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STUDY PROTOCOL

# A Novel Extreme Weather Risk Insurance System for Kenya (NEWRISK): Encouraging preparedness, planning, community co-design, and protection of Kenya's health system from the effects of extreme weather

[version 1; peer review: awaiting peer review]

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## Abstract

Kenya is a frontline country for extreme weather and faces long droughts, flooding and heat waves. This study will focus on the broader, pervasive health risks associated with the reduction or catastrophic withdrawal of health services. Our aim is to determine what extreme weather hazards Kenya faces, and how resulting impacts on the population and health service can be mitigated, creating scalable tools that inform planning. This study will be carried out in four counties, selected to represent the different climatic regions of Kenya.

We will conduct a mixed methods study drawing on qualitative participatory approaches, climate modelling, health facility surveys and health economic modelling. We will conduct a policy document review; non-participant observations of key county budgeting and planning events; in-depth interviews with health managers; and stakeholder dialogue workshops to co-create a framework for

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developing extreme weather mitigation plans. We will use the latest climate analysis techniques to provide high resolution data on heat and precipitation for the whole of Kenya. Drawing on secondary data, we will then create a population vulnerability index to spatially represent vulnerable populations.

We will create a tool to assess the readiness of public health facilities across four counties. We will map this data to understand the interactions between extreme weather, population vulnerability, and the health system. We will present this information during community consultation and stakeholder workshops to get input and co-develop mitigation plans. Finally, we will use health economics methods to estimate the costs of doing nothing versus various protective strategies.

We will create a set of tools and methods that can be combined to analyse the extreme weather threats posed to health systems or inform a climate risk insurance product. We expect to provide policymakers with practical approaches to protect their health systems and populations.

**Plain Language summary**

Kenya is a frontline country facing prolonged droughts, flooding, and heatwaves. Beyond direct health risks, extreme weather causes widespread harm through the reduction or withdrawal of health services. This study aims to build the evidence base for climate risk interventions to keep health facilities open when needed most. We ask: how do extreme weather, population vulnerability, and health facility readiness interact, and how do we protect crucial health facilities and the patients they serve?

We are studying four Kenyan counties (Kilifi, Kirinyaga, Kisumu, and Turkana) representing different types of climatic zones. Across 80 health facilities, we will survey 80–160 healthcare staff and assess material infrastructure like power and water supplies. We will map population vulnerability and estimate costs using health economics methods. Additionally, we will hold focus group discussions, consultative workshops, and photo-voice activities with community members and leaders, alongside workshops with national and county health managers to co-design protective plans.

As an active study, our findings will provide focused data and mapped interactions between extreme weather events, population vulnerabilities, and health system readiness across Kenya's climatic zones. We will also deliver clear economic evidence comparing the costs and risks of doing nothing against the costs of implementing proactive, protective strategies.

Helping health systems become resilient to extreme weather represents a massive unmet need. By developing practical plans and protective mechanisms to ensure the continuation of health services

during severe weather, this work will directly protect the health and welfare of vulnerable communities most affected by climate change.

**Keywords**
Climate Change, Extreme Weather, Resilience, Health Systems, Climate Risk Insurance, Disaster Risk Reduction

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## List of Abbreviations

ARC: Africa Risk Capacity
CGMRC: Centre for Geographical Medicine Research
CHAIN: Child Acute Illness and Nutrition Network
CIN: Clinical Information Network
COP28: 28th Conference of the Parties to the United Nations Framework Convention on Climate Change
DALYS: Disability-Adjusted Life Years
DHIS2: District Health Information System Version 2
FGDs: Focus Group Discussions
FMC: Facility Management Committees
G7: Group of Seven
GDPR: General Data Protection and Regulation
ICF: Informed Consent Form
ICT: Information Communication and Technology
IT: Information Technology
KCR: KEMRI Community Representatives
KEMRI: Kenya Medical Research Institute
KEMRI-WT: KEMRI-Wellcome Trust
KHDSS: Kilifi Health and Demographic Surveillance Site
KNBS: Kenya National Bureau of Statistics
KWTRP: KEMRI Wellcome Trust Research Programme
KES: Kenya Shillings
KSH: Kenya Shillings
LMICs: Low-and-Middle Income Countries
MICS: Multiple Indicator Cluster Surveys
MNCH: Maternal Newborn and Child Health
MOH: Ministry of Health
NEWRISK: Novel Extreme Weather Risk Insurance System for Kenya
PV: Participatory Video
USD: United States Dollars
WHO: World Health Organisation

## Introduction/Background

Over time, great gains have been made in furthering access to health services across diverse geographies and the successes of global health have been widely celebrated.[1–3] Climate change, and associated extreme weather, have the power to undo this progress.[4–6] The Intergovernmental Panel on Climate Change (IPCC) does not offer a single definition of extreme weather, but suggests that events should be defined by their rarity relative to local historical experience and can include heat waves, droughts, and floods.[7] Extreme weather causes additional health burdens in terms of worsening of a vast range of health conditions;[5] through generating new trauma and acute care needs; and also through widespread and complex effects on the provision of health services.[8]

In addition to providing lifesaving and life-improving healthcare services, health facilities play a crucial role in the social and economic life of all scales of human habitation. They, alongside education delivered through schools and universities, can be considered as ‘anchor’ institutions that have a sustaining effect on villages, towns, and cities and their actions and leadership can inspire change.[9] As it becomes harder to recruit staff to work in the most affected facilities; and it becomes more expensive and difficult to operate hospitals, health centres, and dispensaries, the reduction or closure of health services in particular geographies could lead to reduced economic development in addition to significant impacts on health.[10]

Healthcare supports communities and economies, and that healthcare’s role is even more pronounced during periods of emergency.[11] As droughts, floods, and heatwaves cause havoc to individuals, communities, and economies in LMICs, it is apparent that health systems will be asked to provide higher levels of care to those in need.[12,13] In turn, we believe that the quality of the health system response to this new scale of challenge will directly affect countries’ ability to withstand extreme weather events. Helping health systems become resilient to extreme weather represents a massive unmet need we hope to fill.

Kenya provides a compelling example of why interventions are needed before the situation worsens. Kenya has recently suffered from prolonged drought in the Coastal, Eastern and North-Eastern regions of the country, and regularly faces problems with flooding and heatwaves.[14] Unfortunately, the Kenyan health system is already struggling to meet basic needs and needs to prepare for additional loads and challenges. Despite increasing the number of health facilities being an aim of most county governments in Kenya, and of the MoH[15,16] there still needs to be more coverage especially in rural areas.[17] Additionally, many of the buildings within health facilities are of low quality and are inappropriate for the services they provide. Older hospitals in Kenya are spread across numerous low-rise buildings built in different styles and materials over time, with similar legacy health service buildings in Ghana being highlighted as likely to cause significant disruptions to health services under predicted climatic conditions.[18]

Our recent trial of the WHO facility readiness tool in Bamba sub-county hospital and Kilifi County hospital (both in Kilifi County), undertaken as part of preparatory work for this study illustrates this well. Both facilities struggled with asbestos or corrugate roofing, broken windows, poor positioning relative to the sun and lack of natural shading. In addition, in a stakeholder consultative meeting conducted in the preparatory phase for this work, it was noted that building new hospitals and other health facilities has been popular amongst county governments looking for overt symbols of positive, modernist change. Unfortunately, the new constructions have rarely been built with climate change in mind and feature significant amounts of glass despite the solar warming effects and basic corrugate roofs. There is a substantial opportunity to build better in Kenya.

Additionally, water services could be more robust, and shortages have major consequences for health facilities. A recent national survey indicated that only 44% of county-level health facilities have a safe, reliable water source.[18] This finding accords with the WHO's baseline WASH survey that found 57% of all hospitals had 'basic water services',[19] and also with our own work that found a consistently poor performance in the provision of WASH across 14 Kenyan hospitals.[20] We also found through interviews with facility managers, that they felt their WASH performance was largely dictated by the built facilities they inherited and the lack of budget they received.[20] Electrical blackouts are common too[21] and where solar panels are available to public hospitals, it is often as a result of direct external support despite the fact that long-term leased deals for installations of day-time solar power are financially compelling in addition to being sustainable and more reliable than grid supplies.[22]

Perhaps most importantly however, sub-Saharan Africa needs to add about 2.8 million doctors, nurses and midwives by 2030 to achieve minimum estimated health workforce thresholds for Universal Health Coverage (UHC).[23–25] This is reflected in Kenya where shortages are felt at all levels of the health system across all cadres[26] and, as we have previously shown, the lack of sufficient numbers of skilled workers is directly linked to the quality of care provided.[27,28] This situation is worsened by absenteeism due to both legitimate and unwarranted causes with higher rates of absenteeism in hardship areas.[27,29–31]

The increased disease burden associated with climate change is difficult to quantify, but there is strong evidence that over half of all known pathogenic conditions are likely to be worsened.[5] As extreme weather events put pressure on health facilities, all must be done to avoid the types of collapse that were witnessed during the Ebola outbreak in West Africa[32] and the later COVID pandemic in countries across the world.[33–35] A more subtle, but no less worrying effect, is that weather events are not so extreme as to cause immediate abandonment of particular geographies, but instead that they lead to ongoing migration towards cities ill-prepared to attend to the needs of highly vulnerable populations and unsympathetic to their needs.[36] This effect is not well studied and is controversial[37] but it was clear during a recent assessment of Bamba hospital in Kilifi County (undertaken as preliminary work for this application) that the area has witnessed large-scale abandonment putatively due to the increasingly harsh conditions. Again, this emphasizes the role of Kenyan hospitals as being more than providers of immediate care during periods of extreme weather. Health facilities can contribute to the social, and economic life of their settings and act as important exemplars of sustainable practices.[9]

While there have been many calls for something to be done to help health facilities 'adapt' to climate change, most recently at COP28, exactly how they are to do this remains an open question.[38,39] Similarly, while Kenya's National Adaptation Plan for climate change asks for 'appropriate climate change related interventions for the health sector', there are not yet plans to adapt the health system for the threats faced.[32] This NEWRISK project aims to address this need.

Promisingly, the new and fast-growing field of climate risk insurance offers examples of how the most affected areas and communities can become more resilient to extreme weather and gain some financial protection from its worst impacts. In 2015, the G7 pledged to extend 'climate risk insurance' to 400 million people in the developing world by 2020, focusing on Africa.[40] Though this field is not new, this commitment led to the creation of the InsureResilience platform for index insurance cover and an initial $420 M fund to disperse to LMICs affected by climate change. Similarly, with support from

the UK and German governments, the World Bank launched a $200 M fund in 2018 that has recently been superseded by a larger $3B 'Global Shield' fund. While most climate risk insurance products have targeted agriculture – providing cover to farmers for ruined crops and similar mechanisms – there are increasingly diverse forms of coverage with climate risk insurance used to protect infrastructure, coral reefs, and even schools [42. Our preliminary work with stakeholders in this field such as InsuResilience and the Insurance Development Forum suggests that no tools or development offer coverage for health services.

Climate Risk Insurance products work by determining the likelihood of specific types of climatic event to understand hazards (the weather event extremity and location); exposure (how many people are in the affected area); and risks (how the populations will be affected by the hazard). They share common methods and language for assessing the expected effects and costs linked to specific climate risks. They then use these insights to pool and distribute risk. Climate risk insurance enables actors to predict, and plan for, extreme weather, while 'off-setting' risk via an affordable, planned premium rather than having to generate funds when disasters occur. Additionally, the prospect of reducing the 'premium' for the cover provides an additional incentive to drive mitigation efforts. In this way, the best climate risk insurance systems drive resilience not just through timely payouts, but also through incentivising adaptation.

While there is promise for climate risk insurance, it has its drawbacks. Naomi Klein notes, for example, the pitfalls of the global north dominance of the insurance sector:Given the existential threat posed by extreme weather in resource poor settings, there is an urgent need to develop tools to predict, understand and mitigate climate risks that are focused on the needs of LMIC populations. An important step in this direction is African Risk Capacity (ARC). Launched by the African Union in 2012, ARC works across 35 African countries to help governments improve their capacity to plan, prepare and respond to climate risks. A core aim of ARC is to help countries strengthen their ability to predict and mitigate climate risk and, when needed, provide rapid access to financing when a climate-related catastrophe occurs to minimise the negative impacts on vulnerable populations[42] To date, ARC has provided over $720 million USD worth of support to protect 72 million vulnerable individuals across participating countries.

ARC has provided an important blueprint for how climate risk insurance can be managed by Africa for Africa, and we aim to learn from its experience, summarised recently in a thorough review.[43] Indeed, ARC is the inspiration for NEWRISK's goal to support health systems in Kenya, and then all of Africa, to manage and mitigate climate risks to their health systems.

## Justification for the Study

Kenya like many LMICs has experienced diverse weather conditions including drought and flooding with significant impacts on health infrastructure and the health of populations in affected areas.

This work plans to generate detailed maps that show exactly how extreme weather will affect vulnerable communities and the health facilities that depend upon them. Such a combination of granular climate data and vulnerability has not yet been made into an index which would allow for its use across diverse geographies.

Health facilities which provide much needed care including diseases caused by extreme weather conditions, need to be better prepared to withstand some of these devastating weather conditions. This project seeks to understand the infrastructure needed in these hospitals to withstand these extremes in weather.

Ultimately, this project aims to understand if climate risk insurance can cover the most important elements of the health systems that protect vulnerable people. Although, as stated above, we are not committed to producing a risk insurance system, we will design it in Objective 6 and present it to stakeholders. If such a path is not chosen, we will develop alternative plans to finance the recommended changes and assist the MoH and other stakeholders in pursuing support for whichever funding approach they prefer.

Each Objective is designed to produce proximal outputs that are useful at different levels of the health system in the short term, but they also build towards systemic change and sustainable solutions.

## Objectives

This study has 5 interrelated objectives namely:

1. Understand health system stakeholders' priorities for dealing with extreme weather and what plans and policies, including climate risk insurance, can be created to guide action?

2. (a) Create a comprehensive overview of hazards posed by extreme weather events in a changing climate at the level of individual health facilities in Kenya and develop method s to replicate this approach elsewhere.

2. (b) Explore the scale and impact of effects related to closure or reduced access to health services due to extreme weather on vulnerable populations in Kenya and develop methods to replicate this approach elsewhere.

3. Determine the infrastructural, operational, and health workforce risks posed to health facilities by extreme weather and design new tools for analyzing these risks.

4. Explore how climate risks and their effect on health and health services can be conveyed to community members in Kenya and how their priorities can inform practical adaptive action to ensure local resilience of health facilities.

5. Examine the economic impact of extreme weather events on the Kenyan population and on healthcare facilities and what climate risk strategies can be used to manage risks.

## Patient and Public Involvement

### When and how patients/public were first involved

Community stakeholders and public representatives were first involved during the study's preparatory phase. Preliminary work included a stakeholder consultative meeting and early testing of WHO facility assessment tools at Bamba Sub-County Hospital and Kilifi County Hospital. This involved gathering initial community perspectives on facility readiness and climate vulnerabilities.

### Development of research questions

Research questions were shaped by preliminary community and stakeholder feedback showing that health facilities were unequipped for climate hazards featuring poor shading, corrugate roofs, and unreliable water/power supplies. Early field experiences in Bamba highlighted that extreme weather causes local displacement and health service disruptions, directly informing the project's focus on community co-designed adaptation plans and health system protection.

### Involvement in design, outcomes, and recruitment

- **Design and conduct:** Community members, Facility Management Committees (FMCs), KEMRI Community Representatives (KCRs), and local leaders (chiefs, religious leaders) participate through focus group discussions (FGDs), consultative workshops, and Photovoice participatory action research. In Photovoice, trained community photographers capture visual evidence of climate threats to guide local planning.

- **Choice of outcome measures:** Public and health system stakeholders participate in a modified Delphi exercise to rank and assign weights to health vulnerability indicators. Community workshops directly define localized priority outcomes for health facility readiness.

- **Recruitment:** Recruitment leverages existing, trusted community structures. Participants are identified through local FMCs (drawn from facility catchment areas), elected KCR networks, local chiefs, and religious leadership.

### Dissemination of results

Community members are directly involved in approving and executing dissemination plans. Photovoice participants hold final approval over which images are publicly displayed or shared with policy stakeholders. Findings will be fed back to local communities and facility catchment areas through community consultative workshops, local radio programs, newspaper articles, and public engagement activities led by the KEMRI-WT public engagement team.

## Design and methodology

### Study design

This will be a mixed methods case study utilizing a mix of primary (qualitative and quantitative) data and secondary data, for the different study objectives.

Study Sites will include 4 counties, one each from the different climatic zones in the country, as recognized by the Kenyan Metrological Department (See Table 1). Kilifi county will be included (for the coastal strip climatic zone) due to prior preliminary work conducted. The other three counties are Kirinyaga, Kisumu and Turkana.

**Table 1. Classification of Counties by various Climatic Zone in Kenya.**

| Zone Name | Counties Included | Climate type | Selected Study Site |
|---|---|---|---|
| Coastal Strip | Tana River, Lamu, Kilifi, Kwale | Tropical Savannah | Kilifi |
| Northern Eastern Region | Garissa, Wajir, Mandera, Marsabit, Isiolo, Turkana | Arid desert hot | TBC in discussion with stakeholders including MoH, Council of Governors and Kenya Metrological Department |
| Lake Victoria Basin Region | Busia, Siaya, Kakamega, Bungoma, Trans-Nzoia, Nandi, Baringo, Nakuru, Bomet, Kericho, Kisi, Migori, Homa Bay, Kisumu, Siaya | Tropical Rainforest | TBC in discussion with stakeholders including MoH, Council of Governors and Kenya Metrological Department |
| Highlands Region | Nyandarua, Kiambu, Nyeri, Muranga, Kirinyaga, Meru, Tharakanithi | Temperate, dry summer, warm summer | TBC in discussion with stakeholders including MoH, Council of Governors and Kenya Metrological Department |

The table below provides an overview/summary of the different methodological approaches to be used. Specific details (relevant to each study objectives) are further outlined in Table 2.

### Objective 1

***Understand health system stakeholders' priorities for dealing with Extreme Weather and what plans and policies including, but not limited to, climate risk insurance, can be created to guide action?***

Here, our aim is to provide high quality information to the correct stakeholders. Our project will also elevate the community voices and diverse populations we identify through our work and present relevant, but also financially grounded, realistic options to county governments for the preparation of health facilities.

To do this, we will begin by undertaking a scoping literature review to understand what policies are in place to protect health systems from extreme weather in in LMICs, we will then proceed to undertake a document review of national and county specific documents including policies and plans; conduct non-participant observations of key county health sector budgeting and planning cycle events in the fiscal years between 2025 and 2027. This will entail taking note of key occurrences within the county health sector budgeting and planning cycle. These include public participation meetings, any closed-door meetings that the research team will be invited to attend while keeping a record to map any other meetings or events that the research team may not be invited to. This has the potential to contribute to understanding the spaces, actors and opportunities that may influence priority setting in the health sector. The tool we will use, is adapted from a 'Research methods in health book' by Bowling (2014). We will conduct key informant interviews with national[3–5] and county (12–16 per county) level decision makers to establish county planning frameworks and stakeholders views and perceptions toward climate risk planning; and finally conduct approximately 10 facilitated stakeholders dialogue workshops (two per county and two at national level) with about 25 participants to co-create a framework for developing health facility and county specific extreme weather mitigation plans. During these workshops we will include non-government players such as the private sector (for example, members of architectural associations and engineers' associations), civil society groups involved in climate change advocacy, and departments involved in responses to disasters that could be related to climate change events (e.g. National Disaster Management department, County Disaster Management and Response Departments).

### Objective 2a and 2b

***Create a comprehensive overview of hazards posed by extreme weather events in a changing climate at the level of individual health facilities in Kenya and within the KHDSS and methods to replicate this approach elsewhere; and explore the scale and impact of effects related to closure or limitations of health services or KHDSS field activities due to extreme weather on vulnerable populations in Kenya and methods to replicate this approach elsewhere.***

The causal relationships between environmental changes and human health are complex, often indirect, displaced in space and time, and dependent on several modifying factors. Sustainable policy and decision-making could benefit from evidence integrating the complex interaction between humans and the physical environment (*63*). Recognising this, this objective combines secondary data on populations, and climate risks with newly collected data on the capacities of health

**Table 2. Summary of the study methodological approaches by study objective.**

| Study Objective | Study Site | Procedures | Participants | Numbers | Expected Outcome |
|---|---|---|---|---|---|
| Obj 1: Understand health system stakeholders' priorities for dealing with Extreme Weather and what plans and policies including, but not limited to, climate risk insurance, can be created to guide action? | Global<br>National and county level | Scoping Literature review<br>Documents Reviews | International published and grey literature.<br>National level legislative, policy, and guideline documents<br>County legislative, policy, and guideline documents | To be guided by data saturation | To establish county planning frameworks and stakeholders' views and perceptions toward climate risk planning; and to co-create a framework for developing health facility and county specific extreme weather mitigation plans<br>Study site (geographical) |
| | National and County | Key Informant Interviews | Health systems and climate stakeholders at the national level – MoH, Treasury, Metrological Department etc) and County level (health facility, sub-county, and county level health managers) and other stakeholders in the 4 counties. | 3–5 national level; 12–16 per county. (Specific number to be guided by data saturation) | |
| | County | Non-participant observations | Actors relevant to County budgeting and planning cycle meetings and events including county government staff, climate change advocacy group representatives and community members. | To be determined by the number of meetings and related events recorded. | |
| | County | Facilitated stakeholders dialogue workshops | A wide range of health systems and climate resilience stakeholders | One per county (care will be taken to manage power and information imbalance across participants) | |
| Obj 2a: Create a comprehensive overview of hazards posed by extreme weather events in a changing climate at the level of individual health facilities (by county) in Kenya for the different climatic zones; and | Four counties | This work will mainly utilize publicly available secondary data and the output of Objectives 1 and 3 | This work will mainly utilize publicly available secondary data and the output of Objectives 1 and 3 | N/A | N/A<br>Use spatial and temporal trends by assessing the association between climate indices and indicators associated with vulnerability to examine the potential impact of climatic factors on |



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**Table 2.** *Continued*

| Study Objective | Study Site | Procedures | Participants | Numbers | Expected Outcome |
|---|---|---|---|---|---|
| methods to replicate this approach elsewhere. | | | | | outcomes that will be decided in collaboration with our stakeholders but will include patients known to be vulnerable such as Maternal, Newborn and Child Health (MNCH) and will expand the set-in collaboration with stakeholders.<br>Use ecological analytical studies to examine the relationship between health outcomes and environmental factors at the population level, which will be useful for identifying patterns and trends without establishing a causal relationship. |
| Obj 2b: Explore the scale and impact of effects related to closure or limitations of health services due to extreme weather on the KHDSS and vulnerable populations in Kenya and methods to replicate this approach elsewhere. | Four counties | This work will mainly utilize publicly available secondary data and the output of Objectives 1 and 3. Utilized publicly available secondary data, concerning population, geography, and climate mapping, applying varied statistical and geospatial modelling techniques to address this objective. The objective will also receive input from the Objective 3 outputs, namely, the analysis of the readiness of health facilities for extreme weather. Identifying the periods of adverse weather events within Kilifi County and a retrospective analysis of transport logs and cross-sectional survey among KHDSS field staff. | We will explore online databases of adverse weather events and responses from KHDSS field staff. | As per number of field staff | To identify the periods of adverse weather events within Kilifi County. To develop a guide for planning, mitigation and response to extreme weather affecting field logistics. |
| | National level | Stakeholder engagement using an online Delphi method | Health systems and climate stakeholders. | As per number of stakeholders available in objective 1 and objective 4. | To prioritize health vulnerability indicators of the population to extreme weather events |



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**Table 2.** *Continued*

| Study Objective | Study Site | Procedures | Participants | Numbers | Expected Outcome |
|---|---|---|---|---|---|
| Obj 3: Determine the physical, operational, and workforce risks posed to health facilities by extreme weather and design new tools for analyzing these risks | Four counties | (Modified) WHO climate resilience health facility checklist | Piloting and adapting the WHO climate resilience health facility checklist | As outlined in table below by county | To adapt and refine the WHO climate resilience health facility checklist for the Kenyan context |
| Obj 4: Explore how climate risks and their effect on health and health services can be conveyed to community members in Kenya and how their priorities can inform practical adaptive action to ensure local resilience of health facilities | Facility catchments areas | Group Discussions (FGDs) and consultative workshops | Community members, FMCs, KCRs (for Kilifi) and selected community leaders | One per facility catchment area, 5 to 6 consultative workshops | Develop priorities for the population, set priorities for improving the facility (specifically with FMC members), and set general preparedness plans for the most vulnerable populations |
| | Facility catchments areas | Participatory Action Research | Photovoice will be used to generate participant narratives and provide a deeper exploration of complex areas including attitudes to climate change and how it is impacting communities | N/A | |
| Obj 5: Examine the economic impact of extreme weather events on the Kenyan population and on healthcare facilities and what climate risk strategies can be used to manage risks. | | Data outputs from preceding objectives | Modelling the direct/indirect costs associated with the hypothetical provision of healthcare for individuals affected by projected climate events | N/A | To develop a climate risk insurances mitigation products |



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facilities to cope with extreme weather. In so doing, we can analyse the relationship between extreme weather, health service provision, and effects on vulnerable populations.

The approach for this objective will be based on climate modelling and spatial representation of health facilities and the populations they serve. This objective will utilize publicly available secondary data, mostly external data concerning population, geography, and climate mapping, applying varied statistical and geospatial modelling techniques. Population and health data sources would include health and demographic sites (KHDSS and other partners to be identified), KNBS, DHS, DHIS2, CIN, CHAIN, IHME, among others. The objective will also receive input from the Objective 3 outputs, namely, the analysis of the readiness of health facilities for extreme weather. We will conduct a prioritisation exercise with stakeholders and the community to yield weights for the diverse population and health data identified from multiple data sources in WP2b. The process will consist of an electronic survey comprising two rounds of questionnaires based on the Delphi method,[1] which will rank various indicators according to their significance in evaluating health vulnerability to extreme weather events.

We will assemble historical adverse weather event data from sources such as published newspaper reports, the Kenya Meteorological Department (KMD), EM-DAT, and other climate databases. We will also review the Kilifi County climate risk profile to identify periods of increased vulnerability. We will review work logs and reports from KHDSS field activities to identify disruptions caused by adverse weather events. We will also assess the performance of the HDSS before, during, and after flooding events using metrics such as number of days/man-hours lost due to not working, data collection completion rates, number of people lost to follow-up, etc. We will also conduct electronic surveys targeting field workers to understand how past flooding has affected their ability to perform their duties and map the areas most affected by disruptions to work. This work draws on the most advanced observational and modelling datasets and statistical methods to provide crucial input to the other objectives for the duration of the NEWRISK project. We will begin with a general descriptive analysis of the data to understand the health context, including demography, socioeconomic trends and health status. We will then explore spatial and temporal trends by assessing the association between climate indices and indicators associated with vulnerability to examine the potential impact of climatic factors on outcomes that will be decided as part of this objective in collaboration with our stakeholders but will include patients known to be vulnerable such as Maternal, Newborn and Child Health (MNCH) and will expand the set-in collaboration with stakeholders. We will use ecological analytical studies to examine the relationship between health outcomes and environmental factors at the population level, which will be useful for identifying patterns and trends without establishing a causal relationship.

### Objective 3

***Determine the physical, operational, and workforce risks posed to health facilities by extreme weather and design new tools for analysing these risks***.

The WHO has recently produced guidance that is designed to help facilities prepare for extreme weather and climate change (*65*). The WHO have also issued a complementary checklist approach (*66*). This objective will consist of a formal pilot of the WHO's checklists with a specific aim to understand its strengths and weaknesses. The results of this work will then complement a literature review of evidence on how the tools should be improved. We will then work with experts from a variety of technical disciplines in order to be able to sense-check the new tool. We will then trial the 'definitive use' of the redesigned tool in Kilifi County where we have significant capacity and a strong relationship with the County Government. We will then assess the data collected and present these preliminary findings to expert panels to confirm the re-designed tool.

Finally, the redesigned checklists will be used to compare and contrast the readiness of Kenyan health facilities to cope with extreme weather. A survey will be conducted across 3 counties (Kirinyaga, Kisumu, Turkana) using the new tool and this will involve visits to a broad range of facility types in each of the sub-counties of the selected counties where security and access allows. Each visit will involve establishing contact with the management of the facility and asking their permission to conduct the survey. The results of the survey will be collated and shared with stakeholders in each study county and with the national government.

The initial survey using the WHO's checklist will be carried out in all the seven sub-counties of Kilifi County (only) and we will sample according to Table 3. Data will be collected from each of the 7 sub-counties of Kilifi.

We will then redesign/revise the WHO climate resilience checklist using the findings from the Kilifi piloting, findings from literature review (objective 1) and consultations with experts in the field. The revised tool will then be used to conducted surveys in health facilities across the remaining 3 counties as per table 4 below. While we aim to enlist the

**Table 3. Health Facility selection in Kilifi County for Piloting and Testing of WHO Resilience Checklist.**

| Facility Type | Type | Qty Total[44] | Sample | Logic |
|---|---|---|---|---|
| Level 4 | Hospital | 4 | 6 (100%) | 100% - Crucial to care provision |
| Level 3 | Health Centre | 17 | 7 (41%) | 1 per sub-county |
| Level 2 | Dispensary | 123 | 21 (17%) | 3 per sub-county |

health facilities as shown in Table 4, we will do so in consultation with the county health department, a process that might modify the actual sample size of health facilities.

Sample sizes for the selection of facilities are determined by 100% coverage at level 4 and 5 due to the volume of patients treated by these facilities and the high degree of variety in design, function, and staffing. At Level 3, one health centre is chosen from each sub-county to ensure that the different geographies and populations are represented. At level 2, three dispensaries will be surveyed. Although this is a small percentage of the total number, there is only a small degree of variety across these facilities and so this is felt to be sufficient.

The Level 3 and Level 2 facilities will be purposively sampled across the counties. Because the counties selected are expansive. These level two and three facilities should represent diverse areas of the counties that might experience different climatic conditions.

The data collected through both the WHO checklist and the revised survey tool relate to the operations of the health facilities. Hence, they include information about the construction of the facility; the electrical power system and functionality; the water system and functionality; drainage and sewerage; and the type of roofing and insulation. The survey will also determine what arrangements have been made to prepare for various extreme weather events such as floods or other similar emergencies.

### Objective 4

***Explore how climate risks and their effect on health and health services can be conveyed to community members in Kenya and how their priorities can inform practical adaptive action to ensure local resilience of health facilities.***

We will conduct four focus group discussion with members (approximately 9 to 12) of Facility Management Committees (FMCs) of level 3 facilities (health centres) in each county. FMC members are community members drawn from around facility catchment areas and have oversight over facility management including contributing community views on the running of the facility. We will also conduct consultative workshops with approximately 20 other community members in each county identified from among community leaders such as local Chiefs, religious leaders, and leaders of local

**Table 4. Breakdown of health facilities by county for conducting facility surveys using the revised WHO climate resilience tool.**

| Facility Type | Type | Qty Total (Per County) | Sample | Logic |
|---|---|---|---|---|
| **County 2 (Northeastern Region)** | | | | |
| Level 4&5 | Hospital | | (100%) | 100% - Crucial to care provision |
| Level 3 | Health Centre | TBC | TBC | 1 per sub-county |
| Level 2 | Dispensary | TBC | TBC | 3 per sub-county |
| **County 3 (Lake Victoria Region)** | | | | |
| Level 4 | Hospital | TBC | (100%) | 100% - Crucial to care provision |
| Level 3 | Health Centre | TBC | TBC | 1 per sub-county |
| Level 2 | Dispensary | TBC | TBC | 3 per sub-county |
| **County 4 (Highlands)** | | | | |
| Level 4 | Hospital | TBC | (100%) | 100% - Crucial to care provision |
| Level 3 | Health Centre | TBC | TBC | 1 per sub-county |
| Level 2 | Dispensary | TBC | TBC | 3 per sub-county |

community-based organizations. In Kilifi, we will include the "KEMRI Community Representatives" – a network of 255 elected (by the community) who are regularly involved/consulted by KEMRI Kilifi in research activities.[45]

In each of the four counties, sites will be chosen in the catchment areas served by the health facilities we survey as part of Objective 3.

Consultative workshops will initially lead to input into study/project and clarifying community priorities. The consultative workshops will also utilize methods such as rich pictures to draw on data collected to co-develop or propose mitigation plans.[46]

Data collection will be done on the grounds of the health facilities unless there is a safe location deemed more suitable by the community, in which case the meetings and FGDs will be conducted at that location.

We will aim to have approximately 20 participants in each full-day consultative workshop. It is important that the participants are broadly representative of the community or communities served by the health facility identified to be part of this project. FGDs and consultative workshops will cover:

- Perceptions and attitudes of the 'community' towards the health facility in general; recent background and history of the perceived functionality of the facility; importance of the facility to the population; history of improvement efforts; efforts on behalf of the facility to engage the community in planning health services.
- Perceptions of climate change and direct impacts of climate change on the community
- Perceptions of extreme weather and direct impacts on the community.
- Experiences of different populations in the community.
- We will then make a presentation of the risks posed by extreme weather to the facility. This will include information on:
- Overall climate change in the county
- Specific risks to the facility

The assessed vulnerability of the population and how this will be affected by access issues stemming from extreme weather.

We will then conduct a planning session with the community groups where we aim to:

- Develop priorities for the population.
- Set priorities for improving the facility (specifically with FMC members)
- Set general preparedness plans for the most vulnerable populations (all groups)

We will also collect information pertaining to the involvement of health workers, community members, and community leaders in this research project. Photovoice will be used to generate participant narratives and provide a deeper exploration of complex areas including attitudes to climate change and how it is impacting communities, families, and individuals. These methods involve training purposively selected small groups of participants (5–8 per group) in filmmaking/photography and supporting them to create films/media to capture important issues of concern. The photographers will receive training on the ethical use of the camera, including how to operate the camera and instruction not to take identifiable photographs of people without their consent.

As is consistent with participatory research the nature of the communication i.e. what and to whom, will depend on discussions with each group but will be within the boundaries of the study objectives. It is anticipated that the process of producing digital media will facilitate learning, articulation of views and confidence-building for the participants, as well as giving researcher insights into the views of the participants. The use of the footage/media will be governed by the

facilitators, participants, and other stakeholders (see ethics section.) Participant observation and digital recording may be used to collect data, including capturing decision-making and prioritization processes. Again, as is consistent. With a qualitative methodology, data collection related to specific areas of interest will continue until data saturation is achieved.[47]

### Objective 5

***Examine the economic impact of extreme weather events on the Kenyan population and on healthcare facilities and what climate risk strategies can be used to manage risks***.

This objective will involve identification and assessment of secondary data pertaining to economic impacts of the predicted extreme weather events.

The preceding objectives will provide valuable information on the impact of negative climate events on vulnerable population groups. Once this information is available, we can model the direct/indirect costs associated with the hypothetical provision of healthcare for individuals affected by projected climate events. This will be done based on a detailed, bottom-up micro-costing approach using region-specific epidemiological data.

We also know that disruptive climate events will likely result in the loss of DALYs at large scale; yet little is known about the effect size. Using information from preceding Objectives on the impact of negative climate events among vulnerable population groups, we will employ the most suitable DALY estimation approach given the available data.[48] Following this, the estimated DALYs-impact will be monetised to represent the loss in economic terms. This monetisation exercise will be based on the costs of premature mortality and lost productivity due to disability.

We will also seek to estimate the health economic impact associated with potential damages to the built environment of healthcare facilities as a result of negative climate events, and how such damage will disrupt the provision of healthcare. This will be achieved through a mixed-methods approach, including a costing analysis (costing damaged built environment) and a scenario analysis (estimating the demand and supply of healthcare during decreased healthcare service availability). The direct damage to healthcare facilities from negative climate events can be represented in monetary terms. The indirect damage, defined by a decrease in the capacity to provide services, is more difficult to estimate. If healthcare facilities will be dysfunctional, further health will be lost as saturation points of high demand for healthcare will be met by an undersupply of healthcare. During the COVID-19 pandemic, disruptions to healthcare provisions was increasingly studied. Employing a scenario analysis, we will model essential healthcare service coverage disruptions from climate events at different thresholds to identify the associated health and health economic impact.[49]

Finally, we will estimate the financial size of a potential insurance premium in the context of the expected economic impact estimated under the preceding objectives of this Objective. We will then consider potential risk prevention and reduction strategies that would soften the health economic impact from negative climate events, and through a cost-benefit analysis estimate what the net-present value of such risk reduction interventions would be.

## Data management

### Data collection

a) *Variables to be collected.*

The data collected in objective 1 with policymakers and in objective 4 with community members will be qualitative in nature and will cover issues pertaining to each community's access to healthcare and how this might be affected by extreme weather.

The survey tool used for assessing the readiness of health facilities for extreme weather (objective 3) will be made up of closed questions regarding the material readiness of the facility in different technical areas including water, electricity, logistics, roofing, and other similar structural and supporting elements.

The electronic questionnaire administered to various stakeholders and community members will contain a list of indicators considered for assessment of health vulnerability of the Kenyan population to extreme weather (objective 2b) which will then be ranked to derive weights for each indicator.

b) *Study tools*

Various data collection tools shall be utilized to collect relevant data to meet each of the study objectives. (see appendices). The tools include:

- Semi-structured interview template for interviewing health system and climate stakeholders (Objective 1)
- Non-participant observation tool (Objective 1)
- KHDSS field staff extreme weather event questionnaire (Objective 2)
- WHO health facility resilience assessment checklist (Objective 3)
- Semi-structured interview template for community leaders and health facility users (Objective 4)
- Community discussion guide (Objective 4)
- Delphi method questionnaire for health system and climate change stakeholders (Objective 2)

## Data storage

We will collect qualitative data in the form of audio files using encrypted digital voice recorders and hand-written notes taken during the interviews. The audio files will be transcribed verbatim. The files and transcripts will be kept in a secure folder in a password protected computer and server and backed up in line with the KEMRI Wellcome Trust Research Programme (KWTRP)/KEMRI-CGMRC data governance policies. This data will be made accessible to the research team only. Data from interviews will be anonymized: all identifiers will be removed during storage and transcription. To ensure internal verification and validity of the study, we will audiotape the interviews, transcribe them verbatim and conduct frequent random checks for accuracy and completeness of interview transcripts. Audio recorded data will be destroyed 5 years after the study is concluded in keeping with KWTRP/KEMRI-CGMRC policy.

We will collect quantitative data on health facilities and their readiness for extreme weather and fieldworker experiences using the RedCAP software that is recommended by KWTRP. We will also administer an online questionnaire using software such as Stat59 recommended for Delphi methods to collect stakeholder and community perception on various health vulnerability assessment indicators. All files will be stored in a secure folder in a password protected computer and server and backed in line with the KWTRP data governance policies. To ensure construct validity, we will provide all operational definitions or instructions indicating exactly what should be extracted in each field for all the files and reports. We will also encourage communication between the investigators to clarify even apparently mundane questions. We will cross-check a number of selected items or fields for accuracy and completeness.

## Data analysis

a) *Qualitative Data*

Transcripts from Interviews, focus group discussions records from stakeholder workshops, field notes from interviews and non-participant observations, and documents and literature will be migrated to NVIVO software and subjected to a framework analysis method. This software serves as an efficient means to store and systemize data, ensuring easy access during the analysis phase.

Framework analysis involves a systematic method consisting of sifting, sorting, and charting data while coding it in alignment with pivotal issues and themes, according to reference. Initially, a thorough familiarization with the interviews will take place, through detailed review and potentially auditory engagement with the interview transcripts and audio recordings, initiating abstraction and conceptualization phases.

Post-familiarization, the second step necessitates the application of labels or codes to text deemed significant and pertinent, with codes being derived both inductively and deductively, grounded in existing theories and literature. To ensure consistency—inter-coder reliability—a pilot coding will be conducted. Two researchers will independently code a subset of transcripts, comparing codes thereafter to refine discrepancies and finetune the coding system. Subsequently, the established coding framework will be applied to all remaining transcripts.

In the third step, akin codes will be conglomerated into clearly defined categories or themes, constructing a provisional analytical thematic framework. This framework will incorporate a) a priori issues (those steered by original research objectives and introduced through topic guides), b) issues that surfaced from respondents, and c) analytical themes identified as pertinent and relevant through recurrent views or experiences.

The fourth step embeds charting data into a framework matrix, developed utilizing the NVIVO software. This charting summarizes data categorically from each transcript and transitions into the final framework analysis stage—interpretation. The approach aspires to yield findings and interpretations conducive to policy-making and pragmatic recommendations.

b) *Quantitative Data*

The survey data pertaining to the readiness of health facilities for extreme weather will be collected in RedCap or similar software with the data securely held on KEMRI-Wellcome databases. Any facility documents used as source data to create the secondary (electronic) dataset will not be taken away from the facilities and will only be used with the hospital's permission. Data collected on site will be entered into laptops on-site that are password-protected with encryption. These computers will be securely stored by the data collection teams. No patient data, nor clinical data will be collected.

The survey results will be analysed and presented to each participating facility as a digital report specific to that facility. Very little analysis of the data is required, but appropriate graphical approaches will be adopted to ensure comprehension to audiences of different levels of training. The data will also be collated and shared with County government, other stakeholders, and the national ministry of health.

Our hypothesis is that the AWEs will have a direct influence on health outcomes and health service provision, and disruption to field activities of the KHDSS. We will conduct an ecological analysis to assess the impact of flooding on all-cause mortality. Results from KHDSS fieldworker survey will be analysed and presented to the KHDSS operations and management team and may be used to guide updating or formulation of mitigation policies around adverse weather events and minimizing disruptions to services.

Data collected from diverse health systems and climate change stakeholders will be synthesized using descriptive statistics to yield average scores of the different rankings. The results will provide a weight for the various indicators which will then be incorporated into the health vulnerability assessment.

## Intellectual property

Any Intellectual property rights that arise from the work will be safeguarded according to the KEMRI IPR Policy of 2015 and the Industrial Property Act of 2001, sections 32, 58 and 80. The scientific and intellectual contributions of all persons involved in the research will be appropriately acknowledged in all publications and presentations arising from the work. We consider it unlikely that this project will result in generation of IP.

## Ethical considerations

### Human subjects

i. *Potential Risks*

i) *First, do no harm.*

This study does not involve patients and all data pertaining to patients used in developing the vulnerability model of patients (Objective2b) will be secondary.

Regarding our work with stakeholders and policy makers (Objective1), we see minor risks. We will conduct interviews lasting about one hour with sub-county, county and national level health managers, non-participant observations of government-initiated events attended by relevant actors of the health sector budgeting and planning cycle and stakeholder workshops with approximately 25 stakeholders (county and national health managers, climate change advocacy group leaders, representatives from the Meteorological department) lasting half a day. These data collection activities may yield potentially sensitive information. To prevent harms, we will ensure that all data are confidential and anonymised, and we will also endeavour to ensure that this research causes minimal disruption to the delivery of care within county government facilities.

Regarding our visits to health facilities there are very few risks to those who facilitate our visits. Each visit will involve asking a senior member of staff to complete a survey designed to determine the readiness of the facility for extreme weather. Completing the survey may take between 20 to 30 minutes. None of the questions are expected to create difficulties or stress for the respondents.

Our work with communities will involve full-day consultative workshops with about 20 people and FGDs with approximately ten people lasting one and a half hours. We will follow local norms on the format and location of these meetings, while also attempting to ensure gender, class, and ethnic differences are accounted for.

The prioritization exercise for health vulnerability assessment indicators by various stakeholders and the community, will involve completion of a 20–30 minute questionnaire accessed through a link shared via emails. The sharing of the questionnaire necessitates the collection of email addresses, and all responses will be anonymised.

Finally, fieldworkers will voluntarily respond to a 20–30-minute questionnaire either work-provided computers. To send targeted emails, we will require their work email addresses. All responses will be de-identified during analysis.

The time taken to participate in the study will be an inconvenience. Refreshments will be provided during FGDs, stakeholder and consultative meetings. Participants will be reimbursed for transport costs and any out-of-pocket study-related expenses will be compensated according to KEMRI-recommended rates. This includes reimbursement for any vehicle-based travel at a rate of KES 45 per km for own vehicles and return fare for public service vehicles. For airflights and accommodation costs, KEMRI will cover them upfront. Participants of stakeholder workshops (health managers and providers) will be given an out-of-duty station allowance at a rate of KES 2000 per day, and at Kes 500 for FGDs and community consultative workshops with community members in Kilifi. In the other 3 counties, this will be based on the KEMRI accepted rates. No compensation will be required in the Delphi method as the process will be entirely online.

Participants in the photo-voice activity may face the risk of theft or threats through their possession of a camera. Such risks will be discussed with the community and the most suitable solution for camera storage will be agreed upon. For example, it may be decided by the participants that all cameras should be stored in the house of the community head. Participants in the photo-voice activity will be trained in the ethical and safe use of a camera and provided with the opportunity to return the camera and withdraw from the activity at anytime.

When the images from the photovoice activity are shared, they might have the potential to impact negatively on intra- or inter-community relations. To mitigate against this potential risk, we will ensure that the participating communities have the final say in the selection of the photographs that can be used for public display (among their communities, with policy makers in Kenya and to the general public). Furthermore, care will be taken to ensure that, where possible, images with obvious location specific identifiers are not selected for display.

ii) *Direct benefit to study subjects or community.*

There are no direct benefits for individual study participants in this study. Study counties and/or health facilities will benefit from getting localised data on vulnerability and extreme weather risk to facilitate localised risk planning.

This study plans not only to map out which extreme weather conditions hospitals and communities are exposed to but also seeks to understand how prepared these facilities are. In addition, we seek to understand the economic implications that extreme weather might have. From these we will engage the policymakers at national and county level and health managers to develop strategies to make the health systems more prepared to face extremes in weather in our setting. We anticipate the lessons learnt from this work can be transferrable to other health systems within low- and middle-income countries.

iii) *Informed consent by study participants.*

Before the start of the study in each county government office, discussions will be held with the senior managers to explain the role of the researchers especially when they are present as observers and to discuss the best approach to undertaking the study, clarifying the aim of the study, and allaying any fears of the study being an assessment of competence or ethics. When reporting any study results, we will protect the identity of individuals and facilities.

In addition, all study participants will be provided with a detailed study information sheet and will sign an informed consent form to provide consent to participate in the study except the attendees of the non-participant observation meetings and events. For this activity, seeking individual consent may not be practical due to the diverse and changing composition of meeting attendees, the tightly scheduled agendas, and the objective to observe without influencing the context, dynamics, or actions within and around key county health sector budgeting and planning cycle meetings and events. The researcher will describe the purpose of attending the meetings/events during engagement activities as well as at the beginning of the meetings if an opportunity is provided. Emphasizing that the observations will contribute to learning about how county health sector priorities are influenced, to identify potential opportunities for the prioritisation of climate risk preparedness within the health system.

iv) *Community and Stakeholder Engagement*

By its nature, this project is based on engagement with a range of identified stakeholders. These include communities, frontline health providers, their managers, health and climate policymakers and stakeholders, The project team will pay great attention to maintaining and building upon stakeholder relationships through active and frequent stakeholder and community engagement activities.

Engagement activities cover a full spectrum of activities ranging from deeper engagement involving fewer people but in more interactive ways such as meetings and workshops (including engaging stakeholders and selected community groups to co-design elements of the research and consulting them on how to conduct the research and the policy and public engagement), through to wider engagement aimed at reaching many people through activities such as radio programmes, newspaper articles and policy briefs. The latter are more information-sharing and dissemination activities than consultations and research feedback. The group of stakeholders most deeply engaged in the research will be the stakeholder engagement group in Kenya, many of whom are also be listed as collaborators on the protocol.

Before the start of the study in the KHDSS and each county government office, discussions will be held with the senior managers to explain the role of the researchers especially when they are present as observers and to discuss the best approach to undertaking the study, clarifying the aim of the study. When reporting any study results, we will protect the identity of individuals and facilities.

Wider, less in-depth engagement plans will involve information sharing through regular meetings with all hospital managers. The research approach and emerging findings will also be shared with the general public through activities organised by the KEMRI-WT public engagement team, including radio programmes and newspaper articles. Teaching activities in universities linked to KEMRI-WT will also be an opportunity to disseminate lessons on the research approach and emerging findings. We will log all stakeholder engagement meetings to keep track of our activities.

The results will then be fed back to all health facilities, health and climate stakeholders and policy makers at the county and national government level and other interested health and climate stakeholders. The international scientific community will be targeted via publications in peer-reviewed journals as well as conferences.

v) *Data sharing and availability*

Data sharing is not applicable to this article as no data were created or analysed in this research.

All data gathered by the project will be stored in secure KEMRI-Wellcome Trust Research Programme/KEMRI CGMRC servers with specified researchers provided password protected access. Data held on these servers are backed-up in mirror servers also within the KEMRI-Wellcome Trust Research Programme. Requests for access to primary data by people other than the investigators will be submitted to the KEMRI-Wellcome Trust Research Programme data governance committee as a first step, who will advise on the need for additional ethical review by the KEMRI Research Ethics Committee.

## Animal subjects

Not Applicable.

## Ethical permission

This project was granted ethical permission to proceed by the Kenya Medical Research Institute on July 2024, PROTOCOL NO. KEMRI/SERU/CGMR-C/315/4971 (resubmission ofinitial submission): A Novel Extreme Weather Risk Insurance System for Kenya (NEWRISK): Encouraging preparedness,planning, community co-design, and

protection of kenya's health system from the effects of extreme weather. Permission was also granted by Kenya's National Commission for Science,Technology & Innovation (NACOSTI), License No: NACOSTI/P/25/4182338.

## Expected application of the results

We aim to create long-term global impact by encouraging the widespread adoption of climate risk insurance products that will cover LMIC health systems during periods of extreme weather. We hope that this work will lead to the protection of health services that will treat hundreds of millions of people when they need it the most.

Within the 4 years of this project however, the aim of this research is not to create an insurance system but rather to uncover what are the greatest risks to Kenya's health system and whether climate risk insurance should be designed to address these risks and if it would be feasible and effective. If we determine that it would not, then we will direct our findings in two ways: to the climate risk insurance industry we would seek to ensure that they do not waste money and time on ill-conceived plans we have proved cannot work; and to the Kenyan health system, we will present other, more efficient ways of preparing their health systems from extreme weather. Importantly, an effective and affordable insurance system can only be built upon high-quality research on the risks faced and the costed, co-designed interventions we will identify.

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