $)," The World Bank, 2020.

country comparisons.[167]

Another commonly used indicator to measure the level of wealth and amount of goods and services available to the population of a country is GDP per capita. However, whereas GDP per capita measures all transactions within a country's borders, GNI per capita also includes the transactions by citizens living abroad.

Periodicity: Annual

Limitations: Data on GNI may be underestimated in lower-income economies because these contain a more substantial informal sector. This economic indicator does also not reflect inequalities in income distribution. The GNI is calculated using the Atlas method to convert local currencies into US dollars based on official exchange rates. This method does not account for differences in domestic price levels.

Indicator: Unemployment

Unemployment is a critical indicator of the socio-economic susceptibility of a population. Unemployment rates do not always accurately indicate levels of economic development. Countries with high levels of economic development can have high unemployment rates, while countries with low levels of economic development can have low unemployment rates. However, high and sustained levels of unemployment suggest significant inefficiencies in human resource allocation.[168] Unemployment is a key indicator to measure and monitor whether a country is showing progress in implementing the Sustainable Development Goal 8 that promotes sustained, inclusive and sustainable economic growth, including decent employment and full and productive jobs for all. Decent employment includes proper labor market conditions and social protection mechanisms. In countries with welfare benefits and well-developed safety nets, unemployed workers can decide to wait for an appropriate job. In countries that do not have widespread safety nets or welfare benefits in place, people often work in vulnerable labor conditions and are more at risk of losing their livelihood security in the wake of natural disasters.[169]

Details

Indicator name: Unemployment, total (% of the total labor force) (modeled ILO estimate)

167 World Bank Group.
168 World Bank Group, "Unemployment, Total (% of Total Labor Force) (Modeled ILO Estimate)," The World Bank, 2020.
169 United Nations Department of Economic and Social Affairs, "Employment, Decent Work for All and Social Protection," United Nations Department of Economic and Social Affairs, 2020.

Definition: Unemployment describes the share of the total labor force that is currently "without work but available for and seeking employment".[170]

Description: The definition used for unemployed persons is "those individuals without work, seeking work in a recent past period, and currently available for work, including people who have lost their jobs or who have voluntarily left work."[171] People who are currently not looking for employment but who have an agreement for a future job are also considered unemployed in this dataset. The series is part of the ILO estimates and is standardized to make comparability across countries and over time possible. These estimates are mainly based on survey data on national labor force statistics, with supplementary data of population censuses and nationally reported estimates when no survey data is available for a country.[172]

Periodicity: Annual

Limitations: The inclusion criteria for people who are considered to be looking for employment, people currently without a job, or people seeking a job for the first time differ across countries. There may also be people of working age that are currently not actively seeking employment, even though they would want to work. This can have various causes. Persons might perceive job opportunities as limited, face severe restrictions in labor market mobility, experience discrimination, or suffer structural, social, or cultural barriers to find employment. The omission of persons who would want to work but are not seeking work (often referred to as "hidden unemployed") is an issue that affects the total unemployment rate and comparison of data between countries. Moreover, data on employment in countries with large agricultural sectors may also be distorted as employment and unemployment in agriculture are especially difficult to measure. For instance, the specific timing of a survey determines the inclusion or exclusion of seasonal (un)employment in agriculture. Employment in the informal sector employment is equally challenging to quantify since informal activities are commonly not recorded.[173]

Indicator: Gender

Gender equality, women's empowerment and climate change, are directly interrelated. On the one hand, women are disproportionately susceptible to and affected by the impacts of climate-related disasters. On the other hand, women do not enjoy equal participation in the development and implementation of risk reduction strategies

170 World Bank Group, "Unemployment, Total (% of Total Labor Force) (Modeled ILO Estimate)."
171 World Bank Group.
172 World Bank Group.
173 World Bank Group.

and climate change adaptation and mitigation policies, yet they could play a significant role.[174]

Generally, in situations of poverty, women are disproportionately affected by the impacts of climate change. In economically less developed or rural societies, women are often responsible for gathering and producing food, collecting water from water sources, and obtaining fuel for heating and cooking. Climate change is placing pressures on the availability of food, water, and energy supplies and thus producing challenges for women in these critical areas. In addition, climate change has disproportionate effects on the world's population most poor and vulnerable. According to recent statistics, currently, about 70% of the world's population living below the international poverty line are women.[175] Also, the unequal possibilities and participation of women in the labor market compound inequalities and reduce women's capacity to cope with the impact of climate events. Women often experience more discrimination in the labor market in addition to structural, social, or cultural barriers that hold them back from looking for a job. These inequalities lead to disparities in financial resources and livelihood security, as well as exclusion from social safety nets. In this way, gender inequality could restrict the resilience and adaptive capacity of women, households and communities in vulnerable contexts to the impacts of climate change.[176] Research has demonstrated that improved socioeconomic gender equality increases the general level of livelihood, economic and health security within a society.

In addition to the unequal impact of climate change on the livelihood security of men and women in susceptible contexts, women do generally not receive equal participation in decision-making processes. The empowerment of women in politics leads to more gender-responsive socio-economic policies in relation to health, education, and the labor market. Moreover, unequal representation impedes women from potentially contributing to climate-related planning, policymaking, and implementation, while they could play an important role in policy and strategy development to adapt to and mitigate the impacts of climate change. On the regional and local level, women possess local knowledge and expertise of sustainable resource management and practices at the household and community level. The inclusion of women in parliament often leads to more climate change-responsive decision-making and the development and implementation of national climate policies that are gender-responsive. Especially in developing countries, the inclusion of women in leadership at the community level has led to better results of climate adaptation projects and policies. Research

174 Lilianne Fan, Joy Aoun, and Josef Leitmann, "Disasters, Conflict & Fragility: A Joint Agenda" (Berlin: Global Facility for Disaster Risk Reduction and Recovery, 2015), 20; United Nations Development Programme, "Overview of Linkages between Gender and Climate Change" (New York: United Nations Development Programme, 2012), 1.

175 International Union for Conservation of Nature, "Gender and Climate Change," International Union for Conservation of Nature, 2020.

176 International Union for Conservation of Nature.

has demonstrated that women's participation in politics generates greater levels of responsiveness to citizen's needs and enhanced levels of collaboration between disparate political parties which contributes to human development and social stability.[177] When policies or projects are developed and implemented without women's meaningful participation this shapes the risk of enhancing existing socio-economic inequalities and decrease effectiveness.[178]

Details

Indicator name: Gender Inequality Index
Definition: The Gender Inequality Index (GII) represents "the human development costs of gender inequality" or the loss in potential human development caused by the unequal opportunities of women and men in these key dimensions of human development.
Description: The GII is an assessment of gender-based disadvantages along three dimensions of human development: reproductive health, empowerment, and the labor market (economic status). Reproductive health is measured by maternal mortality ratio and adolescent birth rates, empowerment is measured by the proportion of parliamentary seats occupied by females and the proportion of adult females and males aged 25 years and older with at least some secondary education, and economic states – expressed as the labor market – is measured by the labor force participation rate of female and male populations aged 15 years and older. The index is represented as a score ranging between 0 and 1, where 0 means that women and men are treated equally along these dimensions and 1 means that one gender "fares as poorly as possible in all measures dimensions". Thus, the higher the value of the composite index, the more disparities between women and men exist in a society and the higher the costs to human development.[179] Other indicators commonly used to evaluate gender (in)equality include life expectancy at birth, school enrollment, or labor force participation rate differentiated by sex, the number of women in politics, or the prevalence of gender-based violence. However, the GII of the UNDP combines all these dimensions of gender inequality into one composite index that has been updated annually since 2010.[180]
Periodicity: Annual

177 United Nations Framework Convention on Climate Change, "Introduction to Gender and Climate Change," United Nations Framework Convention on Climate Change, 2020.
178 United Nations Framework Convention on Climate Change.
179 Jan Teorell et al., "The QoG Standard Dataset 2020 Codebook" (University of Gothenburg: The Quality of Government Institute, 2020), 321.
180 United Nations Development Programme, "Human Development Data (1990-2018)," United Nations Development Programme, 2020.

Limitations: Employing the GII computed by the UNDP limits analysis of the individual assessment of gender-based disadvantages along the different dimensions of human development (reproductive health, empowerment, and the labor market (economic status)), however including indicators for these dimensions separately would significantly increase the number of datasets in the indicator framework of this risk assessment methodology. Including the GII enhances the straightforwardness, ease of use, and interpretation of the indicator framework for policymakers.

Indicator: Socioeconomic development

The level of socio-economic development of a country essentially measures economic opportunity or exclusion, the extent of socioeconomic choice and freedom, and the level of income and wealth inequality for people within a country. The level of socio-economic development is also indicative of the general level of sustainable development.[181]

Poverty combined with inequality leads to serious social exclusion that fundamentally impedes participation in otherwise potentially functional market economies.

Details

Indicator name: Socioeconomic development

Definition: Socioeconomic development evaluates the degree to which significant parts of the population are fundamentally excluded from society due to poverty and inequality.[182]

Description: This indicator aims to measure the level of social exclusion as a determining factor for economic development and progress. It assesses structural exclusion and not the strength of a country's economy in terms of its output as reflected in macroeconomic data like unemployment rates or GDP growth.[183]

Another indicator often used to evaluate socio-economic development is the Economic sustainability index generated by the UNDP. This composite index contains a selection of twelve indicators that cover economic and social sustainability. The six economic sustainability indicators are: adjusted net savings, total debt service, gross capital formation, skilled labor force, diversity of exports, and expenditure on research and development. The six indicators on social sustainability are old-age dependency ratio, military expenditure, the ratio of education and health expenditure to military expenditure, change in an

181 Bertelsmann Stiftung, "Transformation Index of the Bertelsmann Stiftung 2020: Codebook for Country Assessments" (Gütersloh: Bertelsmann Stiftung, 2020), 26.
182 Bertelsmann Stiftung, 26.
183 Bertelsmann Stiftung, 26.

overall loss in HDI value due to inequality, change in Gender Inequality Index value, and change in the income share of the poorest 40 percent.[184] However, this index is complex in use as it does not provide an overall index score per country but provides a country ranking that is based on relative achievements in relation to the individual indicators and subsequently divides countries into four human development groups. Moreover, even though this index includes measures of inequality and economic opportunities, other indicators – such as military expenditure – are not relevant under this dimension.

Periodicity: Annual

Limitations: Data gathering is based on national assessments and estimates, followed by a process of blind review by experts. Hence, the data might be subject to biases and different conceptualizations and understandings of socioeconomic development, including social exclusion.

Indicator: Infrastructure

The general provision and state of infrastructure within a country – including housing, health, food and water, transportation, communications, energy, finance, and state and administration – is of key relevance in the context of natural disasters and security risk.[185] Widespread and efficient infrastructure is key to ensure the effective functioning and development of a society's economy as it connects different regions and integrates the national market. Infrastructural development also influences the type of economic activities and production in a country and, by extent, the progress of economic sectors. Effective transportation networks allow businesspersons and workers to transfer goods and services from and to the market in a reliable and timely way and facilitate efficient resource allocation. Economies also depend on widespread and reliable telecommunications networks and electricity supplies. Both are essential determinants of the rapid and unrestricted flow of information, which improves overall economic efficiency. The quality and extensiveness of a country's infrastructure can therefore substantially reduce income inequalities, poverty, and poor living standards and reduces socio-economic exposure to natural disasters.[186] Moreover, critical infrastructures include organizational and physical structures and facilities that are of vital importance to a country's society as they provide public safety and security.[187] Inadequate infrastructure can become a critical driver of disaster risk when it substantially contributes to enhanced social and economic susceptibility

184 United Nations Development Programme, "Human Development Report 2019 - Beyond Income, beyond Averages, beyond Today: Inequalities in Human Development in the 21st Century," 243–46.
185 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2016 - Focus: Logistics and Infrastructure" (Berlin: Bündnis Entwicklung Hilft; United Nations University - EHS, 2016), 7.
186 World Economic Forum, "Methodology - The 12 Pillars of Competitiveness."
187 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2016 - Focus: Logistics and Infrastructure," 7.

of populations. The failure of infrastructure to withstand and protect people from natural hazards critically increases the human and economic losses and adverse effects of the ensuing disaster. The total collapse of critical infrastructure can lead to serious disruptions in fundamental activities and functions of social, economic, and political systems.[188]

The design and construction of infrastructure are also important determinants of the resilience of critical infrastructure during the onset of extreme weather events and substantially affects the extent of human, financial, and material losses and damages. A robust and innovative design and construction of infrastructure can significantly decrease the death toll during the occurrence of natural disasters. The resilience of infrastructure also influences the continuity of critical services, such as healthcare, food and water supplies, energy, communications, transportation, education, governance. This indirectly influences the death toll during the aftermath of natural disasters as well as the development of climate security risk. When infrastructure is in unsatisfactory conditions, the ability of governments and aid services to respond in a timely and adequate manner and to provide and coordinate the logistics required in disaster relief is substantially reduced and the impact of a natural disaster can become disastrous.[189]

Details

Indicator name: Quality of overall infrastructure

Definition: This indicator evaluates the quality of overall infrastructure in a country, including transport, telephony, and energy.

Description: This is an assessment of the general state of infrastructure (e.g., transport, communications, and energy) in a given country. The results of this assessment are communicated as scores ranging between 1 and 7 (in which 1 = extremely underdeveloped—among the worst in the world; 7 = extensive and efficient—among the best in the world). This assessment is performed through an Executive Opinion Survey capturing the opinions of business leaders around the world on a broad range of topics for which statistics are unreliable, outdated, or nonexistent for many countries. The topics include quality of roads, railroad infrastructure, port infrastructure, air transport infrastructure, and electricity supply, available airline seat kilometers, mobile telephone subscriptions, and fixed telephone lines.

Data for this indicator has been gathered since 2007. The 2017 edition (after the data editing process) captured the views of 12,775 business executives in over 133 economies.

188 Bündnis Entwicklung Hilft; United Nations University - EHS, 14.
189 Bündnis Entwicklung Hilft; United Nations University - EHS, 10.

Periodicity: Annual

Limitations: Data gathering is based on an Executive Opinion Survey, followed by a reviewing process by experts. Hence, the data might be subject to biases and different conceptualizations and regulations of infrastructure quality.

Dimension: Institutional (in)stability

The susceptibility of persons, livelihoods, and assets to the impacts of hazard events is also shaped by institutional conditions. Institutions refer to the regulatory norms, instruments, and bodies that govern a society. Institutions are important factors of climate security risks. They comprise the relationship between policy setting and policy implementation in relation to sustainable development, disaster risk management strategies, and climate change adaptation.[190] Certain institutional characteristics shape the effectiveness of government institutions. These include legitimacy, accountability, and transparency. Government legitimacy, accountability, and transparency are important drivers of the receptivity and success of government policies. Moreover, they reduce the risk of political fragmentation and tensions. Countries with responsive and legitimate institutions are less susceptible to experience grave losses, damages, and adverse effects of (natural) disasters. Moreover, effective and strong institutions are more likely to enhance sustainable development, disaster risk management strategies, and climate change adaptation. Hence, these countries are more likely to effectively tackle the underlying drivers of climate security risks.[191]

Countries with stronger institutional frameworks commonly suffer fewer fatalities from disasters than institutionally weak countries because resource allocation is better and policies and legislation are more effectively enforced.[192] Effective institutions are also necessary to integrate policies and institutions on all levels of governance, i.e. both national, sub-national, and local levels. For instance, government institutions are important in the development of structural flood protection measures. However, if national government policies and strategies do not have substantial impacts on the local level, or even have negative consequences for local communities, this mismatch can enhance climate security risks. Alternatively, natural disasters can undermine institutional legitimacy and increase the risk to state instability. Natural disasters can put so many demands on state institutions to overload its capacity to effectively deal

190 Birkmann, *Measuring Vulnerability to Natural Hazards*, 30–31; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 85.

191 Thunghong Lin, "Governing Natural Disaster: State Capacity, Democracy and Human Vulnerability," *Social Forces* 93, no. 3 (2014): 1267–1300; Tove Ahlbom Persson and Marina Povitkina, "'Gimme Shelter': The Role of Democracy and Institutional Quality in Disaster Preparedness," *Political Research Quarterly* 70, no. 4 (2017): 833–47.

192 Ilan Noy and Rio Yonson, "Economic Vulnerability and Resilience to Natural Hazards: A Survey of Concepts and Measurements," *Sustainability* 10 (2018): 9.

with them. When a state is not able to provide its citizens with basic resources, safety, and security, this could have negative effects on public attitudes towards government institutions and affect their legitimacy and support among its citizens.[193]

Institutional instability reflects certain characteristics of institutional norms, instruments, and bodies that reduce or constrain their capacity to adequately and effectively govern a society. Countries that experience institutional instability are more susceptible to losses, damages, and adverse effects as a result of (natural) disasters. Moreover, countries with unstable institutions experience more challenges in addressing the underlying drivers of climate security risk.[194] Institutional instability is evaluated regarding the effectiveness and stability of institutions which is measured using two proxy indicators: corruption rates and state fragility.

Indicator: Corruption

Corruption influences the effectiveness and legitimacy of institutions and government policies and strategies. Corruption at both national, sub-national, and local levels impacts agenda-setting, decision-making, resource allocation, and compliance in policy institutions and commonly hinders the implementation of sustainable development projects, disaster risk management strategies, and climate change adaptation programs.[195] Corruption is also a factor in the implementation of disaster risk management strategies. Corruption especially leads to mismanagement of resources and disaster rescue and relief operations. For example, local elites that lack the necessary qualities and sufficient expertise or motivation might be allocated to manage local disaster risk reduction and relief operations. Moreover, local authorities might seek to profit from the resources allocated to disaster relief originating from donor countries.[196] Here, a vicious cycle emerges, when the state's capacity to respond to and cope with natural hazards is insufficient, its legitimacy in the view of its citizens will decline, potentially generating more political segregation and corruption.[197]

Details

Indicator name: Corruption Perception Index

193 Ryan E. Carlin, Gregory J. Love, and Elizabeth J. Zechmeister, "Natural Disaster and Democratic Legitimacy: The Public Opinion Consequences of Chile's 2010 Earthquake and Tsunami," *Political Research Quarterly* 67, no. 1 (2014): 3–15.

194 Birkmann, *Measuring Vulnerability to Natural Hazards*, 30–31; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 86.

195 Birkmann, *Measuring Vulnerability to Natural Hazards*, 466, 470; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 71.

196 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 299–300.

197 United Nations Development Programme, "Reducing Disaster Risk: A Challenge for Development," 72.

Definition: This index evaluates the level of corruption of a country's public sector, defined as the abuse of entrusted power for private gain.[198]
Description: The Corruption Perception Index (CPI) evaluates how corrupt a country's public sector is perceived to be by experts and business executives. It is a composite index that combines 13 surveys and assessments of corruption, gathered by various reliable and respectable institutions.[199] The assessment of experts and business executives covers a range of corrupt behaviors in the public sector, including bribery, diversion of public funds, use of public office for private gain, nepotism in the civil service, and state capture. Some of the data sources also considered the mechanisms available to prevent corruption in a country's public sector, including the government's ability to enforce integrity mechanisms, the effective prosecution of corrupt officials, red tape and excessive bureaucratic burden, the existence of adequate laws on financial disclosure, conflict of interest prevention and access to information, and legal protection for whistle-blowers, journalists and investigators. The results are aggregated in the CPI that scores and ranks countries based on the level of perceived corruption. The CPI has been updated annually since its first launch in 1995.
Periodicity: Annual
Limitations: Data gathering is based on externally conducted polls and surveys. Corruption estimation is mostly subject to definition and quantification issues. For example, corruption is used to refer to activities that can both be legal as well as illegal. In some surveys, all harmful corruption-like activities will be included while in others only activities lawfully defined as "corrupt". In addition, it is highly challenging to measure and quantify instances of corruption, which include a wide range of economic activities and human behaviors from financial transactions to more covert economic or political deals.[200]

Indicator: State fragility

The causes for state fragility are numerous and complex and can include – among others – tensions between identity groups based on differences in language, race, ethnicity, class, caste, clan, religion, etc. Inter-group tensions can deteriorate and lead to societal unrest and conflict through various external mechanisms, such as competition over (scarce) resources, corrupt or fragmented leadership, or unsettled inter-group hostilities. Societal tensions and conflict, in turn, increase state fragility as well as the state's capacity to deal with these drivers of violence and conflict. Fragile states are generally not sufficiently able or motivated to dedicate their resources to protect communities

198 Transparency International, "What Is Corruption?," Transparency International, 2020.
199 Transparency International, "Corruption Perceptions Index," Transparency International, 2020.
200 Tina Søreide, *Is It Wrong to Rank?: A Critical Assessment of Corruption Indices* (Bergen: Chr. Michelsen Institute, 2006).

from and to respond to natural disasters. Moreover, the development of disaster risk management strategies and mechanisms are hindered by ineffective governance and administrative structures that will likely be less effective in implementing these as well as coordinating with relevant private sector actors.[201] A vicious cycle appears again, when the state's capacity to respond to and cope with natural hazards weakens, so will its legitimacy in the view of its citizens, potentially increasing state fragility.[202] Social instability as well, reduces the capacity of people to respond to disaster risk.

Details

Indicator name: State fragility index

Definition: State fragility refers to states that experience one of the following attributes: the loss of physical control over or a monopoly on the legitimate use of force within its national territory; the erosion of legitimate authority to formulate and implement shared decisions; the incapacity to provide its citizens with basic public services; and, the incapacity to cooperate with other states as "a full member of the international community".[203]

Description: The Fragile States Index by The Fund for Peace includes an assessment of a wide range of "state failure risk elements", including the normal pressures that all states experience as well as significant vulnerability factors that could increase the risk of state fragility, and identifies when these pressures and risks exceed a state's capacity to deal with them.[204] The country ratings of the index are based on the total scores of 12 input indicators:

- Social Indicators: 1. Mounting Demographic Pressures; 2. Massive Movement of Refugees or Internally Displaced Persons creating Complex Humanitarian Emergencies; 3. Legacy of Vengeance-Seeking Group Grievance or Group Paranoia; 4. Chronic and Sustained Human Flight.
- Economic Indicators: 5. Uneven Economic Development along Group Lines; 6. Sharp and/or Severe Economic Decline.
- Political Indicators: 7. Criminalization and/or Delegitimization of the State; 8. Progressive Deterioration of Public Services; 9. Suspension or Arbitrary Application of the Rule of Law and Widespread Violation of Human Rights; 10. Security Apparatus Operates as a State Within a State; 11. Rise of Factionalized Elites; 12. Intervention of Other States or External Political Actors.

201 Fan, Aoun, and Leitmann, "Disasters, Conflict & Fragility: A Joint Agenda," 12–14; United Nations Development Programme, "Reducing Disaster Risk: A Challenge for Development," 6.
202 United Nations Development Programme, "Reducing Disaster Risk: A Challenge for Development," 72.
203 The Fund for Peace, "What Does State Fragility Mean?," Fragile States Index, 2020.
204 The Fund for Peace, "Methodology," Fragile States Index, 2020.

Each indicator is calculated and represented as a score between 0 and 10, with 0 indicating the lowest fragility (most stable countries) and 10 indicating the highest fragility (least stable countries). The total index is calculated as the sum of the 12 indicators and represented as a score ranging between 0 and 120. This score should be interpreted as the lower the score, the more the state is considered as being stable.[205]
Periodicity: Annual
Limitations: One major limitation of the Fragile States Index is that the country scores are always retrospective. Once the data is published, new and swift events may already have occurred that alter the stability and functionality of the state. Unexpected events that could significantly affect the stability and capacity of the state in the short term are, for instance, protest movements, revolutions, terrorist attacks, and natural disasters. Such events may trigger a substantial turnaround in a country's scores. Still, the index can create valuable insights and understanding on contexts where risks exist, and longer-term trends of instability are manifest.[206]

205 Teorell et al., "The QoG Standard Dataset 2020 Codebook," 278.
206 The Fund for Peace, "Fragile States Index Annual Report 2020" (Washington, D.C.: The Fund for Peace, 2020), 10.

Appendix 4: Hazard-specific indicators

For the different climate hazards taken into consideration, specific indicators are used on top of the more general set of indicators that apply to all climate hazards. In this appendix, the climate-related hazards that human activity and behavior can influence are coastal flooding, riverine flooding, tropical storms, landslides, droughts, heatwaves, and wildfires.

Coastal flood risk

Defining coastal flooding

Floods from the sea may be caused by a heavy storm (storm surge or tidal flood) – through heavy precipitation or strong winds over the sea surface –, a spring tide, or particularly a combination thereof. Coastal floods can be caused by an overflow, overtopping, and breaching of flood defenses such as dikes as well as flattening dunes/producing dune erosion. Land behind such coastal defenses often experience flooding and/or damage.[207]

The primary cause for the projected increase in people affected annually by coastal flooding is sea-level rise. Sea-level rise enhances the magnitude of coastal floods through higher tides and more extreme storm surges, which cause the sea to more frequently and more severely overtop existing coastal flood protection structures or natural barriers.[208] Climate change has already caused an 11-16 cm rise in the global mean sea level in the twentieth century. Estimates of climate change project that the global mean sea level is highly likely to rise between 20-30 cm by 2050 and 50-70 cm by 2100 under 1.5°C of global warming (or 70-100 under the global warming scenario of 2°C).[209] Without adaptation, a rise of 20-30 cm in the mean sea level by 2050 would affect the homes of approximately 150 million people.[210]

207 Safecoast Project Team, "Coastal Flood Risk and Trends for the Future in the North Sea Region, Synthesis Report," 24.

208 European Commission Joint Research Centre, "Climate Change and Coastal Floods" (Publications Office of the European Union, 2018), 1.

209 European Environment Agency, "Global and European Sea-Level Rise," European Environment Agency, December 4, 2019; Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 7; Scott A. Kulp and Benjamin H. Strauss, "New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding," *Nature Communications* 10, no. 1 (2019): 1–11.

210 Kulp and Strauss, "New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding."

Coastal cities often define a minimal or "nuisance" flooding threshold. When seawater rises above this level; some degree of flooding occurs that renders protective flooding infrastructure ineffective. Flooding thresholds are set on the local level, as impacts vary across geographical areas depending on local typography (the height – or elevation – above mean sea level), land cover, the existence, and, quality of flood defense infrastructure, local hydrological factors, ocean currents as well as the distribution of people, assets and activity in coastal areas.[211] A city located below the normal sea level with sufficient defensive infrastructure placed along the shoreline – like, for example, the Netherlands – will most likely have a lower flooding threshold in comparison to a more elevated city, even if that city does not have considerable flood protection infrastructure – for example, in Norway – as it will naturally be more frequently exposed to coastal flooding events.[212] Also, the same extent of an inundated area might have very different impacts across geographical locations, depending on the distribution of people, infrastructure, and economic activity along a coast.[213]

For reasons of clarity and consistency, this report includes coastal floods that include coastal flooding events that exceed the flood impact threshold applied by the EM-DAT database, which only includes hazards that fulfill at least one of the database's entry criteria: 10 or more people reported killed; 100 or more people reported affected; declaration of a state of emergency; or, call for international assistance.

The impact of coastal flooding

Sea level rise and coastal flooding will have significant security impacts on coastal environments and the people living there through physical exposure, socially, economically and institutionally constructed susceptibility, and the capacity (or the lack thereof) of communities to cope with and adapt to climate change's adverse impacts.

Under the 2°C global warming scenario, over 150 million people live in land area that, without adaptation measures, will be flooded by a rise of 20-30 cm in the mean global sea level. By 2100, over 200 million people could permanently fall below the high tide line. Without mitigation and adaptive strategies, the surge in annual flood heights is projected to affect coastal areas home to over 300 million people by 2050.[214] Even with the implementation of appropriate mitigation and adaptive measures, these impacts will not be completely eliminated.[215]

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211 Frances C. Moore and Nick Obradovich, "Using Remarkability to Define Coastal Flooding Thresholds," *Nature Communications* 11, no. 530 (2020): 2–3; United States Environmental Protection Agency, "Climate Change Indicators in the United States: Coastal Flooding" (Washington, D.C.: United States Environmental Protection Agency, 2016), 1.

212 United States Environmental Protection Agency, "Climate Change Indicators in the United States: Coastal Flooding," 5.

213 Moore and Obradovich, "Using Remarkability to Define Coastal Flooding Thresholds," 2.

214 Climate Central, "Flooded Future: Global Vulnerability to Sea Level Rise Worse than Previously Understood" (Princeton: Climate Central, 2019); Kulp and Strauss, "New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding."

215 European Commission Joint Research Centre, "Climate Change and Coastal Floods," 1.

Certain regions and areas are specifically prone to the adverse impacts of climate change and coastal flooding. These include particularly: coastal areas that already experience some adverse impacts of our changing climate, coastal areas where fresh water resources are likely to be reduced due to temperature rise, coastal areas exposed to various natural and human-induced stresses, including collapsing or deteriorating natural defense structures, coastal areas with substantial flood-plain areas in which populations are considerably exposed to large storm surge hazards, coastal areas experiencing significant barriers to implement adequate and efficient mitigation and adaptation strategies (either technical, environmental, economic or institutional), coastal areas that include farmland, fisheries, and tourist-based economies where severe economic impacts are highly likely, and highly vulnerable coastal systems where the possibilities for inland migration are constrained.[216]

The direct impacts of coastal flooding to natural and human systems include coastal erosion, land loss, destruction and/or alteration of ecosystems, mortality and morbidity, damages to (critical) infrastructure and housing, disruptions in the quantity and quality of food and water supply, destruction of livelihoods, adverse impacts on mental health and human well-being, and forced displacement.[217] Indirectly, these impacts might produce or aggravate existing pressures on societies and produce additional security risks, such as social tensions, increased violence, resettlement, or political instability.[218]

The vulnerability of a society to the impacts of coastal flood events can be substantially averted or mitigated through adequate coping and adaptive strategies, mechanisms, and infrastructures. Strategies, mechanisms, or infrastructures to avert of mitigate the impact of coastal flooding include coastal defense infrastructure, disaster risk management, effective irrigation strategies, sustainable land use and planning, sustainable water management, community-based adaptation, social safety nets, and risk spreading and sharing.[219]

Hazard-specific indicators and data

The data used to evaluate the occurrence and frequency of coastal flooding events to occur on the global level are derived from the Muis et al Coastal Flood datasets, which

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216 Anthony Oliver-Smith, "Sea Level Rise and the Vulnerability of Coastal Peoples: Responding to the Local Challenges of Global Climate Change in the 21st Century" (Bonn: United Nations University - Institute for Environment and Human Security, 2009), 27.

217 Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 10; Oliver-Smith, "Sea Level Rise and the Vulnerability of Coastal Peoples," 28.

218 Oliver-Smith, "Sea Level Rise and the Vulnerability of Coastal Peoples," 41.

219 Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 10.

contains a collection of coastal flood hazard maps for the world for several return periods (2, 5, 10, 25, 50, 100, 250, 500, and 1000 year return period).[220] This risk assessment employed the 25 year return period.[221]

Details

Indicator name: Global Coastal Flood Hazard
Definition: This dataset presents a global reanalysis of storm surge and extreme sea levels.
Description: The Global Tide and Surge Reanalysis (GTSR) datasets by Muis et al. present the first global reanalysis of storm surges and extreme sea levels based on hydrodynamic modeling. The GTSR dataset covers the entire world's coastline and consists of a time series of tides and surges and estimates of extreme sea levels. Validation of the data results demonstrates that there is good agreement between modeled and observed sea levels and that the performance of GTSR is comparable to that of many regional hydrodynamic models.
Periodicity: Annual
Limitations: Validation of the data results by Muis et al. has demonstrated that extreme values are slightly underestimated, especially in tropical areas. More accurate results require an even higher resolution than atmospheric reanalysis data can deliver today. This issue is projected to be resolved under updated versions of the dataset. The method used also does not consider the independence of tide-driven (deterministic) and surge-driven (stochastic) processes or the baroclinic effects (density differences) on sea-level variations. Moreover, flood protection is not included in this analysis.[222]

The indicators and datasets to evaluate the other components of climate security risk in the context of coastal flooding are named in the table below (see Table 2).

220 S. Muis et al., "A Global Reanalysis of Storm Surges and Extreme Sea Levels," *Nature Communications* 7 (2016): 1–11; World Bank Group, "Global Coastal Flood Hazard," The World Bank, 2020.

221 Return periods refer to an estimate of the average frequency at which hazards occur. A 100-year return period for flooding describes an event or an area subject to a 1% probability (one to a 100) of a certain size flood occurring in any given year. The 10-year flood refers to the discharge that will exceed a certain volume which has a 10% probability of occurring each year, and so on.

222 For more details on limitations, see: Muis et al., "A Global Reanalysis of Storm Surges and Extreme Sea Levels," 7–9.

Component	Dimension	Indicator	Source	Latest data
Exposure	*Area* (exposed land)	Total coastline length	World By Map	2018
		Land area where elevation is below 5 meters (% of total land area)	CIESIN	2010
		Land area covered by floods	Open dataportaal van de EU	
	Population (population exposed)	Population living in areas where elevation is below 5 meters (% of total population)	CIESIN	2010
Susceptibility	*Socio-economic susceptibility* (coastal flooding)	Employment in agriculture (% of total employment)	International Labour Organization	2019
		Agriculture, forestry, and fishing, value added (% of GDP)	World Bank and OECD	2019
(lack) of Resilience	*Hazard-specific* (Coastal flooding)	Integrated Water Resource Management	UNEP	2017
		Flood protection standards	FLOPROS	2016

Table 2. Coastal flooding indicators

Indicator: Total coastline length

To be exposed to coastal flooding events as a result of high tides, storm surges, and global sea level rise, a country needs at least to have some proximity to the ocean. The length of the coastline of a country is at least a good indicator for how much land area is exposed to a surge in annual coastal flood heights.

Details

Indicator name: Total coastline length

Definition: The total length in km of the boundary between the land area (including islands) and the sea within a country.[223]

Description: This indicator reflects the total length in km of the boundary between the land area (including islands) and the sea within a country that can potentially be affected by high tides, storm surges, and global sea-level rise.[224]

Periodicity: Annual

Limitations: Measuring coastline lengths is highly challenging. Coastlines are not straight lines and natural coastlines show many inconsistencies, splits,

223 Thomas Brinkhoff, "Coastline Lengths," City Population, May 27, 2020.
224 Mark Monmonier, "High-Resolution Coastal Elevation Data: The Key to Planning for Storm Surge and Sea Level Rise," in *Geospatial Technologies and Homeland Security: Research Frontiers and Future Challenges*, ed. Daniel Z. Sui (Dordrecht: Springer Netherlands, 2008), 229.

ruptures, and curves. Hence, the length value of a coastline depends on how much a measurement method zooms in on the coastline and includes all these irregularities or zooms out and measures the coastline as an average curve-like line. Still, if the same dataset and measurement method is used, this issue has limited consequences for cross-country comparison.

Indicator: Land area where elevation is below 5 meters

Not all coastlines are equally exposed to coastal flood events. Low-elevated land is specifically exposed to increases in sea levels, high tides, and storm surges. For example, in the context of the Netherlands, more than 85% of its coastal zones are located below 5 meters elevation. A rise in the global mean sea level of 20-30 cm by 2050 (under the 1.5°C global warming scenario) would have significant consequences for the Netherlands.[225] A country like Norway, on the other hand, that includes a generally steep and high-elevated coastline is less exposed to global sea-level rise and extreme storm surge events. Still, Norway's coastal regions are very susceptible to the impacts of sea-level rise and more extreme storm surges as many economic activities of its population depend on or are related to the coastal zone which is likely to be subject to coastal erosion.[226] Land area where elevation is below 5 meters is used as a proxy indicator to measure land exposure to coastal flooding events. The higher the percentage of the land area below 5 meters, the greater a country's exposure. A high percentage of the land area below 5 meters also reduces the prospect for persons to transfer or migrate from the hazard-zone in the face of coastal flooding events or structural sea level rise.[227]

Details

Indicator name: Land area where elevation is below 5 meters (% of total land area)

Definition: Land area where elevation is below 5m reflects the percentage of land area, as a share of the total land area of a country, where elevation above the sea level is 5 meters or less.[228]

Description: This indicator measures the total land area of a country where elevation above the sea level is 5 meters or less as a percentage of the total land area of a country.

225 European Commission, "The Economics of Climate Change Adaptation in EU Coastal Areas: Country Overview and Assessment" (Brussels: Policy Research Corporation, 2009), 2–4.

226 Kristin Aunan and Bård Romstad, "Strong Coasts and Vulnerable Communities: Potential Implications of Accelerated Sea-Level Rise for Norway," *Journal of Coastal Research* 24, no. 2 (2008): 403.

227 Xuemei Bai et al., "Coastal Zones and Urbanization" (Bonn: Secretariat of the International Human Dimensions Programme on Global Environmental Change, 2015), 9.

228 World Bank Group, "Land Area Where Elevation Is below 5 Meters (% of Total Land Area) | Data," The World Bank, 2020.

Periodicity: Annual
Limitations: This data is available at intervals of 5 years for the period 1990-2010. The latest available data is thus 2010. Although the land area where elevation is below 5 meters will not change significantly over the years, global mean sea level rise is influencing these statistics and could have altered the data over the last decade.

Indicator: Land area covered by floods

The EM-DAT database also keeps a record of the magnitude or scale of previous coastal flooding events. The inundated area is presented in km$^{2.}$ The scope of recent coastal flooding events can provide an indication of the magnitude of future coastal flooding events if the time gap between these events is not sufficiently long to significantly enhance resilience, for instance through the construction of flood defense infrastructure, to the impact of this natural hazard. Hence, land area covered by floods is a useful indicator of how much land area is exposed to a surge in annual coastal flood heights.

Details

Indicator name: Land area covered by floods
Definition: The scale of past coastal flooding events, considering the total land area covered by flooding events of the past three years.[229]
Description: This indicator reflects the scale of past coastal flooding events, considering the total land area covered by flooding events of the past three years. The larger the inundated area during past events, the more land is exposed and at risk to be affected by future high tides, storm surges, and global sea-level rise.[230]
Periodicity: Annual
Limitations: In the wake of past coastal flooding events or the prospect of sea-level rise and higher tides, a country can enhance their resilience against these extreme weather events by constructing adequate and effective flood defense infrastructure. Hence, the inundated area during past coastal flooding events might not always accurately reflect exposed land under current conditions. However, this methodology sought to limit the discrepancy between the data used and real-life conditions by considering only statistics on the total land area covered by coastal floods of the past three years.

229 EM-DAT, "EM-DAT Guidelines: Data Entry, Field Description/Definition."
230 Monmonier, "High-Resolution Coastal Elevation Data," 229.

Indicator: Population living in a land area below 5 meters

Exposure to coastal flooding events is also influenced by population densities in coastal areas. Not all coastal zones are equally vulnerable to coastal flooding events. While coastal areas containing high population densities, urban metropolises, supplies of subsistence resources, and economic activity would experience very high levels of exposure to coastal flooding events, coastal zones where nearly no people reside would not experience substantial levels of exposure. The number of people residing in coastal zones, in the context of coastal flooding, is measured through the proxy indicator Population living in a land area where elevation is below 5 meters. These people are particularly exposed to a rise in the global mean sea level and projected higher tides and storm surges. The number of people living in a land area where elevation is below 5 meters is also indicative of the density of assets and socioeconomic activity located in flood-prone areas.[231]

Details

Indicator name: Population living in areas where elevation is below 5 meters (% of the total population)
Definition: Population living in areas where elevation is below 5m reflects the percentage of the population, as a share of the total population of a country, living in areas where land elevation above the mean sea level is 5 meters or less.[232]
Description: This indicator measures the total number of people of a country that live in areas where elevation above the sea level is 5 meters or less as a percentage of the total population of a country.
Periodicity: Annual
Limitations: For this dataset, the latest available data is again 2010. In the last decade, the number or share of people living in areas where elevation is below 5 meters could have altered significantly. Coastal population growth and urbanization rates are recognized as critical demographic trends that are increasing the exposure of people and assets to coastal flooding events.[233]

231 Bai et al., "Coastal Zones and Urbanization," 9; Barbara Neumann et al., "Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment," *PLoS ONE* 10 (2015): 2–3.

232 World Bank Group, "Population Living in Areas Where Elevation Is below 5 Meters (% of Total Population) | Data," The World Bank, 2020.

233 Neumann et al., "Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment," 2; Till Sterzel et al., "Typology of Coastal Urban Vulnerability under Rapid Urbanization," *PLoS ONE* 15, no. 1 (2020): 1–24.

Indicator: Employment in agriculture

Employment data provides useful information concerning the type of economic activity that people are dependent on concerning livelihood sustenance. Agricultural production is highly dependent on the availability and quality of natural resources, like freshwater resources. Agriculture (including crops, livestock, fisheries, and forestry) often experience critical and widespread losses and damages as a result of the direct physical impact of natural disasters, especially as a result of floods (both coastal and riverine), storms, and droughts. In the long term, these natural hazards can also lead to soil salinification and degradation, producing more structural livelihood insecurity.[234] Both the direct and indirect effects of natural hazards on agricultural production can severely and critically impact the livelihoods of people employed in this sector. Hence, the share of employment in agriculture is used as a proxy indicator to assess the extent to which people's livelihoods are affected.

Details

Indicator name: Employment in agriculture (% of total employment) (modeled ILO estimate)
Definition: The share of persons employed in the agricultural sector, including activities in agriculture, hunting, forestry, and fishing, indicated as a percentage of the total number of persons of working age who are engaged in any activity to produce goods or services in a country.
Description: The International Labor Organization (ILO) defines employment as persons of working age who are presently (during the reference period) or were previously engaged in any activity to produce goods or services in return for pay or profit. Persons who were previously employed but currently not engaged in any activity to produce goods or services might be on temporary leave from a job, or on working-time arrangements. Employment in the agricultural sector includes activities for pay or profit in agriculture, hunting, forestry, and fishing.[235]
Periodicity: Annual
Limitations: There exist significant disparities in how countries define and measure employment status. Often, self-employed and unpaid family workers are not included in national estimates. In such cases, the number of persons employed in the agricultural sector is highly underrepresented, as people employed in this sector more regularly involve self-employed workers or family businesses including family members that are not necessarily paid in money.

234 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2015 - Focus: Food Security," 16.

235 World Bank Group, "Employment in Agriculture (% of Total Employment) (Modeled ILO Estimate)," The World Bank, 2020.

National estimates also treat unemployed persons differently. In most cases, data includes unemployed people who previously occupied a job. However, some countries do not classify unemployed persons or people currently looking for employment as persons engaged in economic activity. The age groups of people considered to be of working age can also differ per country. These variations in national estimates require caution as they make the size and distribution of employment by economic activity not ideally comparable across countries.[236]

Indicator: Agriculture, forestry, and fishing

The economic sectors particularly susceptible to experience grave losses, damages, and consequences from natural hazards – especially as a result of floods (both coastal and riverine), storms, and droughts – are agriculture, forestry, and fishing, in addition to tourism and navigation. However, the most direct and detrimental impacts on the security of natural hazards are felt in these economic sectors that have immediate effects on the food and livelihood security of many people. The size of the agricultural sector relative to the overall economy determines how severely a country is economically affected by a natural disaster in terms of its GDP. Sectoral information is also relevant to identify general levels of development in a country. Hence, the share of economic production in agriculture is used to assess how severely a country's overall economy is hit, as well as to evaluate the extent of people's livelihoods that are affected. The size of the agricultural sector also indirectly determines how severely a country's food system – in both quantity and quality – are affected.[237]

Details

Indicator name: Agriculture, forestry, and fishing, value added (% of GDP)

Definition: The total value added by all producers in agriculture, including forestry, hunting, fishing, the cultivation of crops, and livestock production. The value added of a sector equals the net output after subtracting the total outputs with intermediate inputs.

Description: Gross domestic product (GDP) represents the total value added by all producers in a country. Value added equals the value of the total output of producers minus the value of intermediate goods and services used in the production process, before accounting for consumption of fixed capital in production. The value added can be either valued at either basic prices (excluding net taxes on products) or at producer prices (including net taxes on products paid by producers but excluding sales or value added taxes). Both valuations do not

236 World Bank Group.
237 The Economist Intelligence Unit, "Global Food Security Index 2019: Strengthening Food Systems and the Environment through Innovation and Investment," 9–10.

include transport charges that are billed separately by producers. Total GDP is measured at purchaser prices. Value added by industry is typically measured at basic prices.[238]

Periodicity: Annual

Limitations: One challenge of gathering data on the total value added on the national level is the extent of unreported economic activity in the secondary or informal economy. Especially in developing countries, the share of unreported economic activity can be substantial, with agricultural output being used for private (household) consumption or being exchanged for something other than money. The total value added of agricultural production is often based on an estimate of inputs, yields, and area under cultivation. This approach sometimes generates values that divert from the true value. Also, some agricultural inputs that cannot be clearly assigned to specific agricultural outputs are omitted and replaced by rough estimates as well.[239]

Indicator: Integrated water resource management

Integrated Water Resources Management (IWRM) refers to the co-ordinated planning, design, development, and management of the quantity and quality of water resources across all water uses. IWRM is based on the principles of social equity, economic efficiency, and environmental sustainability.[240] IWRM includes the whole system of institutions, policies, infrastructures, mechanisms, and information systems that support and regulate the management of water resources. The objectives of WRM are to ensure that sufficient water of adequate quality is and remains available for drinking water and sanitation services, food production, energy generation, inland water transport, and other water-based sectors of the economy such as tourism, as well as the preservation of water-dependent ecosystems and natural creeks, rivers, and lakes.

Besides, water resource management involves the protection and management of water resources for all uses in the context of water-related risks, including water contamination, droughts, floods, and storms.[241] Natural disasters can to cause critical damage to or pollute essential water supply systems. This has devastating effects on human lives, health and well-being, water-dependent livelihoods and businesses, and vital ecosystems. At the same time, the availability of fresh and clean drinking and sanitation water is vital in the wake of natural disasters and determines the coping capacity of societies to deal with and recover from the impact of such disasters.

238 World Bank Group, "Agriculture, Forestry, and Fishing, Value Added (% of GDP)," The World Bank, 2020.
239 World Bank Group.
240 The International Water Association, "Integrated Water Resources Management: Basic Concepts," IWA Publishing, 2020.
241 World Bank Group, "Water Resources Management," The World Bank, September 20, 2017.

Decisions concerning how to allocate and use water resources are therefore essential to sustainable development and social stability and security. Integrated water resource management directly affects the availability of fresh and clean water for drinking and sanitation purposes. Sustainable and integrated water resource management strategies influence the coping capacity and resilience of societies to critical threats to fresh and safe water supplies, such as the impact of natural disasters.

Details

Indicator name: Degree of SDG 6.5.1 Integrated water resource management implementation
Definition: Indicator 6.5.1 Integrated water resource management tracks the degree of integrated water resources management (IWRM) implementation, by assessing the four key dimensions of IWRM: enabling environment, institutions and participation, management instruments, and financing.
Description: Integrated water resource management at all levels, goal 6.5.1 of the SDGs, offers a framework to make sure that water resources are acquired, utilized, and administered in a coordinated, sustainable, fair, and efficient way.[242] The allocation and use of water resources are regulated by national or sub-national governments.[243] To monitor and evaluate progress on the implementation of water resource management targets, the UN has developed the Water Integrated Monitoring Initiative that tracks and reports progress on indicator 6.5.1 of the SDGs. This indicator monitors the extent to which countries implement integrated water resources management (IWRM) through the assessment of four main dimensions of IWRM: enabling environment, institutions and participation, management instruments and financing.[244] The four main dimensions of IWRM are defined by the UN as following: 1. "Enabling environment: The conditions that help to support the implementation of IWRM, which includes the most typical policy, legal and strategic planning tools. 2. Institutions and participation: The range and roles of political, social, economic and administrative institutions and other stakeholder groups that help to support implementation. 3. Management instruments: The tools and activities that enable decision-makers and users to make rational and informed choices between alternative actions.

242 United Nations Environment Programme, "Progress on Integrated Water Resources Management. Global Baseline for SDG 6 Indicator 6.5.1: Degree of IWRM Implementation," 7.
243 United Nations Environment Programme, 1.
244 United Nations, "Indicator 6.5.1 – Integrated Water Resources Management," United Nations, 2020.

4. Financing: The budgeting and financing made available and used for water resources development and management from various sources."[245]

These four dimensions are assessed at both the national, subnational, local, basin/aquifer, and transboundary levels of water management to reflect the objective of goal 6.5.1 to implement integrated water resource management "at all levels".[246]

The IWRM indicator is measured on a scale from 0 to 100 based on the extent of implementation and the results of a 33 questions long self-assessment questionnaire. These results are consequently assessed between relevant stakeholders, including national and subnational ministries and other institutions involved in water resource management as well as relevant NGOs, academia, and businesses.[247] The data is reported by 172 countries.

Periodicity: Annual

Limitations: Data on 6.5.1 is collected through a questionnaire. Even though responses are assessed by relevant stakeholders, institutions involved in water resources management, NGOs, academia, and business, stakeholders could employ differing definitions and measurements of the three principles of IWRM: social equity, economic efficiency, and environmental sustainability.

Indicator: Flood protection standards

Flood control or flood protection refers to all strategies and methods employed to mitigate or avert the adverse impacts of flooding events. Some commonly used methods in the context of coastal flooding include the placement of sandbags, the installation of rock berms, the development of maintenance of natural dunes with vegetation or the application of soil cement, the construction of levees, dams, dikes, and sea walls, or the creation of barrier islands.[248]

The most advanced flood control and protection technology and systems in the context of coastal flooding can be found in Europe. Many countries in Europe consist of areas that are located below sea level. These, together with many other low-elevated coastal countries around the world, are particularly exposed to the challenges of rising sea levels and more frequent and severe flooding events.[249]

245 United Nations Environment Programme, "Progress on Integrated Water Resources Management. Global Baseline for SDG 6 Indicator 6.5.1: Degree of IWRM Implementation," 10.
246 United Nations Environment Programme, 10.
247 United Nations, "Indicator 6.5.1 – Integrated Water Resources Management."
248 International Water Association, "Flood Control and Disaster Management," The International Water Association Publishing, 2020.
249 International Water Association.

Details

Indicator name: Flood protection standards

Definition: Flood control or flood protection refers to all strategies and methods employed to mitigate or avert the adverse impacts of flooding events.

Description: The (first) global database of FLOod PROtection Standards, FLOPROS, was developed specifically to inform global assessments on flood risks. The FLOPROS database is an open-source and community-informed database of flood protection standards, compiling data from different information sources: policy documents, modeling techniques, and specialized literature. This information is intended to be continually updated.[250]

The information in FLOPROS covers different spatial scales: from the national to the district level of flood protection infrastructures. The database consists of three layers of information:

1. "The design layer: containing information about protection defined by engineers in the design and realisation of currently existing river and coastal flood protection infrastructure.
2. The policy layer: specifying the legislative and normative (or required) standards of protection from river and coastal floods.
3. The model layer: for river flood protection, which is based on a flood-modelling approach and on the observed relationship between per capita wealth and protection."[251]

The design and policy layers consist mainly of information on structural measures of flood protection, including construction works such as dikes, levees, reservoirs, and river bypass channels as well as on hazard-reducing measures including flood management plans and other flood-risk reduction strategies.[252]

The study considers the design layer to be the most reliable to represent existing protection standards as it includes direct information on the standards used when designing and constructing protection infrastructure. The information contained in the policy and model layer serves as a proxy for actual protection. The policy layer, although it indicates the intended or required standard of protection, does not reveal whether the protection standards are enforced and realized. The study deems the model layer as ranking third in order of reliability because even though the information in this layer is partially authenticated against expert observations, it involves a modeling method that indirectly attributes protection information.[253]

250 P. Scussolini et al., "FLOPROS: An Evolving Global Database of Flood Protection Standards," *Natural Hazards and Earth System Sciences* 16 (2016): 1049–61.
251 Scussolini et al., 1050–51.
252 Scussolini et al., 1056.
253 Scussolini et al., 1051.

Each of the three information layers on flood protection standards can be employed independently. However, for large-scale applications of the database, the study recommends integrating the three layers. In this *merged* layer approach, gaps in data availability of one layer are substituted by data of the other layers.[254]

Periodicity: 2016

Limitations: Gaps in the data persist, even when using all three layers of analysis, and the data is already five years old. Moreover, this data does not communicate maintenance to flood protection infrastructure or the effectiveness of actual protection.

Riverine flood risk

Defining riverine flooding

River flooding refers to floods caused by an overflow or overtopping of rivers above a minimum flooding threshold or that exceed flood protection standards.[255] Riverine floods may also cause breaching of flood defenses such as dikes and embankments. Land behind such coastal defenses experience flooding and/or damage.

River floods may be caused by extreme rainfall events, including monsoon rains, and heavy glacier melt, which cause the overflowing of rivers over banks or river levees.[256] Climate change is changing temperature and precipitation patterns globally. In some regions, these patterns take the shape of declining precipitation, the evaporation of soil water, and/or decreasing of the amount of snowfall and consequently snowmelt. These regions are becoming drier and may experience a declined frequency in riverine floods, though extreme rainfall events might still give rise to flash floods. In other regions, climate change is increasing moisture in the atmosphere, increasing the frequency and intensity of rainfall events, and generating wetter storms, thereby increasing the risk of riverine flooding. Changing patterns in glacier melt runoff: earlier in the season (during already more wet periods) and more rapid melt off from snow and glaciers due to rises in temperatures or rainfall on snow. These dynamics lead to greater volumes of meltwater. Also, heavy (monsoon) rainfall is projected to increase in both frequency and intensity due to global temperature rise. As a result of these two processes, the global risk for riverine flooding is also increasing.[257]

254 Scussolini et al., 1051.
255 Alfieri, Dottori, and Feyen, "Task 9, Rivers Floods," 5; Feyen et al., "Climate Change Impacts and Adaptation in Europe," 18.
256 Safecoast Project Team, "Coastal Flood Risk and Trends for the Future in the North Sea Region, Synthesis Report," 24.
257 Alexander M. Milner et al., "Glacier Shrinkage Driving Global Changes in Downstream Systems," *Proceedings of the National Academy of Sciences*, 2017, 1–9.

River flooding is a naturally occurring process that re-nourishes soils and supports many ecosystems in river basins and flood plains. In many regions, human societies have historically relied on river flooding for fertilizing soil and agricultural lands. However, climate change is now shifting riverine flooding patterns and increasing the frequency and intensity of river water overflowing its banks. Moreover, natural flood defense structures – including floodplains, marshes, and swamps – control flooding by absorbing the runoff and overflow of rivers and lakes. Where human settlement patterns and economic activity have removed such wetlands, destructive river floods are more likely. In the absence of wetlands, water levels can rise more rapidly and is less able to absorb and flow-off floodwaters.[258]

The impact of riverine flooding

Extensive flooding events are increasingly affecting human livelihoods and communities, annually causing a loss of human life and economic damages. Between 1980-2013, riverine flooding resulted in more than 200,000 deaths and over $1 trillion in damages globally. The impact of riverine flooding is projected to increase due to both climatic and socio-economic alterations.[259] Socially constructed susceptibility to riverine flooding will increase due to projected increases in the number of people living and working in floodplains. This implies that more and more people are at risk from flooding — a condition that is estimated to deteriorate further under climate change scenarios.[260] Without any further adaptation to riverine flood risk, the sum of people affected globally may rise (under the 2°C global warming scenario) from a current average of 39 million persons per year to 134 million persons per year by 2050. Of this increase, about one-third can be ascribed to population growth, the other two-thirds will likely be due to more severe and more frequent riverine flooding events because of our global changing climate.[261] Certain regions and areas are specifically prone to the adverse impacts of climate change and riverine flooding. The countries of which the population will be relatively most affected (where the largest share relative to the total population will be affected) include particularly countries located in Southeast Asia and Sub-Saharan Africa. Especially major river systems that contain flat and low-elevated floodplains and river basins are extremely exposed and susceptible to riverine flooding.[262]

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258 Department of Regional Development and Environment Executive Secretariat for Economic and Social Affairs, "Floodplain Definition and Flood Hazard Assessment," in *Primer on Natural Hazard Management in Integrated Regional Development Planning* (Washington, D.C.: Organization of American States, 1991); Sciencing, "What Is a River Flood?," Sciencing, 2020.

259 Francesco Dottori et al., "Development and Evaluation of a Framework for Global Flood Hazard Mapping," *Advances in Water Resources* 94 (2016): 87.

260 Philip J. Ward, "River Flood Risk" (The Hague: PBL Netherlands Environmental Assessment Agency, 2018), 1.

261 Dottori et al., "Development and Evaluation of a Framework for Global Flood Hazard Mapping," 87; Ward, "River Flood Risk," 1.

262 Baky, Islam, and Paul, "Flood Hazard, Vulnerability and Risk Assessment for Different Land Use Classes Using a Flow Model," 225.

River floods have adverse impacts on human livelihoods, physically damaging agricultural lands, crops, fisheries, houses, infrastructure, and local institutions as well as generating a direct and indirect economic loss, food and water insecurity, health issues, enhanced inequality, and displacement. These impacts can be effectively averted or mitigated through adequate coping and adaptive strategies, mechanisms, and infrastructures, including the construction of levees, dikes, and dams, the restoration of natural wetlands and floodplains, disaster risk management programs, employing sustainable land use and planning, sustainable water management, effective irrigation strategies, and community-based adaptation, the presence of social safety nets as well as and widespread risk spreading and sharing.[263]

Hazard-specific indicators and data

The data used to evaluate the occurrence and frequency of riverine flooding events to occur on the global level are derived from the EM-DAT database.

The indicators and datasets to evaluate the other components of climate security risk in the context of riverine flooding are named in the table below (see Table 3).

Component	Dimension	Indicator	Source	Latest data
Exposure	*Area* (exposed land)	River length	The World Factbook	2020
		Land area where elevation is below 5 meters (% of total land area)	CIESIN	2010
		Land area prone to floods	JRC data	2016
	Population (population exposed)	Population living in areas where elevation is below 5 meters (% of total population)	CIESIN	2010
Susceptibility	*Socio-economic susceptibility* (riverine flooding)	Employment in agriculture (% of total employment)	International Labour Organization	2019
		Agriculture, forestry, and fishing, value added (% of GDP)	World Bank and OECD	2019
(lack) of Resilience	*Hazard-specific* (riverine flooding)	Integrated Water Resource Management	UNEP	2017
		Flood protection standards	FLOPROS	2016

Table 3. Riverine flooding indicators

263 Feyen et al., "Climate Change Impacts and Adaptation in Europe," 35; Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 10.

Indicator: River length

The presence of rivers is an important indicator for exposure to riverine flooding events. Without the presence of waterways, there is no risk to security impacts of riverine flooding. The lands situated adjacent to rivers, also referred to as floodplains, are often flat areas in river valleys. Such lands experience frequent inundation by the natural overflowing of river flows over its banks. Floodplains are therefore, "flood-prone". [264] Floodplains have historically attracted human settlement due to their adjacency to fresh water supplies, fertile and arable soils, water transportation, power generation, and flat landscapes attractive for buildings and construction. Consequently, a large share of the world population now lives in such floodplains and this number is expected to increase due to population growth and urbanization rates.[265] The land use of floodplains is a critical determinant of the impact of riverine flooding. The flooding of floodplains is harmful to human activities if the socioeconomic susceptibility and vulnerability of those activities exceeds an acceptable level. For example, floodplains are often used for agriculture and crop farming. If crops that can withstand short inundation floods are cultivated on the floodplain, seasonal low volume flood events are not significantly harmful. However, the urbanization of floodplains increases human-constructed susceptibility to riverine flooding events.[266] To assess land area exposed to riverine flooding, the presence and length of rivers is used as a proxy indicator.

Details

Indicator name: River length
Definition: River length refers to the total length of navigable rivers, canals, and other inland bodies of water.
Description: This indicator maps the total length of navigable rivers, canals, and other inland bodies of water in a country.[267]
Periodicity: 2020
Limitations: Only navigable rivers, canals, and other inland water bodies are included in this dataset of the World Factbook. Smaller canals or streams, lakes and reservoirs are not included, and this should be kept in mind.

264 Department of Regional Development and Environment Executive Secretariat for Economic and Social Affairs, "Floodplain Definition and Flood Hazard Assessment."
265 Department of Regional Development and Environment Executive Secretariat for Economic and Social Affairs; DHI Group, "Floodplains," DHI, 2020.
266 Department of Regional Development and Environment Executive Secretariat for Economic and Social Affairs, "Floodplain Definition and Flood Hazard Assessment."
267 Central Intelligence Agency, "The World Factbook," Central Intelligence Agency, 2020.

Indicator: Land area prone to floods

Areas that have previously experienced flooding are likely to be located along rivers or permanent water bodies, including lakes and reservoirs. The flood-prone areas of the world indicator are employed as a proxy indicator to assess area exposed to riverine flooding.

Details

Indicator name: Flood-prone areas of the world – 10-year return period
Definition: The dataset represents flood-prone areas on a global scale for flood events with a 10-year return period.
Description: The map represents flood prone areas on a global scale for flood events with a 10-year return period. The resolution of this map is 30 arcseconds (approx. 1km). Cell values indicate water depth (in m). The map can be used to assess flood exposure and the risk of population and assets. This layer is provided in the GloFAS interface as an additional information layer that provides a rough indication of where to expect inundations in case of flooding. Permanent water bodies were derived from the Global Lakes and Wetlands Database and the Natural Earth lakes map.
Periodicity: 2016
Limitations: Terrain datasets are a source of uncertainty in any flood model and particularly in large scale models, due to general limitations regarding data voids and challenges pertaining to vertical accuracy depending on terrain types and land cover. These challenges also occur regarding the reproduction of river networks of which the depth value is even harder to detect.[268] Another limitation of this dataset is that flood extents might be overestimated because potential peak wave reduction during high flows through the use of water storage in flooded areas is not accounted for. Also, information on flood defense infrastructure – both the presence and quality of it – is absent on this global scale.[269]

268 Dottori et al., "Development and Evaluation of a Framework for Global Flood Hazard Mapping," 99; Christopher C. Sampson et al., "A High-Resolution Global Flood Hazard Model," *Water Resources Research* 51, no. 9 (2015): 7376–77.

269 Dottori et al., "Development and Evaluation of a Framework for Global Flood Hazard Mapping," 98–99.

Tropical storms risk: cyclones, hurricanes, typhoons

Defining tropical storms, cyclones, hurricanes, and typhoons

Tropical storms, cyclones, hurricanes, and typhoons, although named differently, refer to the same natural hazard. Essentially, these extreme weather events refer to a large-scale closed-circulation storm system which combines a low-pressure center, spiral rain bands, and strong winds that rotate counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. Depending on the location and strength of the tropical storm, the storm is referred to as either a tropical cyclone (in the Southern Pacific/Indian Ocean), a hurricane (in the Western Atlantic/Eastern Pacific), or a typhoon (in the Western Pacific).[270] For the exact locations of the basin domains and their tropical storm seasons, see Table 4 below.[271]

Storms are referred to as tropical storms – either tropical cyclones, hurricanes, or typhoons – when the maximum sustained wind speed exceeds 63 km/h. The storm is then also assigned a name.[272] Tropical storms are fueled by the heat that is released when moist air rises and the water steam it contains condenses. Therefore, the seawater temperatures must be at least 27 °C, which is why tropical storms arise seasonally. Global sea level and temperature rise as well as warmer sea surface temperatures are increasing the risk to future tropical storms by intensifying their wind speeds and making these storms wetter.[273]

Cyclones: Tropical storms originating in the Indian Ocean and South Pacific Ocean are called cyclones. Cyclones originate over tropical or subtropical waters and rotate in the same direction as the earth (counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere). Cyclones contain a warm-core cyclonic form with closed surface wind circulation and spiral rainbands around a well-defined low-pressure center.[274] With tropical cyclones, the maximum sustained surface wind speed (using the U.S. 1-minute average) ranges between 63 km/h to 118 km/h.[275]

Hurricanes: Hurricanes are tropical storms that originate in the Caribbean and affect the Western Atlantic or Eastern Pacific (specifically: the Caribbean Sea, the Gulf of Mexico, the North Atlantic Ocean, and the Eastern and Central North Pacific Ocean).

270 Cousineau, "Tropical Storm Definition"; Doocy et al., "The Human Impact of Tropical Cyclones," 2; National Hurricane Center and Central Pacific Hurricane Center, "Glossary of NHC Terms."
271 Nadia Bloemendaal et al., "Generation of a Global Synthetic Tropical Cyclone Hazard Dataset Using STORM," *Scientific Data* 7, no. 1 (2020): 4; World Meteorological Organization, "Tropical Cyclones," World Meteorological Organization, April 8, 2020.
272 World Meteorological Organization, "Tropical Cyclones."
273 International Federation of Red Cross and Red Crescent, "Meteorological Hazards: Tropical Storms, Hurricanes, Cyclones and Typhoons," International Federation of Red Cross and Red Crescent, 2020.
274 Cousineau, "Tropical Storm Definition"; National Hurricane Center and Central Pacific Hurricane Center, "Glossary of NHC Terms."
275 World Meteorological Organization, "Tropical Cyclones."

Hurricanes contain maximum sustained wind speeds of 119 km/h or more. The term hurricane is used for Northern Hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian.[276]

Typhoon: The term typhoon is used for tropical storms that orginate in the Western Pacific Ocean: tropical cyclones north of the Equator west of the International Dateline.[277]

Tropical storm type	Basin name	Season
Cyclone	North Indian (5°-60°N, 30°-100°E)	1 April – 30 June 1 September – 30 November
	South Indian (5-60°S, 10°-135°E)	1 November – 30 April
	South Pacific (5-60°S, 135°-240°E)	1 November – 30 April
Hurricane	Eastern Pacific (5°-60°N, 180°-coastline of North America on the North Atlantic)	1 June – 30 November
	North Atlantic (5°-60°N, coastline of North America on the Eastern Pacific - 360°)	1 June – 30 November
Typhoons	Western Pacific (5-60°N, 100°-180°E)	1 May – 30 November

Table 4. Tropical storms basins and seasons

The impact of tropical storms

Tropical storms, either cyclones, hurricanes, or typhoons, significantly affect populations in the Americas, Southeast Asia, and the Western Pacific.[278] When making landfall, tropical storms affect a relatively small stroke of the coastline (<500 km). Losses and damages in relation to tropical storms are caused by three major forces that generally impact coastal populations simultaneously: damaging and destructive winds reaching over 300 km/h, storm surges that raise the sea level up to 10 meters and drive water forcibly ashore at high speeds, and flooding events produced by the torrential rain.[279] Specifically, flooding events and storm surges are the main cause of death during tropical storms. In addition to global warming, settlement in low-elevation coastal zones (LECZ) and rising urbanization rates of such coastal settlements are significantly increasing

276 Daisy Dunne, "Global Warming Has 'Changed' Spread of Tropical Cyclones around the World," Carbon Brief, May 4, 2020; National Hurricane Center and Central Pacific Hurricane Center, "Glossary of NHC Terms."
277 Dunne, "Global Warming Has 'Changed' Spread of Tropical Cyclones around the World"; National Hurricane Center and Central Pacific Hurricane Center, "Glossary of NHC Terms."
278 Doocy et al., "The Human Impact of Tropical Cyclones," 1–2.
279 Bloemendaal et al., "Generation of a Global Synthetic Tropical Cyclone Hazard Dataset Using STORM," 1; Doocy et al., "The Human Impact of Tropical Cyclones," 1–2; World Meteorological Organization, "Tropical Cyclones."

the impact of tropical storms.[280] The LECZ is generally defined as the "contiguous and hydrologically connected zone of land along the coast and below 10 m of elevation". Most of the world megacities – cities containing ten million people or more – are in the LECZ and population growth and coastal migration are projected to increase the demographic development of low-lying coastal areas even further.[281]

The direct impacts of tropical storms include mortality, injuries, mental health effects, destruction of housing and infrastructure, the interruption of critical lifeline systems and basic public health services (including food and water), extensive damage to agriculture (crops, fisheries, and livestock), the devastation of livelihoods, and displacement. Indirect effects include severe economic losses, interruptions in food production, deficiency of fresh-water, sanitation, and energy supplies, water and vector-borne diseases, disablement, trauma, increased inequality, and potentially a rise in gender-based violence.[282] These impacts can be effectively averted or mitigated through adequate coping and adaptive strategies, mechanisms, and infrastructures. Concerning, to tropical storms, these include building sufficient levees, dikes, and dams, the construction of resilient infrastructure and housing, disaster risk management programs, installing adequate forecasting and monitoring systems, regional warning systems, establishing temporary shelters, employing sustainable land use and planning, sustainable water management, effective irrigation strategies, and community-based adaptation, the presence of social safety nets, and widespread sharing and spreading of risk, in particular financial risk.[283]

Hazard-specific indicators and data

The data used to evaluate the occurrence and frequency of tropical storms to occur on the global level are derived from the EM-DAT database.

The indicators and datasets to evaluate the other components of climate security risk in the context of tropical storms are named in the table below (see Table 5).

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280 Bloemendaal et al., "Generation of a Global Synthetic Tropical Cyclone Hazard Dataset Using STORM," 1; Doocy et al., "The Human Impact of Tropical Cyclones," 1–2; James Shultz et al., "Mitigating Tropical Cyclone Risks and Health Consequences: Urgencies and Innovations," *The Lancet Planetary Health* 2 (2018): 103.

281 Neumann et al., "Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment," 2.

282 Nicholas K Coch, "Inland Damage from Hurricanes," *Journal of Coastal Research* 36, no. 5 (2020): 1093–1105; Doocy et al., "The Human Impact of Tropical Cyclones," 2–28; Food and Agriculture Organization of the United Nations, "The Pacific Islands: Tropical Cyclone Harold Situation Report - May 2020" (Rome: Food and Agriculture Organization of the United Nations, May 2020); M. Z. Hossain et al., "Impact of Tropical Cyclones on Rural Infrastructures in Bangladesh," *Agricultural Engineering International: The CIGR Ejournal*, no. 2 (2008): 1–13.

283 Lincoln Fok and Lewis T. O. Cheung, "Evaluating the Impact Reduction Strategies for the Tropical Cyclone Hazard in Hong Kong," *Asian Geographer* 29, no. 2 (2012): 121–29; Shultz et al., "Mitigating Tropical Cyclone Risks and Health Consequences," 103–4.

Component	Dimension	Indicator	Source	Latest data
Exposure	*Area* (exposed land)	Total coastline length	World By Map	2018
		Land area in the LECZ	CIESIN	2010
		Land area covered by floods	JRC data	2016
	Population (population exposed)	Total population living in the LECZ	CIESIN	2010
Susceptibility	*Socio-economic susceptibility* (tropical storms)	Employment in agriculture (% of total employment)	International Labour Organization	2019
		Agriculture, forestry, and fishing, value added (% of GDP)	World Bank and OECD	2019
(lack) of Resilience	*Hazard-specific* (tropical storms)	Integrated Water Resource Management	UNEP	2017
		Flood protection standards	FLOPROS: global database of flood protection standards	2016

Table 5. Tropical storms indicators

Indicator: Land area in the LECZ

The LECZ is the zone of land along the coast and below 10 m of elevation. The destructive winds, storm surges, and flooding events produced by tropical storms reach considerable inland land areas. Hence, the LECZ is often used as a proxy indicator to assess land (and population) exposure to tropical storm hazard.

Details

Indicator name: Land area in the LECZ

Definition: This indicator represents the land areas in the LECZ – i.e. land area where elevation is below 10 meters.

Description: The Low Elevation Coastal Zone (LECZ) Urban-Rural Population and Land Area Estimates, Version 2 data set consists of country-level estimates of urban population, rural population, total population and land area country-wide and in LECZs for years 1990, 2000, 2010, and 2100. The LECZs were derived from the Shuttle Radar Topography Mission (SRTM). 3 arc-second (~90m) data were post processed by ISciences LLC to include only elevations less than 20m contiguous to coastlines and to supplement SRTM data in northern and southern latitudes. The population and land area statistics presented in this dataset are summarized at the low coastal elevations of less than or equal to 1m, 3m, 5m, 7m, 9m, 10m, 12m, and 20m. The spatial coverage of this data set includes 202

of the 232 countries and statistical areas delineated in the Gridded Rural-Urban Mapping Project version 1 (GRUMPv1) data set. The 30 omitted areas were not included because they were landlocked, or otherwise lacked coastal features.[284]
Periodicity: 1990, 2000, 2010, 2100
Limitations: Land area estimates on the global level are constrained by the limitations in spatial accuracy of data sets on this scale. The elevation data used to define the sea level, SRTM has a vertical accuracy in low slope areas of approximately +/- 4-5 meters, Therefore, certain low-lying island countries in the LECZ data set might have lower elevation ceilings than indicated. These limitations are present in the SRTM data set and be extent also in the data processing for the LECZ. Moreover, sea level rise is altering coastlines and elevation statistics globally, though at different rates. This might alter elevation data of coastal zones.[285]

Indicator: Total population living in the LECZ

In addition to global warming, settlement in LECZ and rising urbanization rates of such coastal settlements are significantly increasing population exposure to tropical storms.[286] Hence, data on populations residing in the LECZ are employed as a proxy indicator to assess the exposure of populations to tropical storms.

Details

Indicator name: Total population living in the LECZ
Definition: This indicator represents the total population living in the LECZ – i.e. the land area where elevation is below 10 meters.
Description: The Low Elevation Coastal Zone (LECZ) Urban-Rural Population and Land Area Estimates, Version 2 data set consists of country-level estimates of urban population, rural population, total population and land area country-wide and in LECZs for years 1990, 2000, 2010, and 2100. The LECZs were derived from the Shuttle Radar Topography Mission (SRTM). 3 arc-second (~90m) data were post processed by ISciences LLC to include only elevations less than 20m contiguous to coastlines and to supplement SRTM data in northern and southern latitudes. The population and land area statistics presented in this dataset are

284 Center For International Earth Science Information Network-CIESIN-Columbia University, "Low Elevation Coastal Zone (LECZ) Urban-Rural Population and Land Area Estimates, Version 2" (NASA Socioeconomic Data and Applications Center (SEDAC), 2013).
285 Center For International Earth Science Information Network-CIESIN-Columbia University, 3.
286 Bloemendaal et al., "Generation of a Global Synthetic Tropical Cyclone Hazard Dataset Using STORM," 1; Doocy et al., "The Human Impact of Tropical Cyclones," 1–2; Shultz et al., "Mitigating Tropical Cyclone Risks and Health Consequences," 103.

summarized at the low coastal elevations of less than or equal to 1m, 3m, 5m, 7m, 9m, 10m, 12m, and 20m. The spatial coverage of this data set includes 202 of the 232 countries and statistical areas delineated in the Gridded Rural-Urban Mapping Project version 1 (GRUMPv1) data set. The 30 omitted areas were not included because they were landlocked, or otherwise lacked coastal features.[287]

Periodicity: 1990, 2000, 2010, 2100

Limitations: Population data is based on estimates (from 2013) for 2010 and 2100 by applying urban and rural growth rates from the United Nations World Urbanization Prospects 2011 Revision to the GRUMPv1 and GPWv3 2000 estimates. These estimates might diverge from current scenarios and population projections.

Landslides risk

Defining landslides

Landslides refer to the downward and outward movement – either sliding, spreading, falling, toppling, flowing (when assisted by water), or a combination thereof – of slope-forming materials, like soil, rock, or debris under the influence of gravity.[288] Climate change is increasing the risk of landslides by affecting the stability of natural and engineered slopes due to changing precipitation and snowmelt patterns as well as temperature rise.[289] Landslides are triggered by river erosion, glaciers, ocean waves, weakening rock or soil slopes due to water saturation by snowmelt or heavy rainfall, earthquakes, volcanic eruptions, or by human activity including changes made to natural landscapes and man-made structures including stockpiling of rock or waste.[290] Climate change is increasing the risk to rainfall-triggered landslide events due to changing precipitation patterns – particularly more intense rainfall events after longer dry periods. Moreover, global temperature rise that is altering snowmelt patterns and increasing glacier melt. Also, important drivers of landslide risk are soil degradation as a result of overexploitation of natural resources and deforestation as well as greater susceptibility of exposed populations as a result of growing urbanization, occupation of marginal land, and uncontrolled land-use.[291]

287 Center For International Earth Science Information Network-CIESIN-Columbia University, "Low Elevation Coastal Zone (LECZ) Urban-Rural Population and Land Area Estimates, Version 2."

288 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 561; United Nations Office for Disaster Risk Reduction, "National Disaster Risk Assessment: Governance System, Methodologies, and Use of Results 2017," 21.

289 Stefano Luigi Gariano and Fausto Guzzetti, "Landslides in a Changing Climate," *Earth-Science Reviews* 162 (2016): 227–52.

290 United Nations Office for Disaster Risk Reduction, "National Disaster Risk Assessment: Governance System, Methodologies, and Use of Results 2017," 22.

291 Farrokh Nadim et al., "Global Landslide and Avalanche Hotspots," *Landslides* 3, no. 2 (2006): 159; World Bank Group, "The Global Landslide Hazard Map - Final Project Report" (London: The World Bank, 2020), 11–12.

The impact of landslides

Landslides are a frequently occurring natural hazard in many parts of the world. According to the EM-DAT database, 26,000 people lost their lives as a result of landslides in the period 2000-2014. Most landslide disasters occur in countries in South Asia, along the Himalayan belt, in East Asia, South-East Asia, and in Central and South America. In most developed countries where landslides occur, these events do not develop as disasters due to the low exposure of populations in most landslide-prone areas as well as adequate landslide risk management strategies, including landslide mitigation policies and infrastructure. In areas that are highly vulnerable to landslide risks, however, landslides can produce severe losses and damages. Especially exposed and susceptible to landslide disasters are (deprived) populations living adjacent to improperly designed man-made slopes and steep hillsides that are prone to landslide events and debris flows during heavy rainfall.[292] Physical susceptibility of buildings, including housing, and infrastructure is largely a function of the intensity of the landslide event and the resistance levels of these exposed elements. In addition to fatalities and widespread destruction of housing and infrastructure, landslides can cause damage to agricultural lands, increase soil degradation, and severely pollute freshwater resources. These impacts can be averted or mitigated through adequate coping and adaptive strategies, including adequate land planning and forest and natural hill vegetation renovation. Moreover, real-time hazard mapping of future landslide events, installing resilient slope infrastructure, enhancing sustainable and responsible land use and settlement, developing public awareness campaigns, and including local-level stakeholders in regional-decision making as informed experts of their own environments could significantly mitigate landslide disaster risk.[293]

Hazard-specific indicators and data

The data used to evaluate the occurrence and frequency of landslides to occur on the global level are derived from the EM-DAT database.

The indicators and datasets to evaluate the other components of climate security risk in the context of landslides are named in the table below (see Table 6).

292 Qigen Lin et al., "The Vulnerability of People to Landslides: A Case Study on the Relationship between the Casualties and Volume of Landslides in China," *International Journal of Environmental Research and Public Health* 14, no. 2 (2017): 1–12; United Nations Office for Disaster Risk Reduction, "National Disaster Risk Assessment: Governance System, Methodologies, and Use of Results 2017," 26–27; World Bank Group, "The Global Landslide Hazard Map - Final Project Report," 11.

293 Katarzyna Cieslik et al., "Building Resilience to Chronic Landslide Hazard Through Citizen Science," *Frontiers in Earth Science* 7, no. 278 (2019): 1–19.

Component	Dimension	Indicator	Source	Latest data
Exposure	*Area* (exposed land)	Landslide Hazard Assessment for Situational Awareness (LHASA) Model	NASA	2018
		Agriculture area actually irrigated (% of Agricultural land)	FAOSTAT	2018
	Population (population exposed)	Physical exposition to landslides triggered by earthquakes	NGI	2018
		Physical exposition to landslides triggered by precipitations	NGI	2018
Susceptibility	*Socio-economic susceptibility* (landslides)	Employment in agriculture (% of total employment)	International Labour Organization	2019
		Agriculture, forestry, and fishing, value added (% of GDP)	World Bank and OECD	2019
(lack) of Resilience	*Hazard-specific* (landslides)	Sustainable forest management	FAOSTAT	2015

Table 6. Landslides indicators

Indicator: Global Landslide Hazard Distribution

Land areas that have experienced landslides in the past are prone to experience them in the future, as they largely maintain comparable environmental conditions, such as topography, geology, soil, geomorphology and land use.[294] Though land use and settlement patterns might alter, statistics on the past occurrence of landslides are useful to assess the land exposed to future landslide events. Hence, this landslide hazard map serves as a proxy indicator to measure land area exposed.

Details

Indicator name: Landslide Hazard Assessment for Situational Awareness (LHASA) Model

Definition: The Landslide Hazard Assessment for Situational Awareness (LHASA) Model provides information on the spatial distribution of landslide hazards.

Description: The Landslide Hazard Assessment for Situational Awareness (LHASA) Model combines TRMM and GPM near real-time precipitation data with a global landslide susceptibility map to generate estimates of where and when rainfall-triggered landslides are likely to occur around the world. The landslide susceptibility map is derived from information on slope, geology, road networks, fault zones, and forest loss. Precipitation data from the Global Precipitation Measurement (GPM) mission are used to identify rainfall conditions from the

294 J. Corominas et al., "Recommendations for the Quantitative Analysis of Landslide Risk," *Bulletin of Engineering Geology and the Environment* 73 (2013): 223.

past 7 days. When rainfall is considered to be extreme and susceptibility values are moderate to very high, a "nowcast" is issued to indicate the times and places where landslides are more probable.[295]

Periodicity: 2018

Limitations: There exist inherent limitations of the LHASA model as a result of the geographic scope and variables considered. There is specifically a need for improved, spatially consistent landslide inventories to better parameterize and validate LHASA at regional and global scales, which is now still lacking. Another limitation is the inability to resolve landslides occurring at higher latitudes where snow, frozen precipitation, or freeze-thaw processes may significantly impact landslide occurrence. Moreover, the method now used to measures soil degradation resulting from precipitation variables is consistent across geographical contexts. However, the speed at which soil moisture declines will not be consistent across the globe or for different soil horizons.[296]

Indicator: Physical exposition to landslides (triggered by earthquakes and by precipitations)

To assess the exposure of people to landslide hazards, the Physical exposition to landslides datasets developed by the International Centre for Geohazards and the Norwegian Geotechnical Institute are employed as proxy indicators.

Details

Indicator name: Physical exposition to landslides (triggered by earthquakes and by precipitations)

Definition: Physical exposition to landslides (triggered by earthquakes and by precipitations)

Description: These datasets include estimates of the annual physical exposition of landslide triggered by earthquakes and by precipitations. It depends on the combination of this trigger and physical susceptibility characterized by six parameters: slope factor, lithological (or geological) conditions, soil moisture condition, vegetation cover, precipitation and seismic conditions. A population grid for the year 2010, provided by LandScanTM Global Population Database is employed. Unit is expected average annual population (2010 as the year of reference) exposed (inhabitants). This product was designed by International Centre for Geohazards /NGI for the Global Assessment Report on Risk Reduction (GAR). It was modeled using global data.

295 Jaison Thomas Ambadan et al., "Satellite-Observed Soil Moisture as an Indicator of Wildfire Risk," *Remote Sensing* 12, no. 1543 (2020): 1–14.
296 Ambadan et al.

Periodicity: 2011

Limitations: This hazard map has last been updated in 2011. In the mean time, critical changes in precipitation patterns, settlement patterns, land use, and soil degradation might have altered the global distribution of landslide hazards.

Indicator: Sustainable forest management

Sustainable forest management is defined as the coordinated planning, design, development, and management of forest land at all levels that aim to maintain and enhance the economic, social, and ecological values of all types of forests. Managing forests in a sustainable manner imply optimizing their productivity for society's needs, including timber and contributions to food security, as well as conserving and maintaining the forest's ecosystems, biodiversity, vitality, and regeneration capacity for the benefit of present and future generations. For example, sometimes using forest land for agricultural purposes is more financially attractive in the short-term compared to forest management. However, large-scale agricultural production leads to extensive deforestation and land-use changes. In the long-term, this will have negative implications for productivity, livelihoods of people, clean air and water, and biodiversity. The three pillars on which sustainable forest management is based include social equity, economic viability, and ecological soundness – the three principles of sustainability. Sustainable forest management includes the whole system of institutions, policies, infrastructures, mechanisms, and information systems that support and regulate the management of water resources.[297]

Through the management and use of forests and forest lands in a way that maintains their productivity, biodiversity, vitality, and regeneration capacity and their potential to fulfill relevant economic, social, and ecological functions now as well as in the future, sustainable forest management can also lower GHG emissions and support adaptation to climate change. Managing forests in a sustainable manner can preserve or improve forest carbon stocks and sustain forest carbon sinks. Furthermore, it can avert and reduce soil degradation, preserve land productivity, and potentially even reverse the adverse effects of climate change on ecosystems, biodiversity, and soil degradation. In this way, sustainable forest management also generates socio-economic advantages. Reversing and reducing soil degradation can produce cost-effective, immediate, and long-term social and economic benefits to communities and builds resilience to climate security risks.[298]

297 Food and Agriculture Organization of the United Nations, "Sustainable Forest Management," Food and Agriculture Organization of the United Nations, 2020; Programme for the Endorsement of Forest Certification, "What Is Sustainable Forest Management?," Programme for the Endorsement of Forest Certification, 2020.

298 Intergovernmental Panel on Climate Change, "Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems - Summary for Policymakers" (Geneva: Intergovernmental Panel on Climate Change, 2020).

Details

Indicator name: Degree of SDG 15.2.1 Progress towards sustainable forest management

Definition: Indicator 15.2.1 Progress towards sustainable forest management tracks progress towards Sustainable Forest Management (SFM) by assessing five sub-indicators: forest area annual net change rate, above-ground biomass stock in forests (t/ha), the proportion of forest area within legally established protected areas, the proportion of forest area under a long-term forest management plan, and forest area certified.

Description: Goal 15.2.1 of the SDGs offers a framework to promote the implementation of sustainable forest management for all types of forests, to halt deforestation, to restore degraded forests, and to substantially increase afforestation and reforestation globally.[299] Together with indicator 15.1.1, this indicator ensures forests are efficiently managed, and a better balance is struck between conservation and sustainable use of natural resources.

While the dashboard illustrates the progress on the individual sub-indicators, there is no weighting of the relative importance of the sub-indicators. Hence, the values forindividual sub-indicators still need to be combined. This is done by assigning them all equal weight.[300]

Periodicity: Annual

Limitations: The five sub-indicators employed to track progress towards sustainable forest management do not fully encompass all aspects of sustainable forest management. Especially social and economic aspects are still inadequately covered. Data on SDG 15.2.1 is collected through national data on forest area and country-level estimates. Even though national data is assessed by relevant stakeholders, institutions involved in forest management, NGOs, academia, and business, countries could employ differing definitions and measurements of the five sub-indicators of sustainable forest management. Furthermore, there are some data gaps, and the trends of some of the sub-indicators reflect different sets of countries.

299 United Nations, "15.2.1 Progress Towards Sustainable Forest Management," Global SDG Indicator Platform, 2020, 1.

300 Food and Agriculture Organization of the United Nations, "Metadata Indicator 15.2.1: Progress towards Sustainable Forest Management" (Food and Agriculture Organization of the United Nations, September 2020).

Drought risk

While some regions are projected to become wetter due to climate change, others will become much drier. Global rising temperatures and shifting precipitation patterns will increase the intensity and duration of droughts.

Defining droughts

Droughts can be defined as prolonged periods of abnormally dry weather conditions, causing critical shortages of water that drop below normal levels of soil moisture, groundwater, rivers, or lakes.[301] Drought is a relative term as the a natural occurring phenomenon that encompasses specific spatial and temporal features and can refer to either: meteorological or climatological drought (indicating a lack in precipitation), hydrological drought (referring to groundwater, streamflow, and reservoir), agricultural drought (referring to soil moisture), and socioeconomic drought (referring to the supply and demand of water). All four of these types of droughts are influenced by climate change through changing or decreasing precipitation patterns and/or greater evaporation.[302] The first three types of drought are influenced by natural processes, even though human influence increases from meteorological to hydrological to agricultural drought, while socioeconomic drought is entirely produced by anthropogenic influence.[303] A megadrought is an abnormally lengthy and pervasive drought, usually lasting a decade or more.[304] Drought events should not be confused with aridity, low water stream flows, desertification, water scarcity, or with related extreme weather events like heatwaves or wildfires.[305]

All four types of drought result from deficient levels of precipitation and greater evaporation influenced by climate variability. Essentially, meteorological drought can be considered as being the first stage of a drought event, with agricultural, hydrological, and socioeconomic droughts constituting follow-up phases. Meteorological drought, in combination with temperature anomalies, precipitation deficits, poor water management, and/or human demand pressures on surface or subsurface water supplies can lead to hydrological and agricultural drought. Socioeconomic drought is essentially the impact of meteorological, hydrological, and agricultural drought on regular supply-levels of some economic goods. This relationship indicates the conjunction of the

301 World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance," 6.
302 Vogt et al., "Drought Risk Assessment and Management: A Conceptual Framework," 11.
303 Vogt et al., 6; World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance," 6.
304 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 559.
305 World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance," 6.

climatological features of meteorological drought events and human systems which give rise to natural hazards.[306]

The impact of droughts

Droughts differ from other types of hazards, like flooding and tropical storms, in several regards. First, unlike floods and storms, droughts are slow-onset events as they are the result of a lengthy period (lasting months to years) of below-average (or below expected) levels of precipitation. Sometimes, droughts can even last one or more decades. Second, droughts can occur anywhere around the world – except for desert regions where the incident does not have any significance – as opposed to floods or storms that can only transpire in certain regions and along largely well-defined geographical fault lines, like river networks or coastlines. And third, the exposure of susceptible elements to a slow-onset hazard like droughts differs in important ways from rapid-onset hazards. Even though drought events can produce substantial socioeconomic and environmental impacts, they generally do not show the same (direct) mortality rates as swift hazards.[307]

Droughts can produce far-reaching implications, including reduced water quality, saltwater intrusion, soil degradation, and diminished river flows. Droughts produce the most severe losses and damages in highly populated areas and societies that are dependent on agriculture, livestock farming, or other water-intensive industries such as energy production.[308] Especially in central North America, Southeast South America, West Africa, the Mediterranean, and northwest Australia droughts are projected to become more frequent and more extreme in the near to mid-term future.[309] These regions contain many countries in which the livelihoods of people are dependent on activities that rely on fertile land, including livestock farming and agriculture. These sectors are highly sensitive to precipitation patterns and soil moisture. Moreover, droughts in these countries have devastating impacts on food security, potentially causing widespread hunger and disease.[310] Another drought-sensitive sector is energy production, especially nuclear power generation owing to the cooling water requirements of nuclear power stations.[311] In some countries of the Middle East that are highly dependent on energy production for their GDP, decreasing precipitation and more frequent and severe

306 Hagenlocher et al., "Drought Vulnerability and Risk Assessments," 1; Hugo Carrão, Gustavo Naumann, and Paulo Barbosa, "Mapping Global Patterns of Drought Risk: An Empirical Framework Based on Sub-National Estimates of Hazard, Exposure and Vulnerability," *Global Environmental Change* 39 (2016): 110.

307 Carrão, Naumann, and Barbosa, "Mapping Global Patterns of Drought Risk," 110–11.

308 Center for Climate and Energy Solutions, "Resilience Strategies for Drought" (Arlington: Center for Climate and Energy Solutions, 2018), 1.

309 Carrão, Naumann, and Barbosa, "Mapping Global Patterns of Drought Risk," 108; Intergovernmental Panel on Climate Change, "Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty," 196.

310 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2015 - Focus: Food Security," 16.

311 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2016 - Focus: Logistics and Infrastructure," 14.

drought periods can have significant impacts on the livelihoods and security of the populations of these countries.

More intense and longer-lasting droughts have the potential to generate severe safety and security implications, posing wide-ranging challenges to food, water and energy supplies for human societies and ecosystems, affecting health, causing economic loss and destructing livelihoods, generating displacement, and conflicts over resources in dry areas. When combined with existing pressures such as prevailing food and water stress, social tensions, oppressive policies, or weak governance, drought events have the potential to produce widespread mortality, famine, instability, intra- and interstate hostility.[312] Increased drought risks in agriculture and livestock farming dependent regions will also increase risks to global food and water security.[313]

The impacts of droughts can be averted or mitigate through various coping and adaptive strategies and mechanisms. An important strategy comprises integrated water resource management, including the construction of innovative infrastructure and technologies to harvest water and enhance water supply for domestic consumption and livestock production. Moreover, innovative climate-smart and drought-resilient agriculture, including soil water retention and drought-resilient crops, and education and awareness-raising programs on drought-coping mechanisms need to be developed and implemented at the community level to build resilience against food, water, energy, and livelihood insecurity as well as the health impacts associated with drought periods. The effectiveness and sustainability of these mechanisms and strategies depend on the active participation and coordination of various stakeholders from all levels of administration and all uses of water.[314]

Hazard-specific indicators and data

Since all four types of drought are produced by deficient levels in precipitation that cause critical below-average levels of soil moisture, groundwater, and/or water in rivers or lakes, precipitation data can serve as a proxy indicator for drought events in connected environmental-human systems.[315]

The data used to evaluate the occurrence and frequency of drought events to occur on the global level are derived from the EM-DAT database.

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312 Carrão, Naumann, and Barbosa, "Mapping Global Patterns of Drought Risk," 108–9.
313 Bündnis Entwicklung Hilft; United Nations University - EHS, "WorldRiskReport 2015 - Focus: Food Security," 16; Carrão, Naumann, and Barbosa, "Mapping Global Patterns of Drought Risk," 108.
314 Global Water Partnership Eastern Africa, "Building Resilience to Drought: Learning from Experience in the Horn of Africa" (Entebbe: Global Water Partnership, 2016), 2–3.
315 Carrão, Naumann, and Barbosa, "Mapping Global Patterns of Drought Risk," 110.

As a slow-onset hazard, the impact of drought events is different from rapid-onset hazards whose sudden physical collision with natural and human systems cause immediate destruction, mortality, and morbidity in defined geographic locations. Though drought events indirectly – in conjunction with external pressures – lead to mortality and disease, the direct impacts of drought events on human systems are largely socioeconomic. And while hazards like floods and landslides are more spatially bound, droughts generally arise across larger geographical areas.

The specific features of drought events have implications for the conceptualization and measurement of exposed elements. Above all, exposure cannot effectively be measured by combining population data with well-defined geographical fault lines. Existing drought risk assessments generally evaluate exposure by using proxy indicators that characterize exposure – or elements subject – to the four types of drought. These proxy indicators generally contain data on the following: domestic/industrial water use (hydrological drought), crop or agricultural land, and livestock farming (agricultural drought), and human population distribution (socioeconomic drought).[316]

Adaptation and mitigation measures to droughts could be targeted at the demand and the supply side of water stress and/or scarcity. Supply-side measures include, above all, adequately informed and effective water management, including the protection and conservation of critical water resources, traditional rain and groundwater harvesting, recycling of wastewater and water from storms, and the development and construction of non-conventional water sources and storage systems (including aquifer recharge and recovery).[317] Demand-side measures are more focused on making societies and their people resilient to drought periods. Measures include, among others, regulatory frameworks on water consumption and allocation, installing early warning systems on drought projections, shifting from conventional energy production (fossil fuel) to renewable energy production (wind and solar), water pricing, and other incentives to consider water allocation and savings and develop water-conserving behaviors, (investments in) the development of water-conserving technologies and techniques including more efficient irrigation techniques, manipulating the water requirement of crops, increasing the production of drought-resistant crops, implementing more efficient cooling technologies.[318]

The indicators and datasets to evaluate the other components of climate security risk in the context of droughts are named in the table below (see Table 7).

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316 Carrão, Naumann, and Barbosa, 111–12; United Nations Office for Disaster Risk Reduction, "Global Assessment Report on Disaster Risk Reduction 2019" (Geneva: United Nations Office for Disaster Risk Reduction, 2019), 182; Vogt et al., "Drought Risk Assessment and Management: A Conceptual Framework," 17.

317 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 19; World Bank Group, "Water Resources Management."

318 Feyen et al., "Climate Change Impacts and Adaptation in Europe," 31, 34; World Bank Group, "Water Resources Management."

Component	Dimension	Indicator	Source	Latest data
Exposure	*Area* (exposed land)	% of Agricultural land	FAOSTAT	2018
		Surface soil moisture anomalies	NASA-USDA	2019
		Live animals (stock)	FAOSTAT	2018
	Population (population exposed)	Population living in dry areas (Gridded population data)	GHS	2015
Susceptibility	*Socio-economic susceptibility* (droughts)	Employment in agriculture (% of total employment)	International Labour Organization	2019
		Agriculture, forestry, and fishing, value added (% of GDP)	World Bank and OECD	2019
		Crops (production)	FAOSTAT	2018
		Electricity production from oil, gas and coal sources (% of total)	World Bank/IEA Statistics	2018 2015
(lack of) Coping capacity	*Water accessibility* (slow-onset event (droughts))	Baseline Water Stress	Aqueduct Water Risk Atlas	2020
(lack) of Resilience	*Hazard-specific* (droughts)	Integrated Water Resource Management	UNEP	2017

Table 7. Drought indicators

Indicator: Agricultural lands

Exposure to drought includes all vital land resources and economic sectors that are located in drought-prone areas. Agricultural production is an economic sector that is extremely exposed to all drought hazard types. The share of agricultural land will influence the scope of the potential impact of droughts. People rely on this sector for their food consumption, income, energy supply, and general economic productivity. Moreover, the larger the share of agricultural lands relative to the total land area of a country, the fewer opportunity people have to diversify their livelihoods and convert economic sectors and produce to ones that are less drought prone.[319] The share of agricultural land is used as an exposure indicator to agricultural drought.

Details

Indicator name: Share in agricultural land
Definition: The total land area used for the cultivation of crops and animal husbandry within a country.

319 World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance," 10–11.

Description: This indicator measures the percentage share of agricultural and forest land of the total land area of a country. Agricultural land refers to the total-of-land areas under the FAOSTAT land-use indicators "Cropland" and "Permanent meadows and pastures". Croplands include both arable land – land used for temporary crops, temporary meadows and pastures, and land with temporary fallow – and land for permanent crops – long-term crops which do not have to be replanted for various years (such as cocoa and coffee) as well as trees and shrubs producing flowers (such as roses and jasmine). Croplands do not include land that is potentially cultivable but is not normally cultivated. Permanent meadows and pastures refer to land used permanently (5≥ years) to grow – through cultivation or naturally – forage crops (wild prairie or grazing land). This category includes grazing in wooded areas (e.g., agroforestry areas), grazing in shrubby zones (heath, maquis, garigue), grassland used for grazing in the plain or low mountain areas, and steppes and dry meadows used for pasture.

The agri-environmental indicators of the Food and Agriculture Organization of the United Nations (FAOSTAT) are obtained from existing data collected from FAO members through yearly questionnaires of "Land Use, Irrigation, and Agricultural practices" and distributed in the FAOSTAT domain Inputs-Land Use.[320]

Periodicity: Annual

Limitations: The questionnaires on land use of the FAO may not represent all land used for agriculture in a country. These statistics exclude forestland and generally do not include lands that are not registered, such as land used informally by roaming pastoralists, or land currently not under irrigation.

Indicator: Surface and subsurface soil moisture anomalies

Surface and subsurface soil moisture – or soil water content – is an important variable of drought risk. Soil moisture anomalies represent deviations relative to a climatological reference period. Soil moisture anomalies are an important variable of agricultural drought events, defined as prolonged periods with drier than average soils that have adverse impacts on vegetation growth and crop production.[321] Hence, anomalies in soil moisture conditions are important indicators to effectively identify land areas where drought events can produce severe human impacts. Specifically, anomalies in the degree of surface and subsurface soil moisture are an important determinant of land areas exposed to drought risk.

320 Food and Agriculture Organization of the United Nations, "FAOSTAT Release Aug 2020 – Land Use Indicators Methodological Note" (FAOSTAT Release Aug 2020 –Land Use Indicators, 2020).

321 Carmelo Cammalleri et al., "Comparing Soil Moisture Anomalies from Multiple Independent Sources over Different Regions across the Globe," *Hydrology and Earth System Sciences* 21, no. 12 (2017): 6329.

Details

Indicator name: Surface and subsurface soil moisture anomalies
Definition: Surface and subsurface soil moisture provides global daily information about moisture conditions in different soil layers (surface and subsurface). Soil moisture anomalies represent abnormalities relative to a climatological reference period.
Description: The NASA-USDA SMAP Global soil moisture data provides soil moisture information across the globe at 0.25°x0.25° spatial resolution. This data set includes surface and subsurface soil moisture (mm), soil moisture profile (%), surface and subsurface soil moisture anomalies (-). Soil moisture anomalies were calculated based on the climatology of the day of interest. The climatology was estimated based on the full data record of the SMAP satellite observation and the 31-day centered moving window approach.[322]
Periodicity: 2015 - present
Limitations: This dataset only dates back to 2015 which precludes analysis of trends over longer periods of time.

Indicator: Livestock

The density of livestock in a country is another important variable for exposure to agricultural drought. Livestock farming – both the grazing lands and the animals themselves – represent another economic sector that is highly affected by drought periods. Live animals are used as a proxy indicator for livestock farming and included in the assessment of exposure to droughts. Live animals are also exposed to all drought hazard types. Even though it is possible to move livestock to other, less-drought-prone pastures during the drought season – which can considerably lower the drought impact to the agriculture sector – this is not always a possibility in drought-prone countries with very large numbers of live animals. Moreover, moving livestock – especially in already vulnerable countries – might give rise to social tensions. Therefore, it is important to know how are and where livestock is present.[323]

322 Karen Mohr, "NASA-USDA Global Soil Moisture Data," NASA Earth Sciences (Susannah Pearce and Nate Perrin, October 23, 2020).

323 World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance," 10.

Details

Indicator name: Live animals (stock)

Definition: The sum number of live animals (in heads) cultivated either for draft purposes or for meat, eggs and dairy production or kept for breeding throughout in the year.

Description: This indicator refers to the sum number of animals of the species present in the country at the time of enumeration. It includes animals cultivated either for draft purposes or for meat, eggs and dairy production or kept for breeding. Live animals in captivity to produce fur or skin are not included in these statistics (wool production statistics are). Livestock statistics are reported as the number of heads (units), except for poultry, rabbits and other rodents which are reported in thousand units. Live animals include asses, beehives, buffaloes, camelids, camels, cattle, chickens, ducks, geese, goats, horses, mules, pigeons, pigs, rabbits and hares, sheep, and turkeys.[324]

The data for this indicator is gathered and compiled from FAO members through national publications and yearly FAO questionnaires. The FAO validates and makes this data conform in cooperation with various relevant national or international agencies or organizations. Sometimes, data is supplemented with data from unofficial sources.[325]

An alternative indicator is the Livestock density index, which provides the number of livestock units per hectare of utilized agricultural area. However, this indicator of the FAOSTAT contains most recent data for 2010. These statistics do not provide an accurate representation of the volume of livestock in the world today.[326]

Periodicity: Annual

Limitations: Not all countries employ the same reference year. Some countries do not employ the standard calendar year but give data for agricultural years ending either 30 May, June, or September. For non-reporting countries as well as for countries reporting incomplete data, estimates have been made. In certain countries, statistics on chickens, ducks, and turkeys do not yet seem to represent the total number of these birds.[327]

324 Food and Agriculture Organization of the United Nations, "Live Animals," Food and Agriculture Organization of the United Nations, 2020.
325 Food and Agriculture Organization of the United Nations, "Methodology: Agricultural Production - Livestock" (Food and Agriculture Organization of the United Nations, 2020).
326 Food and Agriculture Organization of the United Nations, "Livestock Systems - Global Distributions," Food and Agriculture Organization of the United Nations, 2020.
327 Food and Agriculture Organization of the United Nations, "Methodology: Agricultural Production - Livestock."

Indicator: Population living in dry areas

Exposure to drought is also measured in relation to people. Even though people still have the opportunity to move from drought-prone areas, the higher the share of population living in dry areas, the less likely this possibility becomes. The magnitude of the impact of a drought period critically increases if already a large number of people lives in dry regions.[328] Hence, this indicator evaluates the exposure of people through an assessment of the share of the population living in dry areas.

Details

Indicator name: Population living in dry areas
Definition: Population living in dry areas is defined as the number of people living in areas that experience water scarcity.
Description: The Global Human Settlement - Population dataset measures the spatial distribution and density of a country's population. This spatial raster dataset depicts the distribution and density of population, expressed as the absolute number of inhabitants per cell. Residential population estimates for target years 1975, 1990, 2000 and 2015 provided by CIESIN GPWv4.10 were disaggregated from survey or administrative units into grid cells, informed by the distribution and density of built-up as mapped in the Global Human Settlement Layer (GHSL) global layer per corresponding aera. The resolution available for this dataset are 250m, 1km, 9 arcsec, and 30 arcsec.
Periodicity: target years (1975, 1990, 2000 and 2015)
Limitations: The Global Human Settlement - Population dataset has latest statistics on 2015. Population growth, migration and urbanization rates may have significantly altered these statistics over the past five years. Hence, these statistics may not accurately represent current conditions.

Indicator: Crops

Because the agricultural land indicator of the FAOSTAT includes data on the share of cropland, this indicator already functions as a proxy indicator for the land area utilized for the production of crops. However, statistics on the volume of crop production is still valuable in a country for it reveals how much long-term damage a severe drought period can cause to a country's food stocks and economic output. Hence, crop production is also included as a proxy indicator for socio-economic exposure. Certain crops are more prone to be affected by droughts. However, this is very complex to determine.

328 World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance," 10.

Certain crops may be more vulnerable to droughts in some countries than in others due to variations in species and irrigation practices. Moreover, droughts indicate severe changes in the level of precipitation and evaporation. Critical changes to the environmental and cultivation conditions of a crop may be critical for a large range of crops, regardless of its sort. Hence, the volume of crop production is an important variable for people's socio-economic susceptibility to agricultural drought.[329]

Details

Indicator name: crops (production)
Definition: The sum amount of crops (in tones) produced in the year.
Description: This indicator refers to the sum amount of crops (in tonnes) produced in a country in a given year. These statistics are reported under the calendar year under in which the total harvest or the majority of it took place. Crops include cereals, vegetables, fruit, bananas and plantains, and tree nuts.[330] The data for this indicator is gathered and complied from FAO members through national publications and yearly FAO questionnaires. The FAO validates and makes this data conform in cooperation with various relevant national or international agencies or organizations. Sometimes, data is supplemented with data from unofficial sources.[331]
Periodicity: Annual
Limitations: The adoption of a calendar-year time reference period (unavoidably) implies that, in the case of various crops, crops assigned by countries to a particular split year may be counted under two distinct calendar years.[332]

Indicator: Energy production

Energy production is a variable of socio-economic susceptibility to droughts when the type of energy production relies on regional water resources and therefore on the volumes, quality, and temperature of the river discharge water as well as groundwater.[333] These types of energy production are susceptible to hydrological drought and include hydropower, oil and gas, coal (fossil fuels), and ethanol power production.[334] The type

329 World Bank Group, 10.
330 Food and Agriculture Organization of the United Nations, "Crops," Food and Agriculture Organization of the United Nations, 2020.
331 Food and Agriculture Organization of the United Nations, "Methodology: Agricultural Production - Crops Primary" (Food and Agriculture Organization of the United Nations, 2020).
332 Food and Agriculture Organization of the United Nations.
333 E. S. Spang et al., "The Water Consumption of Energy Production: An International Comparison," *Environmental Research Letters* 9, no. 10 (2014): 1; World Bank Group, "Assessing Drought Hazard and Risk: Principles and Implementation Guidance," 12.
334 Spang et al., "The Water Consumption of Energy Production."

and scope of energy production as a share of the total economy are indicative of the extent to which water is required as cooling water, which influences the overall net water consumption of a country, as well as the extent to which water is significant to the overall economic productivity and the livelihoods of people within that country. For example, shifting from conventional energy production (fossil fuel) to renewable energy production (wind and solar) could decrease the net water consumption of an economy by diminishing the cooling water demand of the energy sector.[335]

Details

Indicator name: Energy production
Definition: Energy production is defined as energy production from electricity production from hydropower and electricity production from oil, gas and coal sources.
Description: This combined indicator measures energy production by combining statistics on electricity production from hydropower and electricity production from oil, gas and coal sources (% of total). Electricity production from hydropower is defined as electricity derived from flowing water. This indicator is measured as electricity generation in GWh.[336] Electricity production from oil, gas and coal sources (% of total) is defined as electricity generated from oil (crude oil and petroleum products), gas (natural gas, excluding natural gas liquids), and coal (all coal and brown coal, both primary (including hard coal and lignite-brown coal) and derived fuels (including patent fuel, coke oven coke, gas coke, coke oven gas, and blast furnace gas)). This indicator is measured as a percentage of total energy generation.[337]
Periodicity: Annual
Limitations: This data is available for a more limited number of countries. However, dataset represents the most adequate and relevant dataset on energy statistics for the current study.

Indicator: Baseline water stress

The short-term capacity of a country to cope with drought periods is largely determined by its short-term access to renewable water resources, including short-term water storage. Areas with greater water stress – chronic water stress – will likely suffer greater depletion of surface and groundwater resources in the face of critical changes in

335 Feyen et al., "Climate Change Impacts and Adaptation in Europe," 31.
336 Organisation for Economic Co-operation and Development, "Energy - Crude Oil Production," OECD Data, 2020.
337 World Bank Group, "Electricity Production from Oil, Gas and Coal Sources (% of Total)," The World Bank, 2020.

precipitation and evaporation patterns, including the associated implications for water quality and other ecosystem services. Hence, the onset and magnitude of a drought period will be more severe and lead to more competition amongst water users. Such areas are less able to manage the impacts of drought periods on the short term and are more likely to experience water-related risks.[338] Hence, water stress is incorporated as a variable of coping capacity.

To measure the degree of water-related challenges already present in a country, Baseline water stress is employed as a proxy indicator. The value of baseline water stress is inverted to incorporate its negative causal relationship with a country's coping capacity.

Details

Indicator name: Baseline water stress
Definition: Baseline water stress refers to the ratio of total water withdrawals relative to annual available renewable surface and groundwater supplies.
Description: Baseline water stress is a measurement of the ratio of total water withdrawals relative to annual available renewable surface and groundwater supplies. Water withdrawals include withdrawals for domestic, industrial, irrigation, and livestock consumptive and non-consumptive purposes. Available renewable water supplies include an evaluation of the impact of upstream consumptive water users and of large dams on downstream water availability. Higher values of Baseline water stress indicate more competition among users.[339]
Periodicity: Annual and monthly
Limitations: Baseline water stress is indicated for a country as a value range of: 'low' (<10%), 'low-medium' (10-20%), 'medium-high'(20-40%), 'high' (40-80%), and 'extremely high' (>80%). No detailed country scoring can be derived. Although the underlying data – from the PCR-GLOBWB 2 global hydrological model and HydroBASINS 6 hydrological sub-basin delineation – of this indicator have been validated by the WRI, the results are not. Water stress remains a subjective issue and is highly complex to measure directly. Moreover, the water stress indicator does not explicitly include environmental flow requirements, water quality, or access to water. Different views exist as to what should be included in a water stress indicator.[340]

338 Global Forest Watch Water, "Baseline Water Stress," Global Forest Watch Water, April 2, 2019; Rutger Hofste et al., "Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators," *WRI Publications*, 2019, 10.
339 Hofste et al., "Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators," 10; Aqueduct, "Aqueduct Water Risk Atlas," Aqueduct Water Risk Atlas, 2020.
340 Hofste et al., "Aqueduct 3.0: Updated Decision-Relevant Global Water Risk Indicators," 11; D. Vanham et al., ""Physical Water Scarcity Metrics for Monitoring Progress towards SDG Target 6.4: An Evaluation of Indicator 6.4.2 'Level of Water Stress'," *Science of the Total Environment* 613–14 (2018): 218–32.

Heat waves risk

Defining heat waves

Heat waves refer to periods (at minimum two-three days) of abnormally hot and dry or hot and humid weather.[341] Two general types of heatwaves exist. Dry heatwaves are characterized by stable periods of extremely warm weather with clear skies and substantial inputs of solar radiation, sometimes including windy conditions that increase heat stress. Dry heatwaves commonly occur in the Mediterranean climate. Humid heatwaves are characterized by extremely warm weather and oppressive moist air conditions during both day- and night-time that result in nocturnal cloud cover which prevent heat release. Humid heatwaves commonly occur in mid-latitude temperate and maritime climates.[342]

While extreme heat is highly related to other natural hazards, like droughts and wildfires, heat waves also produce other critical impacts on human environments. In urban areas, extremely hot temperatures can heat up buildings, roads, and other infrastructure. Such stored heat may increase urban temperatures with 1 to 5˚C degrees in comparison to outlying areas, producing a city-specific hazard termed urban heat island (UHI) effects which further aggravates heat stress.[343] Still, the occurrence of heatwave events can equally severely disrupt non-urban populations as highly populated urban communities. Unlike many other natural hazards, like storms and floods, heatwaves are very geographically dispersed and transpire over large areas.[344] Globally, the exposure of people to heatwaves is exacerbating. Climate change is increasing temperatures worldwide as well as the frequency and intensity of extreme temperature events. Accordingly, climate change is projected to increase the frequency, intensity, and/or length of heat waves over land areas across Europe, North America, and Australia. Already between 2000 and 2016, the number of persons exposed to heatwaves rose with 125 million.[345]

The impact of heat waves

Multiple consecutive days of abnormally hot weather can produce severe impacts on human health and wellbeing. Both day- and night-time temperatures are important in relation to the health effects of heatwaves, which include heat rash, heat cramps, heat exhaustion, heat stroke, and mortality. Especially susceptible to be adversely affected by

341 Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 560.
342 World Health Organization, "Heatwaves and Health: Guidance on Warning-System Development" (Geneva: World Health Organization, 2015), 1.
343 Zhao et al., "Interactions between Urban Heat Islands and Heat Waves."
344 World Health Organization, "Heat-Waves," 2015, 1.
345 World Health Organization, "Heat-Waves: Risks and Responses" (Geneva: World Health Organization, 2004), 15; World Health Organization, "Heatwaves," World Health Organization, 2020.

heat waves are elderly people, people with diseases, people who work outdoors, or poor and marginalized people who have less access to personal heat mitigation measures. Severe heat waves can generate high fatality rates as well as widespread health issues or illness.[346] Between 1998-2017, more than 160,000 people have died globally as a result of heatwaves, of which 70,000 during the 2003 heatwave that struck Europe.[347] Heatwaves can also severely burden water, food, and energy supplies – producing power shortages or even blackouts – and disturb transportation. Critical water, food, and livelihood insecurity may arise or increase as a result of widespread losses and damages to crops and livestock.[348] Population ageing increases the impact of heat waves on populations. Population ageing is an important demographic trend in many developed countries around the world.[349] Another demographic trend that increases the impact of heat waves on populations is urbanization. The continued and increasing migration of people from rural areas to the city, especially to already sizable cities, amplifies the risk to a phenomenon called the urban heat island effect.[350] Also, the conjunction of the impacts of heatwaves and air pollution might further aggravate human stress and health issues in densely populated areas.[351]

There exists a wide range of mitigation and adaptation measures to the impact of heat waves. These include science-based, heat resilient urban planning and infrastructure design, including the adapted design and insulation of housing and critical infrastructure including hospitals and other health services. Enhanced urban planning is the most effective measure to prevent and mitigate urban heat island effects. Measures and strategies of urban planning include, among others, amplifying vegetation cover and the number of trees, installing reflecting or green rooftops, and installing reflecting or permeable pavement.[352]Also, changes in land use planning, such as more green urban spaces as well as the cultivation of drought-resilient crops can reduce critical losses and damages to food security and livelihoods. Effective early warning mechanisms and heat health warning systems, including good coordination between health and meteorological organizations and the development of appropriate and community-based intervention measures are essential to lessen the number of fatalities during severe heatwaves. Moreover, general and targeted (at the community-level or among specific groups of the population) education and awareness-raising programs on the health risk factors of heat waves and on potential personal mitigation measures need to be established to reduce the susceptibility of people to heatwave events. Socio-economic

346 Feyen et al., "Climate Change Impacts and Adaptation in Europe," 23; World Health Organization, "Heat-Waves," 2004, 19–25; World Health Organization, "Heat-Waves," 2015, xi.
347 World Health Organization, "Heatwaves."
348 World Health Organization, "Heat-Waves," 2015, 2; World Health Organization, "Heatwaves."
349 World Health Organization, "Heat-Waves," 2004, 4.
350 Feyen et al., "Climate Change Impacts and Adaptation in Europe," 24.
351 World Health Organization, "Heat-Waves," 2015, 15.
352 Feyen et al., "Climate Change Impacts and Adaptation in Europe," 25; Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, 2012, 19; World Health Organization, "Heat-Waves," 2004, 2–7, 36, 76–78; World Health Organization, "Heat-Waves," 2015, xi.

factors, including occupation and level of education, can critically increase people's exposure and susceptibility to the health effects of heatwaves. Whereas socioeconomic deprivation is a significant factor of heat-related deaths in developing countries, age represents the most critical risk factor of heat-related deaths in developed countries.[353]

Hazard-specific indicators and data

The data used to evaluate the occurrence and frequency of heat waves to occur on the global level are derived from the EM-DAT database.

The indicators and datasets to evaluate the other components of climate security risk in the context of heatwaves are named in the table below (see Table 8).

Component	Dimension	Indicator	Source	Latest data
Exposure	*Area* (exposed land)	Degree of urbanization	GHS	2019
		% of Agricultural land	FAOSTAT	2018
	Population (population exposed)	Population distribution	GHS	2015
Susceptibility	*Socio-economic susceptibility* (heat waves)	Employment in agriculture (% of total employment)	International Labour Organization	2019
		Agriculture, forestry, and fishing, value added (% of GDP)	World Bank and OECD	2019
		Crops (production)	FAOSTAT	2018
(lack) of Resilience	*Hazard-specific* (heat waves)	Integrated Water Resource Management	UNEP	2017
		Ambient air pollution attributable DALYs (per 100 000 population, age-standardized, both sexes)	WHO	2016

Table 8. Heat waves indicators

Indicator: Degree of urbanization

Urban planning and build-up areas are important factors determining exposure to heat stress. Specifically, adapted urban planning and building design can reduce the UHI effect. Planning measures that provide shade for urban citizens, including trees, narrow streets, and arcades, can reduce the absorption of heat in cities, as can light-colored materials. The size and density of the built-up area can impact the intensity of the UHI effect as well. Higher building density may aggravate the UHI effects due to the

353 World Health Organization, "Heat-Waves," 2015, 9.

amplifying effects that urban sites have on one another, although there does not exist clear consensus on the strength of this correlation. More spread-out cities allow for more vegetation cover, higher cooling rates, and less build-up of pollutive substances. Hence, reducing building density, planting trees and laying out green spaces reduces heat stress in urban environments.[354]

Details

Indicator name: Degree of urbanization - The GHS Settlement Model grid (GHS-SMOD)
Definition: The degree of urbanization refers to the population size and density of a country's population living in urban areas.
Description: The GHS Settlement Model grid defines settlement typologies based on a given country's population size and population and built-up area densities.
Periodicity: 2019
Limitations: Data on population settlement is based on the population and settlement data from 1975, 1990, 2000 and 2015. Population growth, migration and urbanization rates may have significantly altered these statistics over the past five years. Hence, these statistics may not accurately represent current conditions.

Indicator: Population distribution

As heatwaves are very geographically dispersed and transpire over large areas, the spatial distribution of persons with a country's total territory are employed as a proxy indicator for population exposure.

Details

Indicator name: population distribution
Definition: Population distribution refers to the spatial distribution and density of a population in a given country.
Description: The Global Human Settlement - Population dataset measures the spatial distribution and density of a country's population. This spatial raster dataset depicts the distribution and density of population, expressed as the absolute number of inhabitants per cell. Residential population estimates for target years 1975, 1990, 2000 and 2015 provided by CIESIN GPWv4.10 were

354 A. Lemonsu et al., "Vulnerability to Heat Waves: Impact of Urban Expansion Scenarios on Urban Heat Island and Heat Stress in Paris (France)," *Urban Climate* 14 (2015): 586–605; Yunfei Li et al., "On the Influence of Density and Morphology on the Urban Heat Island Intensity," *Nature Communications* 11, no. 1 (2020): 1–9; World Health Organization, "Heat-Waves," 2004, 78.

disaggregated from survey or administrative units into grid cells, informed by the distribution and density of built-up as mapped in the Global Human Settlement Layer (GHSL) global layer per corresponding aera. The resolution available for this dataset are 250m, 1km, 9 arcsec, and 30 arcsec.
Periodicity: target years (1975, 1990, 2000 and 2015)
Limitations: The Global Human Settlement - Population dataset has latest statistics on 2015. Population growth, migration and urbanization rates may have significantly altered these statistics over the past five years. Hence, these statistics may not accurately represent current conditions.

Indicator: Ambient air pollution

Poor air quality, in combination with heat stress, may critically increase the risk to heat health effects. Two pollutants are critically relevant to increase the risk to heat health effects during heatwaves, namely: ozone and particulate matter with a diameter less than 10 micrometers (PM10). Although it is largely difficult to separate the effects of heat stress and pollution, it is possible that there occurs both an additive effect as well as a synergistic effect. Especially in relation to European urban areas, research – including the WHO's EuroHEAT project – has demonstrated the synergistic effect of high temperatures and ozone exposure on mortality. Hence, air pollution is incorporated as a variable of resilience against heatwaves.[355]

To measure the degree of air pollution challenges already present in a country, ambient air pollution is employed as a proxy indicator. The value of ambient air pollution is inverted to incorporate its negative causal relationship with a country's adaptive capacity or resilience.

Details

Indicator name: Ambient air pollution attributable DALYs (per 100 000 population, age-standardized, both sexes).
Definition: Ambient air pollution attributable DALYs (disability-adjusted life years) refers to the burden of disease attributable to ambient air pollution.
Description: This indicator measures the burden of disease attributable to ambient air pollution. Ambient air pollution is produced by emissions from industrial activity, households, cars and trucks which contain complex mixtures of air pollutants, many of which are harmful to health. Of these pollutants, fine particulate matter has the most critical impact on human health. Burden

355 World Health Organization, "Heat-Waves," 2015, 15.

of disease is determined by combining data on the increased (or relative) risk of a disease resulting from exposure, with information on how widespread the exposure is in the population (in the case of ambient air pollution, the annual mean concentration of particulate matter to which the population is exposed). Together these statistics allow for the calculation of the 'population attributable fraction' (PAF), which is the fraction of disease observed in a certain population that can be ascribed to the exposure – the annual mean concentration of particulate matter. Applying this fraction to the total burden of disease (e.g. cardiopulmonary disease expressed as deaths or DALYs), provides the total number of deaths or DALYs that are the consequence of ambient air pollution. Age-standardizes rates adjust for differences in population age distribution by applying the observed age-specific mortality (or other health outcomes) rates for each population to a standard population. The use of age-standardized rates allows for cross-country comparison without being affected by the differences in age distribution between countries.[356]

Periodicity: 2016

Limitations: Data on the increased (or relative) risk of a disease resulting from exposure to fine particulate matter is obtained from civil registration with complete coverage and medical certification of cause of death. Accuracy of this data thus depends on the quality of civil administration and medical institutions' administration. Not all death cases related to ambient air pollution might be registered as such or registered at all.

Wildfires risk

Defining wildfires

Wildfires refer to widespread and destructive unintended fires burning forests and wildlands driven by weather-related conditions, including high temperatures, dry conditions, and high winds. However, the direct ignition of wildfires is often due to human activity or lightning events. Wildfires are unplanned extreme fire incidents characterized by "rapid fire spread, intense burning, long-range fire spotting and unpredictable shifts" and especially devastating when they arise at the intersection of wildland and urban areas.[357] Wildfire risk rises in exceptionally hot and dry conditions and during high winds. Though wildfires are often ignited by human influence or

356 World Health Organization, "Ambient Air Pollution Attributable DALYs (per 100,000 Population, Age-Standardized)," World Health Organization, 2020.
357 European Commission, "Forest Fires: Sparking Firesmart Policies in the EU," 6, 10–11; Feyen et al., "Climate Change Impacts and Adaptation in Europe," 18; World Health Organization, "Wildfires."

lightning, climate change is increasing the frequency and intensity (both the size and the spread) of wildfires due to rising global temperatures and changing precipitation patterns – which are increasing the rates of evaporation and vegetation dry-out – as well as more extreme and lengthy periods of drought.[358] In addition, the substantial greenhouse-gas emissions and forest loss produced by annual wildfire events are likely to accelerate climate change further, leading to a reinforcing and critically dangerous feedback loop.[359]

The impact of wildfires

Regions that are particularly vulnerable to increased frequency and severity of wildfires are southern Europe, Northwest North America, Central South America, and Australia. The fire seasons in these regions are becoming longer too. Although wildfires are a naturally occurring event, the frequency, intensity, and scope at which wildfire incidents have recently transpired in these regions are changing at a pace to which neither ecosystems nor human communities can adapt.[360] During the 2019-2020 bushfire season in Australia alone, over eighteen million hectares of land were burned down, 5,900 buildings (of which 3,500+ homes) were destroyed, and billions of animals were killed. 34 people lost their lives.[361]

Wildfires cause severe ecological and socio-economic impacts. Wildfire events lead to losses in human lives, widespread losses in animal life and ecosystems, severe physical and mental health issues, extensive destruction of housing and infrastructure, and displacement. Economically, wildfires affect primarily forestry, agriculture (grazing land, livestock, and crops), and ecosystem-dependent service sectors, but also energy production may be affected.[362] Be destroying both property and vegetation, wildfires produce critical and threatening consequences for food security and people's livelihoods.[363]

Often, the direct cause to wildfires are human activities, including poor maintenance of energy infrastructure, arson, and negligent behavior (e.g., throwing away cigarettes, burning trash, or making campfires). Therefore, adaptation and mitigation measures include widespread awareness and preparedness campaigns and wildfires prevention

358 Center for Climate and Energy Solutions, "Wildfires and Climate Change," Center for Climate and Energy Solutions, September 11, 2020; O, Hou, and Orth, "Observational Evidence of Wildfire-Promoting Soil Moisture Anomalies," 1.
359 United Nations Environment Programme, "Ten Impacts of the Australian Bushfires," UN Environment, January 22, 2020; Rongbin Xu et al., "Wildfires, Global Climate Change, and Human Health," *The New England Journal of Medicine*, 2020, 1.
360 European Commission, "Forest Fires: Sparking Firesmart Policies in the EU," 11.
361 United Nations Environment Programme, "Ten Impacts of the Australian Bushfires."
362 Katie Hoover and Laura A Hanson, "Wildfire Statistics" (Washington, D.C.: Congressional Research Service, October 1, 2020); United Nations Environment Programme, "Ten Impacts of the Australian Bushfires"; Xu et al., "Wildfires, Global Climate Change, and Human Health," 2–4.
363 O, Hou, and Orth, "Observational Evidence of Wildfire-Promoting Soil Moisture Anomalies," 1.

programs. Effective sustainable and science-based forest management as well as land use and water conservation strategies can also mitigate the impacts of climate change on forests and vegetation. Moreover, effective information systems for emergency responses, wildfires risk prevention and risk monitoring, integrated fire management, and risk-informed decision-making (including synergy between national and subnational levels) can significantly reduce the risk to and impacts of wildfire events.[364] For instance, increasing public awareness on the health risks from smoke clouds, both at regional and local levels, could reduce human health impacts. Through science-based landscape management, natural fire breaks can be designed to effectively avert the spread of fire and delimit the area burned. Finally, fuel reduction management or prescribed burning can decrease the build-up of fuels (e.g., biomass) and thereby reduce forest vulnerability.[365]

Hazard-specific indicators and data

The data used to evaluate the occurrence and frequency of heat waves to occur on the global level are derived from the EM-DAT database.

The indicators and datasets to evaluate the other components of climate security risk in the context of wildfires are named in the table below (see Table 9).

Component	Dimension	Indicator	Source	Latest data
Exposure	*Area* (exposed land)	% of Agricultural land	FAOSTAT	2018
		Surface soil moisture anomalies	NASA-USDA	2019
	Population (population exposed)	Population living in dry areas (Gridded population data)	GHS	2015
Susceptibility	*Socio-economic susceptibility* (wildfires)	Employment in agriculture (% of total employment)	International Labour Organization	2019
		Agriculture, forestry, and fishing, value added (% of GDP)	World Bank and OECD	2019
		Crops (production)	FAOSTAT	2018
(lack) of Resilience	*Hazard-specific* (wildfires)	Integrated Water Resource Management	UNEP	2017
		Sustainable forest management	FAOSTAT	2015

Table 9. Wildfires indicators

364 European Commission, "Forest Fires: Sparking Firesmart Policies in the EU," 6–7, 12, 17–18.
365 Feyen et al., "Climate Change Impacts and Adaptation in Europe," 43.

Indicator: Surface and subsurface soil moisture anomalies

Surface and subsurface soil moisture is an important variable of wildfire risk. In humid regions, there is a correlated relationship between decreased soil moisture, for instance resulting from decreased precipitation during the winter, and increases in severe wildfire events during the dry season.[366] Alternatively, in arid regions, wetter-than-average surface and subsurface soils can generate sufficient biomass growth required to fuel and spread large wildfires. Hence, soil moisture conditions are important indicators to effectively identify areas where wildfires hotspots might develop. Specifically, anomalies in the degree of surface and subsurface soil moisture are an important determinant of areas exposed to wildfire hazard.[367]

Details

Indicator name: Surface and subsurface soil moisture anomalies
Definition: Surface and subsurface soil moisture provides global daily information about moisture conditions in different soil layers (surface and subsurface). Soil moisture anomalies represent abnormalities relative to a climatological reference period.
Description: The NASA-USDA SMAP Global soil moisture data provides soil moisture information across the globe at 0.25°x0.25° spatial resolution. This data set includes surface and subsurface soil moisture (mm), soil moisture profile (%), surface and subsurface soil moisture anomalies (-). Soil moisture anomalies were calculated based on the climatology of the day of interest. The climatology was estimated based on the full data record of the SMAP satellite observation and the 31-day centered moving window approach.[368]
Periodicity: 2015 - present
Limitations: This dataset only dates to 2015 which precludes analysis of trends over longer periods of time.

366 Ambadan et al., "Satellite-Observed Soil Moisture as an Indicator of Wildfire Risk," 1–2.
367 O, Hou, and Orth, "Observational Evidence of Wildfire-Promoting Soil Moisture Anomalies."
368 Mohr, "NASA-USDA Global Soil Moisture Data."

Appendix 5: Climate Security Risk Country List

This section provides the country's climate security risk scores for climate-related hazards. The countries are ranked based on the total risk score, with countries scoring relatively the highest climate security risk score ranking 1. For every hazard, a number of countries receive the risk score of '0'. This is due to various reasons. First, the country does not experience exposure to a certain hazard. In the case of coastal flooding, countries without a coastline receive a '0' for this component. Second, the country does not experience a probability of a certain hazard because the hazard has never appeared in and/or adversely affected the country (or does not appear in the EM-DAT database). Third, a country might receive the score of '0' because of issues with data availability.

Coastal flooding

Country	Iso-Code	Rank
India	IND	1
Indonesia	IDN	2
Vietnam	VNM	3
China	CHN	4
Thailand	THA	5
Philippines	PHL	6
Bangladesh	BGD	7
Russia	RUS	8
Brazil	BRA	9
Sri Lanka	LKA	10
Canada	CAN	11
Nigeria	NGA	12
Malaysia	MYS	13
Mauritania	MRT	14
Mexico	MEX	15
Myanmar (Burma)	MMR	16
Italy	ITA	17
Gambia	GMB	18

Country	Iso-Code	Rank
Mozambique	MOZ	19
Argentina	ARG	20
Japan	JPN	21
Ecuador	ECU	22
Greece	GRC	23
Benin	BEN	24
Colombia	COL	25
Haiti	HTI	26
Panama	PAN	27
Senegal	SEN	28
Australia	AUS	29
Cambodia	KHM	30
Somalia	SOM	31
United Kingdom	GBR	32
Turkey	TUR	33
Pakistan	PAK	34
Tunisia	TUN	35
Egypt	EGY	36

Country	Iso-Code	Rank
Honduras	HND	37
Belgium	BEL	38
North Korea	PRK	39
Netherlands	NLD	40
Guinea	GIN	41
France	FRA	42
Guyana	GUY	43
Spain	ESP	44
Guinea-Bissau	GNB	45
Peru	PER	46
Dominican Republic	DOM	47
Nicaragua	NIC	48
United States	USA	49
Venezuela	VEN	50
Angola	AGO	51
Yemen	YEM	52
South Korea	KOR	53
Iran	IRN	54

Country	Iso-Code	Rank
Uruguay	URY	55
Albania	ALB	56
Iraq	IRQ	57
Liberia	LBR	58
Togo	TGO	59
Sierra Leone	SLE	60
Suriname	SUR	61
Kenya	KEN	62
New Zealand	NZL	63
Ghana	GHA	64
Germany	DEU	65
Côte d'Ivoire	CIV	66
Romania	ROU	67
Saudi Arabia	SAU	68
Tanzania	TZA	69
Cuba	CUB	70
Portugal	PRT	71
Chile	CHL	72
Belize	BLZ	73
Djibouti	DJI	74
Maldives	MDV	75
Guatemala	GTM	76
South Africa	ZAF	77
Costa Rica	CRI	78
Poland	POL	79
Georgia	GEO	80
El Salvador	SLV	81
Sudan	SDN	82
Madagascar	MDG	83
Papua New Guinea	PNG	84
Morocco	MAR	85
Fiji	FJI	86
Algeria	DZA	87
Ukraine	UKR	88
Ireland	IRL	89
Solomon Islands	SLB	90
Norway	NOR	91
Seychelles	SYC	92
Kuwait	KWT	93

Country	Iso-Code	Rank
Namibia	NAM	94
Kiribati	KIR	95
Jamaica	JAM	96
Bahamas	BHS	97
Croatia	HRV	98
Cameroon	CMR	99
Libya	LBY	100
Marshall Islands	MHL	101
Lithuania	LTU	102
Congo - Brazzaville	COG	103
Bulgaria	BGR	104
St. Vincent & Grenadines	VCT	105
Timor-Leste	TLS	106
Israel	ISR	107
Oman	OMN	108
Trinidad & Tobago	TTO	109
Niger	NER	110
United Arab Emirates	ARE	111
Cape Verde	CPV	112
Moldova	MDA	113
Qatar	QAT	114
Gabon	GAB	115
Eritrea	ERI	116
Congo - Kinshasa	COD	117
Lebanon	LBN	118
Puerto Rico	PRI	119
Slovenia	SVN	120
Comoros	COM	121
Vanuatu	VUT	122
St. Lucia	LCA	123
Finland	FIN	124
Paraguay	PRY	125
Bosnia & Herzegovina	BIH	126
Mauritius	MUS	127
Bolivia	BOL	128
Samoa	WSM	129
Afghanistan	AFG	130

Country	Iso-Code	Rank
Rwanda	RWA	131
Mali	MLI	132
Burundi	BDI	133
Mongolia	MNG	134
Laos	LAO	135
French Polynesia	PYF	136
Palestinian Territories	PSE	137
Syria	SYR	138
Tajikistan	TJK	139
Belarus	BLR	140
Montenegro	MNE	141
Nepal	NPL	142
Botswana	BWA	143
Malawi	MWI	144
Jordan	JOR	145
Serbia	SRB	146
Taiwan	TWN	147
Aruba	ABW	0
Anguilla	AIA	0
Andorra	AND	0
Armenia	ARM	0
American Samoa	ASM	0
Antarctica	ATA	0
French Southern Territories	ATF	0
Antigua & Barbuda	ATG	0
Austria	AUT	0
Azerbaijan	AZE	0
Burkina Faso	BFA	0
Bahrain	BHR	0
St. Barthélemy	BLM	0
Bermuda	BMU	0
Barbados	BRB	0
Brunei	BRN	0
Bhutan	BTN	0
Central African Republic	CAF	0
Switzerland	CHE	0
Cook Islands	COK	0

Country	Iso-Code	Rank
Curaçao	CUW	0
Cayman Islands	CYM	0
Cyprus	CYP	0
Czechia	CZE	0
Dominica	DMA	0
Denmark	DNK	0
Estonia	EST	0
Ethiopia	ETH	0
Falkland Islands	FLK	0
Réunion	REU	0
Mayotte	MYT	0
French Guiana	GUF	0
Martinique	MTQ	0
Guadeloupe	GLP	0
Faroe Islands	FRO	0
Guernsey	GGY	0
Equatorial Guinea	GNQ	0
Grenada	GRD	0
Greenland	GRL	0
Guam	GUM	0
Hungary	HUN	0
Isle of Man	IMN	0
Cocos (Keeling) Islands	CCK	0

Country	Iso-Code	Rank
Christmas Island	CXR	0
Iceland	ISL	0
San Marino	SMR	0
Jersey	JEY	0
Kazakhstan	KAZ	0
Kyrgyzstan	KGZ	0
St. Kitts & Nevis	KNA	0
Liechtenstein	LIE	0
Lesotho	LSO	0
Luxembourg	LUX	0
Latvia	LVA	0
Monaco	MCO	0
Macedonia	MKD	0
Malta	MLT	0
Northern Mariana Islands	MNP	0
Montserrat	MSR	0
New Caledonia	NCL	0
Norfolk Island	NFK	0
Niue	NIU	0
Nauru	NRU	0
Pitcairn Islands	PCN	0
Palau	PLW	0
Western Sahara	ESH	0

Country	Iso-Code	Rank
South Sudan	SSD	0
Singapore	SGP	0
South Georgia & South Sandwich Islands	SGS	0
St. Helena	SHN	0
St. Pierre & Miquelon	SPM	0
São Tomé & Príncipe	STP	0
Slovakia	SVK	0
Sweden	SWE	0
Swaziland	SWZ	0
Sint Maarten	SXM	0
Turks & Caicos Islands	TCA	0
Chad	TCD	0
Turkmenistan	TKM	0
Tonga	TON	0
Uganda	UGA	0
Uzbekistan	UZB	0
Vatican City	VAT	0
Wallis & Futuna	WLF	0
Zambia	ZMB	0
Zimbabwe	ZWE	0

Riverine floods

Country	Iso-Code	Rank
China	CHN	1
Indonesia	IDN	2
Russia	RUS	3
Vietnam	VNM	4
India	IND	5
Brazil	BRA	6
Bangladesh	BGD	7
Thailand	THA	8
Philippines	PHL	9
Colombia	COL	10

Country	Iso-Code	Rank
Malaysia	MYS	11
Mauritania	MRT	12
Myanmar (Burma)	MMR	13
Argentina	ARG	14
Sri Lanka	LKA	15
Italy	ITA	16
Nigeria	NGA	17
Mexico	MEX	18
Mozambique	MOZ	19
Benin	BEN	20

Country	Iso-Code	Rank
Gambia	GMB	21
Japan	JPN	22
Greece	GRC	23
Senegal	SEN	24
Cambodia	KHM	25
Ecuador	ECU	26
Peru	PER	27
Congo - Kinshasa	COD	28
United Kingdom	GBR	29
United States	USA	30

Country	Iso-Code	Rank
Pakistan	PAK	31
Haiti	HTI	32
Egypt	EGY	33
Panama	PAN	34
Netherlands	NLD	35
Bolivia	BOL	36
Australia	AUS	37
Belgium	BEL	38
Turkey	TUR	39
Tunisia	TUN	40
North Korea	PRK	41
France	FRA	42
Iran	IRN	43
Romania	ROU	44
Spain	ESP	45
Honduras	HND	46
Cuba	CUB	47
Albania	ALB	48
Nicaragua	NIC	49
South Korea	KOR	50
Guinea	GIN	51
Venezuela	VEN	52
Angola	AGO	53
Dominican Republic	DOM	54
Somalia	SOM	55
Germany	DEU	56
Guyana	GUY	57
Iraq	IRQ	58
Yemen	YEM	59
Guinea-Bissau	GNB	60
Saudi Arabia	SAU	61
Sudan	SDN	62
Ghana	GHA	63
Uruguay	URY	64
Togo	TGO	65
Papua New Guinea	PNG	66
Sierra Leone	SLE	67
Côte d'Ivoire	CIV	68

Country	Iso-Code	Rank
Liberia	LBR	69
Suriname	SUR	70
Kenya	KEN	71
Maldives	MDV	72
Portugal	PRT	73
Canada	CAN	74
New Zealand	NZL	75
Tanzania	TZA	76
Kuwait	KWT	77
Guatemala	GTM	78
Poland	POL	79
Morocco	MAR	80
Georgia	GEO	81
Ukraine	UKR	82
Belize	BLZ	83
Afghanistan	AFG	84
Croatia	HRV	85
Costa Rica	CRI	86
Algeria	DZA	87
Seychelles	SYC	88
Paraguay	PRY	89
Djibouti	DJI	90
Ireland	IRL	91
El Salvador	SLV	92
Central African Republic	CAF	93
Madagascar	MDG	94
Namibia	NAM	95
Laos	LAO	96
Mali	MLI	97
Bahamas	BHS	98
Jamaica	JAM	99
Zambia	ZMB	100
Fiji	FJI	101
Solomon Islands	SLB	102
Chile	CHL	103
Bulgaria	BGR	104
Libya	LBY	105
Kiribati	KIR	106

Country	Iso-Code	Rank
South Africa	ZAF	107
Marshall Islands	MHL	108
Qatar	QAT	109
Hungary	HUN	110
Congo - Brazzaville	COG	111
United Arab Emirates	ARE	112
Cameroon	CMR	113
Malawi	MWI	114
Lithuania	LTU	115
Norway	NOR	116
Cape Verde	CPV	117
Kazakhstan	KAZ	118
Israel	ISR	119
Moldova	MDA	120
Oman	OMN	121
Trinidad & Tobago	TTO	122
St. Vincent & Grenadines	VCT	123
Timor-Leste	TLS	124
Niger	NER	125
Lebanon	LBN	126
Gabon	GAB	127
Czechia	CZE	128
Eritrea	ERI	129
Finland	FIN	130
Slovenia	SVN	131
Bosnia & Herzegovina	BIH	132
St. Lucia	LCA	133
Comoros	COM	134
Puerto Rico	PRI	135
Vanuatu	VUT	136
Mauritius	MUS	137
Serbia	SRB	138
Belarus	BLR	139
Austria	AUT	140
Samoa	WSM	141
Tajikistan	TJK	142

Country	Iso-Code	Rank
Switzerland	CHE	143
Slovakia	SVK	144
Mongolia	MNG	145
Kyrgyzstan	KGZ	146
Uzbekistan	UZB	147
Syria	SYR	148
French Polynesia	PYF	149
Palestinian Territories	PSE	150
Turkmenistan	TKM	151
Jordan	JOR	152
Luxembourg	LUX	153
Aruba	ABW	0
Anguilla	AIA	0
Andorra	AND	0
Armenia	ARM	0
American Samoa	ASM	0
Antarctica	ATA	0
French Southern Territories	ATF	0
Antigua & Barbuda	ATG	0
Azerbaijan	AZE	0
Burundi	BDI	0
Burkina Faso	BFA	0
Bahrain	BHR	0
St. Barthélemy	BLM	0
Bermuda	BMU	0
Barbados	BRB	0
Brunei	BRN	0
Bhutan	BTN	0
Botswana	BWA	0
Cook Islands	COK	0
Curaçao	CUW	0

Country	Iso-Code	Rank
Cayman Islands	CYM	0
Cyprus	CYP	0
Dominica	DMA	0
Denmark	DNK	0
Estonia	EST	0
Ethiopia	ETH	0
Falkland Islands	FLK	0
Réunion	REU	0
Mayotte	MYT	0
French Guiana	GUF	0
Martinique	MTQ	0
Guadeloupe	GLP	0
Faroe Islands	FRO	0
Guernsey	GGY	0
Equatorial Guinea	GNQ	0
Grenada	GRD	0
Greenland	GRL	0
Guam	GUM	0
Isle of Man	IMN	0
Cocos (Keeling) Islands	CCK	0
Christmas Island	CXR	0
Iceland	ISL	0
San Marino	SMR	0
Jersey	JEY	0
St. Kitts & Nevis	KNA	0
Liechtenstein	LIE	0
Lesotho	LSO	0
Latvia	LVA	0
Monaco	MCO	0
Macedonia	MKD	0
Malta	MLT	0
Montenegro	MNE	0

Country	Iso-Code	Rank
Northern Mariana Islands	MNP	0
Montserrat	MSR	0
New Caledonia	NCL	0
Norfolk Island	NFK	0
Niue	NIU	0
Nepal	NPL	0
Nauru	NRU	0
Pitcairn Islands	PCN	0
Palau	PLW	0
Rwanda	RWA	0
Western Sahara	ESH	0
South Sudan	SSD	0
Singapore	SGP	0
South Georgia & South Sandwich Islands	SGS	0
St. Helena	SHN	0
St. Pierre & Miquelon	SPM	0
São Tomé & Príncipe	STP	0
Sweden	SWE	0
Swaziland	SWZ	0
Sint Maarten	SXM	0
Turks & Caicos Islands	TCA	0
Chad	TCD	0
Tonga	TON	0
Taiwan	TWN	0
Uganda	UGA	0
Vatican City	VAT	0
Wallis & Futuna	WLF	0
Zimbabwe	ZWE	0

Tropical storms

Country	Iso-Code	Rank
Bangladesh	BGD	1
Philippines	PHL	2
Vietnam	VNM	3
China	CHN	4
India	IND	5
Mexico	MEX	6
Japan	JPN	7
Thailand	THA	8
Bahamas	BHS	9
Dominican Republic	DOM	10
Haiti	HTI	11
Madagascar	MDG	12
Netherlands	NLD	13
Australia	AUS	14
United States	USA	15
Mozambique	MOZ	16
Argentina	ARG	17
South Korea	KOR	18
Canada	CAN	19
Myanmar (Burma)	MMR	20
Belgium	BEL	21
Sri Lanka	LKA	22
Indonesia	IDN	23
Gambia	GMB	24
Belize	BLZ	25
Malaysia	MYS	26
Russia	RUS	27
Honduras	HND	28
United Kingdom	GBR	29
Cambodia	KHM	30
Egypt	EGY	31
Cuba	CUB	32
Jamaica	JAM	33
Nicaragua	NIC	34
Italy	ITA	35
El Salvador	SLV	36
North Korea	PRK	37

Country	Iso-Code	Rank
Tonga	TON	38
France	FRA	39
Brazil	BRA	40
Solomon Islands	SLB	41
Pakistan	PAK	42
Antigua & Barbuda	ATG	43
Denmark	DNK	44
Germany	DEU	45
Senegal	SEN	46
Mauritania	MRT	47
Latvia	LVA	48
Panama	PAN	49
Spain	ESP	50
Oman	OMN	51
New Zealand	NZL	52
Somalia	SOM	53
Ireland	IRL	54
Guatemala	GTM	55
Gabon	GAB	56
Papua New Guinea	PNG	57
Maldives	MDV	58
Vanuatu	VUT	59
Guinea-Bissau	GNB	60
Trinidad & Tobago	TTO	61
Greece	GRC	62
South Africa	ZAF	63
Liberia	LBR	64
Nigeria	NGA	65
Uruguay	URY	66
Fiji	FJI	67
Costa Rica	CRI	68
Lebanon	LBN	69
Turkey	TUR	70
Norway	NOR	71
Portugal	PRT	72
Colombia	COL	73
Poland	POL	74

Country	Iso-Code	Rank
Yemen	YEM	75
Mauritius	MUS	76
Seychelles	SYC	77
St. Lucia	LCA	78
Marshall Islands	MHL	79
Samoa	WSM	80
Ukraine	UKR	81
Chile	CHL	82
Djibouti	DJI	83
Iran	IRN	84
Sweden	SWE	85
Sierra Leone	SLE	86
Albania	ALB	87
Tanzania	TZA	88
Benin	BEN	89
Barbados	BRB	90
Grenada	GRD	91
Romania	ROU	92
Peru	PER	93
Lithuania	LTU	94
Israel	ISR	95
Guinea	GIN	96
Comoros	COM	97
Morocco	MAR	98
St. Kitts & Nevis	KNA	99
Georgia	GEO	100
Estonia	EST	101
Venezuela	VEN	102
St. Vincent & Grenadines	VCT	103
Kiribati	KIR	104
Dominica	DMA	105
Cayman Islands	CYM	106
Moldova	MDA	107
Finland	FIN	108
Algeria	DZA	109
Timor-Leste	TLS	110
Cape Verde	CPV	111

Country	Iso-Code	Rank
Ghana	GHA	112
Puerto Rico	PRI	113
Cyprus	CYP	114
Turks & Caicos Islands	TCA	115
Bulgaria	BGR	116
Saudi Arabia	SAU	117
Palau	PLW	118
Eritrea	ERI	119
Croatia	HRV	120
Slovenia	SVN	121
Bermuda	BMU	122
New Caledonia	NCL	123
Palestinian Territories	PSE	124
Sudan	SDN	125
French Polynesia	PYF	126
Guam	GUM	127
Congo - Kinshasa	COD	128
Syria	SYR	129
Jordan	JOR	130
Taiwan	TWN	131
Bosnia & Herzegovina	BIH	132
Sint Maarten	SXM	133
Aruba	ABW	0
Afghanistan	AFG	0
Angola	AGO	0
Anguilla	AIA	0
Andorra	AND	0
United Arab Emirates	ARE	0
Armenia	ARM	0
American Samoa	ASM	0
Antarctica	ATA	0
French Southern Territories	ATF	0
Austria	AUT	0
Azerbaijan	AZE	0
Burundi	BDI	0

Country	Iso-Code	Rank
Burkina Faso	BFA	0
Bahrain	BHR	0
St. Barthélemy	BLM	0
Belarus	BLR	0
Bolivia	BOL	0
Brunei	BRN	0
Bhutan	BTN	0
Botswana	BWA	0
Central African Republic	CAF	0
Switzerland	CHE	0
Côte d'Ivoire	CIV	0
Cameroon	CMR	0
Congo - Brazzaville	COG	0
Cook Islands	COK	0
Curaçao	CUW	0
Czechia	CZE	0
Ecuador	ECU	0
Ethiopia	ETH	0
Falkland Islands	FLK	0
Réunion	REU	0
Mayotte	MYT	0
French Guiana	GUF	0
Martinique	MTQ	0
Guadeloupe	GLP	0
Faroe Islands	FRO	0
Guernsey	GGY	0
Equatorial Guinea	GNQ	0
Greenland	GRL	0
Guyana	GUY	0
Hungary	HUN	0
Isle of Man	IMN	0
Cocos (Keeling) Islands	CCK	0
Christmas Island	CXR	0
Iraq	IRQ	0
Iceland	ISL	0
San Marino	SMR	0
Jersey	JEY	0

Country	Iso-Code	Rank
Kazakhstan	KAZ	0
Kenya	KEN	0
Kyrgyzstan	KGZ	0
Kuwait	KWT	0
Laos	LAO	0
Libya	LBY	0
Liechtenstein	LIE	0
Lesotho	LSO	0
Luxembourg	LUX	0
Monaco	MCO	0
Macedonia	MKD	0
Mali	MLI	0
Malta	MLT	0
Montenegro	MNE	0
Mongolia	MNG	0
Northern Mariana Islands	MNP	0
Montserrat	MSR	0
Malawi	MWI	0
Namibia	NAM	0
Niger	NER	0
Norfolk Island	NFK	0
Niue	NIU	0
Nepal	NPL	0
Nauru	NRU	0
Pitcairn Islands	PCN	0
Paraguay	PRY	0
Qatar	QAT	0
Rwanda	RWA	0
Western Sahara	ESH	0
South Sudan	SSD	0
Singapore	SGP	0
South Georgia & South Sandwich Islands	SGS	0
St. Helena	SHN	0
St. Pierre & Miquelon	SPM	0
Serbia	SRB	0
São Tomé & Príncipe	STP	0

Country	Iso-Code	Rank
Suriname	SUR	0
Slovakia	SVK	0
Swaziland	SWZ	0
Chad	TCD	0
Togo	TGO	0

Country	Iso-Code	Rank
Tajikistan	TJK	0
Turkmenistan	TKM	0
Tunisia	TUN	0
Uganda	UGA	0
Uzbekistan	UZB	0

Country	Iso-Code	Rank
Vatican City	VAT	0
Wallis & Futuna	WLF	0
Zambia	ZMB	0
Zimbabwe	ZWE	0

Landslides

Country	Iso-Code	Rank
India	IND	1
Indonesia	IDN	2
China	CHN	3
Nepal	NPL	4
Pakistan	PAK	5
Afghanistan	AFG	6
Philippines	PHL	7
Ecuador	ECU	8
Colombia	COL	9
Bangladesh	BGD	10
Guatemala	GTM	11
Turkey	TUR	12
Brazil	BRA	13
Bolivia	BOL	14
Mexico	MEX	15
Japan	JPN	16
South Korea	KOR	17
Italy	ITA	18
Peru	PER	19
Myanmar (Burma)	MMR	20
Malaysia	MYS	21
Russia	RUS	22
Iran	IRN	23
Chile	CHL	24
Sri Lanka	LKA	25
Vietnam	VNM	26
Argentina	ARG	27
Azerbaijan	AZE	28
Spain	ESP	29

Country	Iso-Code	Rank
Trinidad & Tobago	TTO	30
Thailand	THA	31
Armenia	ARM	32
Papua New Guinea	PNG	33
France	FRA	34
Kenya	KEN	35
El Salvador	SLV	36
Switzerland	CHE	37
Uganda	UGA	38
South Africa	ZAF	39
Rwanda	RWA	40
Austria	AUT	41
Ethiopia	ETH	42
Australia	AUS	43
Sierra Leone	SLE	44
Costa Rica	CRI	45
Algeria	DZA	46
Nigeria	NGA	47
Nicaragua	NIC	48
Germany	DEU	49
Guinea	GIN	50
Yemen	YEM	51
Kazakhstan	KAZ	52
Romania	ROU	53
Mozambique	MOZ	54
Iceland	ISL	55
Côte d'Ivoire	CIV	56
Bosnia & Herzegovina	BIH	57

Country	Iso-Code	Rank
Tanzania	TZA	58
Cameroon	CMR	59
St. Lucia	LCA	60
Angola	AGO	61
Uzbekistan	UZB	62
Mongolia	MNG	63
Zambia	ZMB	64
Aruba	ABW	0
Anguilla	AIA	0
Albania	ALB	0
Finland	FIN	0
Andorra	AND	0
United Arab Emirates	ARE	0
American Samoa	ASM	0
Antarctica	ATA	0
French Southern Territories	ATF	0
Antigua & Barbuda	ATG	0
Burundi	BDI	0
Belgium	BEL	0
Benin	BEN	0
Burkina Faso	BFA	0
Bulgaria	BGR	0
Bahrain	BHR	0
Bahamas	BHS	0
St. Barthélemy	BLM	0
Belarus	BLR	0
Belize	BLZ	0
Bermuda	BMU	0

Country	Iso-Code	Rank
Barbados	BRB	0
Brunei	BRN	0
Bhutan	BTN	0
Botswana	BWA	0
Central African Republic	CAF	0
Canada	CAN	0
Congo - Kinshasa	COD	0
Congo - Brazzaville	COG	0
Cook Islands	COK	0
Comoros	COM	0
Cape Verde	CPV	0
Cuba	CUB	0
Curaçao	CUW	0
Cayman Islands	CYM	0
Cyprus	CYP	0
Czechia	CZE	0
Djibouti	DJI	0
Dominica	DMA	0
Denmark	DNK	0
Dominican Republic	DOM	0
Egypt	EGY	0
Eritrea	ERI	0
Estonia	EST	0
Fiji	FJI	0
Falkland Islands	FLK	0
Réunion	REU	0
Mayotte	MYT	0
French Guiana	GUF	0
Martinique	MTQ	0
Guadeloupe	GLP	0
Faroe Islands	FRO	0
Gabon	GAB	0
United Kingdom	GBR	0
Georgia	GEO	0
Guernsey	GGY	0
Ghana	GHA	0
Gambia	GMB	0
Guinea-Bissau	GNB	0
Equatorial Guinea	GNQ	0
Greece	GRC	0
Grenada	GRD	0
Greenland	GRL	0
Guam	GUM	0
Guyana	GUY	0
Honduras	HND	0
Croatia	HRV	0
Haiti	HTI	0
Hungary	HUN	0
Isle of Man	IMN	0
Cocos (Keeling) Islands	CCK	0
Christmas Island	CXR	0
Ireland	IRL	0
Iraq	IRQ	0
Israel	ISR	0
San Marino	SMR	0
Jamaica	JAM	0
Jersey	JEY	0
Jordan	JOR	0
Kyrgyzstan	KGZ	0
Cambodia	KHM	0
Kiribati	KIR	0
St. Kitts & Nevis	KNA	0
Kuwait	KWT	0
Laos	LAO	0
Lebanon	LBN	0
Liberia	LBR	0
Libya	LBY	0
Liechtenstein	LIE	0
Lesotho	LSO	0
Lithuania	LTU	0
Luxembourg	LUX	0
Latvia	LVA	0
Morocco	MAR	0
Monaco	MCO	0
Moldova	MDA	0
Madagascar	MDG	0
Maldives	MDV	0
Marshall Islands	MHL	0
Macedonia	MKD	0
Mali	MLI	0
Malta	MLT	0
Montenegro	MNE	0
Northern Mariana Islands	MNP	0
Mauritania	MRT	0
Montserrat	MSR	0
Mauritius	MUS	0
Malawi	MWI	0
Namibia	NAM	0
New Caledonia	NCL	0
Niger	NER	0
Norfolk Island	NFK	0
Niue	NIU	0
Netherlands	NLD	0
Norway	NOR	0
Nauru	NRU	0
New Zealand	NZL	0
Oman	OMN	0
Panama	PAN	0
Pitcairn Islands	PCN	0
Palau	PLW	0
Poland	POL	0
Puerto Rico	PRI	0
North Korea	PRK	0
Portugal	PRT	0
Paraguay	PRY	0
Palestinian Territories	PSE	0
French Polynesia	PYF	0
Qatar	QAT	0
Western Sahara	ESH	0
Saudi Arabia	SAU	0
Sudan	SDN	0
South Sudan	SSD	0
Senegal	SEN	0
Singapore	SGP	0

Country	Iso-Code	Rank
South Georgia & South Sandwich Islands	SGS	0
St. Helena	SHN	0
Solomon Islands	SLB	0
Somalia	SOM	0
St. Pierre & Miquelon	SPM	0
Serbia	SRB	0
São Tomé & Príncipe	STP	0
Suriname	SUR	0
Slovakia	SVK	0
Slovenia	SVN	0

Country	Iso-Code	Rank
Sweden	SWE	0
Swaziland	SWZ	0
Sint Maarten	SXM	0
Seychelles	SYC	0
Syria	SYR	0
Turks & Caicos Islands	TCA	0
Chad	TCD	0
Togo	TGO	0
Tajikistan	TJK	0
Turkmenistan	TKM	0
Timor-Leste	TLS	0
Tonga	TON	0

Country	Iso-Code	Rank
Tunisia	TUN	0
Taiwan	TWN	0
Ukraine	UKR	0
Uruguay	URY	0
United States	USA	0
Vatican City	VAT	0
St. Vincent & Grenadines	VCT	0
Venezuela	VEN	0
Vanuatu	VUT	0
Wallis & Futuna	WLF	0
Samoa	WSM	0
Zimbabwe	ZWE	0

Droughts

Country	Iso-code	Rank
China	CHN	1
India	IND	2
Brazil	BRA	3
Ethiopia	ETH	4
Guatemala	GTM	5
Thailand	THA	6
Kenya	KEN	7
Ecuador	ECU	8
Pakistan	PAK	9
Italy	ITA	10
Mexico	MEX	11
Honduras	HND	12
Afghanistan	AFG	13
Nepal	NPL	14
Bangladesh	BGD	15
Somalia	SOM	16
Sudan	SDN	17
South Africa	ZAF	18
South Korea	KOR	19
Malawi	MWI	20
Niger	NER	21

Country	Iso-code	Rank
Chad	TCD	22
Haiti	HTI	23
Philippines	PHL	24
Bolivia	BOL	25
Russia	RUS	26
Spain	ESP	27
El Salvador	SLV	28
Madagascar	MDG	29
Greece	GRC	30
Argentina	ARG	31
Portugal	PRT	32
Israel	ISR	33
Tanzania	TZA	34
Malaysia	MYS	35
Peru	PER	36
Timor-Leste	TLS	37
Iran	IRN	38
Mozambique	MOZ	39
Zimbabwe	ZWE	40
Mali	MLI	41
Guyana	GUY	42

Country	Iso-code	Rank
Azerbaijan	AZE	43
Indonesia	IDN	44
Mauritania	MRT	45
Paraguay	PRY	46
Australia	AUS	47
Vietnam	VNM	48
Jordan	JOR	49
Colombia	COL	50
Jamaica	JAM	51
Burkina Faso	BFA	52
North Korea	PRK	53
Chile	CHL	54
Sri Lanka	LKA	55
Uganda	UGA	56
Armenia	ARM	57
Cambodia	KHM	58
Trinidad & Tobago	TTO	59
New Zealand	NZL	60
Mauritius	MUS	61
South Sudan	SSD	62
Macedonia	MKD	63

Country	Iso-code	Rank
Panama	PAN	64
Burundi	BDI	65
France	FRA	66
Angola	AGO	67
Hungary	HUN	68
Lesotho	LSO	69
Cyprus	CYP	70
Nicaragua	NIC	71
Senegal	SEN	72
Georgia	GEO	73
Morocco	MAR	74
Cameroon	CMR	75
Rwanda	RWA	76
Uruguay	URY	77
Zambia	ZMB	78
Namibia	NAM	79
Poland	POL	80
Grenada	GRD	81
Mongolia	MNG	82
Denmark	DNK	83
Guinea	GIN	84
Papua New Guinea	PNG	85
Uzbekistan	UZB	86
Ukraine	UKR	87
Bulgaria	BGR	88
Romania	ROU	89
Cuba	CUB	90
Iraq	IRQ	91
Lithuania	LTU	92
Gambia	GMB	93
Costa Rica	CRI	94
Moldova	MDA	95
Botswana	BWA	96
Croatia	HRV	97
Bosnia & Herzegovina	BIH	98
Cape Verde	CPV	99
Solomon Islands	SLB	100
Samoa	WSM	101
Marshall Islands	MHL	102

Country	Iso-code	Rank
St. Lucia	LCA	103
Tonga	TON	104
Barbados	BRB	105
Aruba	ABW	0
Anguilla	AIA	0
Albania	ALB	0
Finland	FIN	0
Andorra	AND	0
United Arab Emirates	ARE	0
American Samoa	ASM	0
Antarctica	ATA	0
French Southern Territories	ATF	0
Antigua & Barbuda	ATG	0
Austria	AUT	0
Belgium	BEL	0
Benin	BEN	0
Bahrain	BHR	0
Bahamas	BHS	0
St. Barthélemy	BLM	0
Belarus	BLR	0
Belize	BLZ	0
Bermuda	BMU	0
Brunei	BRN	0
Bhutan	BTN	0
Central African Republic	CAF	0
Canada	CAN	0
Switzerland	CHE	0
Côte d'Ivoire	CIV	0
Congo - Kinshasa	COD	0
Congo - Brazzaville	COG	0
Cook Islands	COK	0
Comoros	COM	0
Curaçao	CUW	0
Cayman Islands	CYM	0
Czechia	CZE	0
Germany	DEU	0

Country	Iso-code	Rank
Djibouti	DJI	0
Dominica	DMA	0
Dominican Republic	DOM	0
Algeria	DZA	0
Egypt	EGY	0
Eritrea	ERI	0
Estonia	EST	0
Fiji	FJI	0
Falkland Islands	FLK	0
Réunion	REU	0
Mayotte	MYT	0
French Guiana	GUF	0
Martinique	MTQ	0
Guadeloupe	GLP	0
Faroe Islands	FRO	0
Gabon	GAB	0
United Kingdom	GBR	0
Guernsey	GGY	0
Ghana	GHA	0
Guinea-Bissau	GNB	0
Equatorial Guinea	GNQ	0
Greenland	GRL	0
Guam	GUM	0
Isle of Man	IMN	0
Cocos (Keeling) Islands	CCK	0
Christmas Island	CXR	0
Ireland	IRL	0
Iceland	ISL	0
San Marino	SMR	0
Jersey	JEY	0
Japan	JPN	0
Kazakhstan	KAZ	0
Kyrgyzstan	KGZ	0
Kiribati	KIR	0
St. Kitts & Nevis	KNA	0
Kuwait	KWT	0
Laos	LAO	0
Lebanon	LBN	0

Country	Iso-code	Rank
Liberia	LBR	0
Libya	LBY	0
Liechtenstein	LIE	0
Luxembourg	LUX	0
Latvia	LVA	0
Monaco	MCO	0
Maldives	MDV	0
Malta	MLT	0
Myanmar (Burma)	MMR	0
Montenegro	MNE	0
Northern Mariana Islands	MNP	0
Montserrat	MSR	0
New Caledonia	NCL	0
Norfolk Island	NFK	0
Nigeria	NGA	0
Niue	NIU	0
Netherlands	NLD	0
Norway	NOR	0
Nauru	NRU	0
Oman	OMN	0

Country	Iso-code	Rank
Pitcairn Islands	PCN	0
Palau	PLW	0
Puerto Rico	PRI	0
Palestinian Territories	PSE	0
French Polynesia	PYF	0
Qatar	QAT	0
Western Sahara	ESH	0
Saudi Arabia	SAU	0
Singapore	SGP	0
South Georgia & South Sandwich Islands	SGS	0
St. Helena	SHN	0
Sierra Leone	SLE	0
St. Pierre & Miquelon	SPM	0
Serbia	SRB	0
São Tomé & Príncipe	STP	0
Suriname	SUR	0
Slovakia	SVK	0

Country	Iso-code	Rank
Slovenia	SVN	0
Sweden	SWE	0
Swaziland	SWZ	0
Sint Maarten	SXM	0
Seychelles	SYC	0
Syria	SYR	0
Turks & Caicos Islands	TCA	0
Togo	TGO	0
Tajikistan	TJK	0
Turkmenistan	TKM	0
Tunisia	TUN	0
Turkey	TUR	0
Taiwan	TWN	0
United States	USA	0
Vatican City	VAT	0
St. Vincent & Grenadines	VCT	0
Venezuela	VEN	0
Vanuatu	VUT	0
Wallis & Futuna	WLF	0
Yemen	YEM	0

Heatwaves

Country	Iso-Code	Rank
China	CHN	1
Russia	RUS	2
Italy	ITA	3
France	FRA	4
India	IND	5
Peru	PER	6
United States	USA	7
Mexico	MEX	8
Chile	CHL	9
Spain	ESP	10
Germany	DEU	11
Brazil	BRA	12
Bangladesh	BGD	13

Country	Iso-Code	Rank
Australia	AUS	14
Morocco	MAR	15
Canada	CAN	16
Mongolia	MNG	17
Tajikistan	TJK	18
Afghanistan	AFG	19
Ukraine	UKR	20
Pakistan	PAK	21
Slovakia	SVK	22
Thailand	THA	23
Liberia	LBR	24
Austria	AUT	25
Jordan	JOR	26

Country	Iso-Code	Rank
Israel	ISR	27
Switzerland	CHE	28
Kazakhstan	KAZ	29
Croatia	HRV	30
South Korea	KOR	31
Netherlands	NLD	32
Albania	ALB	33
Belarus	BLR	34
Serbia	SRB	35
Slovenia	SVN	36
Bolivia	BOL	37
New Zealand	NZL	38
Argentina	ARG	39

Country	Iso-Code	Rank
Nepal	NPL	40
Algeria	DZA	41
Guatemala	GTM	42
Turkey	TUR	43
Macedonia	MKD	44
Japan	JPN	45
Romania	ROU	46
Greece	GRC	47
Bosnia & Herzegovina	BIH	48
Moldova	MDA	49
North Korea	PRK	50
Armenia	ARM	51
Uruguay	URY	52
Belize	BLZ	53
Montenegro	MNE	54
Bulgaria	BGR	55
Aruba	ABW	0
Angola	AGO	0
Anguilla	AIA	0
Finland	FIN	0
Andorra	AND	0
United Arab Emirates	ARE	0
American Samoa	ASM	0
Antarctica	ATA	0
French Southern Territories	ATF	0
Antigua & Barbuda	ATG	0
Azerbaijan	AZE	0
Burundi	BDI	0
Belgium	BEL	0
Benin	BEN	0
Burkina Faso	BFA	0
Bahrain	BHR	0
Bahamas	BHS	0
St. Barthélemy	BLM	0
Bermuda	BMU	0
Barbados	BRB	0
Brunei	BRN	0

Country	Iso-Code	Rank
Bhutan	BTN	0
Botswana	BWA	0
Central African Republic	CAF	0
Côte d'Ivoire	CIV	0
Cameroon	CMR	0
Congo - Kinshasa	COD	0
Congo - Brazzaville	COG	0
Cook Islands	COK	0
Colombia	COL	0
Comoros	COM	0
Cape Verde	CPV	0
Costa Rica	CRI	0
Cuba	CUB	0
Curaçao	CUW	0
Cayman Islands	CYM	0
Cyprus	CYP	0
Czechia	CZE	0
Djibouti	DJI	0
Dominica	DMA	0
Denmark	DNK	0
Dominican Republic	DOM	0
Ecuador	ECU	0
Egypt	EGY	0
Eritrea	ERI	0
Estonia	EST	0
Ethiopia	ETH	0
Fiji	FJI	0
Falkland Islands	FLK	0
Réunion	REU	0
Mayotte	MYT	0
French Guiana	GUF	0
Martinique	MTQ	0
Guadeloupe	GLP	0
Faroe Islands	FRO	0
Gabon	GAB	0
United Kingdom	GBR	0
Georgia	GEO	0

Country	Iso-Code	Rank
Guernsey	GGY	0
Ghana	GHA	0
Guinea	GIN	0
Gambia	GMB	0
Guinea-Bissau	GNB	0
Equatorial Guinea	GNQ	0
Grenada	GRD	0
Greenland	GRL	0
Guam	GUM	0
Guyana	GUY	0
Honduras	HND	0
Haiti	HTI	0
Hungary	HUN	0
Indonesia	IDN	0
Isle of Man	IMN	0
Cocos (Keeling) Islands	CCK	0
Christmas Island	CXR	0
Ireland	IRL	0
Iran	IRN	0
Iraq	IRQ	0
Iceland	ISL	0
San Marino	SMR	0
Jamaica	JAM	0
Jersey	JEY	0
Kenya	KEN	0
Kyrgyzstan	KGZ	0
Cambodia	KHM	0
Kiribati	KIR	0
St. Kitts & Nevis	KNA	0
Kuwait	KWT	0
Laos	LAO	0
Lebanon	LBN	0
Libya	LBY	0
St. Lucia	LCA	0
Liechtenstein	LIE	0
Sri Lanka	LKA	0
Lesotho	LSO	0
Lithuania	LTU	0
Luxembourg	LUX	0

Country	Iso-Code	Rank
Latvia	LVA	0
Monaco	MCO	0
Madagascar	MDG	0
Maldives	MDV	0
Marshall Islands	MHL	0
Mali	MLI	0
Malta	MLT	0
Myanmar (Burma)	MMR	0
Northern Mariana Islands	MNP	0
Mozambique	MOZ	0
Mauritania	MRT	0
Montserrat	MSR	0
Mauritius	MUS	0
Malawi	MWI	0
Malaysia	MYS	0
Namibia	NAM	0
New Caledonia	NCL	0
Niger	NER	0
Norfolk Island	NFK	0
Nigeria	NGA	0
Nicaragua	NIC	0
Niue	NIU	0
Norway	NOR	0
Nauru	NRU	0
Oman	OMN	0
Panama	PAN	0
Pitcairn Islands	PCN	0
Philippines	PHL	0

Country	Iso-Code	Rank
Palau	PLW	0
Papua New Guinea	PNG	0
Poland	POL	0
Puerto Rico	PRI	0
Portugal	PRT	0
Paraguay	PRY	0
Palestinian Territories	PSE	0
French Polynesia	PYF	0
Qatar	QAT	0
Rwanda	RWA	0
Western Sahara	ESH	0
Saudi Arabia	SAU	0
Sudan	SDN	0
South Sudan	SSD	0
Senegal	SEN	0
Singapore	SGP	0
South Georgia & South Sandwich Islands	SGS	0
St. Helena	SHN	0
Solomon Islands	SLB	0
Sierra Leone	SLE	0
El Salvador	SLV	0
Somalia	SOM	0
St. Pierre & Miquelon	SPM	0
São Tomé & Príncipe	STP	0
Suriname	SUR	0
Sweden	SWE	0

Country	Iso-Code	Rank
Swaziland	SWZ	0
Sint Maarten	SXM	0
Seychelles	SYC	0
Syria	SYR	0
Turks & Caicos Islands	TCA	0
Chad	TCD	0
Togo	TGO	0
Turkmenistan	TKM	0
Timor-Leste	TLS	0
Tonga	TON	0
Trinidad & Tobago	TTO	0
Tunisia	TUN	0
Taiwan	TWN	0
Tanzania	TZA	0
Uganda	UGA	0
Uzbekistan	UZB	0
Vatican City	VAT	0
St. Vincent & Grenadines	VCT	0
Venezuela	VEN	0
Vietnam	VNM	0
Vanuatu	VUT	0
Wallis & Futuna	WLF	0
Samoa	WSM	0
Yemen	YEM	0
South Africa	ZAF	0
Zambia	ZMB	0
Zimbabwe	ZWE	0

Wildfires

Country	Iso-Code	Rank
Indonesia	IDN	1
United States	USA	2
Russia	RUS	3
Greece	GRC	4
India	IND	5

Country	Iso-Code	Rank
Spain	ESP	6
Portugal	PRT	7
Nepal	NPL	8
Italy	ITA	9
Chile	CHL	10

Country	Iso-Code	Rank
South Korea	KOR	11
Macedonia	MKD	12
Turkey	TUR	13
Australia	AUS	14
Israel	ISR	15

Country	Iso-Code	Rank
Ecuador	ECU	16
Canada	CAN	17
South Africa	ZAF	18
Mexico	MEX	19
Malaysia	MYS	20
Albania	ALB	21
Iran	IRN	22
France	FRA	23
Dominican Republic	DOM	24
Congo - Kinshasa	COD	25
Afghanistan	AFG	26
Guatemala	GTM	27
Cyprus	CYP	28
Philippines	PHL	29
Brazil	BRA	30
Japan	JPN	31
Paraguay	PRY	32
Bolivia	BOL	33
Argentina	ARG	34
Colombia	COL	35
Algeria	DZA	36
Tunisia	TUN	37
Bulgaria	BGR	38
Honduras	HND	39
Mongolia	MNG	40
Croatia	HRV	41
Nicaragua	NIC	42
Swaziland	SWZ	43
Panama	PAN	44
Guinea	GIN	45
Slovakia	SVK	46
Kazakhstan	KAZ	47
Poland	POL	48
Ethiopia	ETH	49
Sweden	SWE	50
Papua New Guinea	PNG	51
Brunei	BRN	52
Benin	BEN	53

Country	Iso-Code	Rank
Mozambique	MOZ	54
Peru	PER	55
Guinea-Bissau	GNB	56
Lithuania	LTU	57
Costa Rica	CRI	58
Central African Republic	CAF	59
Montenegro	MNE	60
Bhutan	BTN	61
Aruba	ABW	0
Angola	AGO	0
Anguilla	AIA	0
Finland	FIN	0
Andorra	AND	0
United Arab Emirates	ARE	0
Armenia	ARM	0
American Samoa	ASM	0
Antarctica	ATA	0
French Southern Territories	ATF	0
Antigua & Barbuda	ATG	0
Austria	AUT	0
Azerbaijan	AZE	0
Burundi	BDI	0
Belgium	BEL	0
Burkina Faso	BFA	0
Bangladesh	BGD	0
Bahrain	BHR	0
Bahamas	BHS	0
Bosnia & Herzegovina	BIH	0
St. Barthélemy	BLM	0
Belarus	BLR	0
Belize	BLZ	0
Bermuda	BMU	0
Barbados	BRB	0
Botswana	BWA	0
Switzerland	CHE	0

Country	Iso-Code	Rank
China	CHN	0
Côte d’Ivoire	CIV	0
Cameroon	CMR	0
Congo - Brazzaville	COG	0
Cook Islands	COK	0
Comoros	COM	0
Cape Verde	CPV	0
Cuba	CUB	0
Curaçao	CUW	0
Cayman Islands	CYM	0
Czechia	CZE	0
Germany	DEU	0
Djibouti	DJI	0
Dominica	DMA	0
Denmark	DNK	0
Egypt	EGY	0
Eritrea	ERI	0
Estonia	EST	0
Fiji	FJI	0
Falkland Islands	FLK	0
Réunion	REU	0
Mayotte	MYT	0
French Guiana	GUF	0
Martinique	MTQ	0
Guadeloupe	GLP	0
Faroe Islands	FRO	0
Gabon	GAB	0
United Kingdom	GBR	0
Georgia	GEO	0
Guernsey	GGY	0
Ghana	GHA	0
Gambia	GMB	0
Equatorial Guinea	GNQ	0
Grenada	GRD	0
Greenland	GRL	0
Guam	GUM	0
Guyana	GUY	0
Haiti	HTI	0

Country	Iso-Code	Rank
Hungary	HUN	0
Isle of Man	IMN	0
Cocos (Keeling) Islands	CCK	0
Christmas Island	CXR	0
Ireland	IRL	0
Iraq	IRQ	0
Iceland	ISL	0
San Marino	SMR	0
Jamaica	JAM	0
Jersey	JEY	0
Jordan	JOR	0
Kenya	KEN	0
Kyrgyzstan	KGZ	0
Cambodia	KHM	0
Kiribati	KIR	0
St. Kitts & Nevis	KNA	0
Kuwait	KWT	0
Laos	LAO	0
Lebanon	LBN	0
Liberia	LBR	0
Libya	LBY	0
St. Lucia	LCA	0
Liechtenstein	LIE	0
Sri Lanka	LKA	0
Lesotho	LSO	0
Luxembourg	LUX	0
Latvia	LVA	0
Morocco	MAR	0
Monaco	MCO	0
Moldova	MDA	0
Madagascar	MDG	0
Maldives	MDV	0
Marshall Islands	MHL	0
Mali	MLI	0
Malta	MLT	0
Myanmar (Burma)	MMR	0
Northern Mariana Islands	MNP	0

Country	Iso-Code	Rank
Mauritania	MRT	0
Montserrat	MSR	0
Mauritius	MUS	0
Malawi	MWI	0
Namibia	NAM	0
New Caledonia	NCL	0
Niger	NER	0
Norfolk Island	NFK	0
Nigeria	NGA	0
Niue	NIU	0
Netherlands	NLD	0
Norway	NOR	0
Nauru	NRU	0
New Zealand	NZL	0
Oman	OMN	0
Pakistan	PAK	0
Pitcairn Islands	PCN	0
Palau	PLW	0
Puerto Rico	PRI	0
North Korea	PRK	0
Palestinian Territories	PSE	0
French Polynesia	PYF	0
Qatar	QAT	0
Romania	ROU	0
Rwanda	RWA	0
Western Sahara	ESH	0
Saudi Arabia	SAU	0
Sudan	SDN	0
South Sudan	SSD	0
Senegal	SEN	0
Singapore	SGP	0
South Georgia & South Sandwich Islands	SGS	0
St. Helena	SHN	0
Solomon Islands	SLB	0
Sierra Leone	SLE	0
El Salvador	SLV	0
Somalia	SOM	0

Country	Iso-Code	Rank
St. Pierre & Miquelon	SPM	0
Serbia	SRB	0
São Tomé & Príncipe	STP	0
Suriname	SUR	0
Slovenia	SVN	0
Sint Maarten	SXM	0
Seychelles	SYC	0
Syria	SYR	0
Turks & Caicos Islands	TCA	0
Chad	TCD	0
Togo	TGO	0
Thailand	THA	0
Tajikistan	TJK	0
Turkmenistan	TKM	0
Timor-Leste	TLS	0
Tonga	TON	0
Trinidad & Tobago	TTO	0
Taiwan	TWN	0
Tanzania	TZA	0
Uganda	UGA	0
Ukraine	UKR	0
Uruguay	URY	0
Uzbekistan	UZB	0
Vatican City	VAT	0
St. Vincent & Grenadines	VCT	0
Venezuela	VEN	0
Vietnam	VNM	0
Vanuatu	VUT	0
Wallis & Futuna	WLF	0
Samoa	WSM	0
Yemen	YEM	0
Zambia	ZMB	0
Zimbabwe	ZWE	0

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