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Towards Sustainable Community-Based Systems for Infectious Disease and Disaster Response; Lessons from Local Initiatives in Four African Countries

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Abstract: This paper explores the role of decentralised community-based care systems in achieving sustainable healthcare in resource-poor areas. Based on case studies from Sierra Leone, Madagascar, Uganda and Ethiopia, the paper argues that a community-based system of healthcare is more effective in the prevention, early diagnosis, and primary care in response to the zoonotic and infectious diseases associated with extreme weather events as well as their direct health impacts. Community-based systems of care have a more holistic view of the determinants of health and can integrate responses to health challenges, social wellbeing, ecological and economic viability. The case studies profiled in this paper reveal the importance of expanding notions of health to encompass the whole environment (physical and social, across time and space) in which people live, including the explicit recognition of ecological interests and their interconnections with health. While much work still needs to be done in defining and measuring successful community responses to health and other crises, we identify two potentially core criteria: the inclusion and integration of local knowledge in response planning and actions, and the involvement of researchers and practitioners, e.g., community-embedded health workers and NGO staff, as trusted key interlocuters in brokering knowledge and devising sustainable community systems of care.

Keywords: sustainable healthcare; community-based care systems; primary care and response; social wellbeing; resilience

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1. Introduction

Environmental threats to human health are a major challenge for international co-operation and global solidarity. Of particular concern are fatal infectious diseases with zoonotic origins. Before the current Covid-19 pandemic unsettled the world, health specialists paid close attention to the movements and mutations of the Ebola and Zika viruses, amongst other pathogens that are known to migrate from animals to humans. Climate change forms an important trigger for newly emerging infectious diseases more generally,

coinciding with environmental threats such as floods and temperature rises [1,2]. The anticipation and mitigation of environmental threats create a substantial overlap in research and policy agendas for sustainable health, land use, food and water [3]. Local "systems of care" are necessary to respond to such multiple, interconnected crises. Systems of care are the configurations of care that emerge at the community level as a result of evolving relationships between institutions, healthcare workers and ordinary citizens, in response to crises. Systems of care are complementary and often overlap with "health systems", the latter term referring to the more formalised configurations of health facilities, medical technologies and services at a national or even global level [4,5]. Drawing on case studies in four African countries, we show how local innovation and resilience in responding to health threats emerge from and reconfigure systems of care. A better understanding of these local dynamics creates a firm basis for more sustainable community-based health systems.

Researchers agree that climate change is a major driver in the emergence of zoonotic pathogens, primarily through its disturbing effects on the ecologies in which zoonotic diseases thrive and affect human populations. The complexity and huge variation in dynamic, locally-specific risk factors renders existing evidence scattered and incomplete [6]. However, there is little doubt that changes in rainfall patterns and temperature disturb the habitats of animal host species, changing the geographical distribution and incidence of directly transmitted and vector-born zoonoses [7–10]. The ecological disturbance from climate change coincides with other forms of environmental degradation caused by human activity, in particular deforestation and intensive agricultural practices. The importance of these practices, as a source of food and income, means that the impact of climatic and ecological shifts on human health is not limited to infectious diseases. The availability of arable land, forest resources and clean water are crucial assets for human health and wellbeing. The negative impact of environmental threats aggravated by climate change may create a long-term negative cycle of resource depletion, reduced effectiveness of existing support systems and increasing poverty [11,12]. Consequently, sustainable health solutions that increase the capacity of people to coexist in vulnerable ecospheres are most critically needed for people living in poverty.

The current focus on zoonoses, anticipating known and unknown pandemic threats, has manifested in proposals for improving current health systems. Such proposals typically call for interdisciplinary approaches in which a variety of experts and practitioners cooperate in detecting potential cross-over events, aimed at preventing the spread of new and existing viruses within human populations. This requires a concerted effort between governments and scientific organisations to enhance laboratory capacity, allowing for rapid molecular sequencing, geographical information systems producing spatial disease monitoring data, longitudinal patterns of virus evolution and transitions, and mathematical models producing meaningful inferences from such datasets [13,14]. Gearing up sophisticated interdisciplinary surveillance systems will increase the effectiveness of diagnostics, therapeutic treatments and vaccine development. The downsides of such an approach are that it increases the dependency on high-tech equipment and methods that are affordable primarily for high-income countries, favouring western-held scientific knowledge over local knowledge and capacity. Moreover, such approaches strengthen vertical interventions within hierarchical top-down health systems. This creates two important trade-offs. One is a reduction of the roles of the general public and individuals. High-tech surveillance systems require highly educated and trained experts, leaving limited space for citizens' input other than informants sharing data about their health condition, movement patterns and other personal information, or as rule-following clients benefitting from the measures and medical services generated by health experts. Secondly, despite the interdisciplinary input, technology-driven disease prevention systems are narrowly focused on specific targets and particular health risks, primarily highly infectious zoonoses. Environmental challenges and disease risks, however, show much variation in terms of incidence and impact. The effects of climate change also show a huge variation between locations, creating uncertainty about

the kind of hazards and the impact these may have on health and well-being in different communities.

2. Conceptualising Sustainable Community-Based Systems of Care

The concept of sustainability can be a helpful lens to address the variety of interconnected environmental health threats in an integrated way. The concept is increasingly applied at a subnational/district policy level and in health systems research [15]. "Sustainable health systems" scholarship and practice has recognised the importance of "increasing community resilience and promoting local assets" and "promoting innovative models of care" as key components of systems that can adapt and respond to the effects of climate and environmental change [16]. The concept of sustainability in health—the sustaining positive effects of an intervention or policy beyond the initiation phase—continues to generate debate [15]. Sustainability is often construed to mean financial self-sufficiency, including a community's ability to continue to implement it [17], while others have focused on systemic effects—embedding them in organisational structures, planning processes and culture [18,19]. However, sustainability is being increasingly conceptualised as creating a community's capacity to take action and shape its own responses, with different levels of engagement with the formal systems [20,21]. Likewise, sustainability notions in ecology and environmental studies have shifted from rather generic national or even global assessment approaches to more locally-specific methodologies [22].

With an inclusive focus on community perspectives, the sustainability concept provides a broad normative framework for connecting human societies and ecospheric environments with a future-oriented time frame. A sustainability focus highlights particular challenges in situations where the environment poses immediate threats to people's health. These are conditions typically found in the poorer parts of the world, among communities in which most peoples' livelihoods directly depend on the use of environmental resources [23]. Existing health systems in these contexts are often underfunded and face serious difficulties in upscaling case treatment in case of disease outbreaks or calamities. Such limitations are particularly acute when outbreaks and calamities happen in places that are far from urban centres with better equipped health facilities. Remoteness also reduces the response time and effectiveness of external aid. Moreover, there is growing evidence, as underlined by the international Ebola responses in West Africa—mostly in Guinea, Sierra Leone and Liberia—and in central Africa—in the Democratic Republic of Congo—that responses to public health crises are inadequate when they ignore local action [24–27]. These recent Ebola crises stressed the importance of first-responders both within the community and among frontline health workers [25,26,28,29] and have challenged the dominant biomedical approach associated with traditional top-down, high-tech, emergency public health responses that prioritise rapid response and efficiency at the expense of engaging with local knowledge and capacity [24,27]. A focus on sustainable community health systems shifts the attention to first-line responses to disease outbreaks as well as more permanent health challenges.

The interest in community-based health systems to enhance healthcare, including for outbreak responses, in the poorest communities, has been growing, although there is little robust evidence on what works best at this level, or how formal structures can support and sustain first-line disease responses [30,31]. The shift in focus to the community frontline level is important in facilitating a more holistic and integrated horizontal approach to sustainable health systems which seeks to tackle health challenges through strengthening services and systems over the long-term [32]. A shift in focus to the frontline should also seek to value and support local knowledge and capacities for enhancing health and health system responses. However, the literature is scarce on how best to engage, and support frontline responses and lessons do not seem to be readily learned by outbreak-responders. For example, the 2014–2016 Sierra Leone Ebola response showed how national and international responders slowly adapted their top-down responses over time to take into account local concerns and re-build trust to improve the epidemic response [28,29]. Despite this

lesson on the importance of local engagement and trust-building being acknowledged in the response to the prolonged 2018–2020 Ebola outbreak in DR Congo, responders struggled to transform their approaches to do more than "engage" communities to generate information about the local situation—which was not acted on, and there was no joint discussion or planning of solutions [28]. This inability to act on local knowledge may be compounded by the fact that there are very few case studies of "successful" community-led approaches and no comprehensive indicators or definitions for "successful" approaches or how to implement them [33].

With this in mind, the objective of our paper is to examine how frontline responses to endemic health challenges in sub-Saharan Africa have developed and been supported in different ways. We present a series of case studies describing different approaches to community-led outbreak and disaster response. From these, we distil common elements and principles for supporting community-based initiatives for infectious disease response and consider how such initiatives can be connected and supported through mainstream health institutions to promote sustainability.

In the following sections we provide an overview of results of recent and ongoing participatory studies into community initiatives responding to environmental health threats. The first two cases, covering community initiatives in Sierra Leone and Madagascar, highlight the ways in which successive environmental health threats—and their responses—can be connected to each other through time and space. The cases from Uganda and Ethiopia, presented in a single section, show the effectiveness of the enduring cooperation between local communities and various "upstream" institutions in order to address both the need for local environment and health knowledge to inform necessary services and interventions, and the institutional support for those interventions to tackle a variety of health issues. Through the analysis of these case studies, our paper investigates the potential and limitations of community-based systems of care for effective first-line responses to environmental threats.

3. Materials and Methods

The case studies described in this paper are drawn from a range of community-based projects conducted by the co-authors.

All case studies relied on standard participatory research methods for qualitative data collection requiring a long-term engagement which can lead to improved health outcomes [34]. These methods included interviews, observations, participatory workshops as well as the triangulation with quantitative descriptive data on health indicators [35]. However, there are some notable differences between cases in the overall methodological framing of these methods.

3.1. Methods for Case Study I

In the Sierra Leone case, the framing took the shape of a science shop approach. A science shop aims to articulate the demand for community access to science and technology through a series of consultative events [33]. A first exploratory meeting, in January 2017 on the campus of Njala University, brought together about twenty people from Njala University and community workers from Daru in the Jawei chiefdom, Kailahun district. The sessions were spread out over two days, with an overall participation of 60% researchers and 40% community health workers. The aim was to make an inventory of health issues at the village level and potential contributions from research. A second meeting, held in Daru itself in September 2017, was a one-day meeting with community health workers from various villages in the area, known from their earlier participation in an Ebola evaluation study. There were about thirty participants, 80% community health workers and 20% researchers. The meeting comprised several sessions, spread over one day, with the aim to get a deeper understanding of the nature of health issues at the village level, in particular the "knowledge gaps" to which research could contribute. A third two-day meeting was held in the village of Lalehun, selected based on outcomes from the second meeting. The

village chief was asked for permission and requested to invite the participants. The division was roughly 50% villagers, 30% community health workers from surrounding villages, partly also present in the Daru meeting, and 20% researchers. The aim was to discuss the way people were affected by and coping with malaria. Moreover, a set of simple techniques were demonstrated, and the participants were invited to try them for themselves. The aim of the third meeting was to make an inventory of (malaria) knowledge gaps and test tools for addressing these gaps with methods combining learning and problem-solving. In all three meetings, the discussions and activities were initiated by explaining the goals and inviting participants to share their views and experiences, from which further topics for discussion emerged. The second and third meeting also involved parallel sessions in smaller groups. For all meetings and sessions, bilingual research assistants or volunteers took notes and reported back to the plenary meeting. These notes and shared observations from researchers present in the meetings formed the data used for this paper. The data were analysed by the first, third and fourth authors through collaborative topic selection and inductive reasoning.

3.2. Methods for Case Study II

In Madagascar, the overall method of data collection was a participatory action research approach among communities in the coastal area, alongside the Toliara barrier reef. The action comprised coordinated and planned interventions as well as spontaneous and improvised responses to the tropical cyclone Haruna, that hit the coast in February 2013. All actions involved a collective effort by representatives of official aid agencies, community health workers and citizens. The main aid agency, aimed at integrating health and marine conservation, is the Blue Ventures social enterprise [36]. The emergency situation and the nature of the activities implied that the research "subjects" for case II were a varied group of people, and the details of participants were not recorded. The data used for the second case comprised documentation about initiated response actions, requests for support, equipment and construction materials and other "consumable" goods. The long-term presence of Blue Ventures in the area implied the participation in, and the observation of, response activities and evaluative conversations between aid agencies, community health workers and citizens. The fifth author participated in many of these activities, and his experiences and notes from the evaluative conversations form the second component of the data used for this case. The fifth and last author cooperated in the data analysis through topic selection and inductive reasoning.

3.3. Methods for Case Study III

The Uganda and Ethiopia case materials emerged from co-design and co-production methodologies. In both countries, community-based research activities were initiated by universities, partnering with government agencies and non-governmental organisations [37,38]. In Uganda, researchers from Makerere University set up such activities to train field epidemiologists. In the Kasese districts, training in field epidemiology and other types of participatory interaction and case observations covered 91 outbreaks of various diseases. In the Kabale region, community-based projects were set up with Makere's Centre for Climate Change Research and Innovation (MUCCRI), addressing the rising prevalence of malaria due to a change in climatic conditions. In Ethiopia, Jimma University has been developing a range of innovative co-production research techniques with members of the Women's Development Army (WDA), the umbrella organisation of nation-wide community health workers. As in Uganda, the aim of the work was to train WDA members through real cases. The data from the two countries consist of observations, meeting notes and student reports from project activities. The data were collected and collated by the sixth and seventh authors (Uganda) and the eight author (Ethiopia). The data were analysed together with the second and last authors through topic selection and inductive reasoning.

3.4. Ethical Considerations

A key principle and starting point for each case study is a prolonged engagement and trust-building with the communities in which the activities were taking place—often over more than a decade. This is a critical element of working in local settings because courtesy bias is a well-documented challenge in health research [39–42], and the rural communities in all our study countries have a long experience of giving outside agencies the answers they wish to hear. Moreover, in many places, communities often treat consultation as a firm promise to deliver goods or services in line with the work discussed. This presents an ethical dilemma, due to the inability to meet the raised expectations, and thus damaging trust. Although these dilemmas and challenges are difficult to resolve, the continuity in partnerships and recurrent interactions is a crucial methodological principle in research with and for community-based health systems. All data for the three case studies are retrieved from such long-term engagements. For the planned meetings with selected community members, the latter gave their informed consent for inclusion before they participated. For emergency interventions (primarily case II) and situations requiring immediate care support, consent was assumed from the request for support.

4. Results

4.1. Case Study I: Transformative Health Agenda Setting through Science Shops in Sierra Leone

The Ebola Virus Disease struck Sierra Leone in early 2014. All previous outbreaks of this deadly haemorrhagic fever had been in central or eastern Africa. There was no knowledge in the health system of how to handle the disease, and international help was slow to appear. Medical practitioners and communities had to quickly learn about the disease from their own experience. A much early response was developed on the spot and proved effective. It included improvised protection for handling patients, safe burials and a self-imposed quarantine [25,26,43]. The cases in the areas that were first affected were in decline even before a large international Ebola response began to assemble, following the declaration of a Public Health Emergency of International Concern (PHEIC) by the WHO in August 2014. Community leaders had developed bylaws and mobilised volunteers to apply these rules to case finding, the prevention of inter-village movement and burying the dead [26,44]. The community volunteers implementing these bylaws described themselves as Ebola task forces—their own term was Ebola kugbe (in Mende kugbe = force) or Ebola kamajoisia (members of the hunters' guild).

Parts of the research on Ebola responses took place after the epidemic had ended, and the interviewed members of the task forces wondered whether they could play a more permanent role in protecting community health. The expression of a problem by community members to which research may contribute is the essence of a "science shop" model. Science shops developed in Europe as a way of directly linking communities with unmet needs for scientific knowledge with university researchers willing to undertake such work [44,45]. Ensuring that the problem is suitable for scientific treatment and that the community's demand for new knowledge is genuine and not simply a result of the researchers' initiative is an essential first step. Through a short-term collaborative project with Dutch funding, the experiences with the science shop model from Wageningen University (The Netherlands) were shared with staff members from Njala University (Sierra Leone) and tailored to the request from the Ebola task force members.

A first exploratory meeting was held between university staff and task force members at Daru in the Jawei chiefdom, in Kailahun district (a major centre of early mobilisation against Ebola). Here, it was concluded that the biggest unaddressed challenge in local communities post-Ebola was malaria, a major factor in the notoriously high rates of under-5 mortality in the region. It was agreed that the task force would consult with its base about a focus on improved mosquito control as a way of addressing the malaria problem, and that there would then be a meeting of stakeholders to assess the local levels of knowledge concerning mosquito vectors of the disease. The consultation resulted in a clear message that there was a widespread interest to address the mosquito-malaria problem. A second

meeting involving community members was then arranged to assess the local levels of knowledge concerning mosquito vectors. This meeting (also held in Daru) brought together task-force members and representatives of other community groups (elders, women's groups and nurses and community health officers from rural health centres). The participants discussed how people saw the problem of mosquitoes and explored ideas about health implications. A specific question was considered: what might be done to control the risks posed by these insects. The participants examined four photographs of mosquito species to see if they could identify the one responsible for malaria. The most frequently chosen species was the "tiger mosquito" (*Aedes* sp.) on the grounds that malaria was a "fierce" disease and this mosquito looked suitably aggressive. *Anopheles gambiae*, the true vector of the malaria parasite (*Plasmodium falciparum*), was not chosen. It was also widely (and incorrectly) thought that malaria mosquitoes favoured latrines and dirty water for their reproduction, and that a focus on cleaning these sites ought to be a priority for malaria reduction.

The information that *A. gambiae* favoured clean water and often bred in rainwater puddles generated genuine surprise, and the groups expressed interest in meeting with a mosquito specialist to learn more about the insect's life cycle and its involvement in the spread of malaria. It was also agreed that this meeting should be held in a typical village setting and involve (in particular) nursing mothers, known to have the greatest personal stake in protecting vulnerable young children from malaria. The village meeting was arranged in Lalehun, a settlement on the boundary of the Gola Rain Forest National Park, (GFRNP) in the Gaura chiefdom, in January 2018. The project funds enabled the use of the GRFNP visitor centre facilities for the accommodation of visitors, the feeding of village participants and meetings to receive briefings on field tasks and examine specimens. Community groups went out to sites in and around the village to identify mosquito breeding locations and bring back mosquito larvae, which were identified with the help of a mosquito entomologist from Wageningen University. The entomologist also trained villagers in the use of traps to collect mosquitoes from night-time sleeping areas in the village and gave several illustrated presentations on the life cycle of mosquitoes and the Plasmodium parasite.

The participants were highly engaged. A proposed lecture on mosquitoes and malaria by the visiting specialist was cancelled after a heavy day in the field but had to be hastily reinstated when a large number of villagers (many of them nursing mothers) turned up after dark demanding that the lecture go ahead. The presentation was unavoidably lengthy and complex, and lasted late into the evening, but the attention was unflagging, and a lengthy question-and-answer session followed, with several perceptive comments and queries. The trapping devices were less successful, mainly due to the dry season being a time when mosquito numbers are down, but this did not deter some women from spending a good part of the night patrolling their bedroom walls to suck up insects with a hand-held collecting device. These specimens were then identified, and the effectiveness of a mosquito net impregnated with a new kind of insecticide was demonstrated, which was greeted with cheers from the audience. It transpired that most women owned and used bed nets. Once again, however, it turned out that few participants in the workshop could actually identify *A. gambiae* as the source of the malaria problem, thinking that larger mosquitoes posed the threat, especially when they buzzed.

There is little doubt that the meeting with the community members was effective in giving people new knowledge about the mosquito problem and the malaria threat. The experience led to a discussion among the involved researchers on how this new knowledge might be deployed. It was realised that mosquito threats needed to be monitored across the seasons, and that breeding sites needed to be more fully identified before eradication steps could be taken. The participants demonstrated a good capacity to trace mosquito breeding and hiding spots, but had a limited understanding of the plasmodium cycle. Addressing this knowledge gap might then increase the capacity for village- and compound-specific mosquito-control and biting prevention strategies.

The short and exploratory application of the science shop approach shows that there is a role for task-force-like groups to mobilise around risk monitoring activity, especially if some of the younger women could be induced to take an active role, but that it would also be useful to offer a version of the science shop offered in Lalehun as training for Village Health Workers (VHW), to embed the necessary entomological knowledge more firmly at the local level. VHW are community-based volunteers who follow a training programme of 10 training modules, to develop the capability to diagnose and prescribe for common diseases. VHWs also have enough knowledge to refer cases they cannot handle to the nearest community health post, generally located in the chiefdom headquarters town. VHW, it was thought, could supervise community mosquito eradication initiatives. There was enthusiasm to start on such a programme, and workshop participants from outside Lalehun strongly requested for it to cover more than one pilot village. As the science shop model is principally a community-based research and education format for local universities (or other local training and research centres), a further elaboration of the science shop model requires further local institutional embedding and funding. We are currently discussing a continuation with Eastern Polytechnic in Kenema (the newly designated University of Technology). From the exploratory meetings presented here, it can be concluded that implementing the science shop process in rural Sierra Leone was very positive, both for building community relations and for identifying concrete actions for local malaria control.

4.2. Case Study II: Embedded NGOs Supporting Community Health Workers at the Frontline of Hurricane Response in Madagascar

Living alongside the Toliara barrier reef on the arid southwest coast of Madagascar, Vezo fishing communities are among the most remote and underserved communities in the country, with very limited access to healthcare and other essential services. These "people of the sea" rely almost exclusively on the sea for food and income, earning on average less than US$2 per day. Since 2003 marine conservation organisation Blue Ventures has been partnering with them to help rebuild their fisheries and support community-led conservation. Communities from across 26 villages work collectively to manage Madagascar's first Locally Managed Marine Area (LMMA), an area of 500 km^2 of nearshore waters, banning destructive fishing practices and protecting vital marine habitats. The LMMA is governed by a management committee, made of elected members of the local community. To address unmet health needs, local women have been trained as community health workers to provide healthcare and education to their communities, focussing on family planning, maternal and child healthcare, and safe water initiatives. This population of 12,000 relies on a network of community health workers and basic community health clinics for the entirety of its healthcare needs.

Tropical cyclone Haruna reached southwest Madagascar as a powerful category 2 storm in February 2013, with heavy rain and wind speeds of 150 km/h—the largest cyclone in the region for more than 35 years. Homes, schools, government buildings and health clinics were damaged, with many being completely destroyed. The heavy wind and rain meant that families in the communes of Befandefa and Morombe (home to approximately 15,000 people) were unable to fish for up to 2 weeks, resulting in acute food shortages for much of the community. Outbreaks of diarrhoea and malaria resulted from the flooding and contamination of water sources, which also prevented external agencies from reaching the affected area with emergency relief. All roads were completely cut off for over 6 weeks, meaning that the only way to travel in and out of the area was by boat, ox cart or on foot (sometimes wading through chest-deep water).

As the winds and rain from the cyclone ceased, families and community-based institutions rapidly mobilised, determining who needed support, what needed to be done, how tasks were allocated and who would lead and coordinate. Families supported each other, often working with their extended family and neighbours, to rebuild each other's homes. (Repairing homes was one of the most easily implementable actions, since materials could be gathered locally.) Through informal social networks, community leaders and

community health workers were quickly made aware of which families had suffered the most damage and who was most in need. The community health workers, the village leaders and the management committee of the locally managed marine area immediately adopted leadership functions. They gathered information, coordinated with government authorities and, most notably, convened water committees to treat well water in order to make it safe to drink. They also stood guard over the public wells throughout the night to ensure an equitable use of this finite supply of safe water.

Community health workers are trusted community members and leaders. They rapidly organised community education meetings on post-cyclone health risks. They utilised and increased the distribution of supplies that they were already trained to provide, including mosquito nets for people sleeping outside while rebuilding their homes, water treatment products, oral rehydration solution for children with diarrhoea and contraceptives. Being already embedded in the affected areas, Blue Ventures provided logistic support to these community health workers' initiatives. They coordinated with community leaders and local health institutions to manage critical supply chains and transportation, sharing information and coordinating with national disaster response teams.

Community members were willing to play their part in the response, and community health workers undertook whatever was needed in order to protect the wellbeing of the communities they served. Community health workers and community members travelled for hours in ox carts almost completely submerged in water to ensure that all mobile clinic services could be maintained. They carried medical supplies to areas that were completely inaccessible to national disaster response teams. Their work and dedication to their community ensured that regular clinics continued to take place despite the disruption caused by the cyclone; not one clinic was cancelled. Along with all of their other belongings. many people lost their health cards. Since they were receiving services through the CHWs, however, these CHWs had records of their appointments and follow up details (as well as an in-depth knowledge of the communities they served). The continuity of care was therefore maintained throughout the crisis—something that is rarely achieved in crisis-response—which testifies to the resilience, and therefore sustainability, of this community-based care system. The effective coordination with other community efforts, such as those led by the management committee of the LMMA to identify and allocate resources to those most in need of support, enhanced the overall effectiveness of this community response: disease outbreaks were minimised, homes were quickly rebuilt and food was shared with those most in need.

What was witnessed in the aftermath of cyclone Haruna was a true community-led response. Without waiting for or relying upon external support, communities self-organised and mobilised to respond to the crisis. The social capital that existed between community members and community groups, thanks in part to the presence of the highly trusted and valued network of community health workers, proved to be a valuable asset as the community responded to the crisis. Critically, as an NGO embedded in the region (the only international agency present), Blue Ventures had developed a long-standing, supportive relationship of trust with the community, and through this it worked to support the efforts of these community institutions and networks, rather than initiating a separate emergency response that did not take into account this local response. It is unlikely that an external agency, without a good understanding of the local context, or social capital to draw upon, would have been able to formulate a response that would have been as contextually appropriate, even with the benefit of more resources and technical expertise. A parallel response—or, worse still, a response that served to undermine the work that communities were undertaking—could have eroded the social capital that was being drawn upon (and perhaps strengthened) during the crisis.

4.3. Case Study III: Local Universities' Diverse Approaches to Co-Producing Community-Led Health Responses in Uganda and Ethiopia

Uganda has a number of endemic diseases and health conditions, most prominently cholera, malaria and malnutrition, whose effects are becoming more urgent and pressing

due to changes in the local climate. In Kasese districts, ongoing engagements between cholera-affected communities in the district and Makerere School of Public Health (MakSPH) identified the need for community-led responses to cholera epidemics that were recurrent and prolonged, as abnormal rainfall patters lead to drought and then flooding, which displaces populations and overwhelms environmental sanitation capabilities. The area has low lying villages at the foot of Mountain Rwenzori, in western Uganda, along or near lakes Edward and George. The communities have been engaged, over time, to reduce the main outbreak risks by encouraging the boiling or chlorinating of drinking water, building awareness to improve sanitation and using toilets designed for wetlands and the safe disposal of human excreta [38]. Refugee and Fishing communities, in particular, have been engaged and formed their own leadership groups to build elevated latrines and reduce bad defecation practices through peer-to-peer awareness of cholera risks. MakSPH staff also have good relations with the Ministry of Health, with whom they have worked on initiatives to improve field-level epidemiological surveillance, through a "public health fellowship programme" to train field epidemiologists. To date, 30 field epidemiologists have been trained, having covered 91 outbreaks. There is significant interest in the programme, and, as a result, changes have been made to the training of public health practitioners in Uganda, which now includes a core competence in epidemics and health systems management.

Elsewhere, Makerere University's Centre for Climate Change Research and Innovation (MUCCRI) has championed a Community-Based Adaptation (CBA) approach derived from the agricultural sector, to develop participatory action research design and learning-by-doing approaches to involve and empower households and communities in learning processes and activities that can increase their adaptive capacity to the negative effects of local climate change. For example, the highland agrarian region of Kabale faces a rising population, which creates a pressure on land that results in the widespread encroachment on wetlands and the cultivation on steep hill-slopes. This, together with the unprecedented warm weather, causes soil erosion and flooding, which is leading to a rising prevalence of malaria (before the 1960s, Kabale district was malaria-free) as well as malnutrition. Farming, nutrition, health and livelihoods are all interconnected and all adversely affected by climate risk. MUCCRI has been supporting communities in the co-production of climate information services—a collaborative arrangement in which the producers (scientists) and users (communities) of climate information come together to address gaps in climate services. The communities are encouraged to identify their adaptation needs and come up with solutions. These include the co-production of usable information for decision-making on their farming activities and livelihood survival strategies. The communities have used, over time, the co-produced climate information to put up strong adaptation pilots in their communities, through which they learn how to reduce the impact of drought, rainstorms and floods on farming and food security—e.g., by growing drought-tolerant and early maturing crops, practising rain water harvesting and small-scale irrigation farming, practising conservation agriculture, etc. This has made a significant contribution to nutrition and health. Moreover, the participation of a wide range of community members in these processes has helped to avert conflicts that threatened to arise from the scarce land resource. Learning across a diverse array of community members in a manner sensitive to gender, age and income disparities was enabled. It has also facilitated the investigation and evaluation of the adaptation constraints and opportunities for the communities, which has fostered effective, informed and timely adaptation decisions which are critical for resilient communities.

In contrast, Ethiopia presents a very different context. It provides one of the best-known examples of government structures supporting the implementation of organised community responses for public health. Through its Health Extension Workers (a frontline cadre of primary healthcare staff), Ethiopia has mobilised a nationwide network of more than 400,000 groups of multisectoral Women's Development Army (WDA) volunteers (MOH, Addis Ababa, Ethiopia, 2018). The WDA community volunteers reach their im-

mediate neighbours with health promotion activities (e.g., health messages, encouraging pregnant women to go to health facilities for antenatal, delivery and postnatal care), identifying and referring cases of infectious disease, including those of epidemic potential like cholera and measles, while promoting primary education and farming. In the current COVID-19 pandemic, the WDA have been mobilised to raise awareness and inform the public about infection risks. Although concerns have been raised about the nature and impact of the government's enforcement of the WDA programme, it does seem to have had a positive impact on health outcomes [38].

Jimma University has been developing a range of innovative co-production research techniques with WDA members and community health volunteers. These include video-diaries to analyse the role of community health volunteers as mediators of accessible and responsive community health systems. Moreover, the university has worked with WDA members and leaders over several years to collect data on community perspectives and co-produce and validate findings from focus groups and key informant interviews. In one project, researchers worked with influential Abba Gadas and Hadha Siqees (local religious leaders) to identify and co-develop support mechanisms, including local sponsors, for orphans and vulnerable children, and facilitating wider community consultations. Researchers have sought to maintain close links and a continual engagement with health managers and policymakers at national, regional and zonal health offices on the understanding and use of research evidence for decision-making. This has allowed them to bring issues relevant to the communities to the district and national agenda setting and policy development. They have also collaborated with district health systems officials and health centre management teams on the issues of leadership, management and governance. For example, health managers have been actively engaged to identify leadership gaps and co-design the content and approach of training workshops. The original approach of the workshops was modified to meet the needs and schedules of the health managers.

Furthermore, Jimma University sought to realise its educational philosophy of Community-Based Education (CBE), and has long been working with the health system and political administrators in its vicinity. This has involved working with the nearby communities and primary healthcare facilities as a learning site that enables medical and public health students (under- and postgraduate) to adequately prepare for practice. The participating communities benefit from the systematic community health diagnosis, planning, intervention and evaluation activities performed by the students, and there is a good level of buy-in. In all of these stages, community members are engaged through existing community structures and health volunteers, and the communities become the ultimate owners of these health interventions once the students have graduated. The students in the graduating class are attached to a health centre or primary hospital where they serve clients in the facilities and outreach sites. Their activities focus on prevention and promotion activities, along with basic curative services. They also engage in the education of health extension workers, community health volunteers and community members to build their capacities. Students also do epidemic investigation and management activities in collaboration with the district health office, health facilities and community structures.

4.4. Key Overarching Potentialities and Limitations of the Approaches to Building Community-Based Systems of Care

The analysis of the case studies allows us to draw out commonalities in the potentials and limitations of the different approaches to engaging and working with communities to build locally responsive systems of care. Table 1 summarises the key findings across the four case study countries.

Table 1. Generalised Outcomes of case studies.

Country	Problem Addressed	Community-Based Strategies and Resources	Contribution/Impact	Wider Relevance	Limitations
Sierra Leone	New pathogens change perceptions and response capacity for pre-existing and continuous disease pressure (malaria in the post-Ebola context).	Science shops: university-facilitated, community-based research design and co-produced sustainable care solutions.	Increased knowledge of mosquito taxonomy and behaviour contributed to improved disease prevention and sustainable environmental management.	Effective linkages between interdisciplinary research capacity and trusted community arrangements (extending existing task-forces and village health workers) facilitate health-response activities.	Approach requires costly and time-consuming changes in the organisation of university research and education programming to facilitate grassroots-oriented interdisciplinary research and education.
Madagascar	Severe disruption to health services and negative health impact among disaster-prone coastal communities following cyclone Haruna.	Extended international NGO support to emergency health responses through Community Health Workers and community response efforts.	Continuity of basic healthcare support throughout the crisis enhanced overall effectiveness, minimised disease outbreaks and improved food security.	Embedded NGOs can provide locally sensitive and trusted support and coordination for disaster response and emergent health crises.	Needs investments for stand-by equipment and adjustment of NGO staff expertise. Not all crisis-affected areas will have trusted, locally embedded NGOs.
Uganda	Changing outbreak and prevalence patterns resulting from climate change (cholera in Kasese district and malaria in Kabale district).	University research and training in participatory field epidemiology and diagnostics; support of community healthcare services and sanitation.	Community-developed sanitary facilities and improved crop and water management lead to positive effects on health and food security.	Long-term commitment of universities through projects to co-define health challenges and co-produce solutions, can initiate and sustain community-led actions.	Needs a long-term engagement of universities with community leaders and health workers to gain community trust.
Ethiopia	Health threats for vulnerable groups (locally identified health needs including Covid19 response for orphaned children).	"Learning sites" bringing together university researchers and students, Women's Development Army volunteers, local health systems staff and community members.	Community awareness/ involvement in health issues (Covid-19) lead to improved response capacity and health outcomes.	Long-term commitment of universities through projects to co-define health challenges and co-produce solutions, can initiate and sustain community-lead actions.	Needs a long-term engagement by universities to gain community trust.

A striking characteristic across the four country case studies is the importance of having an embedded presence of researchers or NGO workers over many years in order to build the community trust that is necessary for the co-production of locally-relevant responses to health issues and the establishment of sustainable community structures to respond to local needs. The drawback of this is the time it takes and the costs required to enable a continuous presence for years, but the gains are potentially huge if the legacy of such embeddedness is a sustainable network of community-based systems of care that can effectively respond to a range of health challenges as they arise. Our cases show that such engagement can be achieved through a variety of different engagement mechanisms that draw on existing local resources and incorporate local knowledge and action into local planning and decision-making.

5. Discussion

In this paper we have presented case studies of different approaches to supporting communities in four low-income African countries, with the ultimate objective of understanding the characteristics of sustainable responses to complex crises. Although the health systems contexts in these case study countries are varied, they share a similar range of interrelated stressors, including chronic poverty, livelihoods being affected by environmental and climate changes that lead to health crises, including frequent (and possibly increasing) outbreaks of infectious diseases and zoonotic infections, and changing patterns of vector-borne diseases like malaria. Our case studies have shown that, across these different settings, a variety of efforts to build community-led crisis response mechanisms to tackle health and interrelated livelihood and environment challenges, can be effective. In this section, we discuss how the cases can be interpreted as primers for community care systems and, if further elaborated and secured over time, contribute to sustainable health systems.

The Sierra Leone case illustrated a clearly articulated local demand, grounded in experience, for tackling malaria, using the science shop approach. Although malaria was a clear priority, community members and local health workers, recognising a range of interconnected challenges, expressed a desire to move beyond a siloed single-disease approach and expand the activities to Lassa fever and Ebola resurgence, as well as the effects of the changing climatic conditions on local livelihoods. The science shop model is, in essence, a form of citizen science in which community members take an active role from the outset in co-defining research questions and contributing to the research activities designed to address those questions. Elsewhere, for example in Rwanda, such approaches to developing malaria control solutions led to a significant improvement in malaria-related prevention and treatment-seeking behaviour, as well as individual and collective benefits to both volunteers and the society at large [46]. It can also lead to policy change—for example, Loonen et al. [47] used these approaches to highlight ineffective malaria control strategies in DRC which led to a change of strategy at the WHO and the national and local levels. Nevertheless, the approach remains under-evaluated, and further research is needed on how it is best used, localised and sustained in resource-poor settings. The main challenge for the sustainability of the outcomes in Sierra Leone was the lack of resources. First, science shops are expensive to run when they are led by western researchers with specialised expertise. However, this can be overcome when the model is adopted by local universities. The involvement of Njala University for the exploratory science shop was a deliberate choice, as Njala university also runs the national training programme for community health workers. We have now expanded the local institutional involvement to the new University of Technology in Kenema, since it has major training programmes for both nurses and laboratory technicians. Second, the participants requested a training programme on epidemiology and surveillance, for village health workers and members of other villages. Resources need to be found for this, although a less expensive option for making VHW training sustainable would be to include it in the current curriculum offered for all VHWs by the Ministry of Health.

The experience from Madagascar also revealed the huge capacities of local communities and health workers, in this case to quickly and effectively respond to the disastrous effects of a tropical storm, ensuring a remarkable continuity of care in the affected communities. Like in Sierra Leone during the Ebola outbreak, community health workers played a vital role. As a network of women embedded within the communities they served, CHWs could provide accurate and up-to-date information to community leaders and disaster response teams, often travelling between villages on foot to ensure that important information was shared. Key to these activities is trust. CHWs had existing trust-based relationships with various community groups, and coordinating these led to a more efficient and comprehensive community response, with all groups coalescing around a shared purpose. Whilst community health workers were providing emergency health education, for example, they were also well placed to gather information about who was most in need of additional support and could relay this to other community groups able to respond. There is a wide literature on the benefits of CHWs, though also noting that they are often poorly supported [48,49]. Much of the literature, however, is focused on their actions in routine services. The presented cases from Madagascar and the Ebola response in West Africa show that they can be absolutely critical in emergencies [43,50]. In our case study sites in Madagascar, informal discussions with community health workers and community leaders have suggested that communities feel a stronger sense of agency as a result of this community-led response, with some community members stating that they have taken steps to ensure they are better prepared for the next cyclone (such as ensuring they have money saved to buy emergency supplies). Nevertheless, challenges still exist. There is no evidence that better disaster risk planning is being undertaken at the community level, for example, or that the efforts including the CHWs as a cadre can be sustained. Also lacking in the community response was the utilisation of meteorological data to provide an early warning of the cyclone. With a better access to this sort of information, a better preparation for future extreme weather events is possible. A more effective incorporation of early warning systems and disaster risk planning could help to further strengthen the resilience, and therefore sustainability, of these community health services, though much more work is needed on how to do this. In future, it might be possible for embedded NGOs to act as a different form of trusted interlocutor, to support the development of local disaster risk planning capacities or to help interpret and use more specialist meteorological data to help with early-warning in local communities. Where resources are lacking, it is also possible for embedded international NGOs to call for external support (as some did for Ebola support in Sierra Leone) and to coordinate those resources when they come in—but this is best done by embedded NGOs at the most local level possible.

The local co-design of governance structures and health interventions that are prominent in the Ethiopia and Uganda cases raises an issue of wider relevance for community-based sustainable health systems. As also illustrated by the Sierra Leone case, local initiatives like the Ebola task forces gained respect and prominence because of the delayed or failed support from national and international medical aid agencies. Fuelled by dissonant sources of information or no information at all, high levels of mistrust towards foreign and national aid strengthened the respect for the locally recruited Ebola task forces and likely also their effectiveness [28]. National and international health agencies typically respond to mistrust by sending messages of assurance and pledges of betterment. Instead, our findings and other recent studies suggest that a better strategy is to invest in local initiatives that build trust from the grassroots level upwards through co-existing and interacting institutions that work together with greater stakeholder inclusivity [26,43]. The role of local and national universities in brokering these relationships of trust, as in Ethiopia and Uganda, has been under-researched. However, the longstanding presence of these universities in the communities they work with gives them a status of trust that foreign research teams cannot enjoy. Therefore, local universities need to be far more widely seen as important interlocutors in the development of health research and the strengthening of community-based systems of care. Again, returning to DR Congo, the absence of en-

gagement with local university research staff, who could have provided exactly the kind of local understanding and contextualised response that was needed in the Ebola operations, was a source of frustration [27].

Across these case study experiences, two core common, interconnected issues stand out: the integration of local knowledge when developing health-response actions; and the key role of the mechanisms and trusted interlocutors that broker such knowledge over considerable periods of time.

Our cases have highlighted how local forms of knowledge were incorporated and used to shape decisions about local responses to challenges being experienced. There is a growing critique in the public health field of current "monopolies of knowledge" [51] that favour epidemiological, clinical and big-data scientific "knowledge" (leading to "evidence-based medicine") and large-scale mathematical modelling [52]. The focus is beginning to shift, propelled in recent months by collective Covid-19 experiences, to a desire to understand the complexities of communities and healthcare systems in order to develop new ways of "evidence making" which give primacy to "practice-based evidence" [18,53]. Core to this is listening to and then acting on local knowledge as the primary source of "evidence". The health systems literature recognises the "capacity to combine and integrate different forms of knowledge" as one of the key components of managing resilience [21]. The integration of different forms of knowledge and the way such knowledge issues emerge from below also resonate with similar arguments that address sustainability from other angles. For example, the top-down and technology-centred measures against climate change triggered a debate about how to develop such innovations responsibly [54]. Increasingly, the importance of local forms of knowledge about climate and ecology are also being addressed in ways that include grassroots perspectives, opening up the integration between local knowledge and solutions with science-led initiatives for responsible innovation [55]. Sustainable response systems that are community-based are fundamentally about the capacity to combine and act on different types of knowledge through horizontal as well as vertical integration. Our case studies have highlighted certain challenges to this. In Madagascar, the lack of connection between local decision-makers and high-tech meteorological data to provide early warning of cyclones was a clear limitation. Many local environmental changes can be identified locally. However, surveillance skills must then be transferred to communities—in Sierra Leone, communities identified a range of diseases they wanted to monitor, while in Uganda communities were supported to gather and use local climate information to inform their adaptation strategies.

The second, highly connected issue is identifying mechanisms and brokers that enable community-level knowledge to be revealed and then acted upon. Our case studies illustrated a variety of mechanisms for communities, health and other sector actors to gather and respond to different sources/types of knowledge. These include science shops run in partnership with local universities and the longstanding engagement of researchers and NGOs with local communities who have built trust over many years and are able to listen to and support locally embedded health staff (e.g., community/village health workers, community volunteers). The key point from our cases is that external support for infectious-disease or disaster response cannot be flown in. A long-term local presence is essential not only for building trust, but also for developing "interactional expertise" [56]. A large part of this is knowing who the trusted local interlocutors are; in our case studies, these were often community or village health workers. Trust and interactional expertise are thus critically entwined and essential for sustainable community-based health systems [50]. In emergency response, the recent literature suggests that without such trusted interlocutors you are likely to achieve only limited success, as was seen with such devastating consequences in the 2018–2020 DR Congo Ebola outbreak [27]. There is a need for more studies that evaluate and measure community-responses, and the role of these kinds of trusted interlocutors, to health and environmental crises in different settings.

6. Conclusions

While much work still needs to be done in defining and measuring successful community responses to health and other crises, our case studies have identified two potentially core criteria: the inclusion and integration of local knowledge in response planning and actions, and the involvement of researchers and practitioners (including community-embedded health workers and NGO staff) who have a longstanding presence within communities and can act as trusted key interlocuters in brokering knowledge and devising sustainable community systems of care. The case studies profiled in this paper indicate a range of existing community-led co-production initiatives that can contribute to strengthening sustainable community-based health systems. Furthermore, they reveal the importance of expanding notions of health to encompass the whole environment (physical and social, across time and space) in which people live, including the explicit recognition of ecological interests and their interconnections with health.

Further research is needed to build on the studies in this paper to synthesise a wider range of data to distil common lessons on *how* to develop equitable mechanisms for co-producing locally-embedded responses to health crises in different settings, as well as what works and why. A wider pool of data would identify the support and the investments necessary to empower the favourable characteristics of community responses, fill relevant knowledge gaps and strengthen facilities towards more robust community-based health systems. Nevertheless, our case studies have shown that through a focus on the incorporation and brokering of local capacity over time, longer-term resilience can effectively be built at the grassroots level.

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