Full title: **Improving an Integrative Framework of Health System Resilience and Climate Change: Lessons from Bangladesh and Haiti**

Short title: **Integrative Framework of Health System Resilience and Climate Change**

Authors:

Valéry Ridde[1*], Mrittika Barua[2], Emmanuel Bonnet[3], Alain Casseus[4-5], Lucie Clech[1], Manuela De Allegri[6], Shamsul Kabir[2], Jean-Marc Goudet[1], Daniel Henrys[5], Muhammed Nazmul Islam[2], Yunona L'Heureux[1], Camille Masselot[1], Dominique Mathon[5-7], Sofia Meistre[1], and Malabika Sarker[2]

1- Université Paris Cité, IRD, Inserm, Ceped, F-75006 Paris, France
2- BRAC James P Grant School of Public Health, BRAC University, Dhaka, Bangladesh
3- IRD, UMR 215 Prodig, 5, cours des Humanités, Cedex, F-93 322, Aubervilliers, France
4- Zanmi Lasante, Cange, Haiti.
5- École supérieure d'infotronique d'Haïti, Port-au-Prince, Haiti
6- Heidelberg Institute of Global Health, Heidelberg University Hospital and Medical Faculty, Heidelberg University, Germany
7- Université du Québec, Montréal, Québec, Canada

* Corresponding author
E-mail: valery.ridde@ird.fr

Abstract

The analysis of health system resilience has progressed significantly, yet there remains a wide diversity in the conceptual frameworks used. The ClimHB conceptual framework, developed in 2019, integrates two influential models: the Levesque model of healthcare access and DFID's resilience framework. Designed to study health system resilience in response to climate-induced events, the ClimHB framework uniquely positions the population as an active participant on the demand side, complementing the supply side of health services and providers. Characterised by three core dimensions – exposure, sensitivity, and adaptive capacity – this dual focus on demand and supply, and their interactions emphasises the dynamic interplay between both sides in shaping health system resilience.

A workshop utilising framework analysis, and the World Café method refined the ClimHB framework by integrating empirical evidence from Haiti and Bangladesh, alongside insights from a literature review. The revised framework presents a dynamic understanding of interrelated resilience, aimed at informing decision-making across all levels of healthcare. It emphasises the importance of contextual factors, strengthens outcome linkages, and incorporates socio-economic and ecological considerations. Governance, professional awareness, and supply-side feedback loops were also emphasised.

Site studies demonstrated the framework's adaptability and ability to foster synergy between theory and implementation. However, challenges persist in operationalising the framework, particularly for policymakers, emphasising the need for validation, standardised measures, and a deeper understanding of resilience interplays. Future research should explore the framework's implications for structural management, training, and resource allocation, addressing critical gaps in resilience research.

Introduction

With the Ebola crisis in Africa and, above all, the global COVID-19 pandemic, analyses of the resilience of healthcare systems have advanced considerably over the last few years (1–5). These analyses have highlighted the characteristics and factors essential for healthcare systems to cope with crises, adapt, and even transform in order to maintain access to healthcare for the population (6–8). While studies have often focused on the tangible aspects of healthcare systems, an increasing number of authors have suggested that power dynamics and stakeholder interactions should not be overlooked in these analyses (9,10). A recent scoping review has again confirmed our analyses of the lack of consensus on the definition of resilience (5,7). Although the scientific community seems to have made progress on the empirical front, we are still far from reaching a consensus and the conceptual maturity essential to any scientific approach. The diversity of the conceptual frameworks used in these studies and the changing nature of the situation suggests that further progress is needed in clarifying our study objectives (1,5,11,12).

In this context, our article aims to present the improvement of our integrative conceptual framework for analysing the resilience of healthcare systems and structures. The ClimHB framework has constructed an integrative model of health system resilience, considering climate change-induced events and population mobility by integrating the Levesque model of healthcare access (13) and the UK Department for International Development's (DFID) conceptualisation of resilience (DFID, 2011). This framework posits healthcare access as a critical outcome of health system resilience and one of the determinants of population health. Few analytical frameworks appear to offer a global and integrative vision for analysing health system resilience (1,5,9).

Initially conceptualised in 2019 for a grant proposal (14) and published with the study protocol in 2022 (15), the novelty of the ClimHB framework lies in its incorporation of the population as an active demand-side participant, juxtaposed with the supply-side comprising health services and providers. Within this construct, health systems' demand and supply sides are characterised by exposure and sensitivity dimensions, which shape their resilience process in conjunction with adaptive capacities. This process, in turn, influences healthcare access and the population's health status (S1 Appendix). Although the framework was originally designed to study events induced by climate change (such as floods, extreme temperatures, population mobility, etc.), the project faced another major crisis: the complexity of the COVID-19 pandemic (16).

Conceptual frameworks occupy a space between empirical approaches and the theories used to study healthcare systems (17–19). In the study of health systems, conceptual frameworks can be used *a priori* to organise hypotheses and guide data collection, *a posteriori* to understand the empirical data collected inductively, or from a "*bricolage*" perspective to interweave the two approaches (20).

In this paper, resilience is not considered as normative. Therefore, it was imperative for the ClimHB framework of health systems resilience in the context of climate change and population (im)mobilities to possess the capacity to encapsulate, guide our data collection, and summarise our findings in Haiti and Bangladesh to ensure validity and facilitate its application. Without revisiting the details of the original construction of the framework and its justification, which can be found in the protocol (15), we have retained the following definition of health system and structure resilience: “the capacities of a health system and healthcare structure facing shocks, stress or chronic destabilising tensions (unexpected or anticipated, sudden or subtle, internal or external to the system), to absorb, adapt and/or transform in order to maintain

and/or improve universal access to comprehensive, relevant and quality healthcare". The key element is viewed through the lens of healthcare access, seen here as an essential outcome of the health system resilience and as one of the determinants of population health. As the seventy-seventh World Health Assembly reiterated once again, there is an urgent need "*to make health systems more climate resilient"* (21). This objective is now central to the draft of the 'Fourteenth General Programme of Work (GPW 14)' by the WHO for 2025–2028.

As the ClimHB project concluded, we employed a framework analysis approach in our culminating workshop to critically appraise and enhance the conceptual model (22). It is important to note that this analytical framework has been used to study health system resilience, particularly in the context of climate change and (im)mobilities in Haiti and Bangladesh which aimed to (i) assess the relative resilience of local health service providers and (ii) delineate the health status and healthcare access patterns among (im)mobile populations within these diverse environments. This article does not present these empirical results, which are still being analysed, but instead offers some conceptual ideas for improving the framework. Two empirical articles on local contexts, seasonal rural-to-rural migration and mental health issues have been published, providing a context for our analyses (23, 24).

We primarily describe the challenges experienced and perceived by our research consortium team members in implementing the ClimHB conceptual framework, highlighting the need for its adaptation. Then, we present the revised framework considering emerging research findings in Bangladesh and Haiti and based on an interdisciplinary discussion. Finally, we present avenues for its applications and future research.

Material and Methods

This article is one of very few reflective analyses on the use of conceptual frameworks to analyse healthcare systems (5). After a preliminary analysis (25), this paper offers a collective reflective analysis (26) to present results from a group reflection aimed at revising the framework.

We convened an on-site workshop in November 2023 to enhance the ClimHB project's integrative conceptual framework through collaborative engagement with stakeholders (senior and junior researchers) directly involved in the project's execution and oversight.

The workshop's methodological approach was the World Café, a participatory technique designed to facilitate open and creative conversations to shape a collective understanding of the subject matter (27). The workshop was planned by CM, VR, and SM and facilitated by CM. We employed a framework analysis approach to analyse its results (22). Posters of the ClimHB framework were displayed on the walls, and participants were provided sticky notes and markers to offer their corrections directly on this printed version (S2 Appendix).

We structured the workshop into four sequential phases: i) Imagine - participants were prompted to empathise with potential end-users of the framework and articulate their initial reactions and emotional responses upon encountering the framework; ii) Define - participants were tasked with identifying and elucidating a component of the framework they deemed critical, providing a rationale for their selection; iii) Refine - working in groups, participants employed their empirical findings and expert knowledge to propose enhancements to the framework using sticky notes; iv) Synthesis and consensus - the workshop culminated in a plenary session where the modifications suggested by the various sub-groups were collectively examined, and consensus was reached on the amendments to be adopted.

To capture data accurately, the workshop was recorded using Zoom and transcribed verbatim using the Otter.ai service. To ensure confidentiality, no personally identifiable information was included recorded during the transcription process, resulting in anonymised transcripts. CM then corrected the transcripts.

The conceptual framework was refined through a thematic analysis of the workshop transcripts and the visual outputs provided by the participants. Visual aids are often essential for understanding concepts. Dagognet's (28) work clearly shows the extent to which visual images play a part in constructing knowledge. It is worth noting that the first version of the framework benefited from collaborative work between the researchers and a firm specialising in scientific graphic design (Agence IMPAKT Scientifik, https://www.impaktsci.co).

This analysis used a deductive approach to identify required changes in the existing dimensions and links or to pinpoint missing elements. This was supplemented by an inductive approach aimed at uncovering research gaps mentioned by the participants. Representative quotations from the transcripts are incorporated into the results section to substantiate the modifications made to the framework.

Once all the data had been analysed and a first draft of the article had been produced, YL and VR conducted a literature review focusing on the elements that would strengthen the argument and suggest further improvements. Finally, all the article's authors reviewed the paper and provided feedback on how to improve it.

Ethics approval and inclusivity in global research: Ethics approvals have been granted from the Institutional Review Board (IRB) of the BRAC James P Grant School of Public Health, BRAC University (ref: IRB-19 November'20–050) in Bangladesh and from the National Bioethics Committee in Haiti (ref: 2021–10). Information about the study was provided before

data collection, verbal consent was collected, respondents were informed of their right to withdraw at any moment, a debrief with respondents was conducted at the end, and written consent were collected before leaving.

Results

Participants

Twelve people participated in the workshop. Attendees included four members from the Paris-based coordination and research team, two representatives from the research team in Haiti, three from the research team in Bangladesh, and three external collaborators.

Box 1 presents the challenges identified in the comprehension and application of the ClimHB conceptual framework.

- ClimHB framework potential users:
    - Policymakers
    - Researchers
    - Educators
    - Healthcare providers
    - Study participants
- Challenges in its applications:
    - Overly complex for policymakers needing quick, actionable insights
    - Lack of clarity and explicit articulation of components

- Failure to establish several connections necessary for a comprehensive understanding of health system resilience
- Framework perceived differently depending on the user's perspective and needs
- The concepts and complexity of the framework may require a level of literacy and scientific knowledge that is not readily accessible to the study participants

Research teams in Haiti and Bangladesh were the primary users of the ClimHB conceptual framework. During our final workshop, we identified several stakeholders who could benefit from using the ClimHB conceptual framework. These included policymakers, researchers, educators, healthcare providers, and study participants. However, after considering the perspectives of its potential users and uses, it became evident that the ClimHB framework required refinement. Specifically, the conceptual framework appeared overly complex for policymakers who require a quick understanding of actionable areas and the identification of pertinent actors, facilitators, and barriers in decision-making processes.

Similarly, depending on their use, it appeared overly intricate or incomplete for students and researchers. While regarded as a "good summary", the conceptual framework failed to establish several connections between domains necessary for a comprehensive understanding of health systems resilience. The section related to the latter prompted confusion among participants due to a lack of clarity and insufficient articulation of its components.

Below, we describe the new ClimHB conceptual framework (Figure 1), its components, and the changes we made to them.

Figure 1. Revised ClimHB integrative conceptual framework

The ClimHB framework distinguishes itself by the visual representation of the population as a component of the health system - i.e. the demand side - side by side and interacting/interdependencies with the health services and providers - i.e., the supply side, which together includes all dimensions of the health system and access to the healthcare system. In this synergistic model, the demand and supply sides are conceptualised as reflective entities that underscore their equal contribution to the health system's resilience. Both sides mirror each other to highlight their similarity in their contribution to the central resilience process. In the center of ~~the~~ figure 1, we aim to represent the process of resilience and its impacts on the health system or health facilities using the image of a transfusion bag where fluid – comprised of a mixture of exposure and sensitivity (itself containing elements of demand and supply side access) - is flowing. While we acknowledge that other social determinants also affect these outcomes, we have not visually represented them in the figure to avoid overloading it and maintain clarity by focusing only on outcomes directly associated with the healthcare system.

The resilience of the health system, depicted in green, is the combination of the demand side (red) and the supply side (blue) of healthcare access spanning across exposure, sensitivity, and adaptive capacities (pictured in green). The interplay between these attributes—where adaptive capacities are influenced by the nature and magnitude of exposure and sensitivity—determines the health system's ability to respond to disruptions. Exposure concerns “the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources;

infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected" (29) and can be measured as an "assessment of the magnitude or/and frequency" of "disturbing" events (30). Sensitivity is the degree to which a system will/might be affected by, or respond to, a disturbing event (30), such as climate change or variability (29). Adaptive capacities and abilities are determined by the abilities of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or respond to consequences (29), allowing actors "to anticipate, plan, react to, and learn from events" (30). The system's capacity to handle all types of disturbances depends on exposure, sensitivity, and adaptive capacities, with adaptive capacities interacting with the nature and degree of exposure and sensitivity.

Figure 2 and 3 detail the components the demand and supply sides of health systems and how they affect and contribute to its resilience.

Figure 2. Demand-side of healthcare access and health system resilience in the context of climate change and (im)mobilities

In the following lines, we present the framework's dimensions in more detail, as outlined in the previously published protocol (15).

(1) Population (im)mobilities refer to a) all mobilities from daily movements to displacement or long-term migration, and b) all situations of immobility, whether involuntary or voluntary. Mobility is represented by the red tube, while immobility is depicted by the red tube with the knot. The four symbols above represent all events disrupting the determinants of population abilities and healthcare access abilities, such as contexts (political, geographical, economic), sudden shocks (or sudden events), stresses (long-term trends), challenges, and chronic tensions

affecting the supply and/or the demand side. Because the ClimHB project focuses on the context of climate change and population mobilities and (im)mobilities, which may influence other determinants, (im)mobility was selected from the list of determinants from Levesque and included in (1.) with a focus on migratory status, in interaction with shocks and events. Due to the numerous categories of mobilities that might interact with each other, "(im)mobility" was also retained in the determinants (2.), with a focus on physical capacities (ability to move or stay).

(2) Determinants of population abilities include all socio-economic characteristics of the individuals and their communities, ranging from empowerment to various forms of capital and health literacy. These determinants are presented by the red fluid.

(3) Population abilities to access healthcare encompass the five dimensions of access, capturing the demand-side determinants (cited in 2.): the abilities to perceive, seek, reach, pay, and engage. This is represented by the red bag (tube and fluid).

Population (im)mobilities, population abilities, and population abilities to access healthcare (1., 2., and 3.) are presented linearly due to the 2D format but are interconnected in 3D space; i.e., population abilities to access healthcare might be influenced by, and might influence, both population abilities and population (im)mobilities. Events may (or may not) impact mobilities and population abilities.

Figure 3. Supply-side of healthcare access and health system resilience in the context of climate change and (im)mobilities

(4) Routines and Perturbations: These include all events that either disrupt or have the potential to disrupt the supply side's normal, functioning, routines, and habits (healthcare services and providers), represented by the four symbols above. This includes sudden shocks, stresses,

challenges, and chronic tensions, which may stem from climate changes and population (im)mobilities, among other events. The straight blue tube represents the usual functioning (routine) of healthcare access from the supply side, and the second blue tube (with a knot) represents perturbations.

(5) Determinants of supply-side capacities: These include all characteristics impacted by or resulting (or not) from changes following the events, such as the building blocks, the hardware, and software of a health system, or from information screening to transparency outreach as defined by Levesque (13,31). The determinants are represented by the blue fluid.

(6) Healthcare accessibility: This encompasses the five dimensions of service accessibility, capturing the supply-side determinants (the health system dimensions in 5.): approachability, acceptability, availability and accommodation, affordability, and appropriateness.

Routines and perturbations, health system dimensions, and healthcare accessibility (4., 5., 6.) are also presented here linearly. However, they are interconnected and non-linear over time i.e., routines and perturbations impact the determinants of supply-side capacities, which, in turn, interact with healthcare accessibility.

Figure 4. Resilience and outcome of resilience of healthcare access and health system resilience in the context of climate change and (im)mobilities

(7) Resilience: Depending on exposure, sensitivity, and adaptive capacities, healthcare system resilience can be characterised by assessing its outcomes: healthcare access (8.), which might collapse, recover, deteriorate, or improve compared to the usual trend (state and dynamic, without effects from disturbing events); Population health outcomes (9.), these are considered the ultimate indicator of system and structural resilience and are a key result of healthcare

279 access; and socio-ecological outcomes (10.), Other determinants of healthcare access are
280 represented in grey (Figure 4).

281 Box 2 presents the summary of changes in the ClimHB conceptual framework.

- Incorporated contextual factors—political, social, economic and ecological
- Established a clear parallelism between the demand (population) and supply (provider) aspects
- Refined the conceptual model to better articulate the interplay between exposure and sensitivity
- Emphasised temporal and dynamic aspects using a water ripple metaphor
- Expanded the model to include 'Change'
- Integrated socio-economic and ecological outcomes
- Highlighted the symbiotic relationship between various outcomes
- Incorporated the principle of 'Equity'
- Integrated governance, resource allocation, and legal framework on the supply-side

282 **Improved design clarity**

283 Integrating resilience dimensions, we established a clear parallel between the global
284 framework's demand (populations) and supply (providers) aspects. This was achieved by
285 horizontally aligning corresponding terms and centralising related icons to represent their
286 interconnectivity visually. Exposure was defined as a function of events plus dimension 1 or 4;
287 sensitivity as influenced by dimensions 2 and 5; and adaptive capacity as determined by
288 dimensions 3 and 6. We also refined the conceptual model to better articulate the interplay
289 between exposure and sensitivity, which are now encapsulated within a 'bag' metaphor,
290 signifying their interaction. This combined entity subsequently interacts with adaptive

capacity, strategically positioned to symbolise the system's threshold for resistance and elasticity.

Contextual factors

We integrated contextual factors, including political, social, and economic dimensions, into the range of events that impact exposure on both the demand and supply sides. This integration directly emanated from findings in Haiti and Bangladesh and was corroborated by verbatim statements during the workshop. For example, instances of scarcity and inflation in the gas price in Haiti exposed patients and healthcare providers to challenges in accessing healthcare facilities. Likewise, findings in Bangladesh indicate that waterlogging had analogous effects.

> *"Here with the idea of understanding climate change, and the impact of climate change, migration, and even mobilities is an important thing that needs to be separated from the other determinants."*

> *"So, for the gaps, the team's idea was not to increase the level of understanding by trying to understand the governments but also the social systems. So, this is where we tried to do a complex analysis to say, maybe we also missed the fragility of the context of the political situation to some extent. The system is above everything, and then that's something that we didn't see in the framework. But we see that in evidence. That's usually something that's missing."*

Resilience dynamic and temporal aspect

We employed a water ripple metaphor to emphasise the temporal and dynamic dimensions inherent in health system resilience. This metaphor illustrates the propagation of effects over time and the cyclical impact (feedback loops) of specific stressors on the health system's

condition, which subsequently influences its response to future stressors. Our findings demonstrate that the health system's condition at a given point directly impacts its ability to recover or adapt. Hence, we enhanced our model by incorporating "change" as a fundamental aspect of health system outcomes. Additionally, we underscored the value of case studies in elucidating the implications of recovery and transformation within local, regional, and national contexts. Despite being connected to the WHO Operational Framework for building climate-resilient health systems (32), we emphasise that more work is needed to illustrate these temporal and dynamic dimensions for health systems resilience.

"For me, the most complicated part is also what interests me the most today because we can clarify how we define collapse, recovery, and the sufficient timeframe. If we consider the baseline causal system before the shock and the effects of dynamics due to the shock factor, which is different in how we can operationalize it? So, it's like quality over quantity, how can we recover?"

"Other frameworks, for example, have different levels of recovery, and it may be difficult for some people to understand exactly what recovery means and what it doesn't mean. But between recovery and improvement, there are also changes that, in my opinion, just change the system and it becomes different. But I can't say it grows or recovers because it's simply different from how it was before the shock. For example, if you say after COVID, improve or eat or recover, for other places, it simply changed."

"Coming from here, going to healthcare access in population or outcomes. It's more of a cycle, in our opinion. [...] in the case of mental health, or even physical health, certain negative outcomes will go back to stress the system and may keep going in the way I also said that collapse is never something that would happen immediately. So, it will be a cycle of deterioration before things get really bad that we can call it collapse."

"Maybe one point is, what is the outcome of resilience? Because we had many discussions this morning about that. I think this is something very interesting for us. The fact that we have discussions but no consensus about it collectively is notable. Do we need steps or four steps that maybe do not make sense? Do we need a cycle? Do we need to have change/no change? In the literature, there is a huge distribution on that, and nobody is very clear about it. And with that, we can make a contribution."

"The data we collected in the two countries help us understand resilience in terms of four dimensions. The evidence showed that, for the most part, it doesn't make sense. Do we have evidence for that or not? This is just a hypothesis because we do not have enough evidence to explain the situation. The graph that I was showing you yesterday from WHO reports uses the same words, okay. And they use steps also, but it's still not dynamic. The work that we have done as a project for hospitals and residents in France and Brazil was mostly to understand that all the hospitals were able to cope with COVID. But they came back to the situation before, which was not normal or abnormal because of the collapse of the systems and the different reforms. So, it seemed that all the hospitals and facilities worldwide came back to the situation before. I don't think we have seen the agenda. So maybe the idea is to elaborate on that."

Reinforcing the link between the outcomes

In the initial framework (S1 Appendix), the connections between the various categories of health system resilience outcomes we identified, namely healthcare access and population health, were not apparent. After a collective reflection within our workshop group, we clarified the hierarchy among health system resilience outcomes by positioning it above the others.

Subsequently, we realigned the other dimensions of outcomes and introduced bidirectional arrows to highlight their interrelatedness.

> *"Like here, it's a gap for me, it's like we have something missing between the two parts. It has nothing to do with it, but it's not the seven and eight, yes, seven, eight, and nine. [...] I think the missing link is back, back. Yeah. [...] From seven to eight in line, it looks more like we are looking at recover and improve, okay, but where's the liquid collapsing the theory, all of this? It's a cycle arrow that's missing."*

Feedback loop between determinants and routines on the supply-side

Our findings from Haiti and Bangladesh suggest that specific supply-side determinants, such as healthcare professionals' awareness of climate-induced events or (im)mobilities, can directly influence them. Consequently, we incorporated a looping arrow to depict the feedback loop between the determinants of the supply side (5) and routines and perturbations (4).

> *"We think there should be another arrow right here. Because one of the discussions that we had is that from the first one is that we're going into a bunch of systems that already existed. So even on the determinant side, there are certain situations in both countries that feed back into the routine. So regular stresses and challenges that people are facing. And that, you know, constitute a constant exposure to chronic shocks, I'd say that sudden shocks thereafter that go back to effect to keep affecting their capacity to provide health care."*

Governance aspects of supply-side

Upon reflecting on the various applications and uses of the conceptual framework, workshop participants identified its potential applicability across different levels of the healthcare system.

Consequently, we emphasise that governance should be considered a determinant of the supply side.

"And the first gap is, we need to analyse the governance process. It's not clear how they govern the supply side. And we need to understand how the supply side needs to be managed and understood from the perspective of different levels, because here we just say that this is the supply side, but there are different levels of the supply side. And that varies from country to country. But maybe at the very bottom level, their needs and perspectives are different from the upper level. These things need to be understood from different levels of the healthcare system."

Climate change impacts on health system resilience will require health systems to mobilise all actors and enhance collaboration across all levels of governance. Recent studies support this necessity, emphasising that good governance, strategic planning, and stakeholder collaboration are essential for building climate-resilient health systems (33).

However, the demand-side (population) is influenced by governance from the supply side, public trust in government is crucial for adherence to health guidelines, legitimising decisions, and ensuring effective crisis management. Evidence from the Ebola outbreak and COVID-19 shows that higher public trust leads to better compliance and health outcomes, while distrust hampers public health responses (34). Distrusting attitudes often stem from a lack of trust in the government and its institutions and are often associated with the refusal of medical care (34). Therefore, good governance from the supply side shapes the response from the demand side by influencing whether individuals seek out health services. But it is also clear that the governance of sectors other than healthcare (e.g. water and land management) also impacts the governance of the healthcare system, the population and healthcare providers.

Awareness and training of healthcare professionals

Our findings from Haiti and Bangladesh reveal that the training and awareness of healthcare professionals regarding climate change and (im)mobilities significantly impact their sensitivity to events affecting their patients, communities, and the health facilities where they operate. These insights were deliberated during the workshop, prompting us to incorporate them as integral components of the sensitivity dimension within the conceptual framework.

"We need to understand the knowledge of the healthcare provider, how they perceive that this population exists and are experiencing. Maybe we don't know how they're dealing with the heat, or how they're dealing with the other consequences of climate change. So, we need to understand their perception, their knowledge about the population side's problems or challenges. And, how they do their decision-making process."

"What is missing is their expression in the moment of shock, and in their general process, how they seek help, where they go, what problems they face, and why they don't seek help. They also mentioned that they find a way, even when they experience a climate shock or any other shock, they find a way to seek health care immediately or in a very short time if they perceive it as very important. They seek health care either by going to the nearest facility or by moving somewhere outside the city, outside the sub-district or village."

Community Engagement

Involving communities in active decision-making alongside decision-makers is integral to strengthening the health system (35). It builds trust and ensures equity (36). The ClimHB framework differs from other health system resilience frameworks as it is a synergistic model

that mirrors the population (demand side) across the healthcare services/providers (supply side) and reflecting their active contribution to the resilience process of a health system. By involving communities as active partners rather than mere recipients of health services, it can better address the tailored needs of communities, which can lead to improved health outcomes and overall health system strengthening (35). Community engagement is a critical component of "adaptive capacity" within the ClimHB conceptual framework. “Adaptive capacities and abilities are defined as the abilities of systems, institutions, humans, communities, and other organisms to adjust to potential damage, take advantage of opportunities, or respond to consequences” (29), enabling actors to anticipate, plan, react to, and learn from events. This definition includes the capacity of communities to actively engage in planning, implementing, and monitoring context-specific adaptation measures. According to Schwedtle et al (37), community engagement is often underrepresented in existing climate-resilient health system frameworks. However, the literature highlights community engagement as a crucial element necessary for building climate-resilient health system frameworks (38): “Building the climate resilience of communities has the potential to reduce the demand on health systems.” By participating in context-specific adaptation measures, communities contribute significantly by raising awareness and promoting education and developing community-based health programmes and services (37).

Climate Health Literacy

Despite scientific evidence linking climate change and human health, the concept of climate health literacy remains poorly understood by both the general public and many health professionals (40). Very limited data and information have been collected regarding climate health literacy in less developed regions (41). Literature reveals that although a blueprint for climate and health literacy exists, its applicability in low-to-middle-income countries remains

uncertain (40), with a need for much more targeted research and the development of a standardised assessment tool to measure climate health literacy (39).

The ClimHB framework recognises climate-health literacy as a concept transcending the dichotomy between demand (population) and supply (healthcare sector). This perspective highlights the importance of climate-health literacy in building a resilient and climate-adaptive global society. Although our initial assessment of the ClimHB framework did not deeply explore climate-health literacy, we acknowledge its vital importance and encourage further research on this element.

We have determined that the ClimHB framework views climate-health literacy not merely as an aspect of the population (demand) or healthcare sector (supply), but as a concept encompassing our entire global society and decision-makers. This comprehensive perspective ensures that the literacy of the general population and health professionals is integral to the framework's approach. This is reflected in the ClimHB framework's components (2) Population and (5) Healthcare sector.

Integration of socio-ecological outcomes

We acknowledge the intricate nature of complex adaptive systems such as climate change, health systems, and socio-ecological systems (5,42). This is why the ClimHB framework allows the integration of other conceptual approaches as we did with the socio-ecological approach (23) based on complex adaptive systems, and with the configuration approach (24,43). However, it is unrealistic to fully capture the interplay of these dynamics within the confines of a two-dimensional representation that fits into an A4 format due to non-linear interactions (44). Nevertheless, there was consensus on the importance of incorporating these interactions as a health resilience outcome. For instance, zoonotic diseases serve as a

fundamental example illustrating the interconnectedness between human population health and the health of ecological ecosystems.

"There you have the resilience of the population's access to healthcare, and what is missing is a circle to the left for the resilience of the population and community. Afterwards, the resilience of socio-ecological and climatic systems."

Potential application of the framework

As mentioned, various stakeholders can benefit from using the ClimHB conceptual framework. These include policymakers, researchers, educators, healthcare providers, and study participants. Below, we outline two types of potential applications based on the evidence we collected in Haiti and Bangladesh. This final section of the paper, therefore, describes how we believe the framework could be applied and strengthened. We hope that this proposal can be taken up in future research on the resilience of health systems.

Health Systems Actors case study: Facilitating Decision-making

One significant finding from our discussions is that this framework can be interpreted across various levels of health systems. On one hand, employing this framework can unveil the roles of different actors at different levels in relation to resilience. On the other hand, customising it for these specific actors can streamline their decision-making processes or inform policy design. Below is an example of a framework adapted for supply-side of healthcare (Figure 5).

"And I was trying to focus on whether we understand what the people's determinants are. You know, their abilities to have access to health? It's not very clear. And I think this is one thing that might be missing. How to understand and make it clear to the policymakers that there is more to investigate about the people's capacities to access

health. Do they understand they have to have access; do they understand they have the right to it, and all that? I think a few things are missing. It's not only about money, but also more than that—it's about the education aspect as well."

"But then last month, I also mentioned that there is a difference between the implementer and the policy level. They cannot convey their knowledge or wishes to the policymakers about what they actually want to do. So, this is the gap."

Figure 5. ClimHB conceptual framework adapted to healthcare providers. Coloured elements are areas they can act upon or are affected by.

Country case study: illustrating health systems resilience

One advantage of the ClimHB conceptual framework is that it can systematically explain resilience at different scales (national, regional, and local health systems or structures). It helps to identify what research or information systems capture in terms of demand, supply, resilience of the health systems, or data gaps that need to be addressed. Below, we present the results from our qualitative study in Bangladesh (Figure 6) and Haiti (Figure 7).

Figure 6. ClimHB conceptual framework adapted to the case study of Bangladesh

Figure 7. ClimHB conceptual framework adapted to the case study of Haiti

Discussion

Using a framework approach, we enhanced the ClimHB conceptual model. Refinements were made to the conceptual framework, including the incorporation of contextual factors, reinforcing linkages between outcomes, and integrating socio-ecological outcomes.

Governance aspects of the supply side, awareness and training of healthcare professionals, and feedback loops between determinants and routines on the supply side were also emphasised. The revised ClimHB framework now offers a more comprehensive and dynamic depiction of health system resilience, capable of informing decision-making processes and policy design across various healthcare system levels.

Compared to other existing frameworks (2,5,8,32,45–47), the ClimHB framework was designed to enhance health system resilience by integrating climate change-induced events and population mobility impacts, uniquely suited for regions like Haiti and Bangladesh. Building on the WHO operational framework, which addresses health system components (32), ClimHB specifically incorporates socio-ecological systems and emphasises adaptive capacities, exposure, and sensitivity. It balances both demand (population) and supply (health services) sides. Developed with input from diverse researchers and their various disciplines, the framework is adaptable and context-specific, taking into account political, social, and economic dimensions. It also highlights resilience's temporal and dynamic aspects, an element often missing from analyses (5). ClimHB's framework comprehensive approach makes it particularly valuable for areas heavily impacted by these factors, complementing existing frameworks. While we are not experts in the complex systems approach, we are aware of its importance and we have tried to apply it in our conceptual approach (9,44). We acknowledge that further work is required from this perspective.

The framework's adaptability to portray site studies in Haiti and Bangladesh contributes to demonstrating its robustness, but it will need to be tested empirically in other contexts. In our research context, this framework was beneficial in two aspects. First, its conceptual elements helped us design more comprehensive qualitative and quantitative data collection tools for assessing the relative resilience of local health service providers and delineating the health

status and healthcare access patterns among (im)mobile populations within these diverse environments. Second, the results of our qualitative research revealed the adjustments needed for the framework to be applicable. Consequently, we generated a virtuous circle between theorising and implementing the concept of health systems resilience. Furthermore, we demonstrated its potential for adaptation to accommodate the perspectives of key informants, such as healthcare providers. However, ambiguity remains regarding how this framework can be effectively operationalised, particularly among and for policymakers and decision-makers.

We have identified some gaps that require further research and attention to reduce challenges in operationalising the conceptual framework.

Conceptual Challenges

The resilience of health systems is increasingly recognised as a critical component in responding to various challenges, including climate change, polycrises, and public health crises (8,48,49). However, resilience has many definitions (1), lacks consensus (4,5,50), is multidimensional (12,51), and can be interpreted differently among stakeholders and professions, depending on the context (52). This variability presents challenges in enhancing the resilience of health systems and has implications for future research regarding monitoring and evaluation (12,42,51). Differing definitions can lead to miscommunication, incomplete understanding, and issues in research mobilisation and policy implications (52). To operationalise frameworks effectively, concepts must be clear and precise (5,7), allowing for consistent communication and valid empirical study.

The ClimHB framework emphasises the importance of understanding the interconnectedness of various factors influencing climate health resilience. The term "polycrisis" has gained prominence in recent discussions, particularly since the global COVID-19 pandemic

(42,49,53,54) or as a security threat for health systems (55). Though not yet fully understood, this emerging concept is increasingly becoming more recognised by researchers and policymakers. The term "polycrisis" describes the interconnectedness of multiple crises—political issues, climate change, and pandemics—that collectively push global systems out of equilibrium, leading to harmful states (56). Despite its growing usage, the term lacks consistent understanding, especially regarding its application in providing clear guidance for policymakers and crisis management at national and subnational levels. As we face more global crises, largely due to the impacts of climate change, it is urgent to place the concept of polycrisis at the forefront of research within the ClimHB framework and other systems-thinking approaches (49). This will help better understand the causal interactions among different crises, essential for generating actionable insights to address these challenges. While the concept has been articulated globally, there remains debate on how it can be operationalised at the domestic policy level. Existing research on crisis management remains relevant, and the concept of polycrisis should complement, rather than replace established management practices (49,53).

Methodological Challenges

Due to the extensive nature of the conceptual framework, which encompasses climate change, population dynamics, and health service providers, a significant challenge arose in transitioning from conceptualisation to operationalisation for the purposes of data collection and analysis. Our data collection ranged from 2022 to 2024, with quantitative data collected only once in the summer of 2022. The recall period for the quantitative data was 2017, while the inductive qualitative data extended much further back. We also covered a several decades of public health reform and climate analyses dating back to the 1980s (57). Since resilience is both a mechanism and a product of a mechanism, the temporality factor and the scale of the mechanisms are also

essential to consider. The analyses needed to account for varying recall periods, temporalities, and scales. Depending on the discipline, individual, household, community, district, regional, and national data were collected, and our analyses focused on different scales or integrated different scales.

We needed to determine how best to utilise the conceptual framework, and early on, we decided to break it down into several coherent parts, following the development of sub-questions and hypotheses. The attempt to comprehensively address the entire conceptual framework within a single analytical framework in this exploratory project presented significant challenges. To do so, an analysis plan should be conceived at the outset with an hypothetico-deductive approach, which contrasts with our exploratory approach and sequential design, where each phase informs the next. The nature of the data, the novelty of the sub-studies and the team's skills determined the prioritisation in a very pragmatical manner (58). We used quantitative and qualitative methods to collect data in the social and health sciences encountering all the typical challenges of mixed-method integration (59). Climate and environmental data were secondary and were included at a later stage. We had to choose what was most relevant and feasible in line with our research questions, data, and established methodologies to articulate a set of mixed data across disciplines. While mixed methods are frequent in social and health sciences, it was more complex to integrate transdisciplinary data, such as quantitative climate data and qualitative social data.

Another challenge is the lack of a universally developed, standardised tool for measuring climate health system resilience (1,46,60). There is no standardised tool for assessing resilience in healthcare systems, and limited research has been conducted on indicators to measure resilient performance (8,32). The stakes are high, but so is the complexity of developing such an instrument (if relevant), much like the challenge of creating an index to operationalise the

access to care model (31). Such a tool is crucial for operationalising resilience and presenting it to decision-makers, particularly in the context of climate health resilience. The aim is to develop standardised operational indicators for easy evaluation, moving from conceptual thinking to practical applications to address gaps (61).

Developing a standardised climate literacy assessment tool is another important area for further refinement. The level of climate literacy among all health system actors is increasingly recognized as a crucial factor in combating the climate crisis (62), especially since there are currently "little to no assessments on climate change literacy for populations living in lower-to-middle income countries" (63). Despite growing evidence, this knowledge remains limited among the public and many professionals (40). Measuring climate health literacy is complex due to varied definitions and contextual factors (64). Existing health literacy assessment tools, like the WHO's Health Literacy Questionnaire (65), have limitations in capturing the full scope of climate health literacy in this concept, particularly in low-resource settings. Understanding climate change and its health risks is further complicated by cultural background, sociodemographic factors, education level, and residential location. Because climate health literacy can be encompassed by experience, mobility, and community engagement, and cannot be easily quantified, it presents challenges when developing an adequate tool to measure the multi-dimensional concept (64). Climate-specific health literacy among health professionals is crucial for addressing the climate crisis and managing its related impacts (66).

Knowledge Transfer

The current conceptual framework may appear overly complex for policymakers who require a quick understanding of actionable areas and the key actors, facilitators, and barriers in decision-making processes. To address this, developing a simplified version of the framework

for policymakers can enhance its operational use. As we have done in this article, it might also be useful to present only specific parts of the framework, depending on the interests of the decision-makers. However, simplifying complexity without distorting it is never easy, and the construction of a system is already a form of reductionism, which is necessary to build knowledge on complex questions. Effective communication of evidence to policymakers and stakeholders should include concise measures and presented evidence quality (67). Developing a streamlined version of the framework, incorporating insights from researchers, can provide a clear, simplified conceptual framework tailored for decision-making processes (49). Finally, the relevance of such a framework for future studies could be enhanced by involving decision-makers and study participants at key stages of the framework's development (particularly during post-empirical or restitution stages). This would help avoid introducing additional barriers to health literacy and enhance knowledge transfer. But it's easier said than done.

Conclusion

Events linked to climate change are exacerbating existing crises, not to mention the daily challenges faced by those working in healthcare systems under ongoing neo-liberal policies (3,68). It is therefore becoming increasingly urgent to study resilience strategies in the face of this polycrisis to guarantee universal access to healthcare. We hope this new conceptual framework will support international thinking and, above all, actions to achieve outcome 1.1 proposed by the WHO for its general work programme over the next four years: « *More climate-resilient health systems are addressing health risks and impacts* » (48).

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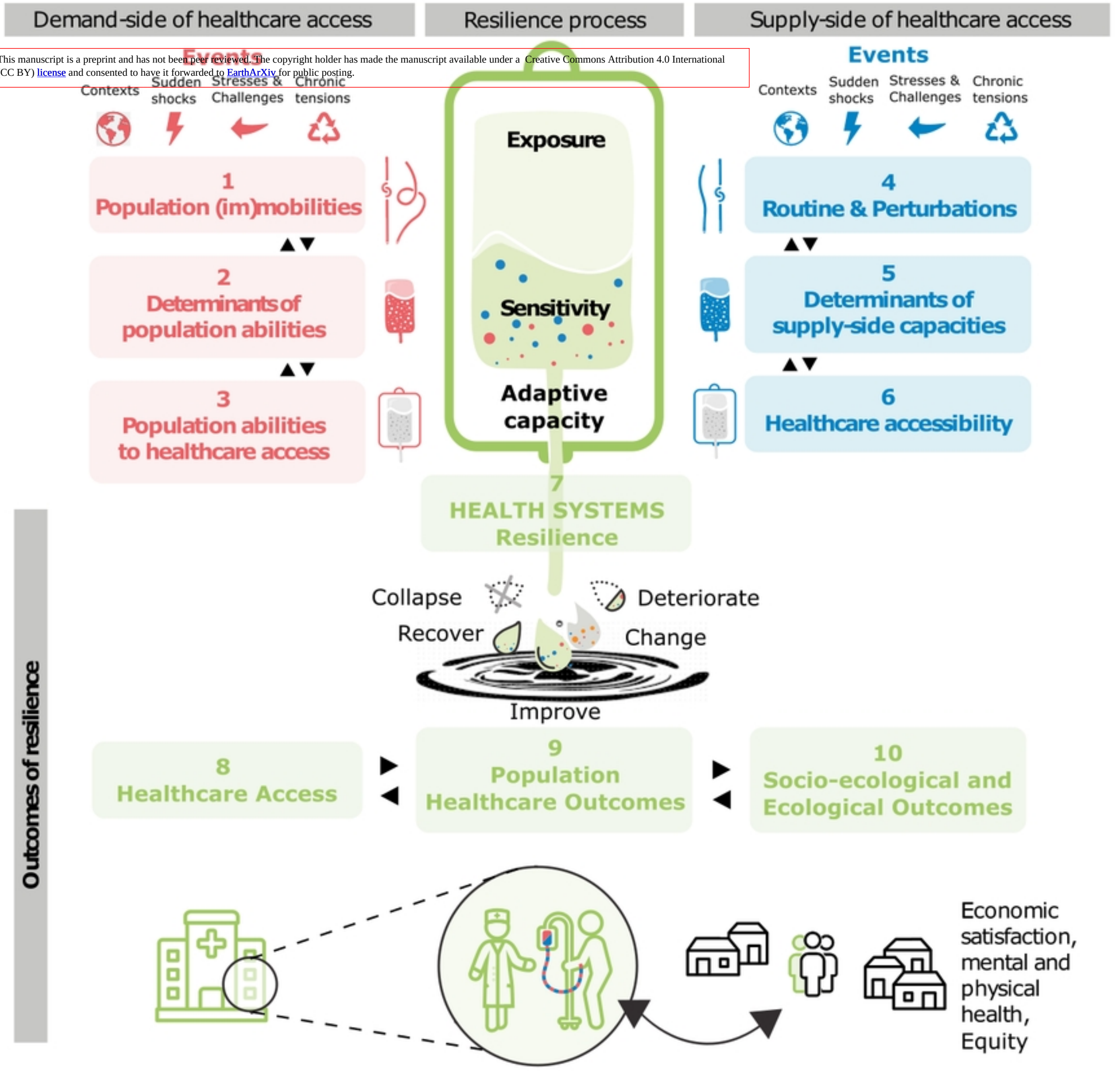

Figure 1

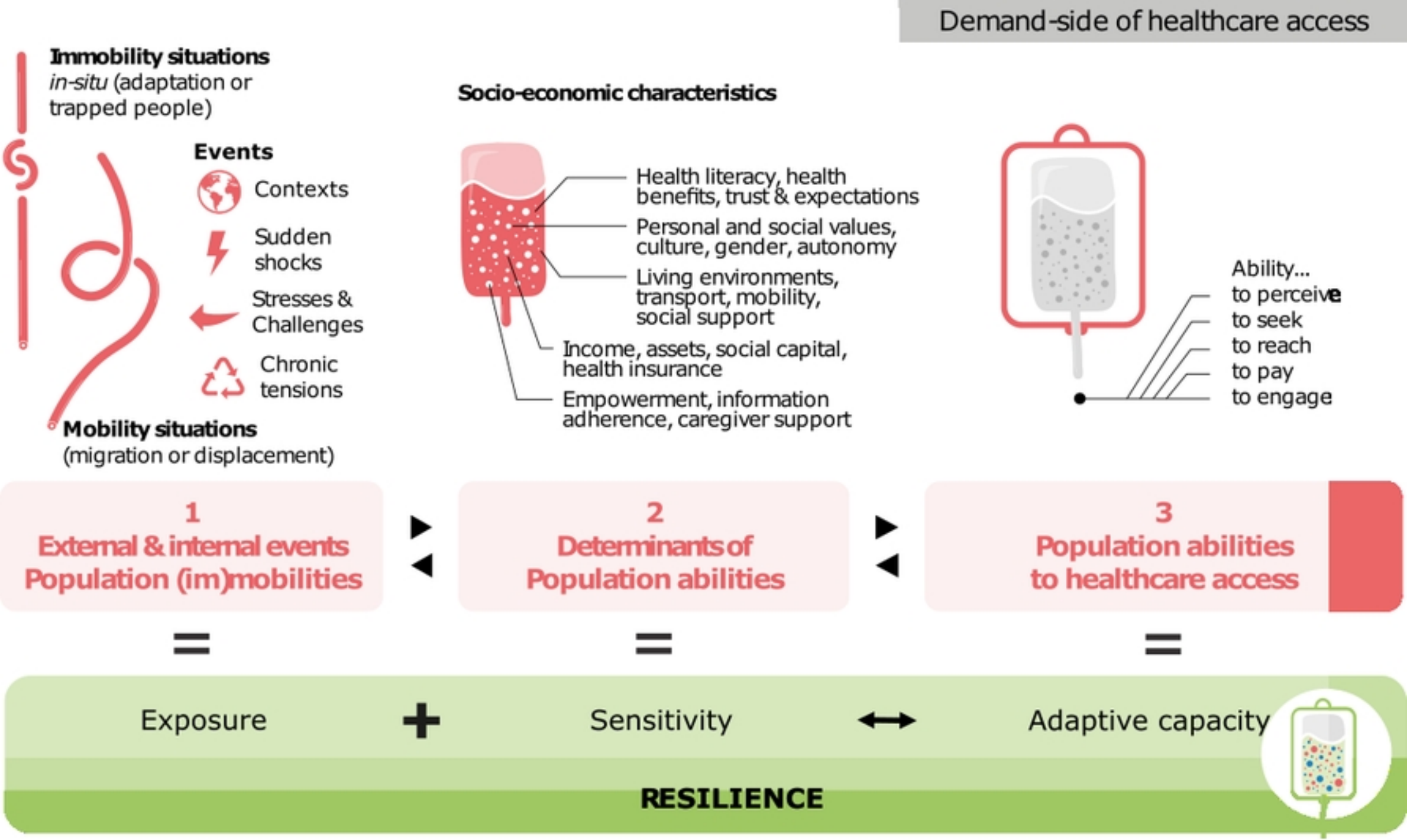
Demand-side of healthcare access
Immobility situations
in-situ (adaptation or trapped people)
Events
Contexts
Sudden shocks
Stresses & Challenges
Chronic tensions
Mobility situations
(migration or displacement)
Socio-economic characteristics
Health literacy, health benefits, trust & expectations
Personal and social values, culture, gender, autonomy
Living environments, transport, mobility, social support
Income, assets, social capital, health insurance
Empowerment, information adherence, caregiver support
Ability...
to perceive
to seek
to reach
to pay
to engage
1
External & internal events
Population (im)mobilities
2
Determinants of
Population abilities
3
Population abilities
to healthcare access
Exposure
Sensitivity
Adaptive capacity
RESILIENCE

Figure 2

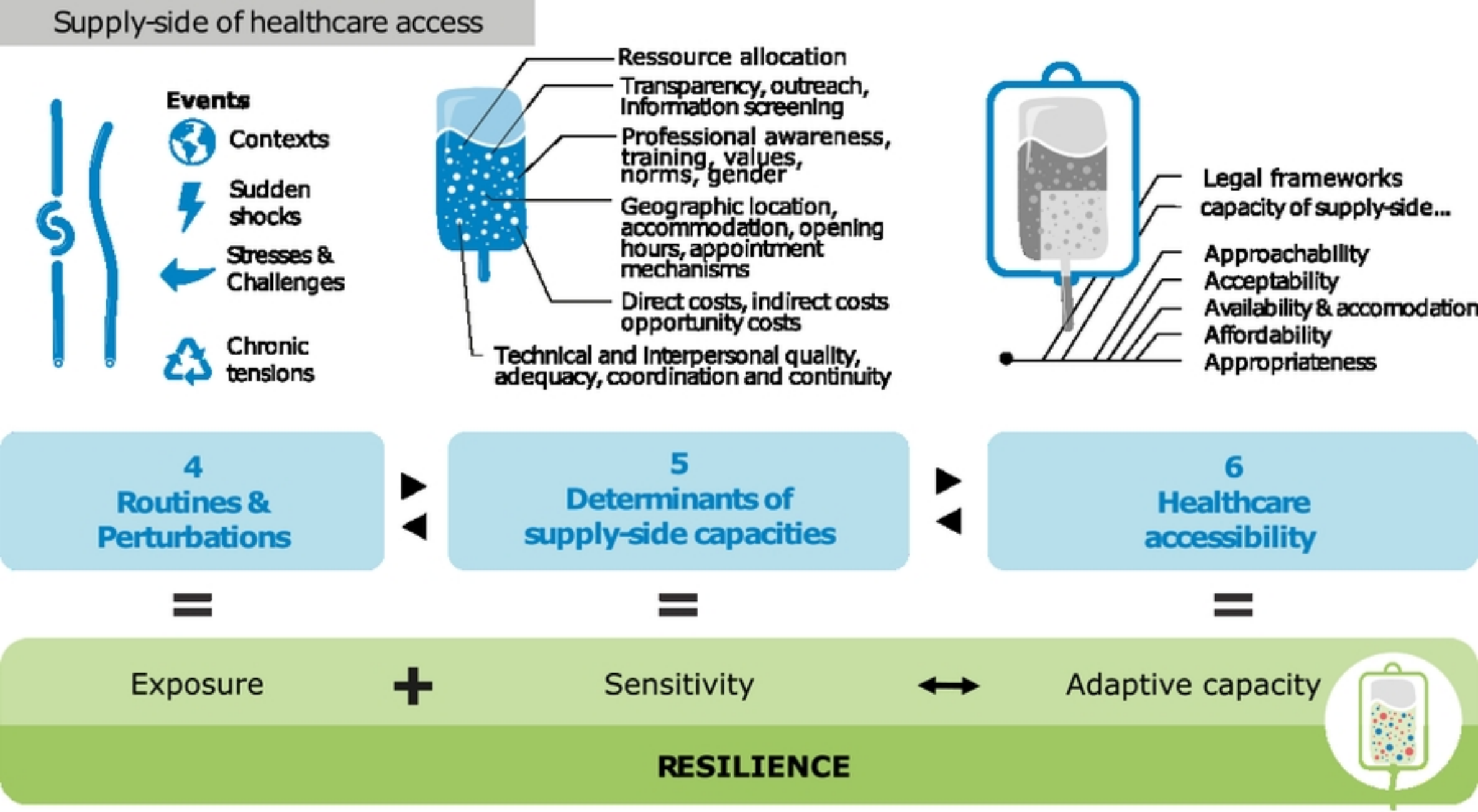
Supply-side of healthcare access
Events
Contexts
Sudden shocks
Stresses & Challenges
Chronic tensions
Ressource allocation
Transparency, outreach, Information screening
Professional awareness, training, values, norms, gender
Geographic location, accommodation, opening hours, appointment mechanisms
Direct costs, indirect costs opportunity costs
Technical and Interpersonal quality, adequacy, coordination and continuity
Legal frameworks capacity of supply-side...
Approachability
Acceptability
Availability & accomodation
Affordability
Appropriateness
4 Routines & Perturbations
5 Determinants of supply-side capacities
6 Healthcare accessibility
Exposure
Sensitivity
Adaptive capacity
RESILIENCE

Figure 3

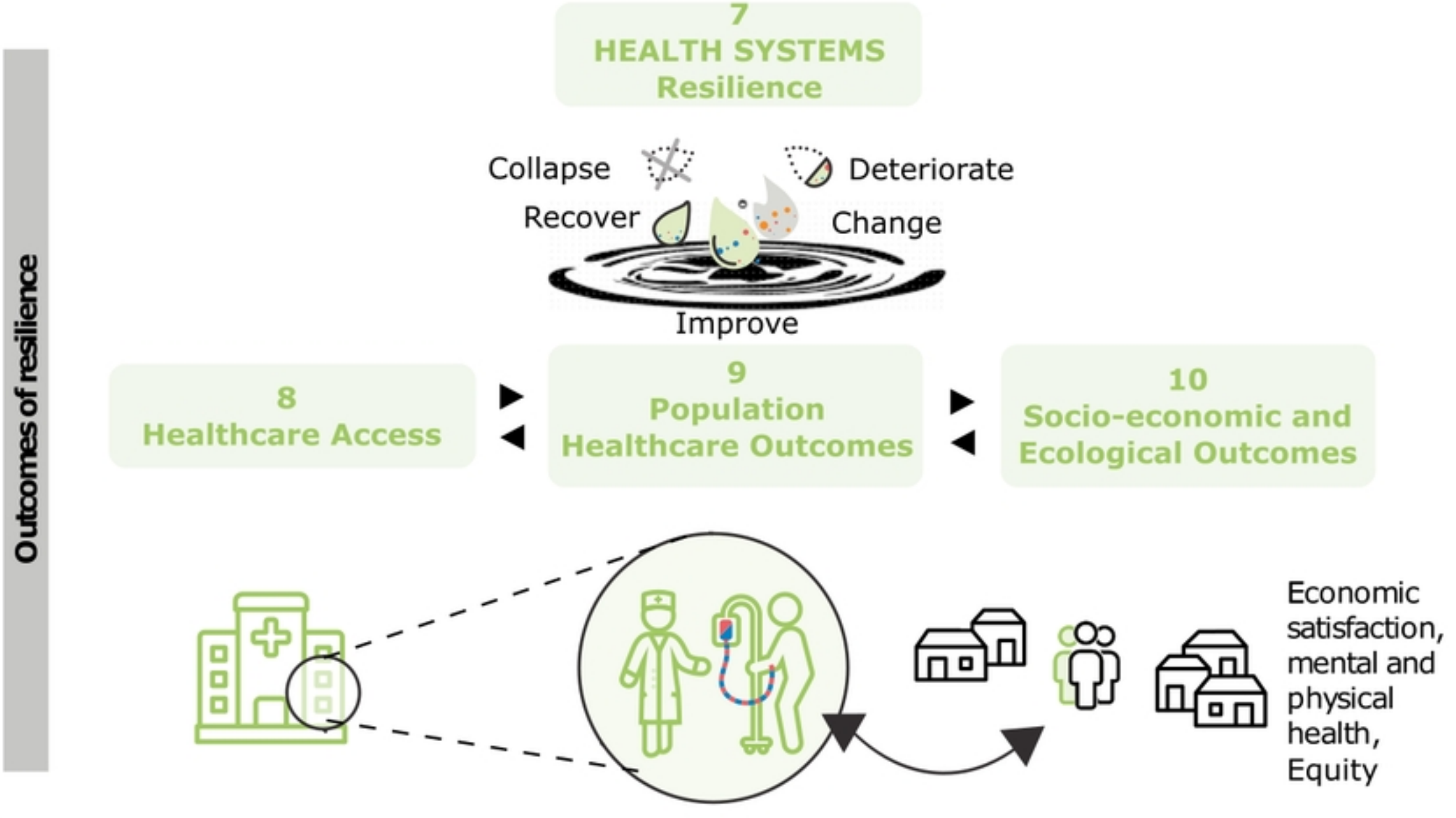
Outcomes of resilience
7
HEALTH SYSTEMS
Resilience
Collapse
Deteriorate
Recover
Change
Improve
8
Healthcare Access
9
Population
Healthcare Outcomes
10
Socio-economic and
Ecological Outcomes
Economic
satisfaction,
mental and
physical
health,
Equity

Figure 4

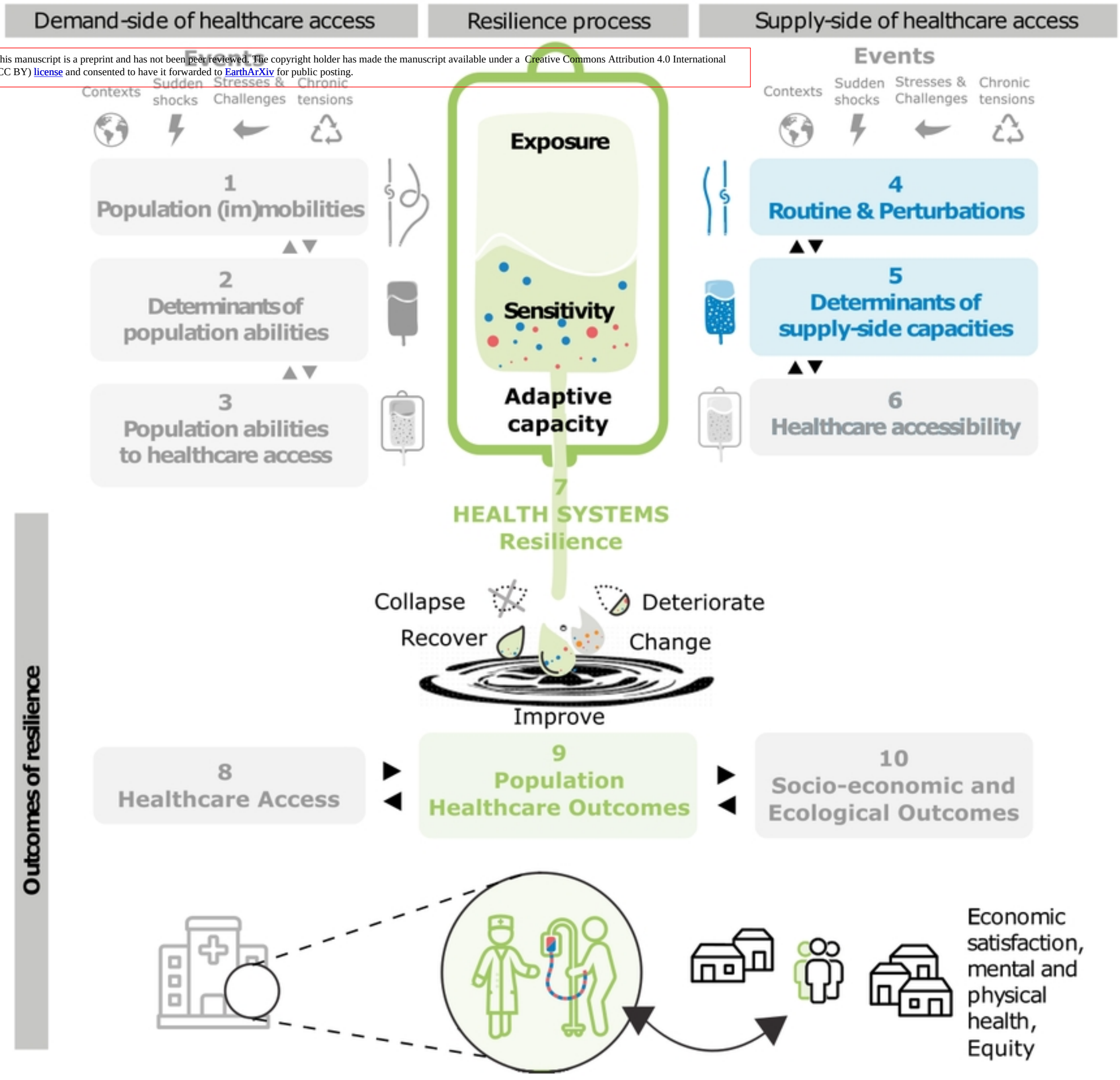

Figure 5

Case Study

Bengladesh, climate change, migration: a health system providers perspective

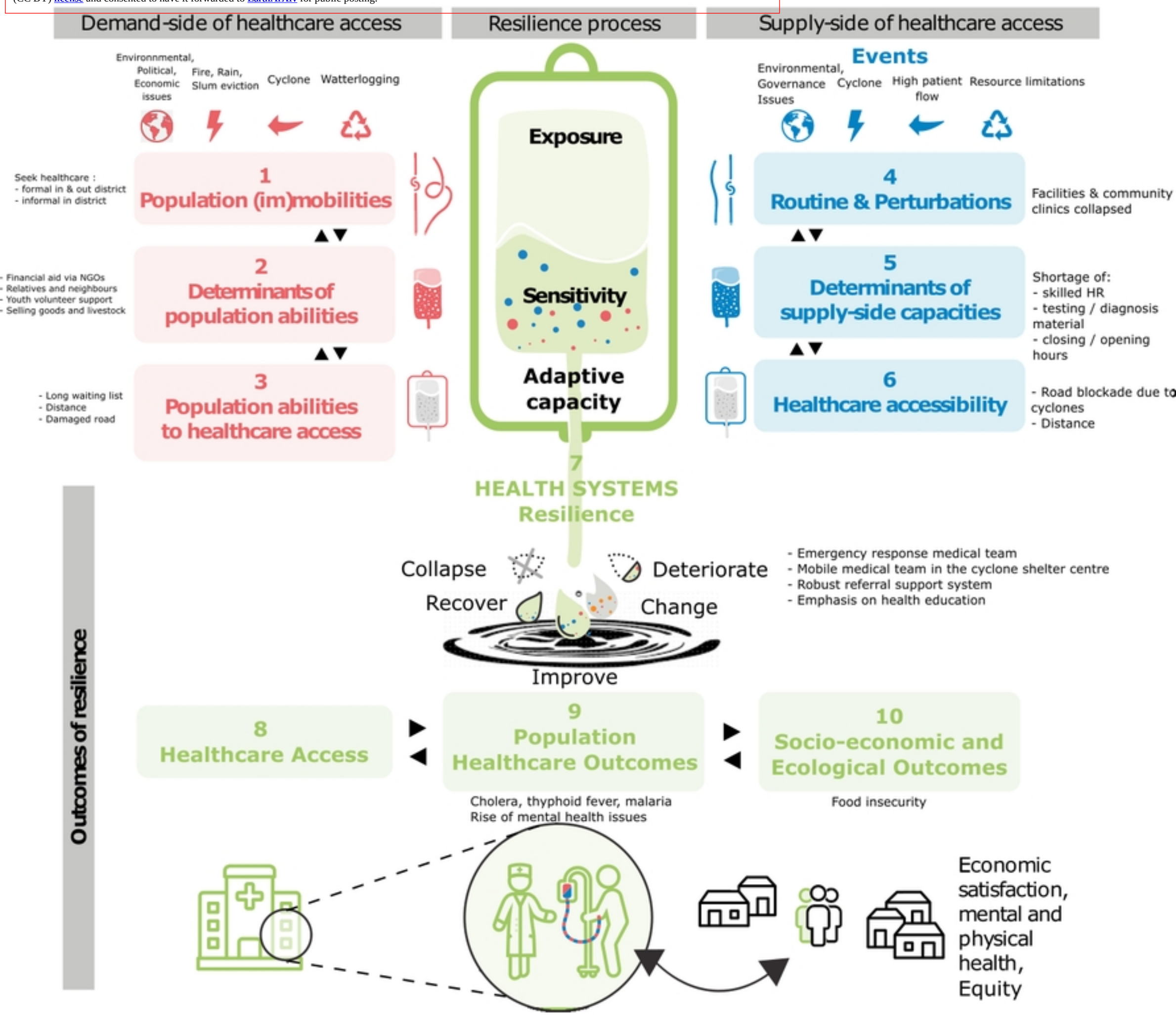

Figure 6

Case Study

Haïti, climate change, migration: a health system providers perspective

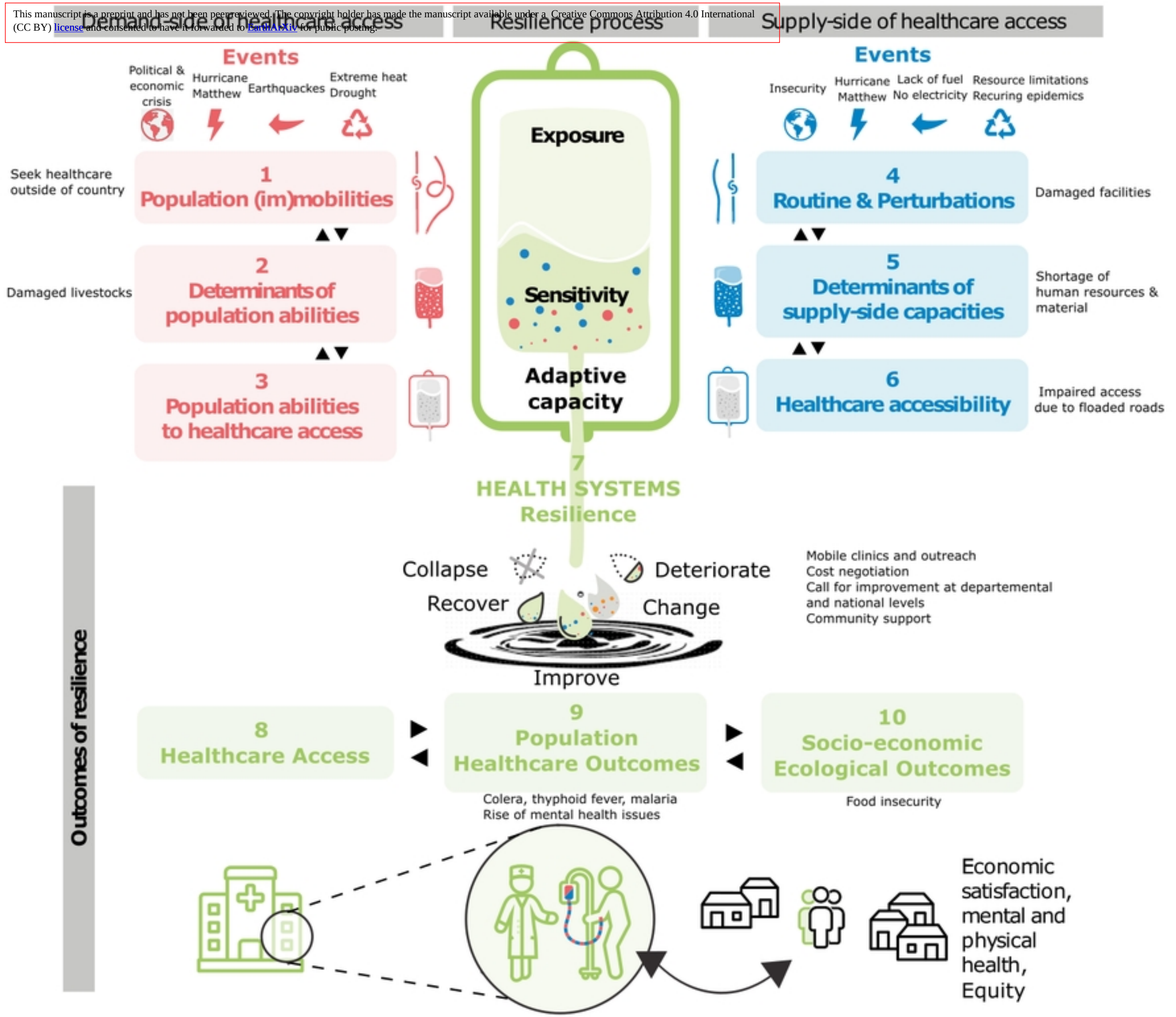

Figure 7