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Building resilience through participation

Mapping interdependencies and climate-related risks of infrastructure systems in Uganda

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Abbreviations

EU	European Union
NGO	Non-governmental organisation
UN	United Nations
USD	United States dollars

Executive summary

Infrastructure assets rarely operate in isolation. They interact with other assets and components, forming a wider complex system. Understanding how those assets operate, how they depend on one another and which ones are critical to the functioning of the entire system is essential to assess the impact of climate events and build resilient systems that can withstand climate shocks. This is because while some infrastructure assets may be directly impacted by climate events, others can suffer indirect and cascading effect due to the nature of interdependency linkages that may exist between infrastructure assets.

Using the theoretical framework of participatory spatial mapping, a six-step tool was developed that combined mapping activities and guided questions to support communities in the identification of climate and infrastructure risks.

The approach was tested in the communities of Awoja and Gerenge in Uganda. The findings show promising results and the potential of the method to fill a relevant gap in bottom-up approaches to tackle infrastructure risks and interdependencies in the event of climate shocks.

The experience provides preliminary indication that the community mapping framework helps to piece together the community knowledge on climate and infrastructure risks, cementing the community memory on the impact of climate on critical infrastructure and stimulating questions around climate action and inaction, which are essential to foster accountability.

The adaptability and flexibility of the framework, which can be tailored to simpler contexts by condensing or removing questions, as well as transposed onto more sophisticated digital tools, adds to its functionality and potential to support climate and infrastructure resilience policies.

Moving from application to effective resilience building will be the challenge. But the action plans that are part of the framework can pave the way by creating tangible steps and a culture of community dialogue and public participation.

In terms of next steps, a second pilot is recommended to compare results and test the method in different contexts to solidify the approach. Countries highly affected by climate shocks could benefit hugely from the method and provide valuable insights regarding its applicability.

1. Introduction

Modern infrastructure systems are highly dependent upon each other to operate. Linkages and interconnections between infrastructure systems create a multiplying effect on risk which can give rise to second-order effects and lead to much larger impacts (Petit et al., 2015). The total consequence of the impact in one system is amplified by the number of the dependencies and interdependencies that exist in relation to other infrastructure systems.

Improving resilience of infrastructure, particularly of critical assets, is an urgent goal in the United Nations' (UN) Sendai Framework for Disaster Risk Reduction (UN Office for Disaster Risk Reduction, 2015). Building resilient infrastructure is also one of the UN Sustainable Development Goals. The focus on resilience is to prevent catastrophic outcomes that can come from disruptions of critical infrastructure systems.

If the complexity of today's infrastructure is already a challenge, climate change adds to the problem and can compound these impacts significantly. This is not only due to the severity of climate events, but mostly because of a lack of preparation to deal with climate shocks in infrastructure, which includes a low level of community engagement in resilience efforts.

The research described in this report focuses on the cascading effects of climate events on infrastructure systems. It is based on a participatory perspective of how preparation can be built from the community level upwards. Two communities in Uganda were selected to test a process of participatory spatial learning and mapping that can help build local awareness of climate impact on infrastructure.

The research findings show promising results and the potential of the method to fill a relevant gap in bottom-up approaches to assess infrastructure risks and interdependencies when climate events occur. Community spatial mapping is a useful framework that can go a long way to support climate learning and dialogue, improve infrastructure awareness and strengthen accountability in communities that are particularly affected by climate shocks.

2. The importance of interdependencies

Infrastructure assets rarely operate in isolation. They interact with other assets and components, forming a wider complex system (OECD, 2019). Understanding how these assets interact, how they depend on one another to operate and which are critical in case of failures is essential to build systems that can work with minimum disruption during shocks.

Preparing infrastructure systems for climate impact follows the same logic and also requires a dependency analysis. Dependencies speak to the ability of an infrastructure asset or system to influence the state of others, whereas interdependency can be thought of as a combination of two dependencies (Setola et al., 2017). Without this perspective, the assessment of how a climate event may affect the functioning of complex infrastructure systems cannot be complete.

Infrastructure interdependencies can be organised into four categories: physical, geographical, cyber and logical (Petit et al., 2015). Physical interdependency exists when material inputs and outputs of assets and systems are linked. Geographic interdependency occurs when the local environment impacts the operation of assets and systems. Cyber interdependency is based on the use of common information to operate different assets and facilities. And logical interdependency is identified when the interconnection between assets and systems derives from linkages other than physical, cyber and geographical.

Untangling the linkages is key to assess the impact of climate on infrastructure. This is because while some infrastructure assets and systems may be impacted directly by extreme climate events, such as flooded roads, others can suffer indirect and cascading effects due to the nature of these interdependencies.

People are reliant on infrastructure to access basic societal functions such as health, education, clean water, a functional government and economic markets, and therefore it is important to understand how climate affects the functioning of these systems and what measures are needed to protect critical assets that people depend on.

3. Resilience and participation

3.1 Methods to map infrastructure interdependencies and climate impact

Different methods have been used to map infrastructure interdependencies in the event of a climate shock. In partnership with Silicon Valley 2.0, the County of Santa Clara (2015) in California developed an interactive tool to predict the impact of climate hazards in different types of infrastructure assets. Combining satellite pictures and climate projections, the tool estimates the damage that climate events can have on multiple infrastructure assets, also quantifying the broad economic impact from shocks.

Working on a regional perspective, the European Union (EU) is piloting a digital platform that brings together geospatial technologies and computational tools for the simulation and analysis of climate impact on critical infrastructure.[1] The platform allows field exercises to be run by EU members which consider both cross-sectoral and cross-border interdependencies.

With a less technological focus, the City of Eugene and City of Springfield (2014) in the United States have used a standard list of questions prepared by experts at the University of Oregon to produce a vulnerability risk assessment to measure infrastructure assets and systems. This is helping public officials of different sectors to study and gauge the level of dependency between infrastructure systems during extreme climate events.

An online survey was used by the City of Sydney (2015) to capture the community's perceptions on interdependencies. The method applied by the city's advisors RPS and KPMG used surveys to cluster connected climate risks by linking, for example, intense rainfall, property damage, power failures and displacement. The focus of the method is on connecting different types of climate risks and allowing them to be linked to key infrastructure.

In a more participatory approach, the City of Toronto (2016) used a series of workshops to discuss climate vulnerabilities in the water, transportation and utility sectors. Employing mapping exercises, participants from public agencies and service providers were able to identify critical interdependencies that could arise in the event of climate shocks. Workshop participants included managerial and technical staff of each organisation as well as Toronto senior staff with experience in risk, climate adaptation, public health and city planning. As recognised by the participants, the exercise helped to enhance awareness of climate events, initiating a dialogue between the organisations and contributing towards resilience building.

From the examples noted above, it is clear how they vary in terms of the methods applied to map interdependencies. From high technology tools in California and the EU, to a structured questionnaire in Oregon, online surveys in Australia and a multidisciplinary workshop in Canada, the variety of tools is evident.[2] Two aspects transpired when reviewing the available methods.

First, there are few examples from the global south. The City of Johannesburg (2009) climate adaptation plan is an example mentioned in the literature, but despite providing some analysis of interdependences between sectors, it does not concretely assess the climate impact on infrastructure assets. Considering that developing countries account for 91% of overall deaths from catastrophic climate disasters (World Bank, 2023a), developing suitable methods for poor contexts is a notable gap.

Second, the identified methods did little to include communities from the affected areas. Given that climate risks affect poor and more vulnerable regions with more severity and frequency, integrating the community voice on these methods can both protect and inform vulnerable groups about climate and infrastructure risks.

[1] EU Geospatial Risk and Resilience Assessment Platform, see: joint-research-centre.ec.europa.eu/geospatial-risk-and-resilience-assessment-platform-grrasp_en

[2] More examples are in C40 Cities/AXA (2019) but they can be broadly categorised into the same groups.

3.2 Challenges in applying the available methods

In addition to the gaps identified in **Section 3.1**, a common challenge observed in the available methods is the level of expertise required from the user. Technical experts from climate, risk and infrastructure backgrounds needed to participate in the processes to guide their application. This creates barriers to the adoption of these methods, particularly in contexts where relevant technical knowledge and skills may not be easily accessible.

Simple ways to map the impact of climate shocks in infrastructure is also lacking in the identified methods. Simplifying complexity is of key importance to assist communities and local leadership in the process of understanding climate risks and building resilience of their infrastructure systems.

The purpose of the research described in this report is to fill the identified gaps in the available methods and to provide better guidance to policymakers and communities. It uses case studies in Uganda to test a participatory mapping approach as a method to identify infrastructure risks and interdependences in the event of climate shocks. The participatory method is described in **Section 3.3**.

3.3 Participatory mapping as means to build resilience from below

The use of participatory mapping in disaster risk reduction is not new. The technique enables communities to identify vulnerable areas to climate risk and shape adequate mitigation measures (Gaillard and Maceda, 2009). It is also a way to bring communities together as studies show that group mapping can contribute towards community connectedness, strengthening ties and allowing participants to learn from one another and best prepare for shocks (Haworth et al., 2016).

By facilitating discussions among stakeholders that may not be well represented in other political arenas, participatory mapping can be a transformative experience that provides access to knowledge, new skills, a sense of direction and a shared vision which can catalyse more interactions in the future, including with authorities (Cochrane et al., 2014).

As an established method already used in disaster reduction, participatory mapping has the simplicity that may be absent in other methods. It is a low-cost and relatively easy-to-use technique that can add the voice of those who are the direct victims and the first to experience the impact of climate events. It has also the transformative component potentially to counter climate inaction and alienation.

As a highly impacted country from climate change, Uganda was selected to test the approach, as explained in **Section 4**.

4. Study design

4.1 Awoja and Gerenge as the case studies

Uganda has been particularly hit by climate events. From 1933 to 2018, the nation saw 20 floods, nine droughts and five landslides, affecting at least 200,000 Ugandans and generating economic damages of about USD 62 million due to floods alone in 2019 (United Nations Office for Disaster Risk Reduction, 2023). Floods are a constant concern in Uganda, owing to the nation's low-lying parts and proximity to Lake Victoria, which puts expanding portions of the country at risk of Nile floods, especially after the rising quantities of rain over the previous decade and the impacts of deforestation in the highlands (World Bank, 2023b).

The climate events exposed vulnerabilities in Uganda's infrastructure. Awoja and Gerenge were selected as the case studies to test the participatory mapping approach as they are poor communities with critical infrastructure at risk of climate events. Gerenge is situated on a peninsula which creates natural accessibility limitations, while Awoja is located in a flood-prone swamp area. The two communities are served by one main road – Garuga Road in the case of Gerenge and Soroti-Mbale road in Awoja – which creates a high dependence in terms of mobility and connectivity. Media outlets report that these roads are often cut off during floods, which indicates a high level of criticality and vulnerability.

The community of Awoja is composed primarily of subsistence farmers, which means that if crops are lost due to a climate event, the risk of food shortages is high and exacerbated by the lack of alternative supply channels to meet community needs if roads are blocked. Gerenge's economic activity is mostly dependent on small-scale tourism and fishing, which can create long-term impact if damaged during climate events. Both communities also undertake sand and murram mining as economic activities.

Two initial mappings were prepared prior to the community engagement. Critical infrastructure was mapped using available information and colour coded for an initial assessment of the local infrastructure. Health, water and sanitation, education, energy, food, economic infrastructure, financial services, communications, roads and logistics were some of the sectors covered. A screenshot of the maps is reproduced in **Figures 4.1 and 4.2**.

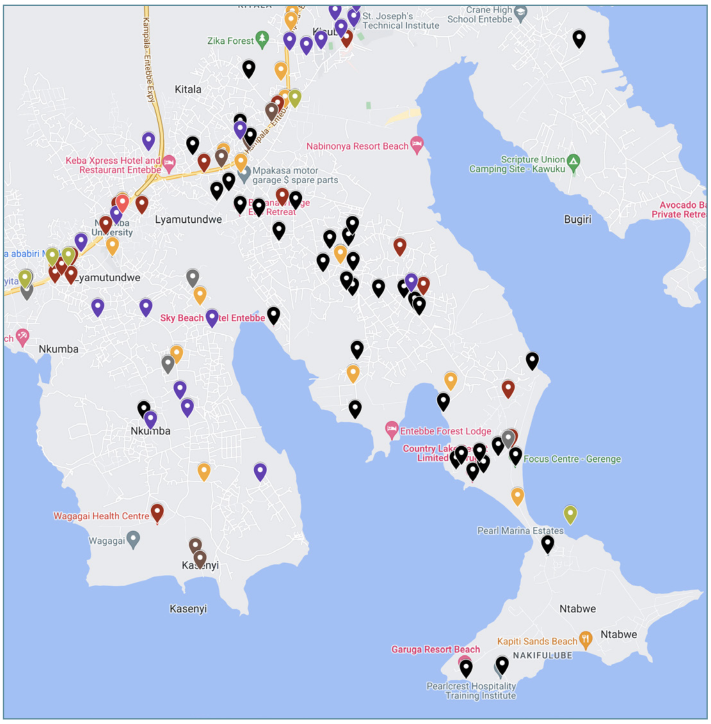

Figure 4.1. Gerenge initial mapping
(Source: www.google.com/maps/d/edit?mid=1CMu8xEcW2IZk0OZ_DO1IH-JSi4lIJKYm&usp=sharing)

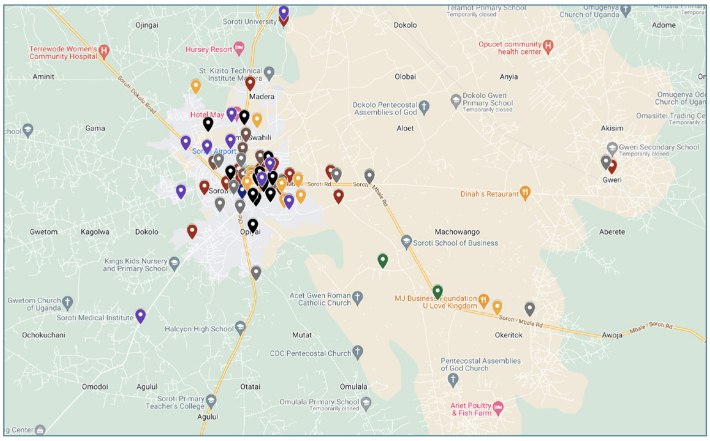

Figure 4.2 Awoja initial mapping
(Source: www.google.com/maps/d/edit?mid=1Y7l13v0iOu1s-Pji8Si0KAoBZlziZ7EBh&usp=sharing)

4.2 The six-step tool

Based on the theoretical assumption that maps produced in a participatory manner convey a collective expression of values and concerns, a six-step tool was developed (see **Appendix 1**) to support communities during the mapping activities in Awoja and Gerenge. The tool is intended to act as a bottom-up approach to identify infrastructure risks and interdependencies in the event of climate impacts, improving climate knowledge and building infrastructure resilience. It is also designed to support community engagement with local authorities.

Community forums, focus group discussions and key informant interviews were used during the application of the tool in the two communities. Presentation materials (see **Appendices 2, 3 and 4**) were also developed to support these activities.

4.3 Preparatory visits

Preparatory visits were carried out to establish contact with community leaders and engage with stakeholders in advance of the data collection. Town councils and sub-counties were also engaged. A list of contacts was compiled for the purposes of the focus group discussions and key informant interviews.

4.4 Data collection

The mapping exercise was conducted in September 2022. In Gerenge, the participants were from Wakiso district, Katabi sub county in Nalugala and Kitala parishes. The participants from Awoja were from the districts of Soroti (including Soroti City – Eastern Division, Aukot and Gweri sub counties), Serere district (from Olio and Atira sub counties) and Ngora district (from Mukura Town Council and Kapir sub county). District councillors and other district administrators were also engaged at the respective district headquarters.

Representatives from local councils, five districts, three sub counties and one village were involved, as were business associations, women and youth groups, local opinion leaders and teachers from community schools. A total of 63 key informant interviews were carried out (70% in Awoja and 30% in Gerenge) and 283 people attended a total of 33 focus group discussions and community forums (18 sessions with 177 participants from Awoja and 15 sessions with 106 participants from Gerenge). Five maps were drawn in each of the communities during the exercise (see **Figures 4.3 and 4.4**).

Only local stakeholders and community leaders were asked to participate in the data gathering process, which increased the quality of the data obtained since they were more exposed to the community's problems and needs. The sample included an equal number of men and women. Following the data collection, the data was cleaned for completeness and analysed using Google Suites tools. Due to the qualitative character of the study, no statistical tests were utilised.

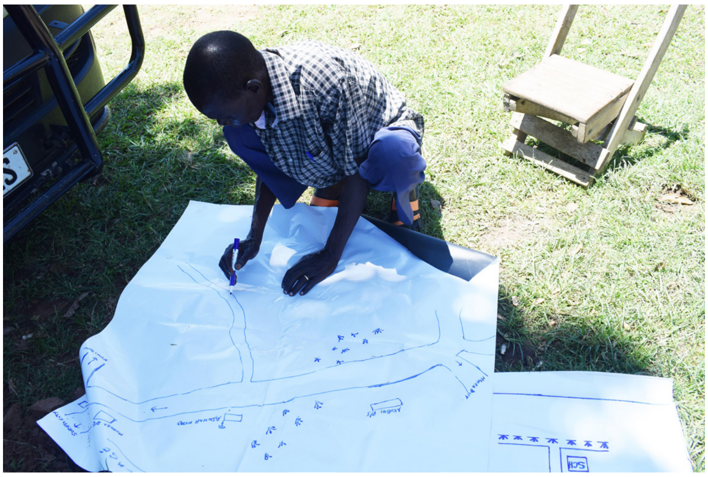

Figure 4.3. Community mapping in Awoja

Figure 4.4. Community Mapping in Gerenge

5. Results

5.1 The impact of climate events

All participants reported being affected by climate events. Uganda's farms are mostly rain-fed, which makes them particularly vulnerable to damage and loss due to droughts, floods and severe rains. But even fishing communities claimed that their businesses have suffered because of the severe rains and flooding.

Droughts were the most often mentioned climate risk in the two locations, being reported by 85% of the participants during the key informant interviews. Severe rains and floods followed, mentioned by 55% and 52% of participants respectively. When their communities are impacted by flooding, moving to higher elevated areas is the coping strategy reported in both Awoja and Gerenge.

The degree of impact is significant. Climate shocks affected 51% of participants' lives every three months while 16% said life in their community is affected weekly. The remainder reported that their everyday lives are impacted by climate difficulties either once a year (13%) or every six months (18%). The climate impact considering each of the communities and the number of group sessions is shown in **Figures 5.1 and 5.2**.

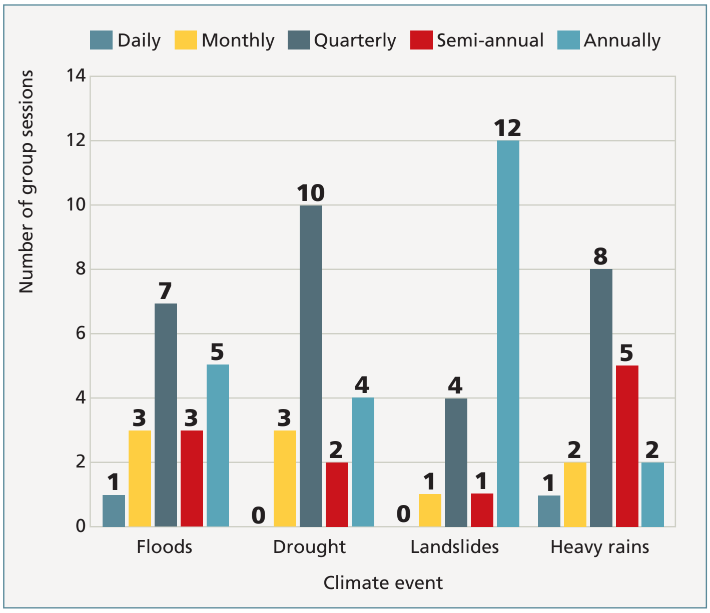

Figure 5.1. Climate impacts reported in Awoja

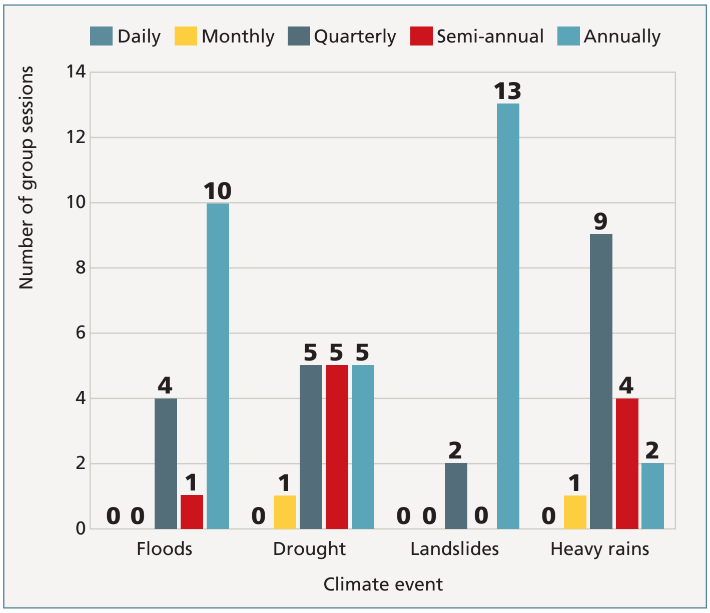

Figure 5.2. Climate impacts reported in Gerenge

5.2 Effect of climate events on critical infrastructure

5.2.1 The impact on roads and the cascading impact

The cascading impact of climate on infrastructure was discussed in the community forums. Nearly three quarters (73%) of all participants believed that climate events had an impact on roads. The most prevalent climate occurrence affecting roads and transportation networks, according to all participants, is heavy rain. During these climate events, all Awoja participants agreed to roads suffering most disruption. In Gerenge, roads are also heavily impacted, except for the sector between Bulega, Busonga and Nalugala, which was reported as passable because roads are tarmacked.

When the main roads are closed, 27% of participants cited a lack of other routes. Gerenge fish landing sites, as well as Kitala village, were cited by 100% of participants as being totally isolated during these events. In Awoja, 100% of Otati village representatives reported the absence of alternative roads during heavy rains. This is a key finding, indicating that roads are a critical infrastructure in the two locations, to the point of complete isolation of relevant portions of these communities.

The finding connects with other evidence collected in the group sessions in relation to the food supply. According to all participants in the 33 group sessions, regardless of the type of the climate event, food supply is always severely impacted.

Given the isolation that is created when roads are obstructed, working on alternative routes of transportation and diversifying the road network is essential to building resilience of the food supply in the two communities.

Participants also reported a cascading impact in terms of healthcare. More specifically, 52% reported that the main roads to their villages are commonly affected by heavy rains, preventing access to medical care outside the community. Officials at Gerenge fish-landing sites reported that during heavy rains people are unable to reach medical centres due to damaged and obstructed roads, as well as a lack of in-village medical clinics and hospitals. Awoja leaders noted that during severe rains, the links to medical services are frequently obstructed, but local governmental and non-governmental organisations (NGOs) assist community members by conducting medical visits to the community and providing alternative transportation. When external assistance is not available, people in the community must find individual alternative means, such as being carried on the shoulders of others for a small fee.

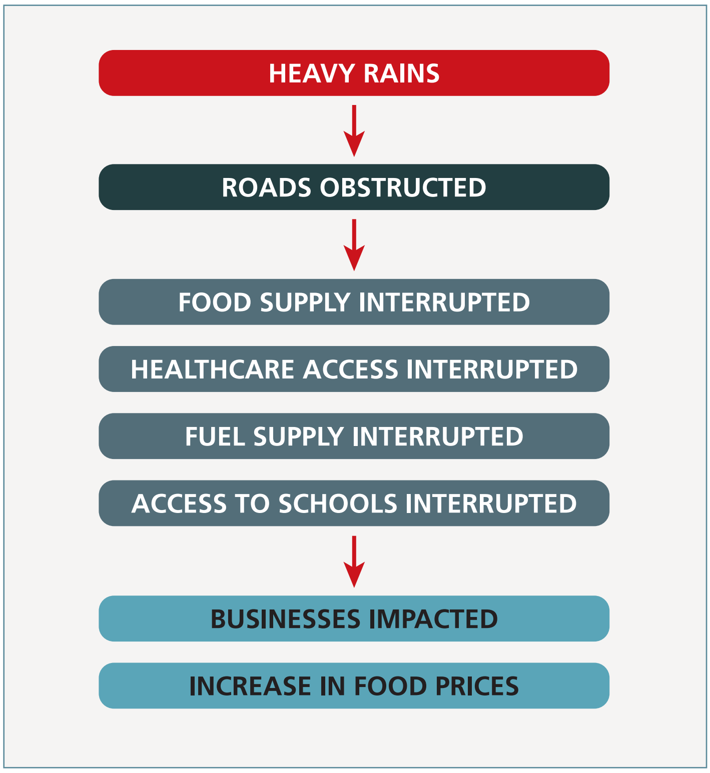

Figure 5.3. Road system interdependencies

Other cascading impacts were also identified. Just over half (52%) of participants reported interruption of the fuel supply to their private motorcycles and cars, as well as to motorcycles for hire (*bodas*), during such climate conditions and this consequently affects food prices. This was reported in both sections of Awoja and Gerenge with no significant difference. The majority of participants (75%) reported that fuel cuts also affect private businesses, such as local shops, service providers, distributors and government services.

The research also interrogated the access to schools in climate events. According to the participants in both communities, for schools away from the communities, access becomes difficult for both students and the teaching and administrative staff whenever there are heavy rains. The research revealed that the most affected are the younger children in pre-primary and lower primary schools.

Figure 5.3 summarises the cascading impact of heavy rains on the road infrastructure system, showing first- and second-order impacts on infrastructure systems as well as economic impacts identified during the mapping exercise.

5.2.2. The impact on electricity and the cascading impact

In 15 group sessions (46% of total sessions), participants believed that climate events had an impact on electricity. Heavy rain was the most reported occurrence affecting electricity supply in the two locations. The issue had less impact in Awoja as its residents rely on alternative sources of energy such as solar home systems, battery lamps and candles. Some Awoja responders noted increased risks from candles and wood fires during climate events, exposing households to the risk of flames and putting their lives and produce at risk.

In Gerenge, the affected individuals attributed the impact on electricity to load shedding, a method to decrease power consumption by making interruptions in some areas to supply power to other areas. Two participants in Gerenge claimed that storms can result in power outages lasting up to three days.

The impact on electricity is more critical when considered from the perspective of the health system. The absence of standby generators or solar systems in health institutions causes significant disruption in service provision. According to 40% of participants, hospitals are affected by power outages during heavy rains, and half of the participants specifically cited that maternity hospitals and critical care facilities are impacted, putting the lives of women and seriously ill patients in danger.

Given that the energy shortages come from a deliberate shutdown by the operator, this finding reveals an infrastructure vulnerability that goes beyond climate conditions alone. Infrastructure planning that fails to consider demand and the needs of the population can worsen climate events and endanger people's lives (Wabukala et al., 2022).

In relation to cascading impacts, 50% of those who had electricity installed in their homes in Gerenge agreed that when power is off, communication becomes more difficult since phone batteries become depleted and people are unable to recharge them. Some community members rely on phones for money transfers or internet banking, which would be unavailable under such situations. There are commercial phone recharging points in trading centres in the communities, but residents must pay to benefit from the services. However, during the heavy rain seasons even these solar-enabled charging points are not reliable since their batteries rarely charge to full capacity when overwhelmed by the community demand to recharge.

When asked if the electrical shortfall following heavy rainfall affects access to clean water, 96% of participants in both locations said no. Their explanations ranged from not relying on electric water pumps to use of boreholes and rainwater harvesting from house roofs.

Figure 5.4 summarises the cascading impact of heavy rains on the energy infrastructure system. In addition to first and second order impact on infrastructure, social impact is also illustrated.

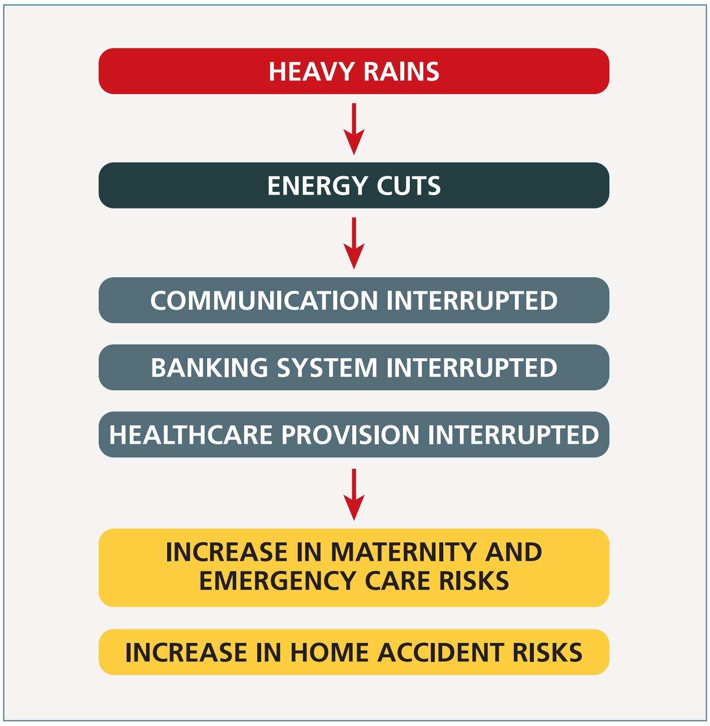

Figure 5.4. Energy interdependencies

5.2.3. The impact on water and sanitation infrastructure and the cascading impact

Public water wells and boreholes were also identified as impacted by climate events. These facilities serve as the primary supply of water for households in the two communities. As reported, heavy rains had a strong impact on the lives of 36% of participants that rely on public water sources.

Similarly, climate events impact sanitation infrastructure and pit latrines. According to 58% of participants, flooding and severe rains have a substantial impact on these vital systems, prompting residents of both locations to seek alternative uses. During these events, community residents reported having to resort to the wilderness, opening ground and digging holes. Community members agreed that these practices increase health and hygiene risks.

Figure 5.5 summarises the cascading impact of heavy rains on the water and sanitation infrastructure systems including first- and second-order impact on infrastructure as well as social impact.

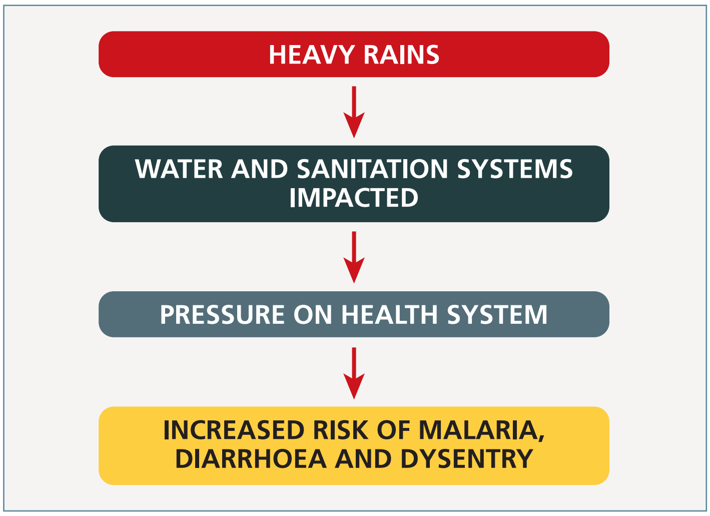

Figure 5.5. Water and sanitation interdependencies

5.3 Economic and social impact from climate events

To get deeper on the economic and social impact of climate events, additional questions were addressed to participants to capture the propagation path from first- and second-order infrastructure impact to economic and social consequences as detailed in **Sections 5.3.1 and 5.3.2**.

5.3.1 Economic cascading impact

During climate events, all participants reported a medium to high impact on their income due to the closure of stores, beaches and coffee shops, as well as any task that requires road or water transit. The group sessions also indicated that 81% of participants do not receive governmental or NGO support in their areas. Only in a few Awoja communities, including Awoja, Acilo, Abelet and Okwanji, did participants disclose financial assistance. Community members reported minor delays in their assistance as a result of climate conditions.

Nearly three quarters (73%) of participants said that climate conditions had a significant influence on several economic activities in the two communities, including cattle grazing, sand mining, tourism and fishing. Climate events, according to 70% of participants, reduce the value of their property due to damage. The most impacted properties are those along the lake and lower lands, as well as those that are partially built or are not well-equipped to withstand climate events.

All participants indicated that the interest in acquiring and use of solar power systems increases following climate events. On the other hand, climate events do not seem to impact the community perception of energy costs, as 65% of participants showed little concern for bills and energy rates increased in the aftermath of climate occurrences (**Figure 5.6**). Finally, all participants agreed that under these conditions, food costs tend to rise in both locations.

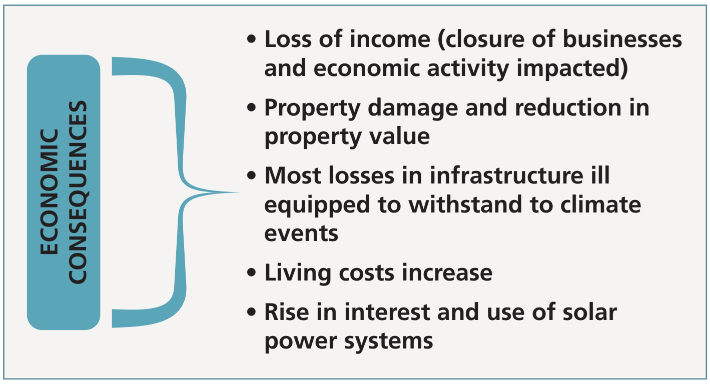

Figure 5.6. Economic consequences

5.3.2 Social cascading impact

A total of 72% of participants in both locations reported that climate circumstances and connection to income, which may be related to job loss and price increases, cause tensions inside homes, which frequently contribute to an increase in the risk of domestic violence. Most participants (85%) said that women, followed by the elderly, are more frequently impacted under such situations, since many of them are single mothers who are obliged to earn an income and care for children at the same time. Two-thirds of the participants denied receiving any help from the government or NGOs in the aftermath of such conditions, while the remaining third confirmed receiving only seeds to sow and, less frequently, food.

Most participants in both locations indicated an increased risk of infections due to weather conditions. For example, dust worsens respiratory difficulties, while mosquitoes, heavy rain and poor sanitation raise the risk of malaria, diarrhoea and dysentery, which in turn put pressure on the public healthcare system. Three quarters (75%) of participants reported an increase in crime rates as a result of climate disasters. Electricity blackouts due to heavy rains, coupled with the increased destruction of farms and price escalation in the two locations create food shortages, which intensify the level of social conflict and violence.

During climate events, 79% of participants indicated increased overuse of natural resources for extra profit. The major actions are overfishing, increased sand and murram mining, and tree cutting for fuel, which can be a catalyst of additional environmental destruction that in turn aggravates climate conditions (**Figure 5.7**).

Figure 5.7. Social consequences

5.4 Mitigation measures

Following the group discussions, participants were asked about the most important options for mitigating the effect of climate events. Improving the way infrastructure is planned was reported as a key mitigation measure, alongside ecosystem preservation, adequate waste management disposal and eco-friendly farming (**Figures 5.8 and 5.9**).

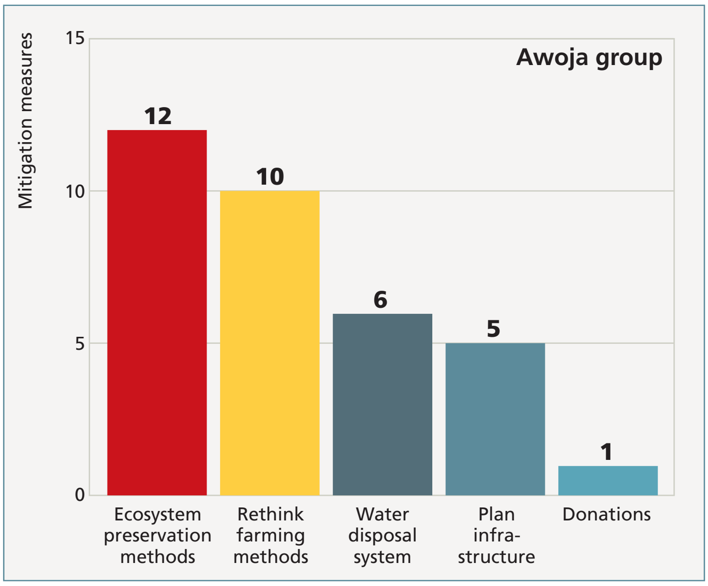

Figure 5.8. Awoja group session views on how to mitigate the effects of climate impact

5.5 Government action and climate aggravation

There was a disparity between the two locations in terms of the government's attempts to warn or increase awareness of climate events and how to deal with them. During the key informant interviews, all Gerenge participants indicated there were no government efforts to alert people and business owners about impending climate events, while all Awoja's leaders claimed awareness from public authorities, mostly from police officers.

In terms of actions related to infrastructure, only 29% of participants (mainly from the Awoja area) reported that climate was considered in the planning of new building projects in their respective areas. But this was reported as measures taken by private landlords, who are constructing sturdier foundations for residences away from flood zones and acquiring solar home systems as back-up power options. No infrastructure mitigation actions were reported in Gerenge's group sessions. Actions by public authorities were not mentioned in any of the two communities.

When asked about economic activities as primary drivers of extreme climate events, 63% of participants in the key informant interviews mentioned that sand mining, especially near lakes, and marsh draining and tree cutting were among the economic operations in both communities contributing to climate impact. This indicates a perception from community leadership of a vicious cycle whereby economic activities may be aggravating the current climate disasters.

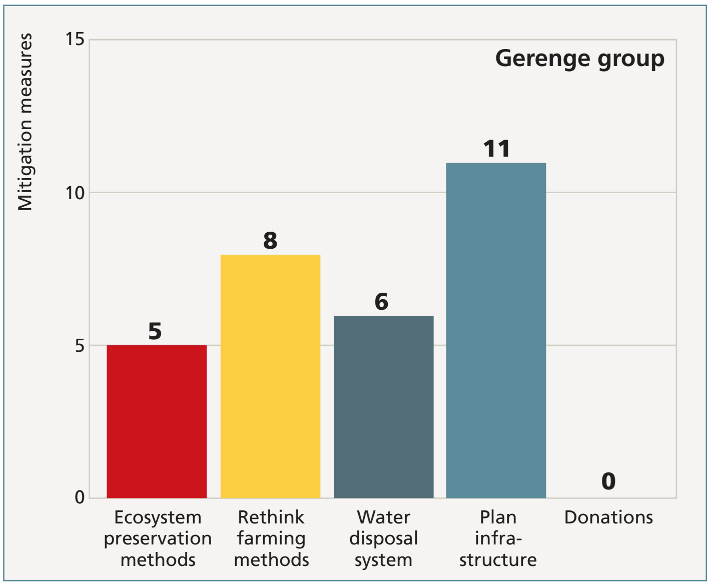

Figure 5.9. Gerenge group session views on how to mitigate the effects of climate impact

5.6 Action plans

In Gerenge, the action plans discussed as part of the group sessions mainly pointed to the need for more environmental management actions centred at the household level. Emphasis was put on improving waste disposal, especially as the plastics that are drained into the lake are affecting fish breeding and silting major road culverts. Participants also pointed out the importance of advocacy campaigns on the dangers of deforestation, particularly in the lake islands where charcoal mainly comes from. Participants also indicated the importance of providing tree seedlings to the island communities.

Gerenge communities noted that the challenge is in translating mitigation measures into action, particularly when funds and resources are required for their efficacy. Participants pointed to ethnic diversity, especially at the fish-landing sites, where language challenges exist because of multiple languages spoken. English and Luganda were the most frequently spoken languages but are not understood by all members of the communities. Therefore, it would take time for the leadership to explain to community members what was agreed upon to generate meaningful action.

In Awoja, the main action agreed upon revolved around promoting sound pro-environment agricultural and fishing practices. For example, preventing bush burning when clearing land and monitoring the use of the catchment area were two actions presented. Awoja communities indicated that there would be little they could do unless authorities intervened with resources. Participants also mentioned that having climate learning taught in schools would be relevant so that children could acquire this knowledge early in their education.

6. Implications

6.1 Strengthening spatial and climate awareness

Five maps were produced in each of the communities. The initial mapping guided the facilitators during the field activities but the perception was that, even without it, community members could easily identify, from memory, the most relevant infrastructure in their communities. Community members could also point to the infrastructure most impacted by climate events.

Having the initial mapping, which is based on simple openly available tools such as Google Maps, nevertheless helped to prepare the facilitators for conducting the mapping activity. This is an important learning in terms of the potential training materials to be made available to future moderators, particularly if they are external to the community where the exercise is to be developed.

During the mapping activity, community members debated what should be included on the maps. The desire for each group member to have a specific element of their interest captured on the map (for example, their own houses and farms) affected in some cases the amount of detail to be included, but without harming the overall exercise.

The representation of the areas on the maps were only accepted once community members agreed that the maps painted on canvas with marker pens represented their neighbourhoods. In Gerenge, retired teachers in the communities led the creation of the maps, which facilitated moderation of the activity.

Sketch mapping techniques are recognised as being useful for extracting communities' views and information but, because they are made from memory, they lack cartographic accuracy (Corbett 2009). Although the community maps were memory-based sketches, the maps produced in both Awoja and Gerenge were able to pinpoint clearly the infrastructure at risk of climate shocks, restoring the community's awareness of its surroundings.

The spatial mapping also linked infrastructure and climate. Participants showed great interest in talking about climate patterns that they had observed over time. The sessions refreshed the community's memory on how heavy rains impact the community life in terms of the effect on mobility, food supply, economic activities and access to hospitals among other impacts identified throughout the guiding questions. By piecing together this information, the mapping activity helped cement the communities' knowledge on climate and infrastructure risks. Knowledge around causes and consequences of climate events is an important first step for resilience building (Weichselgartner and Pigeon, 2015), which the participatory mapping framework helped to kick start in both communities.

6.2 Improving accountability

In terms of the existing infrastructure, a key conclusion of the analysis is the lack of redundancies in the systems in both Awoja and Gerenge. This was evident in the case of the road infrastructure, leading to the isolation of large portions of the two communities during heavy rains. The absence of alternative routes of transportation also cascades to other critical systems such as healthcare and food supply.

The absence of backup systems and components also occurs in the electricity system, which is deliberately disconnected to meet the demands of other areas. The lack of alternative systems is observed in two critical ways: no solar energy or batteries to make the grid more resilient, and no back-up power generators for critical infrastructure such as hospitals.

The water and sanitation infrastructure saw similar challenges related to the absence of redundancies. Once flooded, they offer no option to residents other than resorting to the wilderness, which increases the risk of infections and diseases.

The lack of redundancies in critical systems was noted during the group sessions. Despite not using the word "redundancies", community members identified the issue when they pointed out the lack of generators in maternity hospitals and care facilities, or the fact that people need to be carried on the shoulders of others to overcome flooded roads.

In 16 of the 33 sessions, participants understood that local infrastructure was not adequate and better planning would be needed to avoid similar situations in the future. Having a framework that supports communities to connect climate events and failures of local infrastructure can help communities to ask the right questions and foster accountability.

One example on how accountability can be fostered in practice relates to the information that Awoja landlords are constructing sturdier foundations for residences away from flood zones. The information can be the starting point for community leaders to enquire why actions are taken only by private landlords. The lack of public actions in both Awoja and Gerenge can be the subject of questioning by community leaders to understand better which feasible measures can be taken to start the process of resilience building and climate accountability.

6.3 Filling a relevant gap

The goal of the community mapping framework was to fill gaps and challenges identified in the other climate impact mapping methods in terms of reducing complexity and adding participation. The experiences in Awoja and Gerenge demonstrate promising results. It is a low-cost application that is open to non-expert users, allowing the voice of communities to be central in the process of building climate and infrastructure resilience.

The application of the framework also provided important answers about the infrastructure systems in the two communities. Through a combination of a participatory mapping and a series of guided questions, the communities were able to identify infrastructure assets at risk of climate events, as well as understand how other systems are impacted as second-order consequences.

The framework was applied in Uganda in full, but it can be adapted. The point was raised during the field work in Awoja where the questions were reduced to facilitate the communication with the participants. Rather than a prescriptive script, the full set of questions indicate a thought process that can guide users around issues of infrastructure criticality and interdependencies, and can be condensed by the facilitator for agility and simplicity.

The framework also allows the information gathered in the exercise to be transposed onto more sophisticated tools. A digital dashboard was developed (see **Appendix 4** - https://storymaps.arcgis.com/stories/ba4d108da01a4a8eabdc0b3d4b17da65) with the results of the research in Awoja and Gerenge to exemplify how the dataset collected using the framework can be incorporated into digital tools to support political leaders in assessing the information and designing targeted resilience policies.

6.4 Challenges and limitations

There are limitations in the framework. First, it is a simplification of a complex issue and, as such, not all nuances are captured. For example, the set of questions that guides the mapping activity covers mainly geographic and logical interdependencies between infrastructure systems. Therefore cyber interdependencies as well as other highly technical dependencies between assets are left out given the expertise required to identify and connect these linkages.

Perception and recollection biases are also limitations. Officials participating in the activity may be unaware of all the difficulties that communities experience during climate events, while community members may omit relevant information.

There are also limitations in relation to the impact of the framework and what it can achieve in terms of building effective climate resilience. Sustaining long-term meaningful participation is a limitation already identified in the literature dedicated to participatory mapping. The action plans included in the framework were designed to stimulate engagement with authorities and to extend the dialogue and keep momentum, but the lack of resources available for communities to act on the identified measures may limit the effectiveness of the results.

Finally, the analysis is limited by the small number of individuals who participated in the activity, which included only two small rural communities.

7. Conclusions

The research aimed at improving participation in the way climate and infrastructure risks are assessed. It focused on how methods that identify the impact of climate on connected infrastructure systems could be more tailored to the communities that experience the effects of climate events and the failures of infrastructure at first hand.

Using the theoretical framework of participatory mapping, a six-step tool was developed that combined mapping activities and guided questions to support communities in the identification of climate and infrastructure hazards, helping them better understand their surroundings and how the impact of climate can cascade from and to different infrastructure systems.

The approach was tested in the Ugandan communities of Awoja and Gerenge and, despite the limitations of the study, the findings show promising results and the potential of the method to fill a relevant gap in bottom-up approaches to tackle infrastructure risks and interdependencies arising from climate events.

The experience provides a preliminary indication that the framework helps to piece together the community knowledge on climate and infrastructure risks, refreshing the community memory on the impact of climate on critical infrastructure and stimulating questions around climate action and inaction, which are essential to foster accountability.

The adaptability and flexibility of the framework, which can be tailored to simpler contexts by condensing or removing questions, as well as transposing results onto more sophisticated digital tools, adds to the functionality of the framework and to its potential to support climate and infrastructure resilience policies.

Moving from application to effective resilience building will be the challenge. The action plans that are part of the framework can pave the way by creating tangible steps and a culture of community dialogue and public participation.

In terms of next steps, a second pilot is recommended to compare the results and test the method in a different context to solidify the approach. Countries highly affected by climate shocks could benefit hugely from the method and provide valuable insights regarding its wider applicability.

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Appendix 1: Six-step tool

STEP 1: KNOWING YOUR COMMUNITY
Exercise: As a group, draw a map of the community area and work collectively to identify essential infrastructure. Think about the following areas: food supply channels, water storage and treatment facilities, sanitation and pit latrine facilities, roads and transportation links, healthcare, NGOs and government assistance bodies, banks, electricity transmission lines, petrol/gas stations, etc. To help identify essential infrastructure, think of basic services and facilities that you use in your everyday life.

STEP 2: UNDERSTANDING THE EXTENT OF A CLIMATE EVENT
Extreme climate events have become a norm across the globe. What climate events (floods, drought, landslides, etc) or extreme weather conditions (rainfall, windstorm, etc) affect your community with more frequency and intensity? When this happens, how does it affect community life and livelihood? For example, what challenges emerge to get clean water, access to health, food and shelter, and carry out economic and subsistence activities? **When discussing these issues, think about the following aspects. The questions can be reduced and/or condensed by the moderator for simplicity and agility:**
(a) What climate events or extreme weather conditions affect your community? Floods Drought Landslides Heavy rains Others
(b) What is the frequency of them happening (monthly/quarterly/semi-annual/annually)? Floods Drought Landslides Heavy rains Others
(c) Does the community experience energy or electricity cuts during climate events? Yes No Explain
(d) Is the clean water supply affected by climate events? Yes No Explain
(e) Is the food supply or the community capacity to produce food undermined or affected by climate events? Yes No Explain
(f) Does the community have challenges to find alternative shelter in case households are affected by climate events? Yes No Explain

(g) Does the community have challenges to access healthcare services during climate events? Yes No Explain
(h) To what extent are public wells, taps and boreholes in the community affected whenever climate events occur? No impact Low impact Medium impact High impact Other Explain
(i) How badly are pit latrines and sanitation systems affected during climate events? No impact Low impact Medium impact High impact Other Explain
(j) Do essential roads, bridges and other key transportation systems used by the community (such as ferries, boats, trains, airfields, etc.) become blocked and impassable during climate events? Yes No Explain
(k) Does the occurrence of a climate event impact ongoing assistance services to the community (for example donations and aid from the government or NGOs)? No impact Low impact Medium impact High impact Other Explain
(l) Do community members face disruptions in livelihood sources (e.g. failure to access and conduct businesses), loss of income or difficulties to support their households whenever climate events occur? Yes No Explain
(m) How many men and women are in the community? Do climate events impact these groups differently? Men Women Explain

STEP 3: ASSESSING THE CRITICALITY OF INFRASTRUCTURE
Consider the consequences of a climate event – which infrastructure systems are firstly affected in the community? (*Think about the infrastructure that has been mapped in step 1*) **To help with the discussion, consider the following examples of impact consequences. The questions can be reduced and/or condensed by the moderator for simplicity and agility:**
(a) Is the water supply interrupted or otherwise impacted? For example, do wells, taps and boreholes get damaged or blocked? Yes No Explain
(b) If access to water or wells is interrupted, do communities have access to other processes or devices that help them continue to drink clean water? Yes No Explain
(c) Do sanitation systems such as drainage channels and pit latrine facilities get damaged? Yes No Explain
(d) If sanitation systems become non-operational, does the community have access to alternative adequate facilities to use? Yes No Explain
(e) Do the main transportation links, such as roads and bridges to get in and out of the community get impacted? In this case, are there impediments to access the community? Yes No Explain
(f) In case main roads and bridges are blocked, is there an alternative access? For example, can a different road be used or is there a ferry system, airfield, or other means of transportation to replace the road and resume connectivity in and out the community? Yes No Explain
(g) If the electricity is cut off, does the community have access to generators or solar powered systems (or similar power devices) that can provide electricity until the transmission lines are fixed? Yes No Explain
Exercise: As a group, rank in order of importance the infrastructure systems in your community that are mostly affected by a climate event. Think about the infrastructure that has been mapped in step 1. Also think how long it takes for services to resume after a climate event. For example, how long does it take until the energy supply returns and the access to clean water and food deliveries is re-established?

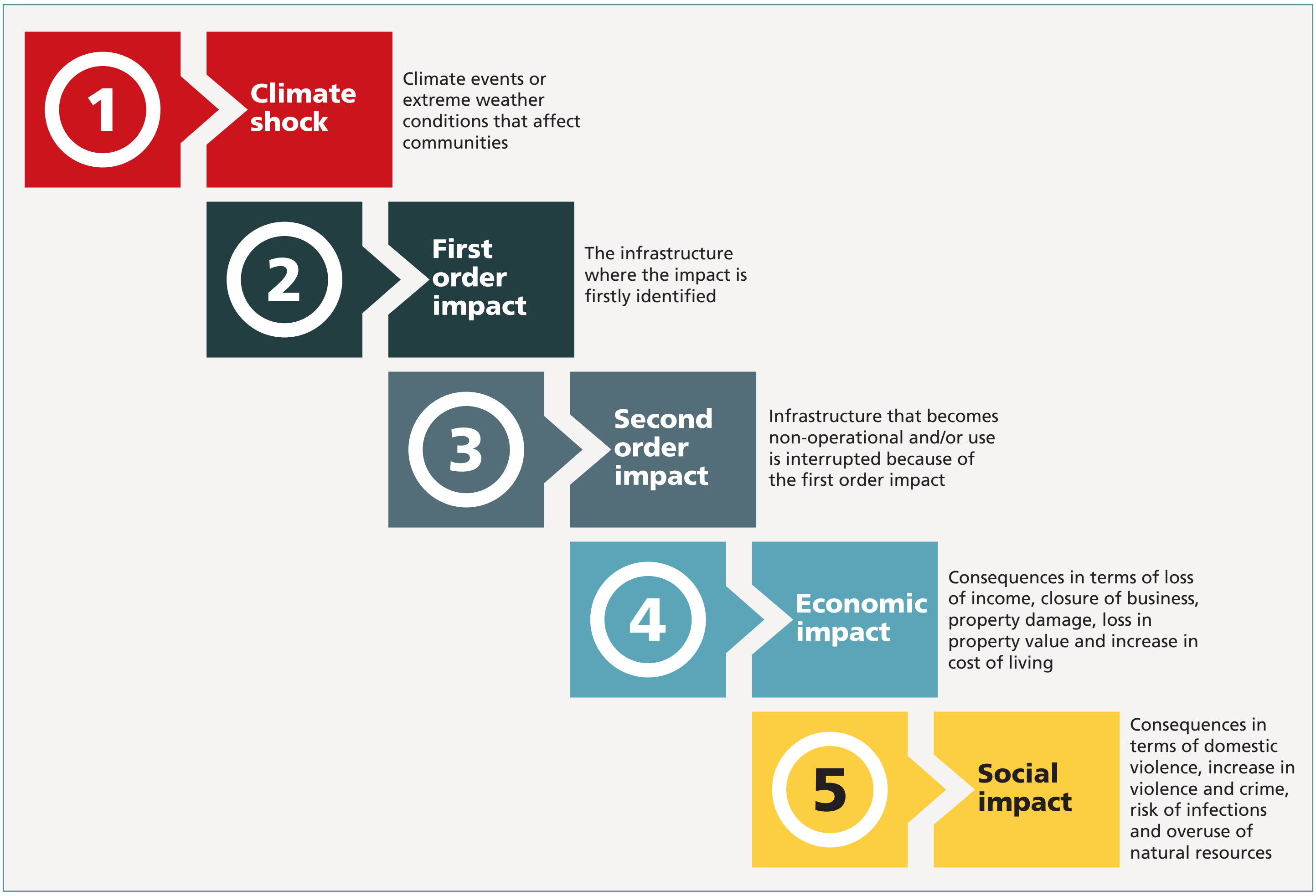
STEP 4: MAPPING INFRASTRUCTURE DEPENDENCIES, INTERDEPENDENCIES AND VULNERABILITIES
Exercise: After considering the consequences of a climate event on critical infrastructure, identify how the firstly impacted systems tend to impact other systems. In other words, how does the climate impact tend to propagate from one infrastructure system to another? Think about the infrastructure systems that have been mapped and ranked in steps 1 and 3, and use arrows to draw the 'propagation path' (i.e. the chain reaction) after a climate event occurs. **To help with the exercise, consider the following examples. The questions can be reduced and/or condensed by the moderator for simplicity and agility:**
(a) When a main road is cut off, are there impediments to accessing healthcare (hospitals/health clinics) and assistance services (for example donations and aid from government and NGOs)? Yes No Explain
(b) When a main road is cut off, are there impediments for goods and services to be delivered? Does this impact the delivery of fuel and gas? Yes No Explain
(c) If fuel cannot be delivered, are other services and facilities undermined? For example, is the ability to run businesses, distribute food and medicines, power energy generators and operate emergency services (such as police, fire brigade and ambulances) undermined? Yes No Explain
(d) When a main road is cut off, are children prevented from going to school? Yes No Explain
(e) When electricity is interrupted, is there an impact on water provision and treatment? For example, if water pumps cannot operate and household appliances do not work, what is the impact on the access to clean water? Yes No Explain
(f) Does the lack of electricity impact the functioning of hospitals? For example, if there is no generator available? Yes No Explain
(g) Does the lack of electricity create communication challenges? For example, by interrupting phone, radio and internet use? Yes No Explain
(h) Does the lack of electricity impede bank payments from being made and received? If so, what is the impact on economic activities in the community? Yes No Explain

STEP 5: IDENTIFYING CASCADING EFFECTS
Climate events tend to affect and disrupt lives. How does a climate event affect citizens' lives and livelihood in your community? **To help with the exercise, consider the following examples. The questions can be reduced and/or condensed by the moderator for simplicity and agility:**
(a) How are economic activities in the community impacted? For example, do activities such as fishing, tourism, crops and agriculture production, outdoor activities at beaches, cattle grazing, sand mining and local businesses experience a negative effect because of a climate event? No impact Low impact Medium impact High impact Explain
(b) Is there any impact on housing conditions following a climate event, for example a decrease in property value? Yes No Explain
(c) Do households experience energy rationing and increased energy prices following a climate event? Yes No Explain
(d) Is there an impact in terms of employment opportunities following a climate event? Yes No Explain
(e) Is there an impact on food prices and living costs following a climate event? Yes No Explain
(f) Does domestic violence and conflicts increase following a climate event? Yes No Explain
(g) Who is most affected in the community? For example, are marginalised populations, women, children, or the elderly impacted more? Yes No Explain
(h) Does the community receive any external support following a climate event? If so, who provides the support (government, NGOs, fellow community members and family)? Yes No Explain

(i) Is there an impact on children's physical and mental health? For example, do children manifest a need for specific support related to trauma following a climate event? Yes No Explain
(j) Is there an impact on children's health conditions, for example more incidence of diseases such as dysentery, cholera and undernutrition following a climate event? Yes No Explain
(k) Does school attendance drop following a climate event? Yes No Explain
(l) Does crime increase following a climate event? Yes No Explain
(m) Does the reliance on NGO and government assistance grow following a climate event? Yes No Explain
Now think about changes in community habits and behaviours. How does a climate event affect the community's habits and behaviours? **To help with the discussion consider the following examples:**
(n) Does a climate event influence how the community uses electricity? For example, are householders pushed to use charcoal and firewood burning with more intensity and frequency? Yes No Explain
(o) Does a climate event change the community's economic prospects? For example, does the lack of business opportunities push the community towards exploring natural resources with more intensity and frequency (for example by overfishing and overgrazing)? Yes No Explain

STEP 6: BUILDING RESILIENT AND ACCOUNTABLE SYSTEMS
Let us focus now on ways to remedy the consequences of climate events. Are there education/information sharing opportunities on detecting and preventing climate events by NGOs, community leaders, or the government? And in terms of support, is the government taking measures to minimise the effects of climate events as well as providing help to the community when shocks occur? **To help with the discussion, consider the following situations:**
(a) What can local authorities do to minimise the impacts (both direct and cascading) of a climate event? Think for example: • Having an alternative transportation route to access the community • A ready-to-go evacuation/emergency plan • Having closer facilities to serve the community, such as a nearby healthcare clinic • Making available water purification and ceramic filters • Locate pit latrines and sanitation in non-flooded areas • Support the diversification of the economy • Diversify the energy mix • Invest on redundancy systems (i.e. backup systems) to protect critical infrastructure • Monitor at-risk areas • Strengthen infrastructure planning • Others
(b) In the context of growing climate events, what can the community do to minimise the impacts (both direct and cascading) of a climate event? Think for example: • Adequate waste disposal systems • Ecosystem preservation / restoration measures • Moving households to non-affected areas • Rethink infrastructure and economic activities in the region • Rethink farming methods and economic activities in the region • Others
Exercise: After discussing potential measures, think on how to prioritise them. As a group, design a community action plan with feasible measures to minimise infrastructure climate impacts, including how to engage with local authorities for support.

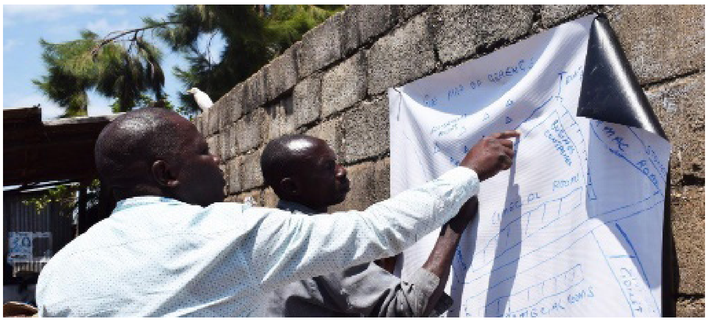
Appendix 2: Climate and infrastructure interdependence schematic



Appendix 3: Fact sheet

Building resilience through participation

Mapping interdependencies and climate-related risks of infrastructure systems in Uganda



Infrastructure assets rarely operate in isolation. They interact with other assets and components, forming a wider complex system. Understanding how those assets operate, how they depend on one another and which ones are critical to the functioning of the entire system is essential to assess the impact of climate events and build resilient systems that can withstand climate shocks. This is because while some infrastructure assets may be directly impacted by climate events, others can suffer indirect and cascading effect due to the nature of interdependency linkages that may exist between infrastructure assets.

The framework and key findings

Using the theoretical framework of participatory mapping, we developed a six-step tool that combined mapping activities and guided questions to support communities in the identification of climate and infrastructure risks.

We tested the approach in the communities of Awoja and Gerenge and the findings show promising results and the potential of the method to fill a relevant gap in bottom-up approaches to tackle infrastructure risks and interdependencies in the event of climate shocks.

The experience provides preliminary indication that the framework helps to piece together the community knowledge on climate and infrastructure risks, cementing the community memory on the impact of climate on critical infrastructure and stimulating questions around climate action and inaction, which are essential to foster accountability.

The framework allows the voice of communities to be central in the process of building climate and infrastructure resilience. It can support community learning and dialogue, also helping to counter climate inaction and alienation.

The 6-step approach:

STEP 1: Knowing your community. Draw a map of the community and identify essential infrastructure that you use in your everyday life.

STEP 2: Understanding the extent of a climate event. When climate events occur, what challenges emerge to get clean water, access to health, food and shelter, and carry out economic and subsistence activities?

STEP 3: Assessing the criticality of infrastructure. Which infrastructure mapped in step 1 is firstly affected in the event of a climate shock?

STEP 4: Mapping dependencies, interdependencies and vulnerabilities. How does the climate impact tend to propagate from one infrastructure system to another?

STEP 5: Identifying cascading effects. What are the economic and social consequences from a climate event and how they impact lives and livelihoods?

STEP 6: Building resilient and accountable systems. Is government and officials taking measures to minimise impact? What actions could help?

Appendix 4: Dashboard screenshots

Mapping Interdependencies and Climate-related risks.

February 10, 2023

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Introduction

Modern infrastructure systems are highly dependent upon each other to operate. Linkages and interconnections between infrastructure systems create a multiplicative effect on risk which can give rise to second-order effects and lead to much larger impact. So much so that the total consequence of the impact in one system is amplified by the number of the dependencies and interdependencies that exist in relation to other infrastructure systems.

Improving resilience of infrastructure, particularly of critical assets, is an urgent goal in the Sendai Framework for Disaster Risk Reduction. Building resilient infrastructure is also one of the Sustainable Development Goals. The focus on resilience is to prevent catastrophic outcomes that can come from disruptions of critical infrastructure systems.

> *The strengthening of infrastructure, specifically crucial assets, is a pressing goal outlined in the Sendai Framework for Disaster Risk Reduction and building resilient infrastructure is one of the key objectives of the Sustainable Development Goals.*

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Methodology

The six-step tool is a participatory mapping approach designed to support communities in identifying and addressing the risks and interdependencies of infrastructure systems in the face of climate impacts.

The tool provides a bottom-up approach to building climate knowledge and resilience by guiding communities through the process of mapping their surroundings and essential infrastructure, understanding the extent of a climate event, assessing the criticality of infrastructure, mapping dependencies and vulnerabilities, identifying cascading effects, and evaluating measures to improve resilience.

Why?

Infrastructure assets hardly operate in isolation. They interact with other assets and components, forming a wider complex system. Understanding how these assets interact, how they depend on one another to operate, and which are critical in case of failures is essential to build systems that can work with minimum disruption during shocks.

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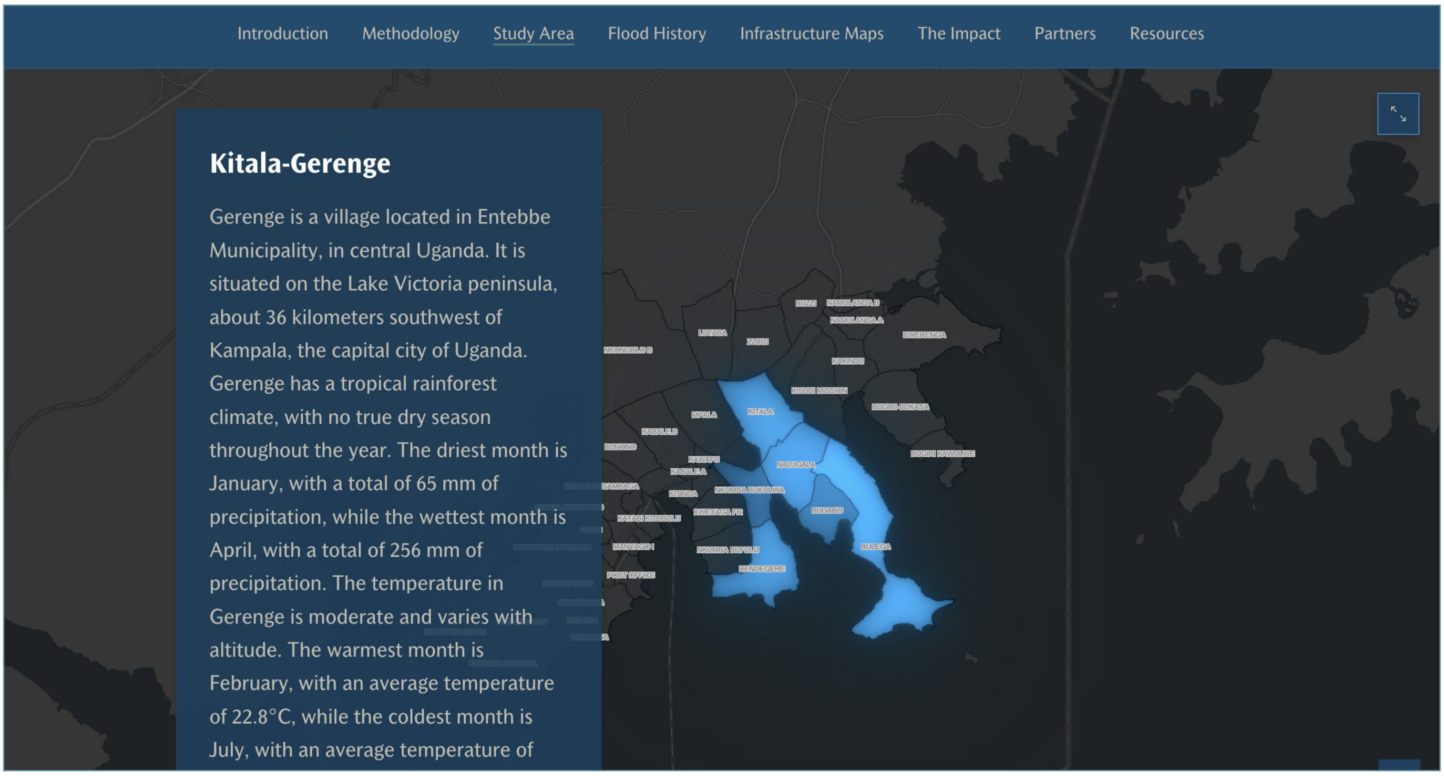
Study Area

Kitala-Gerenge and Awoja

Both Kitala-Gerenge and Awoja are economically disadvantaged communities, with critical infrastructure at risk from climate events. Gerenge is situated in a peninsula, which poses natural accessibility challenges. On the other hand, Awoja is located in a flood-prone swamp area. These communities are dependent on one main road: Garuga Road in Gerenge and Soroti-Mbale road in Awoja. This creates a high dependence on mobility and connectivity, as these roads are reported to be cut off during floods, highlighting the criticality and vulnerability of these communities.

> "Uganda was selected as the test country for our approach due to its high vulnerability to the impacts of climate change. The nation has been particularly affected by climate events. From 1900 to 2018, Uganda experienced 20 floods, 9 droughts, and 5 landslides, affecting at least 200,000 Ugandans and resulting in economic damages of around 62 million USD from floods alone in 2019.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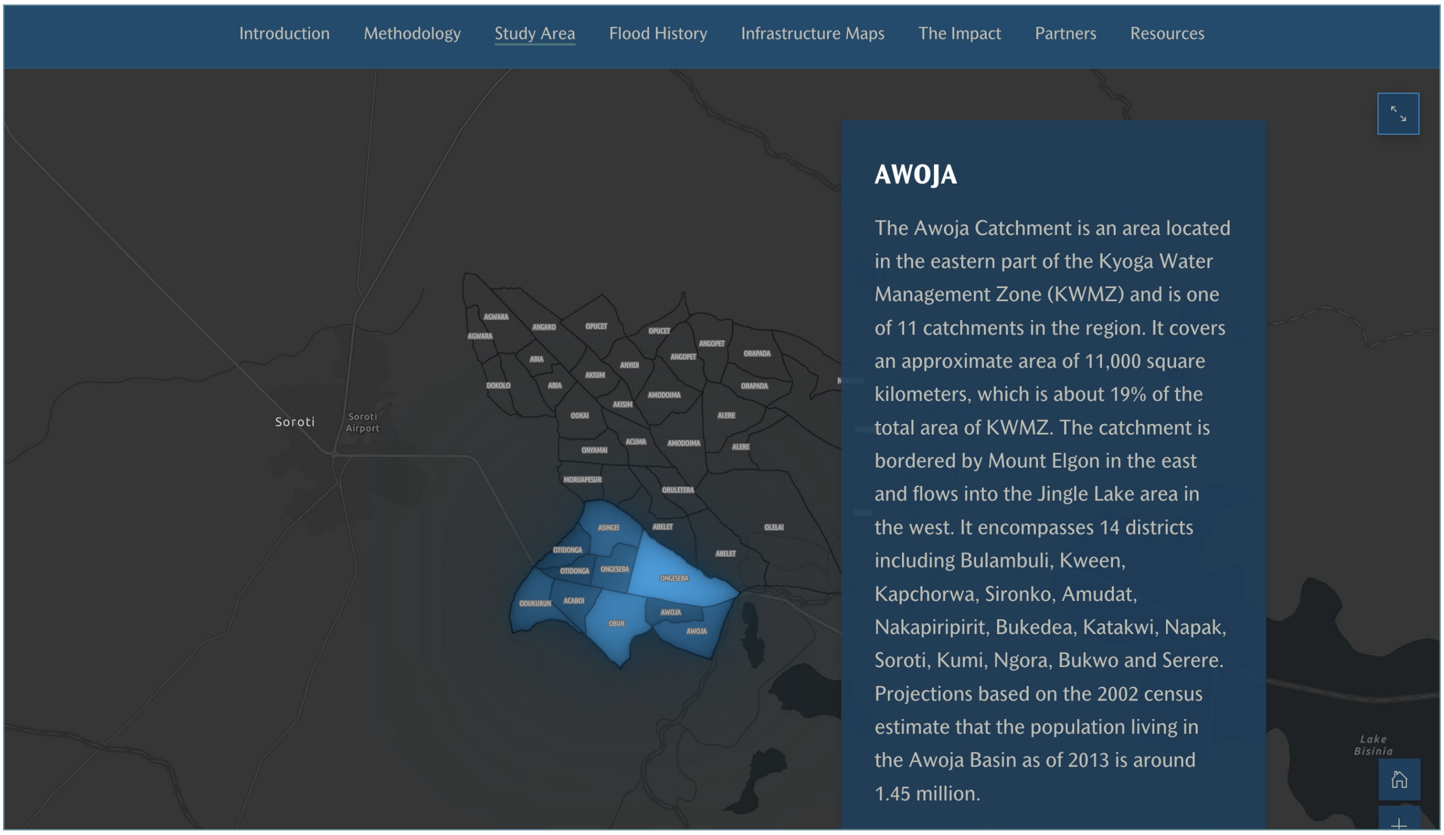
Kitala-Gerenge
Gerenge is a village located in Entebbe Municipality, in central Uganda. It is situated on the Lake Victoria peninsula, about 36 kilometers southwest of Kampala, the capital city of Uganda. Gerenge has a tropical rainforest climate, with no true dry season throughout the year. The driest month is January, with a total of 65 mm of precipitation, while the wettest month is April, with a total of 256 mm of precipitation. The temperature in Gerenge is moderate and varies with altitude. The warmest month is February, with an average temperature of 22.8°C, while the coldest month is July, with an average temperature of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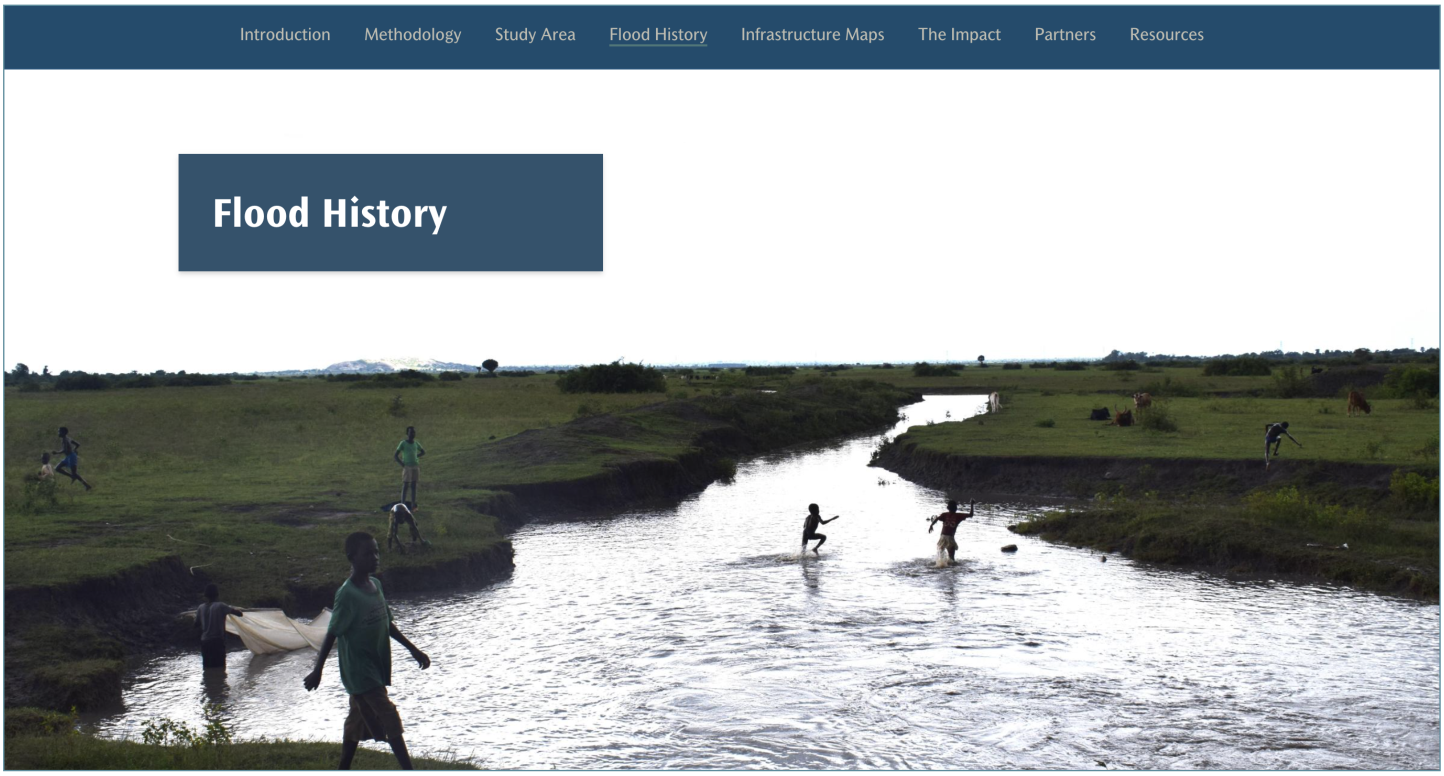
Soroti Airport
AWOJA
The Awoja Catchment is an area located in the eastern part of the Kyoga Water Management Zone (KWMZ) and is one of 11 catchments in the region. It covers an approximate area of 11,000 square kilometers, which is about 19% of the total area of KWMZ. The catchment is bordered by Mount Elgon in the east and flows into the Jingle Lake area in the west. It encompasses 14 districts including Bulambuli, Kween, Kapchorwa, Sironko, Amudat, Nakapiripirit, Bukedea, Katakwi, Napak, Soroti, Kumi, Ngora, Bukwo and Serere. Projections based on the 2002 census estimate that the population living in the Awoja Basin as of 2013 is around 1.45 million.
Lake Bisinia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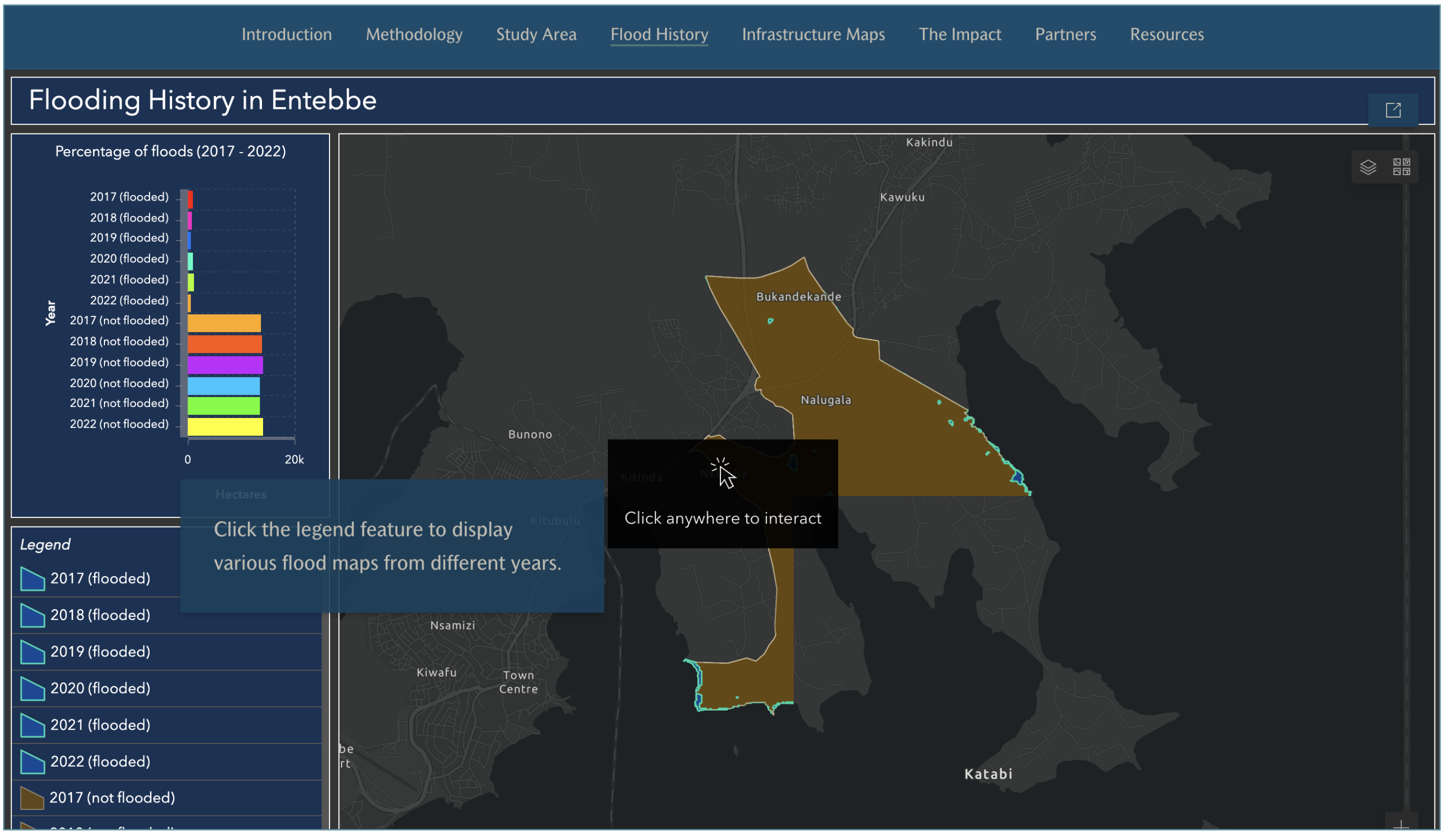
Flood History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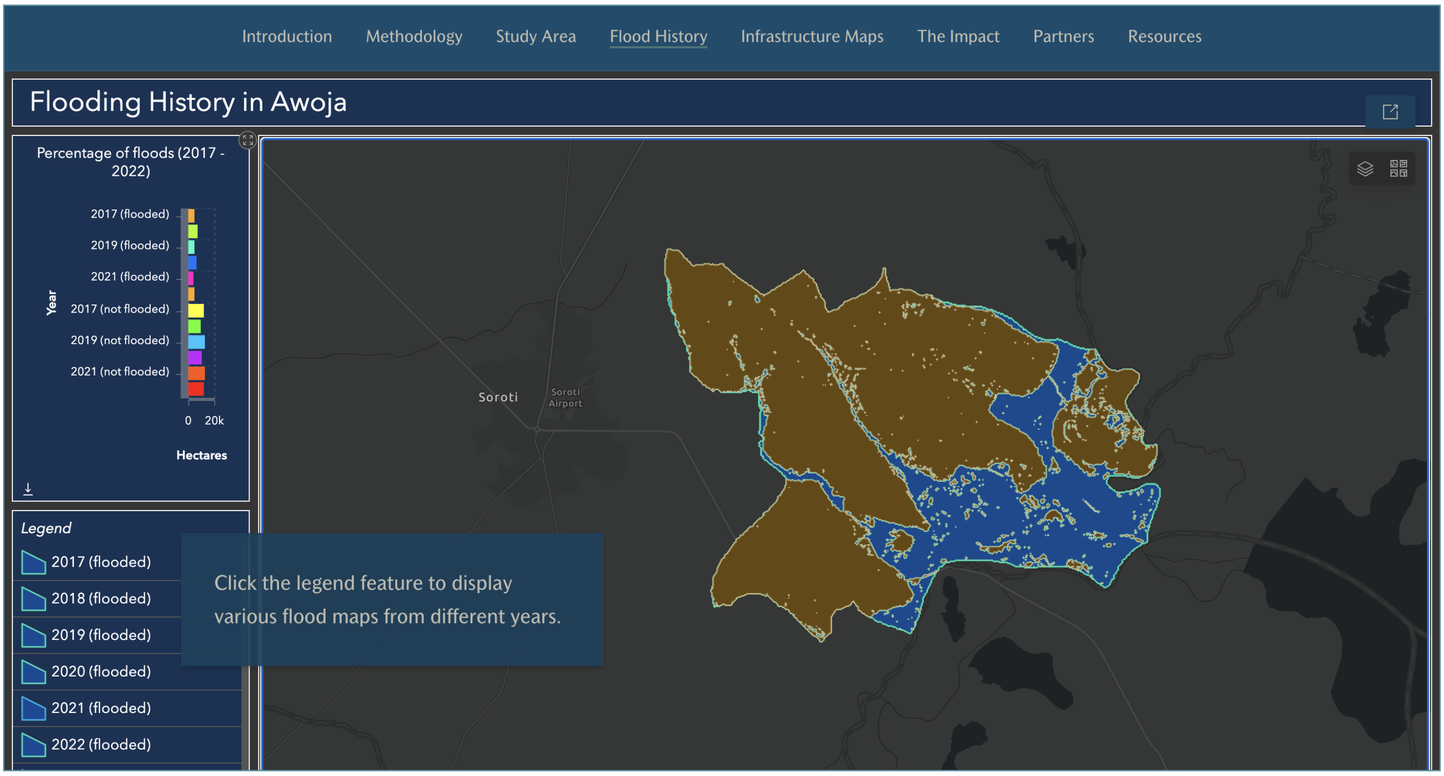
Flooding History in Entebbe
Percentage of floods (2017 - 2022)
Year
2017 (flooded)
2018 (flooded)
2019 (flooded)
2020 (flooded)
2021 (flooded)
2022 (flooded)
2017 (not flooded)
2018 (not flooded)
2019 (not flooded)
2020 (not flooded)
2021 (not flooded)
2022 (not flooded)
0
20k
Legend
2017 (flooded)
2018 (flooded)
2019 (flooded)
2020 (flooded)
2021 (flooded)
2022 (flooded)
2017 (not flooded)
Click the legend feature to display various flood maps from different years.
Click anywhere to interact
Kakindu
Kawuku
Bukandekande
Nalugala
Bunono
Nsamizi
Kiwafu
Town Centre
Katabi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Flooding History in Awoja
Percentage of floods (2017 - 2022)
2017 (flooded)
2019 (flooded)
2021 (flooded)
2017 (not flooded)
2019 (not flooded)
2021 (not flooded)
Year
0
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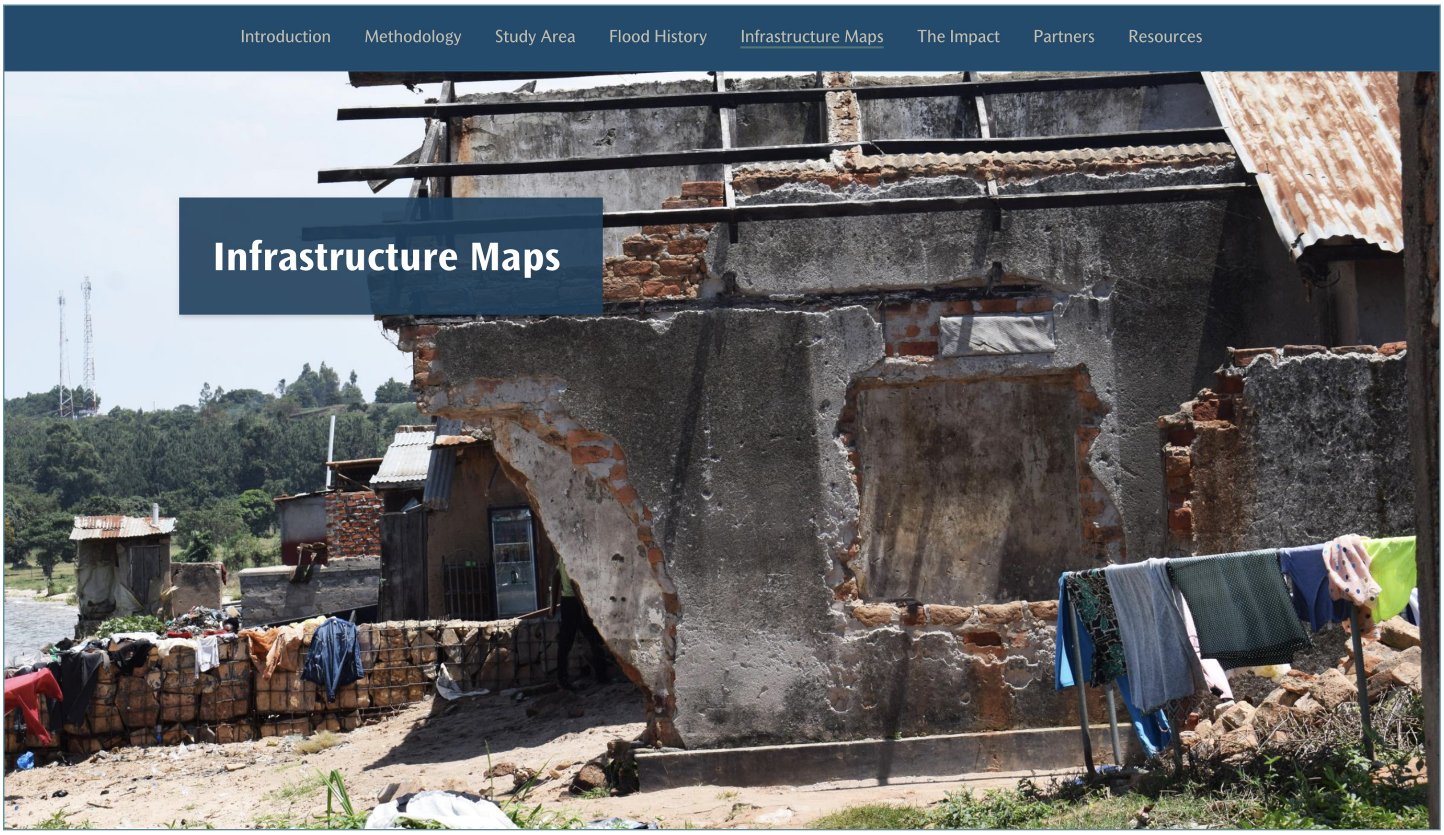
Hectares
Legend
2017 (flooded)
2018 (flooded)
2019 (flooded)
2020 (flooded)
2021 (flooded)
2022 (flooded)
Click the legend feature to display various flood maps from different years.
Soroti
Soroti Airport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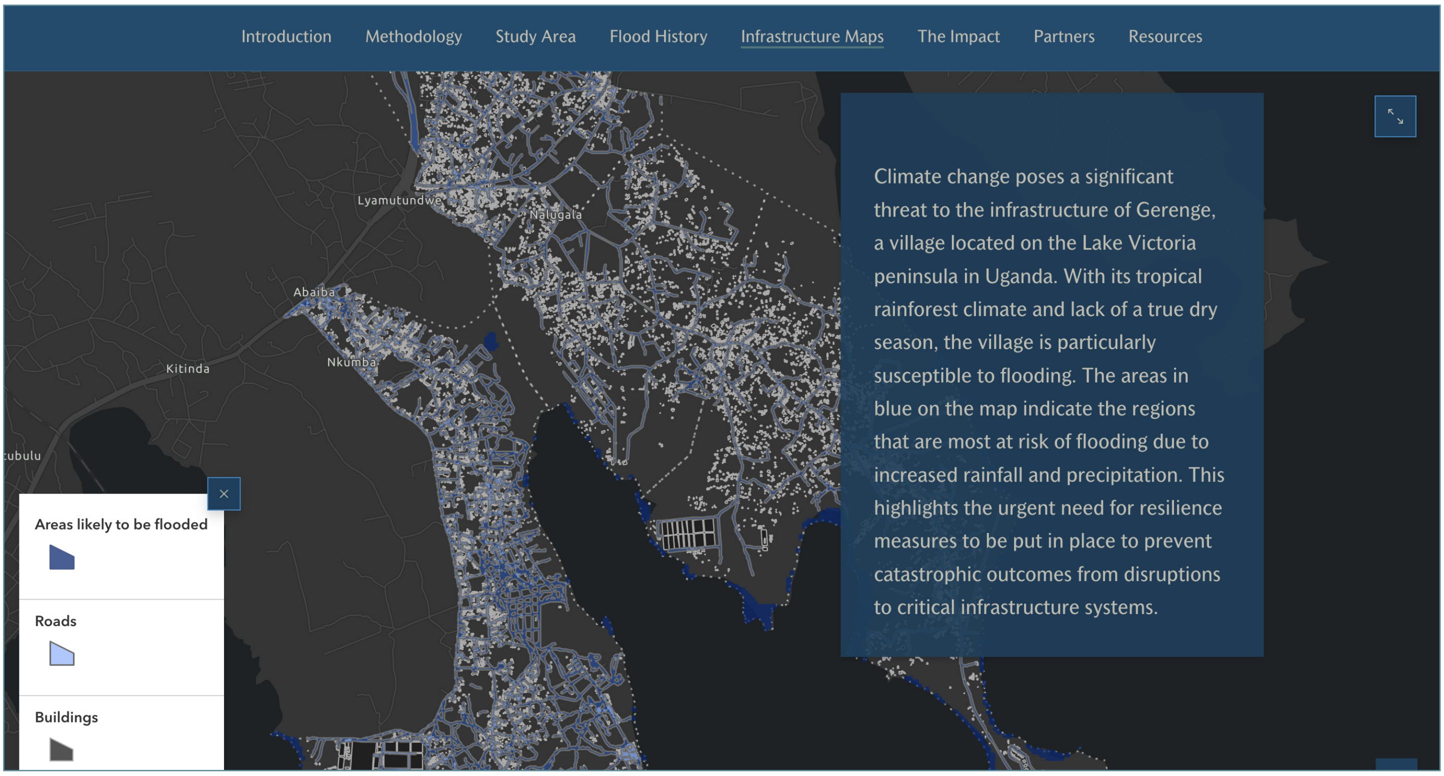
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Lyamutundwe
Nalugala
Abaiba
Nkumba
Kitinda
Areas likely to be flooded
Roads
Buildings
Climate change poses a significant threat to the infrastructure of Gerenge, a village located on the Lake Victoria peninsula in Uganda. With its tropical rainforest climate and lack of a true dry season, the village is particularly susceptible to flooding. The areas in blue on the map indicate the regions that are most at risk of flooding due to increased rainfall and precipitation. This highlights the urgent need for resilience measures to be put in place to prevent catastrophic outcomes from disruptions to critical infrastructure systems.


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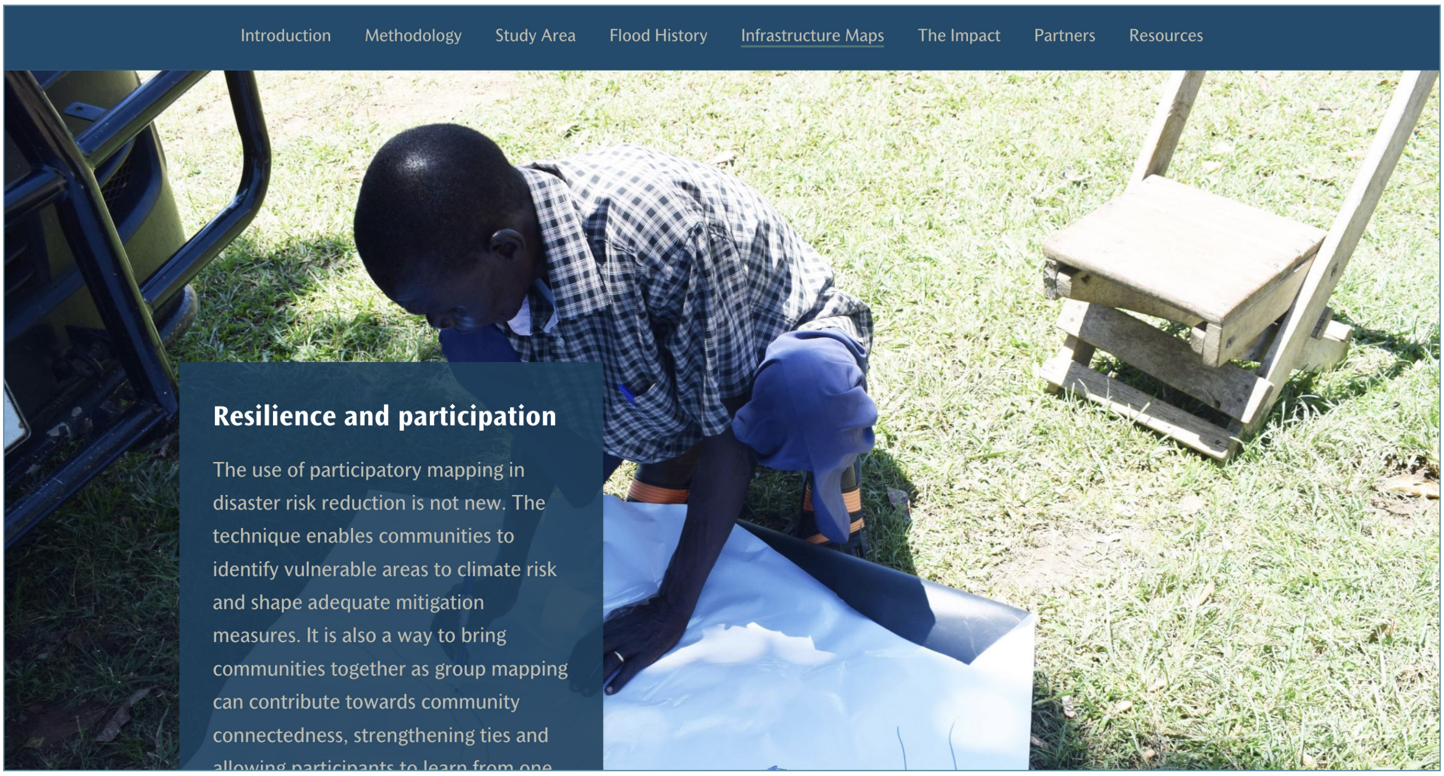
Kumi-Soroti Road
Areas likely to be flooded
Likely to be flooded
Roads
Buildings
Awoja
The Awoja region is particularly susceptible to flooding due to its location in a swamp area. As climate change continues to exacerbate weather patterns, the infrastructure in Awoja, including roads and buildings, is at a high risk of being affected by floods. The areas highlighted in blue on the map are particularly vulnerable, as they are likely to experience severe flooding due to increased rainfall and precipitation levels.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Resilience and participation
The use of participatory mapping in disaster risk reduction is not new. The technique enables communities to identify vulnerable areas to climate risk and shape adequate mitigation measures. It is also a way to bring communities together as group mapping can contribute towards community connectedness, strengthening ties and allowing participants to learn from one


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By facilitating discussions among stakeholders that may not be well represented in other political arenas, participatory mapping can be a transformative experience that provides access to knowledge, new skills, a sense of direction and a shared vision which can catalyse more interactions in the

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When the main roads are closed, 27.3% (77) of the participants cited a lack of other routes. Gerenge landing sites, as well as Kitala village, were cited by 100% of participants as being totally isolated during these events. In Awoja, 100% of Otati village representatives reported the absence of alternative roads during heavy rains. This is a key finding, indicating that roads are a critical infrastructure in the two locations, to the point of complete isolation of relevant portions of these communities.

This finding connects with other evidence collected in the group sessions in relation to the food supply. According to all participants in the 33 group sessions, regardless of the type of the climate event there is an impact on the food supply. Given the isolation that is created when roads are obstructed, working on alternative routes of transportation and diversifying the road network is essential to building resilience of the food supply in the two communities.

Participants also reported cascading impact in terms of healthcare. More specifically, 51.5% (146) of participants reported that the

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Other cascading impact were also identified. 51.5% (146) of participants reported interruption of the fuel supply to their private motorcycles (including motorcycles for hire - bodas) and cars during such climate conditions, which consequently affects food prices. This was reported in both sections of Awoja and Gerenge with no significant difference. The majority of participants 75.1% (213) reported that fuel cuts also affect private businesses, such as local shops, service providers, distributors and government services.

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