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# Bristol in Brief: Extreme weather and their impacts under climate change

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**Global surface temperatures are rising as a result of human activity [1], and as a result global weather patterns are changing. Damaging extreme weather events have been made more likely by human greenhouse gas emissions. More intense and frequent heatwaves, higher tropical storm winds and rainfall rates, and more extreme rainfall are expected in a warmer world, among other changes. The Paris Agreement has a goal of keeping global average temperature rise this century below 2°C above pre-industrial levels, with a more ambitious target of 1.5°C. Achieving the 1.5°C target avoids substantial heat-related mortality and other climate-related risks for human and natural systems compared to 2°C. Increased national climate commitments are needed to meet the Paris Agreement temperature targets.**

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## Changes to Extreme Weather

In a warming climate, changes in extreme weather events have been observed. Deadly heatwaves, damaging tropical storms, extreme rainfall and floods are occurring more frequently or intensely in some parts of the world as a result of human-induced climate change.

### Human-induced Climate Change

Global average temperature has increased by about 1°C since pre-industrial times [1]. Observations for the UK show that the 2009-2018 decade was, on average, 0.3°C warmer than 1981-2000 and 0.9°C warmer than 1961-1990 [2]. All of the 10 warmest years in the UK since 1884 have occurred since 2002 [2].

Rising global [3], [4] and regional temperatures [5] have been robustly attributed to human emissions of greenhouse gases. This means the observed trends of rising temperatures can only be explained with the inclusion of human greenhouse gas emissions. Human influence has contributed to observed increases in extreme temperatures too [6], [7].

***Heatwaves***

Since 1950, some parts of the world have seen more heatwaves [8]. Human-induced climate change has increased the likelihood of record-breaking heatwaves. For example, the 2003 European heatwave that killed over 70,000 people [9] is expected to occur twice a decade under current climate; it would have only occurred once every 1000 years or more without human-induced climate change [10]. In 2019, the UK recorded its new highest temperature of 38.7°C, breaking the previous record set in 2003 [11]. This heat event has been made about 10 times more likely by human-induced climate change [12].

***Tropical storms***

Climate change also affects other extreme weather events such as tropical storms, heavy rains and floods. Higher sea surface temperatures increase the intensity of tropical storms when they form. Rising sea levels, combined with storm surges, increase the risk of coastal flooding when tropical storms make landfall. Human-induced climate change made the extreme rainfall during Hurricane Harvey in 2017 three times more likely [13].

***Heavy rains and floods***

A warmer atmosphere holds more moisture; this can lead to heavy rains and floods. On average, the UK is getting wetter [2]. The risk of the historic floods in England and Wales in autumn 2000, which damaged nearly 10,000 properties, was increased by more than 20% by human greenhouse gas emissions. The heavy rains brought by Storm Desmond to parts of the UK in 2015 were made 60% more likely by human-induced climate change [14].

***Future changes***

More intense and frequent heatwaves, higher maximum wind speeds and rainfall rates associated with tropical storms, and more intense and frequent extreme rainfall are expected in a warming climate [8]. For the UK, milder and wetter winters, and hotter and drier summers are expected to become more common [15]. In addition, hourly rainfall extremes are projected to intensify according to the newest UK climate projections [16].

## The Paris Agreement

Faced with the adverse impacts of climate change, 189 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) ratified the Paris Agreement in 2016, which deals with greenhouse-gas-emissions mitigation, adaptation, and finance. The long-term goal of the agreement is to keep “a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius” [17]. Climate model simulations suggest higher near-surface air temperatures everywhere in a 2°C warmer world than a 1.5°C warmer world (Figure 1), affecting everyone on the planet.

***1.5°C warming vs 2°C***

*Latest science in the Intergovernmental Panel on* Climate Change (IPCC) Special Report on Global Warming at 1.5°C suggests lower climate-related risks for human and natural systems at 1.5°C global warming than 2°C [1]. Smaller increases in hot extremes in most inhabited areas are projected for 1.5°C warming than 2°C. By limiting global warming above pre-industrial levels to 1.5°C instead of 2°C, around 420 million fewer people will be frequently exposed to extreme heatwaves if vulnerability remains the same [18]. Several regions, including high-latitude regions, mountainous regions, east Asia and eastern North America, are projected to have substantially reduced risks of heavy precipitation events in a 1.5°C warmer world compared to 2°C [18]. Limiting global warming to 1.5°C instead of 2°C is also projected to substantially reduce the probability of extreme drought in regions such as the Mediterranean and southern Africa [18].

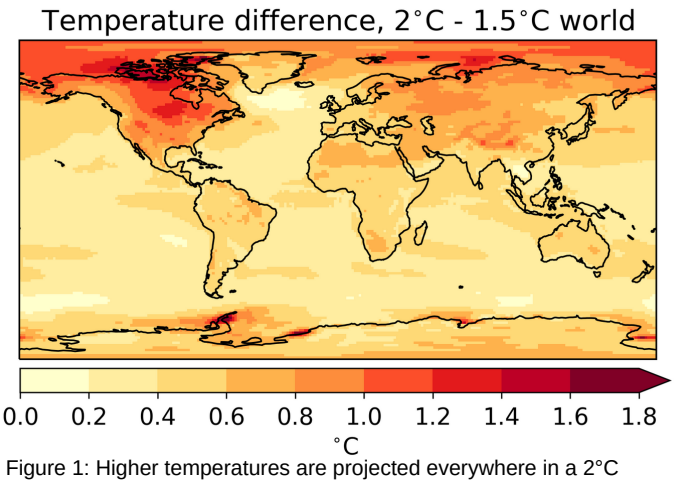


Figure 1: Higher temperatures are projected everywhere in a 2°C warmer world than a 1.5°C warmer world.

***Nationally Determined Contributions***

Parties to the Paris Agreement are required to put forward their intended climate mitigation and adaptation actions through Nationally Determined Contributions (NDCs) every 5 years. NDCs are expected to reflect nations’ highest possible ambition that rachets up over time. However, initial NDCs are consistent with about 3°C global average warming above pre-industrial levels rather than 1.5°C or 2°C [19]. A substantial increase in international mitigation ambition is needed to meet the Paris Agreement temperature goal. The next round of NDCs is expected this year, in 2020.

In their first NDC, the UK and European Union member states pledged to reduce their domestic greenhouse gas emissions by 40% compared to the 1990 levels by 2030 [20]. The UK also pledges to achieve net-zero greenhouse gas emissions by 2050 [21]. This means by 2050, the country aims to offset its greenhouse gas emissions completely by afforestation and technologies such as carbon capture and storage [22].

If the UK’s 2050 net-zero greenhouse gas target is replicated across the world, and nations adopt ambitious near-term emissions reductions, there is a greater than 50% chance of meeting the 1.5°C Paris Agreement target [22].

**Box 1: The HAPPI Project**

The Climate Dynamics Group at University of Bristol's School of Geographical Sciences study how extreme weather events including heatwaves, hurricanes and floods and their impacts may differ between the 1.5°C, 2°C and 3°C warmer worlds.

The Group created, and continue to lead, the Half a degree Additional warming, Prognosis and Projected Impacts (HAPPI) project [23]. Different from the conventional scenario-based approach that results in high uncertainty in the regional impacts of extreme weather; the HAPPI approach quantifies extreme weather impacts by constraining global average temperature rise to 1.5°C, 2°C or 3°C, and modelling the climate about a hundred times in each of these worlds (Figure 2) [23], [24]. This approach not only reduces uncertainty in the assessment of regional extreme weather impacts; it also allows statements to be made regarding policy-relevant extreme weather events that recur about once every 100 years [24], allowing governments and policymakers to plan for different eventualities and put mitigation measures in place.

With collaborators from the UK, USA, UAE, Canada, Australia, Japan, France, India, Germany, Tunisia, Morocco, the Netherlands, Switzerland, Austria, Norway and Bangladesh; HAPPI research covers a wide range of topics in many regions around the world [25]. There have been 58 peer-reviewed publications from HAPPI [25], contributing state-of-the-art scientific evidence to the IPCC Special Report on Global Warming of 1.5°C.

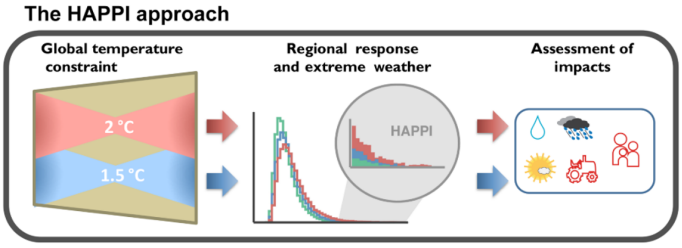


Figure 2: The HAPPI approach reduces uncertainty in the assessment of extreme weather and their impacts under in different warmer worlds [23].

## Heat extremes and human health

***Heat action plans***

High temperatures are known to be associated with substantially increased human mortality risks [26]. Governments around the world developed heat action plans following some historic, deadly heatwaves [27], [28].

For example, the World Health Organisation (WHO) Regional Office for Europe developed comprehensive heat-health action plans to protect public health from extreme heat. As of 2018, 35 of the 53 member states of the WHO European Region had operational heat-health action plans [28].

Health data suggest that heat action plans can be effective in reducing heat-related mortality rates [29], [30]. The Climate Dynamics Group at the University of Bristol (the Group) continue to lead research on extreme heat and its increasing health impacts under global warming, in order to inform public health and adaptation policies.

***Attribution of heat-related mortality***

Collaborating with partners including Public Health England, the Group attributed heat-related deaths in Central Paris and London during the 2003 European heatwave to human-induced climate change. The research found that human-induced climate change increased the risks of heat-related mortality by about 70% in Paris and about 20% in London in summer 2003 [31].

France's record-high temperature in the 2003 heatwave was subsequently broken by a new record of 45.9°C in 2019 [32]. Just days after this record was broken, the Group published a commentary [32], linking heatwaves to public health and urging climate modellers to continue to work alongside medical practitioners, researchers and local officials to provide early heatwave warnings.

***Avoidable future heat-related mortality***

Heatwaves are projected to become more frequent and intense in a warming climate [33]–[35], posing an increasing threat to human life [36]–[38]. The HAPPI methodology has enabled researchers to demonstrate the potential benefits of limiting global average warming from 2°C to 1.5°C in terms of extreme heat exposure [39]–[41], reinforcing the importance of meeting the Paris Agreement's lower temperature target.

The Group estimated a 2.4 times and 1.6 times reduction in the likelihood of a 2003-like mortality event in London and Paris, respectively, if the 1.5°C warmer world is realised rather than 2°C [22]. Another piece of research from the Group estimated that between hundreds and thousands of extreme heat-related deaths could be avoided in individual U.S. cities in a year, if global warming is reduced from the "current trajectory" of 3°C to 1.5°C above pre-industrial levels [42]. These findings provide compelling evidence for the heat-related health benefits of ratcheting up climate ambition in NDCs.

**Box 2: Shaping policy**

The next IPCC Assessment Report (AR6) [43] will be released by 2022 to inform policymakers, international climate negotiators and stakeholders about the latest science of climate change. The Climate Dynamics Group at the University of Bristol is contributing to the report by providing peer-reviewed scientific findings and editing the chapter about human influence on the climate system.

The Group is engaging with Bristol City Council to support the potential development of Bristol Vulnerability Maps, demonstrating vulnerability to climate change and urban heat, and drawing up a heat action plan. The Group also communicates with health professionals locally and internationally [44] to raise awareness about the health risks of climate change, in order to better prepare the health sector for future climate-related health challenges.

## Hurricane impacts on island states

Hurricanes can wreak havoc when they make landfall, particularly over developing island states. The Caribbean Disaster Emergency Management Agency (CDEMA) [45] was established in 1991 to coordinate emergency response and disaster relief for island states in the Caribbean. International and cross-disciplinary research is crucial to increasing preparedness of these island states to rising sea levels and the potential intensification of the most intense tropical storms [46] in a warming climate.

Collaborating with partners in the Caribbean and the US, the Group led a workshop on hurricane hazards in Jamaica in 2018. The Group continue to collaborate with researchers at the University of the West Indies by providing support in storm surge modelling for the region. The Group's newest research suggests an increased likelihood of extreme hurricane rainfall in the Caribbean under 1.5°C and 2°C warming, compared to present-day climate. An event like Hurricane Maria (2017) is projected to be about half as likely to occur in a 1.5°C warmer world compared to 2°C [47].

## Flood risks, water and sanitation

Flood hazard can damage property, crops, livestock and human life. Record river levels in the Ganges–Brahmaputra–Meghna (GBM) basin in Bangladesh caused 1200 deaths and substantial damage in 2017 [48]. The Group found an increase in extreme rainfall and flood hazard in the GBM basin under 1.5°C and 2°C warming, compared to current climate, but with lower flood risk under the 1.5°C scenario [48].

The Group is currently working with the WHO, UNICEF, local partners in Ethiopia and Nepal, other departments at the University of Bristol, and other organisations, to develop indicators that will measure whether drinking water supplies and sanitation in rural areas in Ethiopia and Nepal are resilient to changes in flood and drought risks under climate change [49]. The outcome of this multi-disciplinary project will help vulnerable populations in these countries build resilience of water and sanitation services to a warming climate.

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## Conclusion

Researchers from the Climate Dynamics Group at the University of Bristol and around the world project substantial differences in the frequency, severity and impact of extreme weather events between 1.5, 2, and 3°C global warming above pre-industrial levels. Heat-related mortality and other climate-related risks for human and natural systems can be avoided by limiting global warming to 1.5°C compared to 2 or 3°C. These findings help to drive the conclusion that more ambitious Nationally Determined Contributions (NDCs) are needed, in order to achieve the 1.5°C target, and reduce the impact of extreme weather events across the globe. With renewed NDCs from Parties due this year and the 26th session of the Conference of the Parties (COP 26) scheduled to take place in Glasgow, UK, in November 2021, the Parties will have a golden opportunity to revise their climate commitments to reflect their respective highest possible climate ambitions.

## Endnotes


1. Intergovernmental Panel on Climate Change, “Summary for Policymakers,” in Special Report on Global Warming of 1.5 °C, 2018, pp. 1–33.
2. M. Kendon, M. McCarthy, S. Jevrejeva, A. Matthews, and T. Legg, “State of the UK climate 2018,” Int. J. Climatol., vol. 39, no. S1, pp. 1–55, 2019.
3. S. F. B. Tett et al., “Estimation of natural and anthropogenic contributions to 20th Century Temperature Change,” Sci. Technol., vol. 107, no. October, p. 31, 2000.
4. P. A. Stott and G. S. Jones, “Observed 21st century temperatures further constrain likely rates of future warming,” Atmos. Sci. Lett., vol. 13, no. 3, pp. 151–156, 2012.
5. P. A. Stott et al., “Detection and attribution of climate change: A regional perspective,” Wiley Interdiscip. Rev. Clim. Chang., vol. 1, no. 2, pp. 192–211, 2010.
6. F. W. Zwiers, X. Zhang, and Y. Feng, “Anthropogenic influence on long return period daily temperature extremes at regional scales,” J. Clim., vol. 24, no. 3, pp. 881–892, 2011.
7. S. K. Min, X. Zhang, F. Zwiers, H. Shiogama, Y. S. Tung, and M. Wehner, “Multimodel detection and attribution of extreme temperature changes,” J. Clim., vol. 26, no. 19, pp. 7430–7451, 2013.
8. UK Met Office, “Severe or extreme weather in a changing climate,” 2019.
9. J.-M. Robine et al., “Death toll exceeded 70,000 in Europe during the summer of 2003,” C. R. Biol., vol. 331, no. 2, pp. 171–178, Feb. 2008.
10. N. Christidis, G. S. Jones, and P. A. Stott, “Dramatically increasing chance of extremely hot summers since the 2003 European heatwave,” Nat. Clim. Chang., vol. 5, no. 1, pp. 46–50, 2015.
11. BBC News, “UK heatwave: Met Office confirms record temperature in Cambridge,” 2019. [Online]. Available: https://www.bbc.co.uk/news/uk-49157898. [Accessed: 27-Mar-2020].
12. World Weather Attribution, “Human contribution to the record-breaking July 2019 heatwave in Western Europe,” 2019.
13. G. J. Van Oldenborgh et al., “Attribution of extreme rainfall from Hurricane Harvey, August 2017,” Environ. Res. Lett., vol. 12, no. 12, 2017.
14. World Weather Attribution, “UK Storm Desmond revisited, December 2017,” 2017. [Online]. Available: https://www.worldweatherattribution.org/uk-storm-desmond-revisited-december-2017/. [Accessed: 27-Mar-2020].
15. J. M. Murphy et al., “UKCP18 Land Projections: Science Report,” 2018.
16. Met Office Hadley Centre, “UK Climate Projections: Headline Findings,” 2019.
17. UNFCCC, “Adoption of the Paris Agreement,” 2015.
18. O. Hoegh-Guldberg et al., “Impacts of 1.5°C global warming on natural and human systems,” in 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, V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, Eds. Intergovernmental Panel on Climate Change, 2018, pp. 175–311.
19. J. Rogelj et al., “Paris Agreement climate proposals need a boost to keep warming well below 2 °c,” Nature, vol. 534, no. 7609, pp. 631–639, 2016.
20. UNFCCC, “NDC Registry (interim) United Kingdom,” 2016. [Online]. Available: https://www4.unfccc.int/sites/NDCStaging/Pages/Party.aspx?party=GBR. [Accessed: 27-Mar-2020].
21. UK Government, “UK becomes first major economy to pass net zero emissions law,” 2019. [Online]. Available: https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law. [Accessed: 27-Mar-2020].
22. Committee on Climate Change, “Net Zero: The UK’s contribution to stopping global warming,” no. May, p. 277, 2019.
23. D. Mitchell et al., “Half a degree additional warming, prognosis and projected impacts (HAPPI): Background and experimental design,” Geosci. Model Dev., vol. 10, no. 2, pp. 571–583, 2017.
24. D.Mitchell, R. James, P. M. Forster, R. A. Betts, H. Shiogama, and M. Allen, “Realizing the impacts of a 1.5 °C warmer world,” Nat. Clim. Chang., vol. 6, no. 8, pp. 735–737, 2016.
25. HAPPI, “Half a degree Additional warming, Prognosis and Projected Impacts,” 2020. [Online]. Available: https://www.happimip.org. [Accessed: 27-Mar-2020].
26. A. Gasparrini et al., “Mortality risk attributable to high and low ambient temperature: a multicountry observational study,” Lancet, vol. 386, no. 9991, pp. 369–375, Jul. 2015.
27. K. Knowlton et al., “Development and implementation of South Asia’s first heat-health action plan in Ahmedabad (Gujarat, India),” Int. J. Environ. Res. Public Health, vol. 11, no. 4, pp. 3473–3492, 2014.
28. G. S. Martinez, C. Linares, A. Ayuso, V. Kendrovski, M. Boeckmann, and J. Diaz, “Heat-health action plans in Europe: Challenges ahead and how to tackle them,” Environ. Res., vol. 176, no. March, p. 108548, 2019.
29. J. J. Hess et al., “Building resilience to climate change: Pilot evaluation of the impact of India’s first heat action plan on all-cause mortality,” J. Environ. Public Health, vol. 2018, 2018.
30. 1353. Michael A Palecki, Stanley A Changnon, & Kenneth E Kunkel. (2001). The nature and impacts of the july 1999 heat wave in the midwestern united states: Learning from the lessons of 1995. Bulletin of the American Meteorological Society, 82(7), “The nature and impacts of the july 1999 heat wave in the midwestern united states: Learning from the lessons of 1995. Bulletin of the American Meteorological Society, 82(7), 1353.,” Bull. Am. Meteorol. Soc., vol. Vol. 82, no. Issue 7., pp. 1353–1367, 1999.
31. D. M. and C. H. and S. V. and C. H. and G. M. and B. P. G. and P. F. and A. B. and D. W. and M. Allen, “Attributing human mortality during extreme heat waves to anthropogenic climate change,” Environ. Res. Lett., vol. 11, no. 7, p. 74006, 2016
32. D. Mitchell, K. Kornhuber, C. Huntingford, and P. Uhe, “The day the 2003 European heatwave record was broken,” Lancet Planet. Heal., vol. 5196, no. July, pp. 8–11, 2019.
33. R. Simone, S. Jana, and M. F. Erich, “Top ten European heatwaves since 1950 and their occurrence in the coming decades,” Environ. Res. Lett., vol. 10, no. 12, p. 124003, 2015.
34. N. S. Diffenbaugh, D. Singh, and J. S. Mankin, “Unprecedented climate events: Historical changes, aspirational targets, and national commitments,” Sci. Adv., vol. 4, no. 2, pp. 1–10, 2018.
35. G. A. Meehl and C. Tebaldi, “More intense, more frequent, and longer lasting heat waves in the 21st century,” Science (80-. )., vol. 305, no. 5686, pp. 994–997, 2004.
36. C. Mora et al., “Global risk of deadly heat,” Nat. Clim. Chang., vol. 7, no. 7, pp. 501–506, 2017.
37. K. R. Weinberger, L. Haykin, M. N. Eliot, J. D. Schwartz, A. Gasparrini, and G. A. Wellenius, “Projected temperature-related deaths in ten large U.S. metropolitan areas under different climate change scenarios,” Environ. Int., vol. 107, no. April, pp. 196–204, 2017.
38. S. Hajat, S. Vardoulakis, C. Heaviside, and B. Eggen, “Climate change effects on human health: Projections of temperature-related mortality for the UK during the 2020s, 2050s and 2080s,” J. Epidemiol. Community Health, vol. 68, no. 7, pp. 641–648, 2014.
39. A. D. King and D. J. Karoly, “Climate extremes in Europe at 1.5 and 2 degrees of global warming,” Environ. Res. Lett., vol. 12, p. 114031, 2017.

## Endnotes

40. M. Wehner et al., “Changes in extremely hot days under stabilized 1.5 and 2.0 °c global warming scenarios as simulated by the HAPPI multi-model ensemble,” Earth Syst. Dyn., vol. 9, no. 1, pp. 299–311, 2018.
41. S. Russo et al., “Half a degree and rapid socioeconomic development matter for heatwave risk,” Nat. Commun., vol. 10, no. 1, pp. 1–9, 2019.
42. Y. T. E. Lo et al., “Increasing mitigation ambition to meet the Paris Agreement ’ s temperature goal avoids substantial heat-related mortality in U . S . cities,” Sci. Adv., vol. 5, no. 6, p. eaau4373, 2019.
43. Intergovernmental Panel on Climate Change, “Sixth Assessment Report,” 2020. [Online]. Available: https://www.ipcc.ch/assessment-report/ar6/. [Accessed: 27-Mar-2020].
*44. Collaborative on Health and the Environment, “Climate* Change and Heat: health effects, adaptation strategies, and the benefits of mitigation,” 2019. [Online]. *Available: https://www.healthandenvironment.org/webinars/96495. [Accessed: 27-Mar-2020].*
45. Caribbean Disaster Emergency Management Agency, “CDEMA News,” 2020.
46. M. F. Wehner, K. A. Reed, B. Loring, D. Stone, and H. Krishnan, “Changes in tropical cyclones under stabilized 1.5 and 2.0°C global warming scenarios as simulated by the Community Atmospheric Model under the HAPPI protocols,” Earth Syst. Dyn., vol. 9, no. 1, pp. 187–195, 2018.
*47.* E. L. Vosper, D. M. Mitchell, and K. Emanuel, “Extreme hurricane rainfall affecting the Caribbean mitigated by the Paris Agreement goals,” Environ. Res. Lett., 2020.
48. P. F. Uhe, D. M. Mitchell, P. D. Bates, C. C. Sampson, A. M. Smith, and A. S. Islam, “Enhanced flood risk with 1.5 °c global warming in the Ganges-Brahmaputra-Meghna basin,” Environ. Res. Lett., vol. 14, no. 7, 2019.
49. G. Howard, Y. T. E. Lo, D. M. Mitchell, A. G. Flint, M. Pregnolato, and H. Gadelha, “How tough is WASH? Developing indicators to measure the resilience of WASH to climate change in LMICs,” University of Bristol Research and Enterprise Development, 2019.