GeoHealth

POLICY PAPER
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**Key Points:**

- Earth system science of ecosystems and climate change hardly tells mechanisms of disease-causing organisms, detection, and management
- Revisiting "One Health" amidst "coronavirus disease 2019" is opportune pathway for GeoHealth's influence of climate-sensitive infectious diseases
- Modern Earth system science of climate context of "One Health" is key to maintaining human well-being and ecosystem integrity

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# Earth System's Gatekeeping of "One Health" Approach to Manage Climate-Sensitive Infectious Diseases

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**Abstract** Global response to climate-sensitive infectious diseases has been uncertain and slow. The understanding of the underlying vulnerabilities which forms part of changes created by forces within the Earth system has never before been critical until the coronavirus disease 2019, "COVID-19" pandemic with the initial developmental phase linked to weather elements and climate change. Hence, the heightened interest in climate-sensitive infectious diseases and GeoHealth, evident in the renewed calls for "One Health" approach to disease management. "One Health" explains the commonality of human and animal medicine, and links to the bio-geophysical environment, yet are at crossroads with how forces within the Earth system shape etiologies, incidences, and transmission dynamics of infectious diseases. Hence, the paper explores how these forces, which are multistage and driven by climate change impacts on ecosystems affect emerging infectious diseases, leading to the question "what drive the drivers of diseases?" Three questions that challenge broad theories of Earth system science on boundaries and connectivity emerged to guide study designs to further interrogating disease surveillance and health early warning systems. This is because, climate change (a) drives prevailing biological health hazards as part of forces within the Earth system, (b) shifts disease control services of ecosystems and functioning to effectively regulate disease incidence, and (c) modifies pathogen—species hosts relationships. Hence, the need to rethink pluralistic concepts of climate-sensitive diseases in their infection and management from a GeoHealth perspective, which "One Health" potentially conveys, and to also maintain ecosystem health.

**Plain Language Summary** Climate change, an Earth system process (forces deep inside the earth that bring about adjustments) is considered the greatest threat to human health in the twenty-first century. Climate change has been linked to shifts in ecosystem processes, services and interactions that affect how many organisms thrive including those causing diseases. Yet, how climate change influences specific processes between air, land, life, and water on earth to ultimately affect diseases is still emerging. Collectively partly defined as GeoHealth, it has become topical amidst the coronavirus disease 2019 (COVID-19) pandemic. Thus, its origin partly links to changes in land-atmosphere interactions. Hence, the paper poses questions to better appreciate how climate change influence forces within the Earth system to subsequently impact infectious diseases and management in a holistic approach called "One Health," which GeoHealth is positioned to contribute to. Thus, "One Health" provides pathways to environmentally safeguard and sustain ecosystem health and human well-being.

## 1. Introduction

Risks associated with 10 different disasters of bio-geophysical origins globally including coronavirus disease 2019 (COVID-19) have been found to be interconnected (United Nations University—Institute for Environment and Human Security, UNU-EHS, 2021). The UNU-EHS report conciliates the political space available in health for roles of modern Earth system science in disease origin, early detection, and management, similarly, observed elsewhere (e.g., Gorris et al., 2021; Thazhathedath et al., 2021; Zhu et al., 2020). Of this space is "One Health" which describes the integrated approach to better understand and respond rapidly to diseases at the human-animal-environment interfaces, requiring coordinated, collaborative, multidisciplinary, and cross-sectoral approaches (Lerner & Berg, 2017; Mackenzie et al., 2013). Whilst "One Health" is not new, the urgency has

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resonated with SARS-CoV related zoonotic diseases, from avian influenza H5N1 in 2003 and COVID-19 in 2019. In all these, the contribution of adjustments within the Earth system which involve relationships between air, land, life, and water on earth in shaping the outbreaks remain unsolved. Thus, Earth system science has robust system theories that elicit both mechanistic and deterministic models to potentially complement climate risk models to solve climate-related human health problems, similar to conceptualizations of Yokohata et al. (2019). Yet, the framing of health risks and related incidences of diseases within Earth system science is slowly evolving, leading us to the question "what drive the drivers of diseases?" Climate change is a major health threat and its intersectionality with Earth system elements such as biodiversity in aspects of disease regulation functions of ecosystems is key to solving the question posed. Therefore, we explore the framing of the effects of the multi-stage impacts of climate change on Earth system processes, the changes imposed on ecosystem functions and services, and the downstream influences of infectious diseases. Recent COVID-19 related arguments that health systems must be understood and managed across different sectors are mostly grounded in social-demography, population health, biomedicine, and epidemiology, limiting GeoHealth dynamics and Earth system perspectives. Gorris et al. (2021) make a case for exploring the intersectionality of human and environmental health to benefit from GeoHealth. Therefore, the emphasis on the Earth system as gatekeeper to human health and related dynamics through diverse connectivity phenomena (e.g., Figure 1).

## 2. The Health—Climate Change—Ecosystems Nexus

The Intergovernmental Panel on Climate Change observes that altering ecosystem services in any form shifts their functions significantly especially with warming and exacerbating existing patterns of ill health (Smith et al., 2014). Yet, policy actions of over one hundred countries globally to incorporate climate change into disease monitoring and surveillance has been slow and inconclusive including how infectious diseases result from changing conditions of species (World Health Organization [WHO], 2019). The trend continues amidst ecosystem

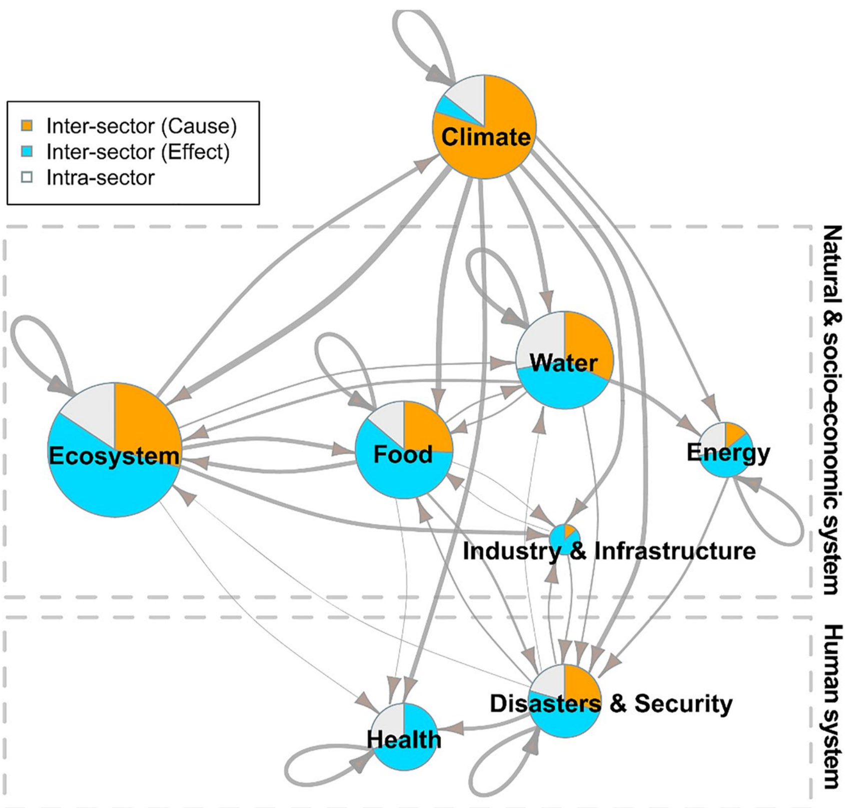


**Figure 1.** Climate risks and their cause–effect relationships shown at the sectoral level, demonstrating the interconnections and the extent of risks, and resulted cause—effect linkages (Yokohata et al., 2019). The arrow thickness indicates the number of risk interconnections represented. Arrows connecting different sectors indicate intersectoral causal relationships, and those looping back to the same sector represent the causal links within the sector, including health.

degradation and the added burden of climate and weather induced shifts to ecosystem functioning found to affect emotional and mental illness amongst several diseases (Sandifer et al., 2017). These typically result from (a) direct impacts related primarily to extreme weather including heat waves, droughts, and heavy rain, (b) effects mediated through natural systems, and (c) systemically mediated by human systems including conflicts, economic instability, and environmental decline (Smith et al., 2014). Therefore, the unpredictable effects of climate change on the interactions between species, and their related functions vis a vis changing patterns in spatial and temporal disease transmission represent one of the largest forecasting uncertainties requiring new perspectives. However, using past, current, and accurate and reliable Earth system data which capture meteorological and climatic information on ecosystem change for health has taken long (Lerner & Berg, 2017; Yokohata et al., 2019).

## 3. One Health Entry for Earth System—The Case of Diarrheal Diseases

Diarrheal diseases which collectively describe cholera, enterotoxigenic *Escherichia coli*, rotavirus, shigellosis, and typhoid is climate-sensitive (Carlton et al., 2013; Dovie et al., 2017). Given that differences in ecosystems influence the feeding habits of different organisms to impose modifications to species and their behavior (Grimm et al., 2013), climate change brings additional burden to resource flow and energy levels within the Earth system that result in further modifications and expected to be different for different Ecosystem Types herein referred to as "Ecotypes" (Figure 2). Therefore, the expected incidence, distribution and transmission characteristics of diarrhea

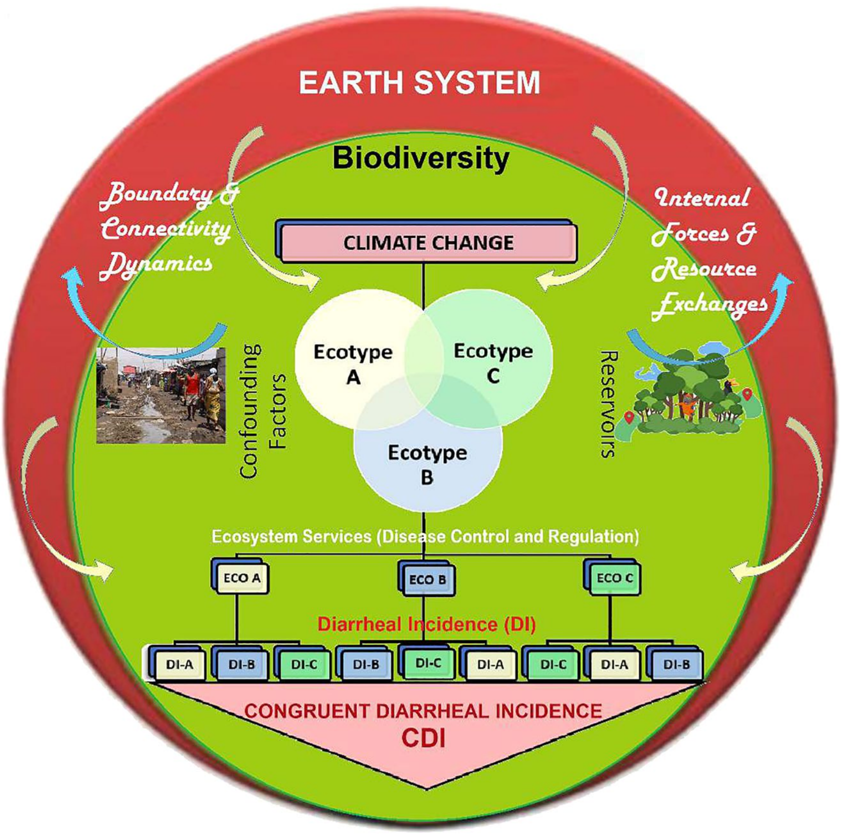


**Figure 2.** Conceptualizing links between diarrheal disease incidence (DI) in different ecosystem types (Ecotype), "A," "B," and "C"; (DI-A)—diarrheal incidence of Ecotype A; (DI-B)—diarrheal incidence of Ecotype B; and (DI-C)—diarrheal incidence of Ecotype C. Diarrhea has multiple sensitivities to ecosystems—related exposure units rather than the direct exposure to the well-established climate change elements such as temperature, precipitation, wind patterns, and their mean conditions. The expected incidence of diarrhea within for example, tropical rainforest areas would differ from coastal areas or savannahs given differences in how climate change drive disease regulation services of the different ecosystems. However, the effects of Earth system process drivers and species reservoirs confound all the ecosystem types, and potentially outweighing and canceling the effects of climate change. Therefore, it is unable to significantly alter the transboundary interactions resulting in a convergence of diarrheal incidence across all Ecotypes (i.e., congruent diarrheal incidence, CDI).

would potentially differ across different Ecotypes. Radiative forcing within the Earth system affects the balance between incoming solar radiation and outgoing infrared radiation, driving the extent to which climate change further adjusts resource flow across ecosystem boundaries of different Ecotypes to additionally drive the disease-causing organisms. It means that for diarrheal diseases, the disease incidence (DI) and subsequent transmission potentially differs for the Ecotypes (Figure 2), from the changing intra-ecosystems processes supporting disease regulation and control services of the different ecosystem types. The ensuing differences in diarrheal DI and function of DI for Ecotype A (DI-A), Ecotype B (DI-B), and Ecotype C (DI-C) will potentially express differently with resultant differences in disease detection and incidence observed. Boundaries and layers within an Earth system, typically the geosphere-biosphere interface is a major determinant of how biodiversity relates to the entirety of the Earth system and disease-causing organisms for which ground water pollution and diarrhea is well established. This has broadly been demonstrated for health in a cause—effect linkage with other sectors impacting health.

## 4. Key Questions for Earth System Science and GeoHealth

The past decade has seen Earth system science research pay attention to the functioning and stability of paleo-ecosystems. Thus, the science has scaled-up the understandings of the interactions among the various components of the Earth system to analyze changes to biodiversity and providing future perspectives on maintaining biodiversity integrity on the unresolved questions of climate change. This has been possible as a result of the mechanization of several theories in Earth systems science for example, boundaries, resilience, connectivity, and interoperability. These broad theories constitute potential formational stages of "One Health" from GeoHealth perspective, and opportunity to frame sector interconnectedness of climate change and health models to interrogate the question "what drive the drivers of diseases."

The resultant energy levels across boundaries in ecosystems, transfer of resources and interactions among species, has been similarly observed for predator-prey interactions, and biodiversity and ecosystem functioning in affecting disease-causing organisms (Grimm et al., 2013). Sorensen et al. (2017) observed that a trigger in natural disasters under irregular climatic conditions force-multiplied the Zika virus, which represents mechanics of multiple sectors across numerous components of the Earth system requiring enhanced observation. Additionally, biodiversity loss has been found to frequently increase the rate of transmission for pathogens associated with over three hundred emerging disease events including the West Nile virus in the Americas, and SARS in humans around the world with climate change as one of the drivers (Keesing et al., 2010). Arguably, there is need to improve understanding of how spatio-temporal processes of climate change and shifts in infectious diseases are predicted (Gorris et al., 2021; Keesing et al., 2010). Thus, the need to establish measurable indicators at the interface of health, climatic factors, and ecosystems and how they feed into temporal trends of the cumulative incidence of climate-sensitive diseases and basis for accounting for the elements of the Earth system across boundaries and connectivity was long overdue. Therefore, prompting the following set of specific sub-questions to comprehensively operationalize data orientation to reduce the awaiting periods of where to start from.

**Question 1** At what thresholds of the impacts of climate change will disease regulation and control services of ecosystems behave in a manner that affect the total expression of diseases?

**Question 2** What attributes of diarrheal diseases related to host—pathogen relationship would be driven potentially by the alteration in the disease control services of ecosystems, and how would this differ for incidence of diarrheal and emerging infectious diseases for different ecosystems?

**Question 3** What sector-interdependent determinants or classifications within the Earth system at scale (e.g., primary, secondary, tertiary, and quaternary) link climate change, ecosystems, character, and expression of diseases beyond the well-known socio-behavioral drivers?

## 5. Conclusion

The transfer and exchange of key resources within the Earth system across the components and boundaries have far reaching implications for biotic interactions including disease-causing organisms. The emerging sub-questions therefore represent pathways to help identify relevant theories as entry points for One Health, the kind of design and data that will be required. Therefore, health sector alone will not offer total understanding for insulating human health against diseases at the intersection of ecosystem integrity and functioning. Hence, pluralistic approaches that encompass technological advances in Earth system science including earth observation systems and more recently artificial intelligence will be pertinent to linking climate change, Earth system processes and disease origin and incidence. Yet the health sector must support the establishment of the indicators of Earth system origin beyond routine health determinants through targeted public health reforms that foster strong health, sustainability and social-ecological resilience for climate-sensitive infectious disease. Hence the need for modern Earth system science research to use recent mechanistic models of climate change to fully assess the effects of varying Earth system models for climate risk prediction and detection of infectious diseases within different anthropocentric and geopolitical contexts of ecosystems which "One Health" supports.

## Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

## Data Availability Statement

There are no underlying data needed to understand, evaluate, and build upon the reported research hence there was no use of any data repository or data from unpublished sources. Any use of figures and other information were directly extracted from the accompanying references in the manuscript and listed under the reference section below. Additionally, no software was used that generated significant impact on the reported research or manuscript.

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