




OPINION ARTICLE

REVISED **Climate change, migration and health systems resilience: Need for interdisciplinary research [version 2; peer review: 1 approved, 3 approved with reservations]**

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Abstract

Climate change is one of today's major challenges, and among the causes of population movement and international migration. Climate migrants impact health systems and how their ability to respond and adapt to their needs and patterns. To date, the resilience of health systems in the context of climate change has barely been explored. The purpose of this article is to show the importance of studying the relationship between climate change, migration, and the resilience of health systems from an interdisciplinary perspective. Resilience is an old concept, notably in the field of psychology, and is increasingly applied to the study of health systems. Yet, no research has analysed the resilience of health systems in the context of climate change. While universal health coverage is a major international goal, little research to date focused on the existing links between climate, migration, health systems and resilience. We propose an interdisciplinary approach relying on the concept of health system resilience to study adaptive and transformative strategies to articulate climate change, migration and health systems.

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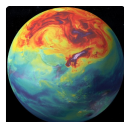
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REVISED Amendments from Version 1

On behalf of our co-authors, we are happy to submit a new version of the document. Thanks to the reviewers' comments, we have improved the manuscript mainly in terms of:

1. Rephrasing better the ideas we wanted to present and the linkages between climate change, migration, health systems resilience, and interdisciplinarity research.
2. Strengthening the arguments and examples (figures and boxes) and making them more explicit in the text to better support our messages.
3. Clarifying sentences and better contextualizing some citations to avoid confusions identified in the precedent version.
4. Integrating since the beginning the message 'for interdisciplinary research' to give robustness our final recommendations/conclusions.

We hope our efforts are reflected on a better comprehension of the reader.

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See referee reports

Introduction

"Four thousand migrants arrive in Dhaka, the capital of Bangladesh due to various 'push' factors including frequent natural disasters"¹. Environmental changes due to climate change are projected to cause substantial increases in population movement, within and between countries, in the coming decades. Haiti faces a similar situation according to a 2008 report it is estimated that 100,000 people have moved for climate change reasons from rural areas to the capital Port-au-Prince². Environmental changes (e.g. drought, soil erosion, extreme weather events, etc.) lead to substantial impacts on health, economic and political dimensions at the population level, including influencing migration patterns and may result in adverse health outcomes, both for displaced and for host populations³⁻⁵. The World Health Organization (WHO) consistently identifies climate change as a defining challenge of the 21st century; and considers it an emerging priority for the public health community to ensure protection against its health impact^{6,7}. In 2015, The Rockefeller Foundation and *The Lancet* published the report of the Commission on Planetary Health⁸ and the UN Sustainable Development Goal 13 calls for "urgent action to combat climate change and its impacts".

For this article, we conducted a heuristic non-systematic literature review on climate change, migration and health systems. As a result of a peer-reviewed article search in the PUBMED database using climate change, health systems, and migrants as keywords, only 10 results published between 1994 and 2017 were identified. Of these, six (60%) were written in the past decade and included: two opinion papers, two study reviews,

one qualitative study, and one protocol for a review that will be completed in 2018.

In this article, we describe and discuss the fundamental role that health care systems resilience can play in this regard and we identify interdisciplinary research as key to better understanding the existing linkages between climate change, migration and health systems and how to build more resilient health systems. We also propose some questions and axes to orient future research proposals.

Climate migrants and health challenges

Climate change can be translated to many forms of environmental degradations, including hurricanes⁹, rising sea levels, and/or reduced rainfall in drylands and water scarcity¹⁰. Populations confronted by climate change consequences such as exposure to hazards, loss in land productivity, absence of habitability, and/or shortage of food/energy/water security may have difficulties to subsist in a given area¹¹. Climate change consequences compounded by socio-economic pressures and/or political instability, increase propensity to migrate. Although evidence is still missing to prove this association, environmental factors are increasingly influencing a complex pattern of human mobility. A recent paper suggests "a statistically significant relationship between fluctuations in asylum applications and weather anomalies"¹². Climate migrants may be forced to leave their homes due to rapid-onset disasters, such as flooding and hurricanes (as in Haiti and Bangladesh for example)^{1,2,13,14}.

Nowadays, there is no conceptual consensus on the notions of environmental refugee or climate change migrants yet, or the more rarely used terms ecomigrants or environmentally displaced persons^{15,16}. Since 2007, the International Organization for Migration (IOM) has defined environmental migrants as "persons or groups of persons who, for compelling reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad"¹⁷. Others suggest restricting the definition to victims of extreme weather, drought/water scarcity, and sea-level rise and excluding the effects of the spread of tropical diseases¹⁶. The simple fact is that the implications climate change are unknown will bear on the distribution of the world population¹⁸. Current estimates range between 25 million and 1 billion people by 2050. and according to the 2017 Lancet Countdown report "the total number of people vulnerable to migration might increase to 1 billion by the end of the century without significant further action on climate change"⁵.

Climate-related migrants may or may not perceive how climate change influences and has an impact on their health needs and social patterns. For example, in Burkina Faso, the close relationship between climate change and flooding is not always fully perceived by the Burkina population suffering from it, as documented by the authors of this manuscript in previous studies. (Box 1) However, climate-related migrants experience difficulties

or face challenges similar to those of refugees fleeing war and/or political persecution: overcrowded settlements, unsanitary conditions, poor nutritional status, unsafety, inequity and limited access to health services^{1,2,19,20}. Although these migrants may experience similar situations with regard to their health and access to healthcare research has focused almost exclusively on the latter rather than on the former. In addition, environmental change migrant population are usually the most vulnerable because migration is often expensive and climate change factors can easily be in addition to other strong socio-economic factors. For example, Haiti and Bangladesh were respectively ranked 3rd and 6th globally in the Long-Term Climate Risk Index (CRI) from 1995 to 2014²¹, while their health systems' performance were ranked by the WHO in 2000 as 138th and 88th, respectively, out of 191 countries²². The very recent Global Climate Risk Index 2018 confirms Haiti and Bangladesh as high risk countries but also shows that several African countries (Mozambique, Malawi, Ghana, Madagascar) are highly affected and have little research on climate migrants²³.

Box 1. Local perception about the link between climate change and flooding by displaced population in Burkina Faso

A recent survey of Sahelian floods in Ouagadougou, Burkina Faso²⁴, reveals that climate change is not perceived by the population as being responsible for the floods. They consider that the responsibility lies more with the authorities who did not act to maintain the water supply facilities. The links with climate change do not seem to be perceived by the citizens of Ouagadougou. In the meantime, they also report changes in overwintering dates, an increase in extreme rainfall incidence and precipitation variability. There are several documented direct and indirect health impacts associated with such patterns such as increases in water-borne and vector borne diseases or food security^{10,25,26}. These patterns in regards to the change in precipitation regimes with increases in the frequency of extreme wet and dry years are known to be intensified in the context of climate change²⁷.

In parallel, some individuals might be escaping slow-onset disasters, such as rising sea levels and declining agricultural yields; their migration patterns may be more similar to those of rural–urban migrants, and they might experience many similar obstacles and barriers to their health as well²⁸. It can be observed from the literature that some health related challenges may be identical between these migrant groups: First, the re-emergence of infectious diseases and geographical migration of diseases²⁹. Migrants spatially re-distribute infections from endemic areas to new populations; they are also exposed to new diseases due to unsanitary living conditions. Second, reduced access to health-care services: mass migration applies population pressure which can exceed the capacity of the local health and social services. Perceptions of long wait times, confusing administrative procedures, or discrimination also impede health system access for migrants³⁰. Third, disrupted social support networks contribute to adverse mental health outcomes³¹, higher risk of violence, and spread of STIs, including HIV infection. Migrants are often perceived as potential security challenges for countries^{18,32}. Niger is one example that has conducted research to understand

the phenomenon of infectious diseases and migration, and how the health system can best adapt (Box 2).

Box 2. Malaria and migration in Niger

Niger, and its Agadez region, has long been known as a crossroads for the regional transhumance and immigration to the North of the Country. Agadez is one of the driest regions of the country with a very low and irregular rainfall level and therefore it's classified as a hypo-endemic region for malaria³³. In 2016, Agadez region reported 55411 malaria cases, 37% in adults aged 25 over and 20% in children aged from 1 to 4. These data contrast with the other countries where adults aged 25 and over account for only 17.4% and children aged 1 to 4 account for 42.6% of malaria cases³⁴. In fact, this is not an isolated case because the data for the last 6 years show a similar pattern. This may be explained in part by the irregularity of malaria transmission, which can lead to a loss of immunity to malaria by the population³⁵. However, it is also important to consider that people that travel through this region are primarily young adults. One hypothesis could be that several cases reported as indigenous cases are, in fact, exported cases that have very different profiles (*Plasmodium falciparum* strain, drug resistance, associated pathology, behaviour toward the illness, etc.). Niger's malaria control programs must adapt to these challenges.

However, the lack of consensus on what constitutes a climate change migrant suggests that the same concept is defined differently across a wide range of non-integrated disciplines, leading to poor documentation of the health needs and health seeking behavioral patterns of climate change migrants.

Climate change and health systems

With its inclusion in Goal 3 of The Sustainable Development Agenda, the concept of Universal Health Coverage (UHC) has obtained consensus from the international community³⁶. UHC, regarded as the third global health transition³⁷, or, according to former WHO director Margaret Chan, “*the most effective concept that public health can offer*”, aims at ensure access to good quality care and limit the impoverishment of people as a result of their illness³⁸. In September 2015, the Director of WHO/PAHO for the Americas, Carissa F. Etienne, stated that “*we must all cooperate to reduce those factors that are contributing to climate change and to mitigate its health effects.*” Health systems are one of the major mediators in this relationship between climate change and population health. Consecutively, in September 2017, the new WHO Director-General has set UHC as his greatest challenge and highlighted at the UN General Assembly on Migration Health in New York City that “*health systems must be sensitive to the needs of migrants.*” The direct and indirect effects of climate change on population health and disease development are now well discussed^{5,39}, but there is still little literature on the health effects of migration (within and between countries) influenced by natural disasters and droughts exacerbated by climate change⁵. In addition, the role of the health care system as a social determinant of health⁴⁰ and its capacity to protect populations affected by climate change was recently identified by WHO⁶ and the Canadian Public Health Association (CPHA)⁴¹. Following the famous Canadian approach to health promotion and the social determinants of health,

CPHA emphasizes, for example, the principles and practices of environmentally responsible health care.

Health systems (and health professionals) suffer the shocks provoked by climate change and migration^{42,43}. These shocks can be the direct consequence of climate change (floods, heat waves, hurricanes, etc) or indirect effects, i.e. the influx of patients suffering from diseases whose emergence or abnormally high frequency is due to climate change⁴⁴. Therefore, health care systems need to adapt to population migration (in and across countries) due to climate changes by considering the effects of both phenomena: 1) the diseases epidemiology evolution⁴⁵ (e.g. dengue vs malaria) and its impact for the population behavior and important skills for health professionals and 2) the identification and response to specific social (e.g. social acceptability of migrants)⁴⁶ and health problems of patients and professionals (e.g. mental health) in this context. In this sense, there is a very close link between UHC and emergency preparedness, as the WHO has just pointed out calling for “*a mutual reinforcement of emergency preparedness and health systems strengthening strategies*”. Health security must also be achieved through good health systems preparedness for disasters caused by climate change⁴⁷. The capacity of health systems and their actors to prepare for and adapt to these climate-related shocks is known as *resilience*.

Current research practice largely overlooks the interconnection between climate change, migration, and health system, so the three areas of work are largely treated in isolation from one another. However, to better understand how health systems may be resilient to climate change shocks, the collaboration and integration of different areas of work is needed.

Health systems resilience in the climate change context: still unclear concepts

According to the Sendai Framework (2015–2030) adopted at the Third United Nations World Conference on Disaster Risk Reduction in March 2015, it is essential “*to enhance the resilience of national health systems*”⁴⁸. Still, very little attention has been paid to the role of the health system resilience in responding to climate change^{42,43,49}. One of the major global health journals (*Health Policy and Planning*) released in November 2017 the first, to our knowledge, supplement issue about “Resilient and Responsive Health Systems”⁵⁰. None of the 11 articles, however, addressed climate change. Similarly, in 2015, WHO proposed an operational framework to build climate resilient health systems within the context of climate change⁴², but the scientific and empirical basis for its production is unclear, and the issue of population migration is not mentioned.

Thus, the question of health system resilience regarding climate migration is still in its infancy regarding the concept itself and its indicators.

Resilience is a longstanding concept in the disciplines of life sciences, psychology (Box 3) and climate change⁵¹, but it is relative new to the study of health systems^{43,52,53}. Health systems are compounded of both hardware (structure, organization, technology, resourcing) and software (values, norms, actors, relationships)

components, and their resilience requires that they be understood and measured accordingly⁵⁴.

Box 3. The origin of the concept of resilience in the field of psychology and its applicability on climate changes consequences today

According to the Merriam Webster dictionary, the first use of the term resilience dates back to 1807. It was then used in physics about the ability of materials to resist shocks or regain their original shape after being compressed or deformed⁵⁵. During the 1970s, in community psychiatry, we look at the phenomenon of so-called “invulnerable” children who, in the confrontation of stress and adversity, do not develop psychological disorders. In 1979, the child psychiatrist Michael Rutter uses the term resilience to describe these children he is studying to understand what are the protective factors that allow them to cope with stress^{56,57}. His work has notably helped to identify social support as one of the main protective factors. The definition of resilience used today to study the capacity of health systems to cope with the consequences of climate change is consistent with this work. The Intergovernmental Panel on Climate Change defines resilience as: “*the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation*”⁵⁸.

Recently, an article has developed a non-normative index for assessing the resilience of health systems, but its validation has not yet been completed⁵⁹. The Lancet Countdown paper series has adopted an iterative and open approach to the development of indicators to identify the links between climate change and public health. The 2018 Lancet Countdown report suggests some indicators in its section 2 to point out how the health sector should be at the forefront of adaptation efforts, ensuring health systems, hospitals, and clinics remain anchors of community resilience. Among those, indicators 2.1, 2.4, 2.6; 2.7, 2.8,) (Box 4), can be useful to understand the link between climate change and health system resilience. Although the concept of health system resilience adoption is still limited and “*does not capture the quality or effectiveness of efforts*”, as it was described for the 2017 report^{5,60} neither the resilience of health staff nor community is taken into account. The authors of this manuscript consider the selected indicators as a good example to highlight the still reductionist and uni-discipline approach of how *resilience* is interpreted.

Box 4. Some 2018 Lancet Countdown indicators about climate change and health systems⁶⁰

- Indicator 2.1: National adaptation plans for health
- Indicator 2.4: Climate change adaptation to vulnerabilities from mosquito-borne diseases
- Indicator 2.6: National assessments of climate change impacts, vulnerability, and adaptation for health
- Indicator 2.7: Spending on adaptation for health and health-related activities
- Indicator 2.8: Health adaptation funding from global climate financing mechanisms

Health systems' resilience cannot be evaluated only in terms of infrastructures. In contrast, from a more holistic and fundamental research perspective, several recent articles propose conceptual frameworks^{52,53,59} that suggest analysing the five main dimensions of a resilient system: awareness, diversity, self-regulation, integration, and adaptiveness⁵³.

For interdisciplinary research

As described above with reference to existing literature, current research practice largely overlooks interconnections between climate change, migration, and health system. Typically, these 3 areas of work are treated by different groups of scholars, and the various dimensions of the links between migration and health are understood in isolation⁴⁵. In the same way, migration, climate, population's health and resilience of health systems are typically analysed as separate components through disciplines and approaches in silos. Research on the intersection between all these components is very scarce. Consequently, there are gaps and a predominant compartmented analysis on the existing links between all of them. In contrast, interdisciplinary indicates a certain level of integration of knowledge, methods and/or ideas to construct and analyse the issue of study^{61,62}. Hence, interdisciplinary research can lead to a better understanding of the links between migration and health. By applying mixed methods⁶³, and the collaboration of environmental, health and social sciences, strategies can be informed and interventions to protect population health. *"By learning from other researchers one increases the possibilities of creative solutions"*⁶⁴.

Climate change is one of the main challenges of our century, having the potential to trigger important changes in population health which includes forcing migration. The role of health systems in the context of targeting universal health coverage may be central to address these challenges. Moreover, in the contexts of vulnerable populations and victims of climate change, health systems certainly have a very important role to play in preventing and alleviating health problems. However, vulnerable populations must be prepared to address these challenges and their resilience to climate change and potential subsequent population movements (climate migrants) is essential. This is why, for example, countries in the Americas Region adopted their health systems resilience policy in 2016 in favor of the UHC⁶⁵.

As revealed in this manuscript, the research on the intersection between climate change, health systems, and migrants is still very scarce. Because of its complexity, we need to move from a multidisciplinary (collaboration of different disciplines not necessarily from the beginning and towards a same issue) to an interdisciplinary approach (integration of different disciplines usually through a common design for a integration and holistic understanding of the same issue)⁶⁴ to understand the multiple pathways that link migration driven by climate change and population's health.

Climate change, and in particular the issue of climate migration, is an extremely complex issue at the crossroads of multiple and fragmented research sectors (migration, population, health system, climate). The guide for interaction of the SDGs is a perfect

illustration of the importance of this intersectorality⁶⁶. Thus, in the face of this complexity, it becomes impossible to mobilize fragmented disciplinary approaches in silos (earth science, demography, political science, economics, anthropology, clinical science, etc.) because they alone will not make it possible to understand the holistic nature of the phenomenon of the relationship between climate migration and health systems. This interdisciplinary approach, "which requires, rather than avoids, disciplinary specialization"⁶⁴ is also essential to understand the concept of health system resilience because knowledge about it is still too fragmented. A recent scoping review of the literature shows that the conceptual of health system resilience has not yet been sufficiently studied from an interdisciplinary perspective⁶⁷. As Bhaskar *et al.* (2017) described "by learning from other researchers one increases the possibilities of creative solutions"⁶⁴ (4) and we definitely need solutions to improve the resilience of health systems for vulnerable population. As a very recent comprehensive review argues, further investments in interdisciplinarity collaborations should be made to unravel the link between climate change, migration, and health system resilience⁶⁸. It is therefore necessary to move beyond sectoral and disciplinary approaches to engage in intersectoral, systemic and interdisciplinary research programs.

We propose a series of interdisciplinary research questions to provide initial guidance in this direction (Box 5). In Table 1 and Figure 1, we suggest a first summarization attempt of the challenges triggered by climate change for the resilience of health systems.

Box 5. Some (non-exhaustive) future research questions

- How is the concept of climate migrant delineated?
- What conceptual frameworks can support research on health systems' resilience to climate change?
- In what ways are the health systems resilient to climate change-related migration?
- What role does climate change play in population movements and what are the health impacts?
- How do people displaced by climate change have access to health systems?
- How to promote health systems' preparedness and resilience in the face of climate change?

Figure 1 illustrates the different possible pathways, the details of which are presented in Table 1. We present them as exploratory to show how many hypotheses there are to test and how many research questions are open. It also shows how only an interdisciplinary approach can certainly help us to respond to them.

The first column of Table 1 proposes four different pathways involving the four elements that concern us here: climate, health system, space, and population. These pathways are more or less direct or complex as shown in Figure 1. The second column presents the possible scenarios in the context of each of these pathways and the last two columns present the challenges they pose to the resilience of health systems. For the first pathway

Table 1. Pathways, scenarios and challenges between climate change, migrations and health systems resilience.

Pathways	Possible scenarios	Challenges for the health system resilience	
		Hard	Soft
1- Climate => Health System	Heat wave, extreme cold	Adaptation of buildings, targeted financing, electricity and water, cold chain strengthening, solar power, health staff uniforms	Engineer and health staff training, ability of the staff to work (and live) on extreme conditions
2- Climate => Space => Health System	Flood, hurricane	Adaptation and location of health facilities, emergency referral system, emergency preparedness	Disaster preparedness training for care and logistics (e.g. drugs), staff delay, staff moods and mental health
3- Climate => Local Population => Health System	Epidemics, new pathologies (dehydration, dengue, etc.),	Organization of an alert system, epidemiological surveillance, adaptation / forecasting of diagnostic capacities (i.e dengue vs malaria tests), vector control prevention	Staff training (pathologies, tests, differential diagnostic, etc.), relationships and trust with the population and between the staffs
4- Climate => Space => Displaced populations => Health System	Population movements, spread of (new) parasites/ viruses, mental health	Logistics anticipation of patients' care, free healthcare, surveillance system, emergency referral system	Migration of staff, social acceptance of the arrival of displaced population and free care for them (all), training of health staff (languages, pathologies, etc.)

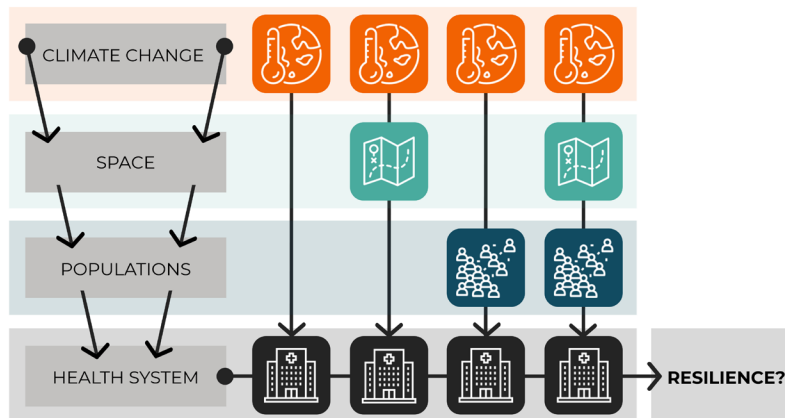


Figure 1. Health systems resilience in the climate change context.

(1), we believe that heat waves and extreme cold pose challenges to health systems (e.g. engineering). The second pathway (2) explains, for example, that climate change can cause floods or hurricanes, which impacts space (territory) and poses new challenges to the resilience of health systems (e.g. training health personnel in disaster preparedness). The third pathway (3) postulates that climate change will have direct effects on local populations, such as the presence of dengue fever in areas where malaria was endemic, which in turn will require the health system and its actors (e.g. power and trust issues) to adapt to these epidemic or pathological changes. Finally, the last pathway (4) we propose is at the heart of our discussion. We propose that it is essential to develop interdisciplinary research to better understand the effects of climate change causing spatial change events (e. g. floods) and thus forcing populations to

migrate (within or between countries), which can have major effects on the resilience of health systems (in home or host countries).

Table 1 is proposed for illustrative purposes, but it shows the complexity of the phenomenon and the multitude of pathways that interdisciplinary research could explore.

Data availability

No data are associated with this article.

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Paddy Enright

University of Waterloo, Waterloo, ON, Canada

Thank you for the opportunity to review this paper. It discusses a topic of growing importance, and hopefully equally growing interest within the research community. Health systems require adaptation in order to meet the needs of migrants and other vulnerable groups. As you point out, interdisciplinary research will be needed to develop, prioritize, implement, evaluate and refine the adaptations needed to build climate-resilient health systems.

In summary your article discusses:

- The role of climate change in driving migration;
- The health impacts of climate change,
- The consequences of both climate change and climate-driven migration for health systems;
- How health system resilience can help address these issues; and
- The need for interdisciplinary research to help build climate-resilient health systems.

I think your paper, particularly Box 5, identifies many important areas where further investigation is needed in order to protect health and wellbeing in both the short and long-term. However, I believe there are some areas where the paper could be strengthened.

In hopes of supporting your efforts to further strengthen the paper, I put forward the following comments for your consideration:

Substantive Comments:

- The abstract states that no research on climate change and health system resilience has taken place, I believe this to be incorrect (e.g. WHO Operational Framework for Building Climate Resilient Health Systems was published in 2015).
- The stated aim of the paper is to advance the case for interdisciplinary research. However, existing barriers to interdisciplinary research and potential options for overcoming these

barriers are not discussed. Highlighting these barriers and suggesting options to address them would substantially add to the paper's value.

- Though you state clearly that this is a non-systematic review, I am believe your search strategy limited your findings and the subsequent results of your paper. For example, by replacing the search term "migrants" with "migration" substantially more results are retrieved. I believe the search could have been further refined to help support the development of the paper. Additionally, a broader review of the grey literature (e.g. climate change and health vulnerability and adaptation assessments conducted by organizations such as the WHO and World Bank) may be beneficial.
- The argumentation throughout the paper is loose and statements that appear definitive or conclusive are made without providing the evidence or context needed to support them. For example, readers are directed towards the text boxes for further information but the information in question isn't concretely discussed within the text boxes.
 - Consider revising Box 1 to link more directly with the text. Currently the text provides more insight on climate change perceptions than on the role of climate change in migration and health.
 - Currently Box 2 does not appear to discussion adaptation, as mentioned in the text that proceeds it (though it mentions adaptation is needed). Consider revising to either discuss adaptation or more concretely discuss the impacts of the intersection of migration and malaria on Niger's health system(s).
- UHC is often discussed, but its role in building climate-resilient health systems isn't made clear. Consider revising the text to better make the connection between UHC and climate-resilient health systems. Additionally, UHC systems still require adaptation to be climate-resilient, what specific adaptations would most benefit migrants?
- The text describing the vulnerability of health systems to climate change could be stronger. I suggest clearly defining what is meant by a health system at the beginning of this section (paragraph 1 page 5 of the pdf version) and detailing examples of impacts to each constituent component (e.g. infrastructure, health workforce, health information systems, health policy and governance, etc.). Providing additional context on how these impacts will influence the health and wellbeing of migrants, or how migration may further strain the components of health systems, would also help readers make the link between health systems and migration and the need for interdisciplinary work in this area.
- You introduce the concept of resilience indicators and provide examples of efforts to measure resilience. However, you do not connect measuring climate-resilience to migration or make the case for resilience indicators that meet the needs of migrants and other vulnerable groups. I suggest revising this section to make the link to the health and wellbeing needs of migrants.
- Greater explanation is needed for how Figure 1 and Table 1 were developed. For example, I assume the possible scenarios column is not meant to be exhaustive? If not, consider making this clearer.
- In Table 1 additional explanation is required for the differentiation between hard and soft challenges and how this differentiation was made. For example, why is logistics a soft challenge? I would propose that the climate hazards that impact health systems may also disrupt health supply chains.

Additional non-substantive items for your consideration:

- In the development of the paper generally, but specifically Figure 1 and Table 1, was any consideration given to cascading or simultaneous hazards or disasters and their impacts? If

- not, considering the role of cascading hazards and their implications for migration and health systems may be a worthwhile area for future research.
- Given that you address the role of 'space' in Figure 1 and Table 1, has any consideration been given for the role of 'place'? How do perceptions of place and identity impact the implications of migration from a health and health systems perspective?
 - Additional research items for consideration within Box 5:
 - How do the health impacts of climate change and access to health care differ for internally displaced populations versus international migrants?
 - What considerations are there for displaced Indigenous Peoples?
 - How is mental health and access to mental health care impacted by climate-driven migration? Do climate-driven changes to space and place impact the views of migrants on returning to their homes?
 - What added considerations are there for those displaced from rural and/or remote regions to urban centres?
 - What long-term implications are there for health systems planning and investments (particularly considering the long lifespan of many health system components)?

Is the topic of the opinion article discussed accurately in the context of the current literature?

Partly

Are all factual statements correct and adequately supported by citations?

Partly

Are arguments sufficiently supported by evidence from the published literature?

Partly

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: health impacts of climate change; climate-resilient health systems; health adaptation

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 21 September 2020

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**Cunrui Huang**

School of Public Health, Sun Yat-sen University, Guangzhou, China

The article describes the significant future research directions on climate change, migration and health systems resilience, and stresses the importance of interdisciplinary methods. It is a topic of interest to the researchers in the related areas, but the article needs significant improvement.

My detailed comments are as follows:

1. The article does not demonstrate the association between climate change, migration, and health system resilience well, making the full text seem rather fragmented. Table 1 and Figure 1 at the end of the article show the relationship and conceptual pathways among climate change, migration, and health system resilience. It might be more suitable to be discussed in detail in the previous part of the article instead of "For interdisciplinary research" section.
2. The article wants to highlight the importance of interdisciplinary research, but it is not well discussed in the "Climate migrants and health challenges" section.
3. In the "Climate migrants and health challenges" section, the authors use the example in Box 1 to illustrate that some climate immigrants do not realize how climate change influences and has an impact on their health needs and social patterns. However, this has nothing to do with the content before and after the article, nor can it intuitively reflect health challenges.
4. At the beginning of the "Climate change and health systems" section, the association between Universal Health Coverage and health systems is not well explained, making the introduction of Universal Health Coverage incongruent here.

Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Yes

Are arguments sufficiently supported by evidence from the published literature?

Partly

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Climate Change and health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have

significant reservations, as outlined above.

Reviewer Report 24 June 2019

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Lucy Gilson 

Health Policy and Systems Division, School of Public Health and Family Medicine, University of Cape Town, Cape Town, South Africa

Thanks to the authors for these revisions, which strengthen the paper.

Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Yes

Are arguments sufficiently supported by evidence from the published literature?

Yes

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health policy and systems research

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 11 February 2019

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Katharina Waha

CSIRO Agriculture and Food (Commonwealth Scientific and Industrial Research Organisation),
Brisbane, Queensland, Australia

The article calls for further research on climate change, migration and health system resilience and an interdisciplinary approach but does not present a convincing line of reasoning. Often the individual paragraphs seem unconnected.

For example, in the section on “Climate migrants and health systems” I am not sure what the authors are trying to do or say. It’s a loose collection of thoughts to me at the moment. The first two paragraphs are about general impacts of climate change and migration and the authors are careful to not link them directly which is good. The next paragraph is about perception of migrants which is interesting and then the authors move into the Burkina Faso example where it is not clear if people have migrated at all.

I think the topic is interesting and very relevant and one thing that might help to structure the article better, is to clarify whether the authors are interested in the effects of climate change on an *individual's* health (migrants) or a *country's* health system or both. This seems to be mixed up in the article. Table 1 and Figure 1 seems to sort of help with that, but they are not integrated in the text at all, they are just added at the end but should be central to the paper.

Other comments:

- “The estimation that is most widely accepted is that over 200 million persons will be displaced globally by 2050 because of climate change^{13,15,18}”. Inappropriate use of literature. McMichael *et al.* (2012) (13) actually says that 200 million is the figure most widely accepted and refers to Myers (2002) as the source of that figure, but also says that the empirical basis has been questioned. This is an important consideration that needs to be added here. The other two references are not needed then, except if they are given to support the notion of ‘most widely accepted’ in which case I would expect more studies.
- Box 1: Conclusion in the last sentence about perceptions of local populations needing to be enhanced does not follow from previous paragraphs. The authors would have to establish a disconnect between perceptions of climate change and flooding and results from a detection and attribution study in order to conclude that.
- Box 4 and the resilience section: These indicators seem to be for resilience and adaptation planning, not just for resilience. The concept of resilience seems to be important in the article but only got mentioned once in the second last section and there it gets mixed up with adaptation indicators. The Lancet Countdown Report gives some of them as “Adaptation Planning and Resilience for Health Indicators”. Can you strengthen this part and explain better why this is an important consideration?

- “The role of health systems in the context of targeting universal health coverage may be central to address these challenges.” The authors speak about universal health coverage only once before and do not give any reason for this conclusion.
- How are health needs and health system resilience different between “climate change migrants” and other migrants that e.g. flee war? The authors state that they “face challenges similar to those of refugees fleeing war and/or political persecution” and “might experience many similar obstacles and barriers to their health as well”, so why the need to study this topic separately?

Is the topic of the opinion article discussed accurately in the context of the current literature?

Partly

Are all factual statements correct and adequately supported by citations?

Partly

Are arguments sufficiently supported by evidence from the published literature?

Partly

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Climate change impact research

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 17 Apr 2019

Ariadna Nebot, Independent Consultant, Pharmacist and Public Health Specialist, Paris, France

Answers to Katharina Waha who approved with reservations

- *The article calls for further research on climate change, migration and health system resilience and an interdisciplinary approach but does not present a convincing line of reasoning. Often the individual paragraphs seem unconnected.*

Thank you for your feedback. In light of Lucy Gilson's comments, we have tried to reorganize some sections of the article. We hope that this will make more sense.

- *For example, in the section on “Climate migrants and health systems” I am not sure what the authors are trying to do or say. It's a loose collection of thoughts to me at the moment. The first two paragraphs are about general impacts of climate change and migration and the authors are careful to not link them directly which is good. The next paragraph is*

about perception of migrants which is interesting and then the authors move into the Burkina Faso example where it is not clear if people have migrated at all.

We have renamed this first section to better show that its objective is to set the scene for the relationship between climate migrants and health. We have made it clear that the people from Burkina Faso affected by Box 1 have been displaced by flooding, thank you for the comment.

- *I think the topic is interesting and very relevant and one thing that might help to structure the article better, is to clarify whether the authors are interested in the effects of climate change on an individual's health (migrants) or a country's health system or both. This seems to be mixed up in the article. Table 1 and Figure 1 seems to sort of help with that, but they are not integrated in the text at all, they are just added at the end but should be central to the paper.*

We have tried to restructure the article to better show that what interests us is not so much the link between climate migrants and health but rather the link between climate migrants and health system because it has not yet been much addressed by research. We have added text to better integrate and explain Table 1 and Figure 1.

- *Other comments: "The estimation that is most widely accepted is that over 200 million persons will be displaced globally by 2050 because of climate change^{13,15,18}". Inappropriate use of literature. McMichael et al. (2012) (13) actually says that 200 million is the figure most widely accepted and refers to Myers (2002) as the source of that figure, but also says that the empirical basis has been questioned. This is an important consideration that needs to be added here. The other two references are not needed then, except if they are given to support the notion of 'most widely accepted' in which case I would expect more studies.*

Thanks for this very relevant comment. Accordingly, and in order to avoid confusion, we have replaced the figure with empirical basis questioned by the following sentence: "the simple fact is that nobody really knows with any certainty what climate change will mean for human population distribution. Current estimates range between 25 million and 1 billion people by 2050." (Brown 2008) and we have also deleted the 2 references (15, 18); not necessary in supporting the argument anymore.

- *Box 1: Conclusion in the last sentence about perceptions of local populations needing to be enhanced does not follow from previous paragraphs. The authors would have to establish a disconnect between perceptions of climate change and flooding and results from a detection and attribution study in order to conclude that.*

Yes, thanks for this suggestion. We have just deleted the last sentence in order to clarify the disconnection suggested by the reviewer.

- *Box 4 and the resilience section: These indicators seem to be for resilience and adaptation planning, not just for resilience. The concept of resilience seems to be important in the article but only got mentioned once in the second last section and there it gets mixed up with adaptation indicators. The Lancet Countdown Report gives some of them as "Adaptation Planning and Resilience for Health Indicators". Can you strengthen this part and explain better why this is an important consideration?*

Yes, thanks for this comment. It is correct that the Lancet Countdown indicator's section 2 refers to "adaptation, planning and resilience for health" and not only to

resilience. The reason is of course that *adaptation* and *resilience* are directly related and this section 2 aims to put at the front the adaptation efforts to promote and achieve community resilience, as we can see in p.13 of the 2018 Lancet Countdown's report:

"With the observed and future health impacts of climate change becoming increasingly evident, and emission trajectories committing the world to further warming, accelerated adaptation interventions are needed to safeguard populations' health. As the 2030 agenda shows, 45 strategies to improve community resilience are often linked to poverty reduction and broader socioeconomic development imperatives, creating the possibility of no regret scenarios".

However, in this same p.13, it is said that, although the 2018 Lancet Countdown report counts on improved indicators for this section, the community resilience is still few explored and that collected data give more insights in adaptation than in resilience:

"The health sector should be at the forefront of adaptation efforts, ensuring health systems, hospitals, and clinics remain anchors of community resilience. This underrecognised, yet growing area of practice, is the focus of this section."

The data are incomplete, providing more insight into adaptation than resilience, and predominantly allow for process-based indicators."

Therefore, the authors of this paper considered some of these Lancet Countdown indicators as a good example to visibilise the still reductionist and uni-discipline approach of how *resilience* is interpreted. In order to make this intention more explicit; we have added these two-lines in p 7.

- *"The role of health systems in the context of targeting universal health coverage may be central to address these challenges." The authors speak about universal health coverage only once before and do not give any reason for this conclusion.*

We have added some clarifications to this sentence, p 9.

- *How are health needs and health system resilience different between "climate change migrants" and other migrants that e.g. flee war? The authors state that they "face challenges similar to those of refugees fleeing war and/or political persecution" and "might experience many similar obstacles and barriers to their health as well", so why the need to study this topic separately?*

Thanks for this comment. According to what we could find in the literature (and therefore, what is already documented) climate migrants health needs may share similar patterns to refugees and/or to rural-urban migrants (P.4). However, in this same paragraph, we also mention the additional vulnerability that this category of population may have: *"In addition, environmental change migrant population is usually the most vulnerable as well because migration is often expensive and climate change factors can easily lie on the top of other strong socio-economic factor."*

Considering this 'additional vulnerability', the author's underlying hypothesis may be that climate migrants health needs and health system resilience may be slightly different. However, the non-integrated disciplines that can be looking at that doesn't allow to further explore this specificities. We have modified the last statement of this paragraph in order to strengthen this idea: *"However, the lack of consensus of climate*

change migrant suggests how the same phenomenon is defined from different and non-integrated disciplines and, therefore, how climate change migrant health needs and patterns are still scarcely documented. "

Competing Interests: No competing interests were disclosed.

Reviewer Report 04 February 2019

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Lucy Gilson 

Health Policy and Systems Division, School of Public Health and Family Medicine, University of Cape Town, Cape Town, South Africa

This is an important paper on a vital topic. It provides useful directions for future research around climate change, migration and health system resilience. Nonetheless, the overall argumentation of the paper is not fully clear – and so it is difficult fully to judge the use of evidence and assess the conclusions.

The broad argument seems to be intended as:

1. Climate change and migration are inter-linked and have negative health consequences ('climate migrants and health systems').
2. Health systems are vital to tackling public health challenges such as those of climate change and migration ('climate change in the global health context').
3. Whilst there is increasing focus on health system resilience, this has not yet included concern for climate change or migration ('health systems resilience in the climate change context').
4. There is a need for 'interdisciplinary research' on climate change, health systems and migrants ('for interdisciplinary research').

However, whilst the last section presents a case for interdisciplinary research, the earlier sections essentially work towards the conclusion that climate change, migration and health systems are interlinked. In addition, although there is reference to the point that current research is conducted in silos with little consideration of the intersection between these terrains on p.5, this point is not clearly argued previously in the paper.

In supporting the final step of the paper's argument (point 4 above), I suggest, then, that there would be value in strengthening the argument around the current silo-based nature of research in these domains as well as discussing further why and how interdisciplinary research is valuable for this area of work. I propose placing both these sets of issues in the section 'for interdisciplinary research' (some are currently in the previous section). There may also be value in clarifying that in this context 'disciplines' are, I think, equated to areas of work (climate change, migration, health

systems) as opposed to e.g. sociology, anthropology, clinical science etc. And then I suggest it would be helpful to: expand on the point that 'interdisciplinary' means 'a certain level of integration of knowledge, methods and/or ideas' (p.5), and to discuss more than the need for mixed methods; clarify why an interdisciplinary approach is better than a multidisciplinary one for this work (p.5); and deepen the point about the value of the focus on resilience and adaptive strategies in supporting interdisciplinary research (p.5) – as well as explaining more of the detail of Table 1 and Figure 1. (As an aside, in Table 1 I would propose there would be value in thinking about health system software as more than staff training, essentially; relationships among staff within the system and with the public also matter, for example).

In terms of the earlier sections of the paper I was not sure why the first section is titled 'climate migrants and health systems', as the focus is on health challenges rather than health systems. I also found that the logic and structure of the sections 'climate change in the global health context', and 'health systems resilience in the climate change context' made it difficult to follow the argument within them. In 'climate change in the global health context', this might be because the very tight referencing practice has overshadowed the argument. In 'health systems resilience in the climate change context', the linkage between the different points presented is not very clear (i.e. the argument connecting them).

Some other minor points for review in p.3:

- What is an heuristic literature review?
- How are the 10 papers that were identified in the PubMed search used in the text, or is the point here that *only* 10 papers were identified?
- At the first mention, briefly clarify the significance of the Lancet Countdown for this paper.

One final comment: given that this is a very closely argued piece, there would be value in some really close copy editing – as, for example, missing words in sentences, long sentences, and sentences that are phrased quite clumsily, hinder understanding.

Is the topic of the opinion article discussed accurately in the context of the current literature?

Yes

Are all factual statements correct and adequately supported by citations?

Yes

Are arguments sufficiently supported by evidence from the published literature?

Partly

Are the conclusions drawn balanced and justified on the basis of the presented arguments?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health policy and systems research

I confirm that I have read this submission and believe that I have an appropriate level of

expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 17 Apr 2019

Ariadna Nebot, Independent Consultant, Pharmacist and Public Health Specialist, Paris, France

Answers to Lucy Gilson's comments, who approved with reservations

- *This is an important paper on a vital topic. It provides useful directions for future research around climate change, migration and health system resilience. Nonetheless, the overall argumentation of the paper is not fully clear – and so it is difficult fully to judge the use of evidence and assess the conclusions.*
- *The broad argument seems to be intended as: Climate change and migration are inter-linked and have negative health consequences ('climate migrants and health systems'). Health systems are vital to tackling public health challenges such as those of climate change and migration ('climate change in the global health context'). Whilst there is increasing focus on health system resilience, this has not yet included concern for climate change or migration ('health systems resilience in the climate change context'). There is a need for 'interdisciplinary research' on climate change, health systems and migrants ('for interdisciplinary research').*

Thank you for this summary which indeed corresponds to the approach we adopted in our paper.

- *However, whilst the last section presents a case for interdisciplinary research, the earlier sections essentially work towards the conclusion that climate change, migration and health systems are interlinked. In addition, although there is reference to the point that current research is conducted in silos with little consideration of the intersection between these terrains on p.5, this point is not clearly argued previously in the paper.*
- *In supporting the final step of the paper's argument (point 4 above), I suggest, then, that there would be value in strengthening the argument around the current silo-based nature of research in these domains as well as discussing further why and how interdisciplinary research is valuable for this area of work. I propose placing both these sets of issues in the section 'for interdisciplinary research' (some are currently in the previous section). There may also be value in clarifying that in this context 'disciplines' are, I think, equated to areas of work (climate change, migration, health systems) as opposed to e.g. sociology, anthropology, clinical science etc. And then I suggest it would be helpful to: expand on the point that 'interdisciplinary' means 'a certain level of integration of knowledge, methods and/or ideas' (p.5), and to discuss more than the need for mixed methods; clarify why an interdisciplinary approach is better than a multidisciplinary one for this work (p.5); and deepen the point about the value of the focus on resilience and adaptive strategies in supporting interdisciplinary research (p.5)*

Thanks for this very pertinent comment. Following your recommendations, we have reviewed each section and introduced at the end of section 1, section 2 and section 4 how interdisciplinarity may be useful to address the current gaps regarding the elements we describe about climate change, migration and health systems resilience. We have also included a few sentences to describe the importance of distinguishing

interdisciplinary from multidisciplinary.

- *As well as explaining more of the detail of Table 1 and Figure 1. (As an aside, in Table 1 I would propose there would be value in thinking about health system software as more than staff training, essentially; relationships among staff within the system and with the public also matter, for example).*

A presentation and explanation have been provided in the article now.

- *In terms of the earlier sections of the paper I was not sure why the first section is titled 'climate migrants and health systems', as the focus is on health challenges rather than health systems.*

The subtitle of this section has been changed to "climate migrants and health challenges".

- *I also found that the logic and structure of the sections 'climate change in the global health context', and 'health systems resilience in the climate change context' made it difficult to follow the argument within them. In 'climate change in the global health context', this might be because the very tight referencing practice has overshadowed the argument.*

We have reviewed the flow of this section, and the subtitle of this section has been changed to "climate migrants and health systems".

- *In 'health systems resilience in the climate change context', the linkage between the different points presented is not very clear (i.e. the argument connecting them).*

We have reviewed the flow of this section and changed its subtitle to emphasize the need to continue research on this concept, which is still a little too vague. The last section has been moved to become the first section on the need for interdisciplinarity.

- *Some other minor points for review in p.3:What is an heuristic literature review?*

A review of the non-systematic literature but which only includes useful articles on the subject and to develop our arguments. We made this clear in the correction.

- *How are the 10 papers that were identified in the PubMed search used in the text, or is the point here that only 10 papers were identified?*

Yes, the point is that only 10 articles have been published, which shows how little is still written on the subject and the most relevant are cited in our article

- *At the first mention, briefly clarify the significance of the Lancet Countdown for this paper.*

Thanks for this suggestion. We have clarified this significance in the text (p.7)

- *One final comment: given that this is a very closely argued piece, there would be value in some really close copy editing – as, for example, missing words in sentences, long sentences, and sentences that are phrased quite clumsily, hinder understanding.*

We had the latest version revised by a scientific editor, Donna Riley. However, for this re-submission, we have asked an additional native English speaker (Lara Schwarz) to review and edit the whole text.

Competing Interests: No competing interests were disclosed.

Comments on this article

Version 2

Reader Comment 02 Aug 2019

Colin Butler, ANU, Canberra, Australia

PS Sorry, I should have typed 2018, not 2019 (for Nature reference) .. also it might be worth clarifying that assertions of "environmental determinism" generally come from social scientists, who very often underestimate the environmental factors involved, including those that are ecological.

Competing Interests: No competing interests were disclosed.

Reader Comment 02 Aug 2019

Colin Butler, Australian National University, Canberra, Australia

Thanks for this; I haven't read the paper fully or very carefully but am motivated to make one main observation.

You state: "Haiti faces a similar situation according to a 2008 report it is estimated that 100,000 people have moved for climate change reasons from rural areas to the capital Port-au-Prince²."

My comment is that while this World Bank working paper (which I have not read) may be correctly interpreted as reaching the conclusion you report, it is my opinion that many factors are involved in this migration, irrespective of whether climate change is one - and I think it is worth a sentence commenting on this, otherwise your paper risks being dismissed as an example of "environmental determinism", when the explanation is much more likely a combination of ecological and social factors.

This is a point which we expand on in a letter in Nature published in 2019 (doi: 10.1038/d41586-018-03795-0) which states in part "environmental and ecological factors interact with social determinants, including those that are economic, demographic and political, to produce phenomena such as migration, conflict and famine .. Including such environmental factors and multipliers will improve understanding of the causes of conflict. Without these, models for studying conflict could become an oversimplified form of social determinism."

I also noticed an incorrect use of "it's".

BTW I am the author of the final reference (68) - thanks for citing it.

Competing Interests: No competing interests were disclosed.

Version 1

Author Response 22 Mar 2019

Ariadna Nebot, Independent Consultant, Pharmacist and Public Health Specialist, Paris, France

Answers to Lucy Gilson comments, who approved with Reservations

- *This is an important paper on a vital topic. It provides useful directions for future research around climate change, migration and health system resilience. Nonetheless, the overall argumentation of the paper is not fully clear – and so it is difficult fully to judge the use of evidence and assess the conclusions.*
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mixed methods; clarify why an interdisciplinary approach is better than a multidisciplinary one for this work (p.5); and deepen the point about the value of the focus on resilience and adaptive strategies in supporting interdisciplinary research (p.5)

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- *As well as explaining more of the detail of Table 1 and Figure 1. (As an aside, in Table 1 I would propose there would be value in thinking about health system software as more than staff training, essentially; relationships among staff within the system and with the public also matter, for example).*

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***** the subtitle of this section has been changed to "climate migrants and health challenges".**

- *I also found that the logic and structure of the sections 'climate change in the global health context', and 'health systems resilience in the climate change context' made it difficult to follow the argument within them. In 'climate change in the global health context', this might be because the very tight referencing practice has overshadowed the argument.*

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- *Some other minor points for review in p.3:What is an heuristic literature review?*

***** A review of the non-systematic literature but which only includes useful articles on the subject and to develop our arguments. We made this clear in the correction.**

- *How are the 10 papers that were identified in the PubMed search used in the text, or is the point here that only 10 papers were identified?*

***** Yes, the point is that only 10 articles have been published, which shows how little is still written on the subject and the most relevant are cited in our article**

- *At the first mention, briefly clarify the significance of the Lancet Countdown for this paper.*

*****Thanks for this suggestion. We have clarified this significance in the text (p.7)**

- *One final comment: given that this is a very closely argued piece, there would be value in some really close copy editing – as, for example, missing words in sentences, long sentences, and sentences that are phrased quite clumsily, hinder understanding.*

***** We had the latest version revised by a scientific editor, Donna Riley. However, for this resubmission, we have asked to an additional native English speaker (Lara Schwarz) to review and edit the whole text.**

Answers to Katharina Waha who approved with Reservations

- *The article calls for further research on climate change, migration and health system resilience and an interdisciplinary approach but does not present a convincing line of reasoning. Often the individual paragraphs seem unconnected.*

***** Thank you for your feedback. In light of Lucy Gilson's comments, we have tried to reorganize some sections of the article. We hope that this will make more sense.**

- *For example, in the section on "Climate migrants and health systems" I am not sure what the authors are trying to do or say. It's a loose collection of thoughts to me at the moment. The first two paragraphs are about general impacts of climate change and migration and the authors are careful to not link them directly which is good. The next paragraph is about perception of migrants which is interesting and then the authors move into the Burkina Faso example where it is not clear if people have migrated at all.*

***** We have renamed this first section to better show that its objective is to set the scene for the relationship between climate migrants and health. We have made it clear that the people from Burkina Faso affected by Box 1 have been displaced by flooding, thank you for the comment.**

- *I think the topic is interesting and very relevant and one thing that might help to structure the article better, is to clarify whether the authors are interested in the effects of climate change on an individual's health (migrants) or a country's health system or both. This seems to be mixed up in the article. Table 1 and Figure 1 seems to sort of help with that, but they are not integrated in the*

text at all, they are just added at the end but should be central to the paper.

***** we have tried to restructure the article to better show that what interests us is not so much the link between climate migrants and health but rather the link between climate migrants and health system because it has not yet been much addressed by research. We have added text to better integrate and explain Table 1 and Figure 1.**

- *Other comments: "The estimation that is most widely accepted is that over 200 million persons will be displaced globally by 2050 because of climate change^{13,15,18}". Inappropriate use of literature. McMichael et al. (2012) (13) actually says that 200 million is the figure most widely accepted and refers to Myers (2002) as the source of that figure, but also says that the empirical basis has been questioned. This is an important consideration that needs to be added here. The other two references are not needed then, except if they are given to support the notion of 'most widely accepted' in which case I would expect more studies.*

***** Thanks for this very relevant comment. Accordingly, and in order to avoid confusion, we have replaced the figure with empirical basis questioned by the following sentence: "the simple fact is that nobody really knows with any certainty what climate change will mean for human population distribution. Current estimates range between 25 million and 1 billion people by 2050." (Brown 2008) and we have also deleted the 2 references (15, 18) not necessary supporting the argument anymore.**

- *Box 1: Conclusion in the last sentence about perceptions of local populations needing to be enhanced does not follow from previous paragraphs. The authors would have to establish a disconnect between perceptions of climate change and flooding and results from a detection and attribution study in order to conclude that.*

*****Yes, thanks for this suggestion. We have just deleted the last sentence in order to clarify the disconnection suggested by the reviewer.**

- *Box 4 and the resilience section: These indicators seem to be for resilience and adaptation planning, not just for resilience. The concept of resilience seems to be important in the article but only got mentioned once in the second last section and there it gets mixed up with adaptation indicators. The Lancet Countdown Report gives some of them as "Adaptation Planning and Resilience for Health Indicators". Can you strengthen this part and explain better why this is an important consideration?*

***** Yes, thanks for this comment. It is correct that the Lancet Countdown indicator's section 2 refers to "adaptation, planning and resilience for health" and not only to resilience. The reason is of course that *adaptation* and *resilience* are directly related and this section 2 aims to put at the front the adaptation efforts to promote and achieve community resilience, as we can see in p.13 of the 2018 Lancet Countdown's report: "With the observed and future health impacts of climate change becoming increasingly evident, and emission trajectories committing the world to further warming, accelerated adaptation**

interventions are needed to safeguard populations' health. As the 2030 agenda shows, 45 strategies to improve community resilience are often linked to poverty reduction and broader socioeconomic development imperatives, creating the possibility of no regret scenarios".

However, in this same p.13, it is said that, although the 2018 Lancet Countdown report counts on improved indicators for this section, the community resilience is still few explored and that collected data give more insights in adaptation than in resilience,:

"The health sector should be at the forefront of adaptation efforts, ensuring health systems, hospitals, and clinics remain anchors of community resilience. This underrecognised, yet growing area of practice, is the focus of this section."

The data are incomplete, providing more insight into adaptation than resilience, and predominantly allow for process-based indicators."

Therefore, the authors of this paper considered some of these Lancet Countdown indicators as a good example to visibilise the still reductionist and uni-discipline approach of how *resilience* is interpreted. In order to make this intention more explicit, we have added this two-lines in p 7.

- *"The role of health systems in the context of targeting universal health coverage may be central to address these challenges." The authors speak about universal health coverage only once before and do not give any reason for this conclusion.*

**** We have added some clarifications to this sentence, p 9.**

- *How are health needs and health system resilience different between "climate change migrants" and other migrants that e.g. flee war? The authors state that they "face challenges similar to those of refugees fleeing war and/or political persecution" and "might experience many similar obstacles and barriers to their health as well", so why the need to study this topic separately?*

****Thanks for this comment. According to what we could find in the literature (and therefore, what is already documented) climate migrants health needs may share similar patterns to refugees and/or to rural-urban migrants (P.4). However, in this same paragraph, we also mention the additional vulnerability that this category of population may have: "In addition, environmental change migrant population is usually the most vulnerable as well because migration is often expensive and climate change factors can easily lie on the top of other strong socio-economic factor."**

Considering this 'additional vulnerability', the author's underlying hypothesis may be that climate migrants health needs and health system resilience may be slightly different.

However, the non-integrated disciplines that can be looking at that doesn't allow to further explore this specificities. We have modified the last statement of this paragraph in order to strengthen this idea: ***"However, the lack of consensus of climate change migrant suggests how the same phenomenon is defined from different and non-integrated disciplines and, therefore, how climate change migrant health needs and patterns are still scarcely documented. "***

Competing Interests: No competing interests were disclosed.

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