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# Strengthening global health security by improving disease surveillance in remote rural areas of low-income and middle-income countries

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**The COVID-19 pandemic has underscored the need to strengthen national surveillance systems to protect a globally connected world. In low-income and middle-income countries, zoonotic disease surveillance has advanced considerably in the past two decades. However, surveillance efforts often prioritise urban and adjacent rural communities. Communities in remote rural areas have had far less support despite having routine exposure to zoonotic diseases due to frequent contact with domestic and wild animals, and restricted access to health care. Limited disease surveillance in remote rural areas is a crucial gap in global health security. Although this point has been made in the past, practical solutions on how to implement surveillance efficiently in these resource-limited and logistically challenging settings have yet to be discussed. We highlight why investing in disease surveillance in remote rural areas of low-income and middle-income countries will benefit the global community and review current approaches. Using semi-arid regions in Kenya as a case study, we provide a practical approach by which surveillance in remote rural areas can be strengthened and integrated into existing systems. This Viewpoint represents a transition from simply highlighting the need for a more holistic approach to disease surveillance to a solid plan for how this outcome might be achieved.**

## Introduction

Emerging zoonotic diseases have had devastating effects globally, especially in low-income and middle-income countries (LMICs). LMICs also bear the brunt of endemic and neglected zoonotic diseases.[1] Diseases such as anthrax, bovine tuberculosis, and rabies are for the most part successfully managed in high-income countries but persist in LMICs,[1] causing billions of cases and millions of deaths annually.[2] These zoonotic diseases tend to persist in LMICs because of socioeconomic and environmental drivers (eg, climate change and social inequality).[3]

Although the global health community has invested in strengthening disease surveillance in LMICs, efforts remain uncoordinated and often fail to reach communities in remote rural areas.[4] Yet, these communities are routinely confronted with zoonotic diseases because of close contact with livestock and wildlife.[5] Inadequate surveillance in remote rural areas can cause delayed detection and ineffective response to disease outbreaks, increasing the risk of pandemics due to latent amplification, regional and global travel, and animal trade.[6,7]

Advances in diagnostic testing, along with adoption of a One Health approach that fosters collaboration between human, animal, and environmental sectors, can make zoonotic disease surveillance in LMICs more accessible, cost-effective, sustainable, and connected across geographical scales.[8,9] However, the practicalities of effectively implementing surveillance in resource-limited and logistically challenging settings have yet to be fully discussed, limiting the potential for this approach to be integrated into existing surveillance systems.

In this Viewpoint, we highlight the need to prioritise surveillance in remote rural areas of LMICs and synthesise a practical framework for extending surveillance into these areas. We define remote rural areas to be areas where communities are geographically removed from urban areas, including mountainous areas in central Asia, as well as rainforests and semi-arid regions of South America and Africa. Although the zoonotic diseases faced by these communities can vary substantially, their representation in surveillance systems is consistently lacking. The framework that we propose considers communities reliant on pastoralism and smallholder agriculture in semi-arid regions in Kenya, which are at high risk from zoonotic disease and frequently marginalised from health-care services. Although wide variation exists between contexts, the approaches outlined in this Viewpoint can be adapted and applied more widely.

## Why invest in zoonotic disease surveillance in remote rural areas?

Around half of people in LMICs live in rural or remote areas.[10] Livestock, many of which are reared in remote rural areas, contribute to approximately 25% of agricultural gross domestic product in LMICs,[11] and support the livelihoods of over 600 million smallholder farmers[12] and 30 million pastoralists in Africa.[13] By sustaining biodiversity, communities in remote rural areas also maintain ecosystem services.[14] Despite these benefits, communities living in these regions are inadequately integrated into health-care services,[15] promoting higher burdens of endemic zoonotic diseases and increased poverty.[2,5] Improving representation of these communities and their animals in disease surveillance systems would improve livelihoods, thereby enhancing nationwide health and livestock production, and increasing national gross domestic product.

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Strong surveillance in remote rural areas of LMICs is also essential to provide early warning of emerging zoonotic diseases. Communities in remote rural areas are at increased risk of exposure to emerging pathogens due to close contact with domestic and wild animals.[5,16] Yet, many aspects of pathogen ecology and evolution are unknown in these settings.[16] Environmental threats, including land use and climate change, are especially pronounced in remote rural areas,[17] and can increase disease transmission between humans and animals.[16] Environmental threats also promote burdens of non-communicable diseases (eg, poor nutrition), which might exacerbate spillover risk. Given the frequent movement of people between urban areas and remote rural areas, and animals across national borders, failure to reach these communities increases the risk that emerging zoonotic diseases will remain undetected, posing a substantial threat to global health security.[6,18]

## Are we doing enough to serve communities in remote rural areas?

### Passive surveillance is the norm in remote rural areas but ill-suited for the context

Passive surveillance is conducted in human and animal systems in remote rural areas of LMICs (ie, physicians and veterinarians report cases to local health officials).[19] Although passive surveillance can cover a large area and be conducted continuously, its effectiveness is contingent on strong connections between health-care services and communities. When these connections are weak (eg, due to geographical inaccessibility of medical facilities, conflict and insecurity, and distrust of governmental authorities), passive surveillance can overlook large segments of the population, thereby missing disease outbreaks and causing substantial under-reporting of human and animal morbidity and mortality.[20,21] Passive surveillance systems are also rarely designed to include mobile populations, particularly populations whose transhumance routes cross national borders, which represent a substantial proportion of people in sub-Saharan Africa and central Asia.[22]

Passive surveillance programmes in remote rural areas are also hindered by poor diagnostic capacity. Health facilities often do not have functional diagnostic capacity (eg, bacterial culture, autopsy, and PCR machines), and where equipment is available, staff might not have adequate training.[20,21] These circumstances make passive laboratory-based surveillance in remote rural areas slow, costly, and prone to cold-chain issues, because samples must be shipped to facilities with diagnostic capacity, typically located in local large cities or internationally. Relying solely on passive surveillance also means that there are no records of asymptomatic cases, which might be especially problematic for surveillance of emerging zoonotic diseases.[21]

Reporting biases due to the aforementioned issues generate inaccurate estimates of disease burden at the county or province level and national level, complicating efforts to identify and respond to disease outbreaks.

### Drawbacks of passive surveillance are not always offset by other surveillance measures

To overcome these limitations, active surveillance of high-priority endemic and emerging zoonotic diseases is increasingly conducted in LMICs. This type of surveillance is characterised by periodic sampling of sentinel populations, which is typically conducted by national and international health authorities or researchers in urban and peri-urban areas.[21] Where active surveillance is conducted in remote rural areas, it is often initiated by external funders.[19] Therefore, support for these programmes tends to be short-lived, without adequate plans for longer term integration into surveillance workflows. Additionally, active surveillance guided by research priorities might be biased towards pathogens and regions of international interest (eg, tourism and military), which might not reflect priorities in rural communities.

### Advances in surveillance do not always reach remote rural areas

Advances in zoonotic disease surveillance are increasingly applied in LMICs. For example, a One Health approach is increasingly used for zoonotic disease surveillance, particularly in food supply chains.[23] Technological advances in data sharing and field-based diagnostic tests, as well as new geospatial (eg, remote sensing), bioinformatic, and statistical techniques have allowed for more accelerated and targeted surveillance in LMICs.[24,25] However, these advances are primarily tested and applied in urban and peri-urban areas,[26] at the expense of remote, resource-constrained rural regions where diagnostic capacity is poor. Weak communication and coordination of stakeholders across regions and sectors also frequently prevent progress made in other settings from reaching and benefiting scientists and practitioners working in remote rural areas.[19]

### Recent progress—tailoring surveillance to remote rural areas

The aforementioned limitations have been raised before,[5,6,21,25] and progress has been made towards developing approaches to facilitate surveillance in remote rural areas. For instance, active surveillance with participatory methods (community-based surveillance activities) has shown promise in remote rural areas, especially when combined with One Health approaches, because this approach links communities with local health agencies, generates trust, and helps improve dialogue across surveillance networks.[25,27]

Similarly, One Health approaches combined with syndromic surveillance (reporting of disease indicators) are well suited for structuring surveillance systems in pastoralist communities because of high contact with livestock.[13,27] However, these advances are currently implemented sporadically in remote rural areas and continue to be infrequent.

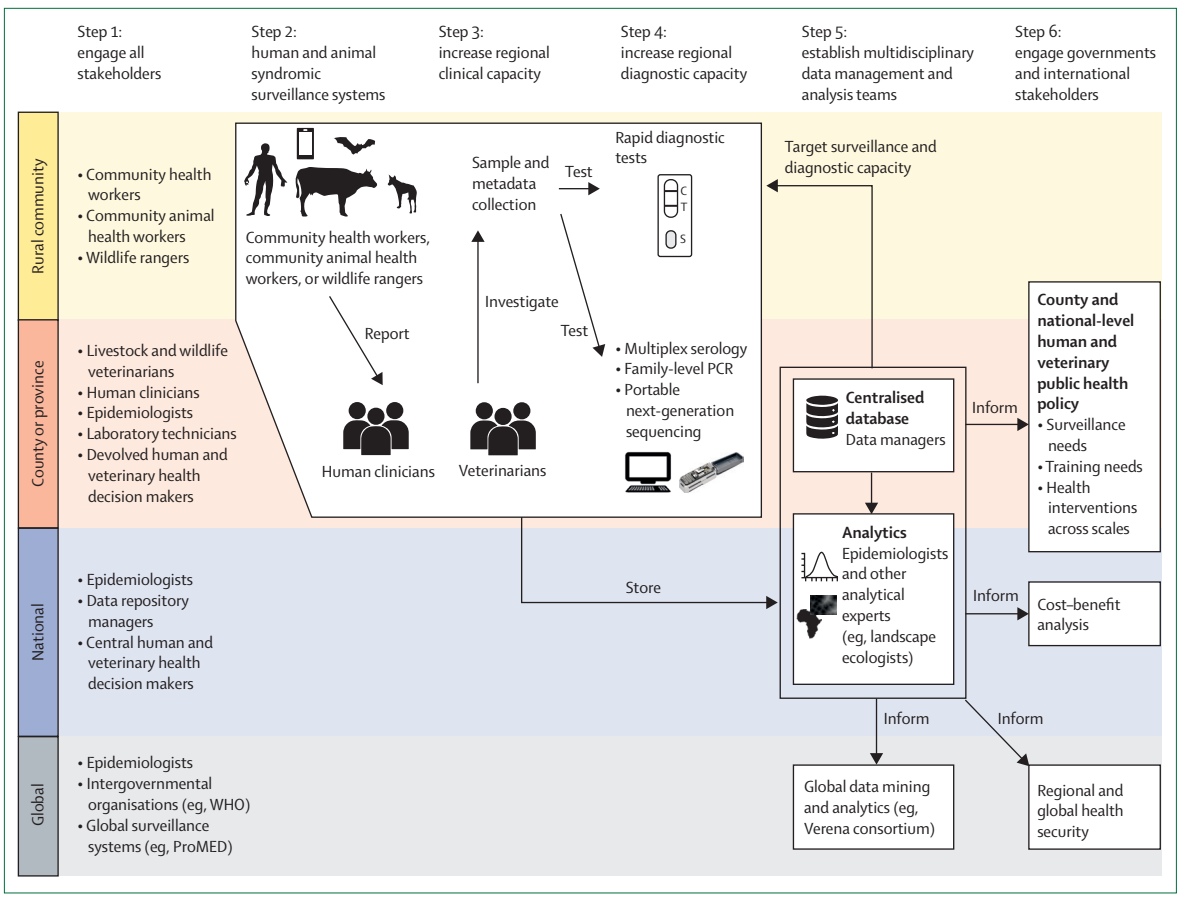


***Figure:*** **Framework for strengthening zoonotic disease surveillance in remote rural areas that would facilitate integration into existing surveillance systems**

## How can we do better?

### A six-step framework

We put forward six steps that need to be taken at different geographical scales—community, county or province, and national—to improve surveillance in remote rural areas of LMICs, and present these steps in the form of a modified disease risk analysis framework (figure). We discuss each step in the context of Kenya because of our teams' expertise in this country, and because Kenya is making substantial progress towards establishing integrated zoonotic disease surveillance.

### Step 1: engage all relevant stakeholders

Zoonotic disease surveillance requires interdisciplinary collaboration across stakeholders in human and animal health, including community representatives, regional and national health workers and scientists (eg, livestock and wildlife veterinarians, physicians, and biologists), and government officials. At present, many stakeholders are not included throughout all stages of surveillance efforts (ie, design, implementation, management, and evaluation), causing the system to be ineffective and short-lived.[20] Kenya has worked to address this issue at the national level by creating the Zoonotic Technical Working Group, which has representatives from different health sectors meet quarterly to discuss approaches to mitigate zoonotic disease outbreaks and maintain One Health practices. However, health services continue to be imbalanced within some counties, partly due to weak stakeholder engagement.[28] To ensure that health issues in remote rural areas in Kenya and other countries are not overlooked, county or province working groups should be established so that all stakeholders are involved in all stages of surveillance efforts in remote rural areas and relay information to national working groups.

### Step 2: establish human and animal syndromic surveillance systems to overcome limitations associated with passive surveillance

Mobile-phone-based syndromic surveillance of people and animals in remote rural areas could overcome barriers related to remoteness and guide veterinary and public health services. Kenya has deployed an integrated human and animal syndromic surveillance system, the Kenya Animal Biosurveillance System (KABS),[29] which targets disease syndromes prioritised by national health agencies, allowing health data from across the country to be rapidly transferred to health authorities. However,

For more on the **Zoonotic Technical Working Group** see http://www.zoonotic-diseases.org/zdu-road-map-to-one-health/

because KABS does not connect beyond clinically trained health-care professionals, its reach within remote rural areas is currently limited. Engaging community health workers, community animal health workers, and wildlife rangers in remote rural areas to conduct syndromic surveillance of humans, domestic animals, and wildlife, respectively, would help to address deficiencies in public health and veterinary capacity in remote rural areas.[6] Community health workers, community animal health workers, and wildlife rangers can provide context-specific knowledge of zoonotic diseases, and ensure that funders and researchers target locally relevant problems, and that human and animal health recommendations are culturally adapted, thereby improving acceptability and reporting.[30,31] Many current mobile phone applications in use could facilitate these efforts. For example, the Spatial Monitoring and Reporting Tool is used by wildlife rangers to monitor biodiversity in remote rural areas across the tropics and could collect baseline wildlife health data in remote rural areas that would be relayed to veterinary services.[32] This surveillance approach would require regular training and close supervision to ensure strong communication between front-line staff and county or province health services.[19]

### Step 3: increase regional clinical capacity

Establishment of syndromic surveillance systems in remote rural areas should be accompanied by the training of clinicians to practise One Health and adapt to different disease scenarios so they can respond to syndromic data submitted by front-line workers (eg, community health workers). Creating zoonotic disease units like the Kenyan Government's Zoonotic Disease Unit (ZDU) would increase One Health training and cross-sector collaborations at national and subnational levels,[33] and efforts to specifically target remote rural areas would be needed. Training veterinarians and physicians working in remote rural areas to collect human, animal, and environmental data should be augmented globally.

This approach will involve strengthening clinician awareness of the presentation, diagnosis, and epidemiology of zoonotic diseases, which will require familiarity with interdisciplinary sampling and investigation techniques (eg, post-mortem procedures and epidemiological assessments of surroundings).

Clinicians in remote rural areas also need regular and structured training and supervision on identifying variations that could indicate novel emerging zoonotic diseases. Kenya's ZDU and partners, including the Centers for Disease Control and Prevention in Kenya, are tackling this gap nationally through One Health training programmes that are focused on rapidly detecting and controlling emerging zoonotic diseases.[33] Such training efforts need to be extended to remote rural areas and applied to other countries. More generally, emphasis needs to be shifted towards providing clinicians with adaptable skills, rather than purely technical skills, so that they can distinguish different disease scenarios. The use of relevant diagnostic tests (eg, next-generation sequencing approaches) and accurately identifying an increase in cases that do not respond to routine therapies are some of the ways clinicians can be trained to identify novel emerging zoonotic diseases.

### Step 4: increase regional diagnostic capacity

To ensure timely response to disease outbreaks, the availability of diagnostic tests and the interpretation and reporting of findings need to be strengthened in remote rural areas. Kenya has substantially increased its diagnostic laboratory capacity by developing training programmes that are supported by the Kenya Medical Research Institute and partners.[34] This training approach could be used in other countries and should expand to remote rural areas. Field-based rapid diagnostic tests and multiplex serological assays could then be used by front-line workers to overcome cold-chain limitations and ensure that a diverse range of pathogens are screened during disease outbreaks. County or province sequencing facilities, along with portable sequencing technologies, should also be incorporated into surveillance efforts to aid in the discovery of novel emerging zoonotic diseases and understand transmission dynamics.[24] Maintaining close connections with centralised centres of excellence (eg, the Biosciences eastern and central Africa–International Livestock Research Institute Hub [also known as the BecA-ILRI Hub] in east Africa) will also ensure appropriate testing and training.

### Step 5: establish interdisciplinary teams responsible for data management, evaluation of surveillance, and risk-based epidemiological analysis

For surveillance in remote rural areas to be effectively integrated into national surveillance efforts, systems should be built to facilitate communication and data sharing between human and animal health sectors, and across geographical scales. An open-source online database maintained by centralised and decentralised data management teams (to ensure standardisation and coordination across county or province scales and national scales) would be key to these efforts. Kenya is pushing for this approach to be adopted, evidenced by the creation of the ZDU, and several regional pilot studies have shown its feasibility.[23] Presence of epidemiologists on these teams for quantitative evaluation of surveillance data and risk-based analysis is also crucial. Further, effective longer term storage and accessibility of biological samples is needed so that epidemiological trends can be monitored across space and time.[35] Epidemiological results should then be conveyed to policy makers and front-line health workers (eg, clinicians and community health workers), so that efforts target higher risk locations, people, and animal species, and ensure that models capture contextual variation.[20,25]

Epidemiologists will need to be familiar with advanced modelling approaches (eg, stochastic compartmental models and machine learning models), and skilled at handling big data (eg, geospatial and metagenomic sequencing data). Training, supervision, and support offered by local universities and research institutes, and by international research groups (through remote learning platforms), would achieve this training requirement.

### Step 6: engage governments and international stakeholders

The guidelines we have outlined are only useful if outputs are effectively communicated to policy makers. Early engagement in the design and implementation phases (as outlined in step 1) will help to achieve this goal, allowing the tangible effects of enhanced surveillance in remote rural areas to be shared. Establishing a government zoonotic disease unit like Kenya's can help to facilitate early engagement. Economic assessments measuring the costs and benefits of extending surveillance to remote rural areas would also be key to this early engagement, along with robust epidemiological assessments as described in step 5.

Efforts to improve surveillance in remote rural areas also require international support, both advisory and financial. Given that zoonotic diseases can have large roles in poverty and are often not limited by country borders, international groups (eg, G8 nations and UN agencies) should commit long-term support for continuous surveillance and response efforts that better serve remote rural communities.[36]

## Conclusions

Strengthening zoonotic disease surveillance in remote rural areas of LMICs has the potential to reduce human and animal morbidity and mortality, and improve pandemic preparedness and national economic security. Our framework aims to mobilise interdisciplinary stakeholders to integrate remote rural communities, their domestic animals, and coexisting wildlife into existing surveillance systems, to invest in training front-line health workers, and to position diagnostic capacity closer to the point of care. In doing so, our framework serves as guidance for health authorities and researchers looking to implement zoonotic disease surveillance in remote rural areas of LMICs.

#### Contributors

KELW-T and JMH conceptualised the Viewpoint. KELW-T drafted the Viewpoint. All authors contributed to further conceptualisation and the writing of subsequent drafts and approved the final manuscript.

#### Declaration of interests

We declare no competing interests.

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