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Supplementary information

Over half of known human pathogenic diseases can be aggravated by climate change

In the format provided by the authors and unedited

Supplement 1. Caveats

Our literature search yielded a much larger number of diseases that were aggravated, rather than diminished, by climatic hazards. This could reflect a real pattern about the impact of climatic hazards upon pathogenic diseases (i.e., climatic hazards make more diseases worse), but it may also reflect a publication bias. We minimized the risk of this pattern being driven by a search bias, by carrying out a literature review using search criteria that did not imply any preference for papers with positively or negatively impacted diseases and by scrutinizing titles, abstracts, and papers regardless of whether reported cases were positive or negative. However, we cannot fully rule out the possibility of a publication bias toward diseases that are aggravated by climate change, or simply, a lack of studies into diseases that have become less concerning due to climatic changes. This suggests that our description of diseases that have been diminished by climatic changes should be taken with caution.

The data collected as part of this review cannot be used to make inferences about the frequency and/or severity and/or pervasiveness with which climatic hazards affected specific diseases. First, the frequency with which papers cited specific links between hazards and diseases cannot be used as an indicator of the significance of such links, as the number of scientific papers is more likely related to novelty than to how frequent or pervasive the given links between hazards or diseases were. Second, it is possible that different papers documenting a given relationship may be based on the same underlying case; in other words, the redundancy in which links were reported by different scientific papers do not necessarily indicate that such a link is common. In short, our paper shows evidence for the linkages between hazards and diseases, but not how common or pervasive such links could be.

We used Google Scholar as our sole platform to search for publications. A likely issue with this choice is the extent to which Scholar may fail to contain papers available in other databases. This effect, however, is likely to be small. A study into this issue revealed that the broad nature of searches carried out using Scholar leads to 100% similarity of papers found on more topic-specific databases[1]. Some studies have suggested that Scholar by virtue of allowing free indexing to journals and having periodic searches of the web results in a higher number of relevant papers[2]. Another issue with Scholar relates to the way it ranks papers; Scholar ranks papers by “relevance” to the search query (i.e., extent to which the keywords are contained

within the full text of each document plus where it was published, who it was written by, as well as how often and how recently it has been cited in other scholarly literature); this ranking could prevent papers with case examples to appear on top of the returning papers for specific searches. To account for this issue, at each of the three level searches, we took random samples of the results from the pairs of keywords and scrutinized papers for case examples to identify the rank at which the paper appeared in the given Scholar search. In our first general search, all case examples appeared within the first 100 papers listed, in our second more specific search, papers with case examples appeared within the first page of results (i.e., ten papers); as a result, we looked over twice that number of papers at each of the two first searches to ensure that papers ranked lower by Scholar were also considered. As mentioned, we scrutinized >77, 000 titles and summaries. Failing to find case examples in papers ranked low by Scholar would be a problem only in the case that such a paper reported a case for which no other paper had previously reported that linkage between a hazard and a disease. To mitigate this problem, we carried out a third search of the literature looking for alternative disease names and taxonomic names for interactions for which we did not find case examples in the first two searches. This minimized the chance that data gaps resulted from searching over an insufficient number of papers. All searches were done in English, which certainly will prevent to find case examples that may exist in other languages.

There are some important caveats when considering our reported number of diseases aggravated by climate change and the number of pathways. There were a few instances in which different pathogens led to generally named diseases or symptoms. *Escherichia coli,* for instance, causes diarrhea but *E. coli* can also be associated with severe gastroenteritis, urinary tract infection, and respiratory illness; in turn, diarrhea can also be caused by other types of organisms. In such cases, where a pathogen could be associated with several generally named diseases, each pathogen name was considered independently. Most commonly, we also maintained the generally named disease to account for cases where the disease was reported but not the underlying pathogen. We found, for instance, several review papers looking into the impacts of floods on diarrhea hospitalizations which failed to report the specific pathogen (s) responsible for the disease. A key goal of this paper was to capture the diversity of human pathogens rather than simplifying a large umbrella of pathogens into a single disease name. Another caveat in our paper relates to the quantification of the number of unique pathways in which climatic hazards

triggered pathogenic diseases. In numerous case examples, the transmission type was not indicated (see Fig. 3), which could be due to the authors not knowing how the specific outbreak was caused, or outlining the transmission was not relevant to the goal of the given study, or the transmission pathway overall is not well known (e.g., contact vs. aerosol transmission in COVID-19, at least in the early phase of the pandemic), among other possibilities. As a result, our estimation of the number of pathways leading to outbreaks is a conservative quantification because we only counted cases in which the transmission was reported in the papers from which we took case examples.

A critical issue in our literature review relates to the attribution and magnitude, in which climatic hazards affected pathogenic diseases. Metcalf et al[3]. elegantly showed the numerous layers of environmental, social, economic, and body health variables related to the emergence of a pathogenic disease, and how such a comprehensive model remains elusive for any disease "often driven by data scarcity" and by the fact that interacting factors can be hard to disentangle with correlative analyses. As such, our goal was simply to identify cases in which climatic hazards were reported to have a role in pathogenic diseases, regardless of the magnitude by which the hazard was responsible for the disease. Case examples were classified to a specific disease and climatic hazard using exclusively the attribution provided in the paper; this was done to avoid any bias on our end. Most of the reported cases found in this review support the idea that while climatic hazards can critically affect the emergence of pathogenic diseases, they rarely acted alone. Thus, it should be safe to assume that climatic hazards play a role in the emergence of specific diseases, but their specific contribution will be difficult to quantify and will most likely vary in extent in different cases.

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2. Shariff, S. Z. *et al.* Retrieving clinical evidence: a comparison of PubMed and Google Scholar for quick clinical searches. *Journal of medical Internet research* **15**, e2624 (2013).

3. Metcalf, C. J. E. & Lessler, J. Opportunities and challenges in modeling emerging infectious diseases. *Science* **357**, 149–152 (2017).