Urban Africa Risk Knowledge

Briefing

October 2018

Keywords

Disaster risk reduction, urban planning, multi-hazard, GIS, Infrastructure

Assessing multi-hazard risk to urban infrastructure using low-cost GIS techniques

Natural hazards (e.g. floods, fires) have the potential to occur at the same time or trigger other natural hazards. These multi-hazards potentially have a greater impact than the individual impacts from the individual hazards involved. Towns and cities are comprised of different infrastructure types (e.g., roads, power, water) of varying quality in different areas which may be impacted by hazards to differing degrees. This briefing outlines how a low-data cost GIS methodology – urban texture – can support the assessment of the differing impacts on different types of infrastructure. We focus here on Nairobi (Kenya) and Karonga (Malawi), but emphasise that our methods are generally applicable.

Assessing multi-hazard risks

Global-scale assessments have found that there are approximately 21 broad types of natural hazards, such as earthquakes, fires, floods and extreme temperatures.[1] Figure 1 lists these 21 natural hazards, which we considered for this research.[2]

Until recently, there has been a focus on single hazard assessments (eg the generation of maps of potential flood risk), and so there is limited data for multi-hazard assessments. Multi-hazard events may worsen the impacts to an urban area (compared to the impacts of the individual hazards combined), and make emergency response more challenging. Multi-hazards can include one natural hazard that:

- **triggers** another natural hazard (eg lightning could trigger wildfires)
- **increases the likelihood** of another natural hazard (eg a fire may remove vegetation, increasing the chance of landslides on slopes), or
- **occurs at the same time** as another natural hazard (eg an earthquake could occur at the same time as a flood).

In the work carried out as part of the Urban ARK programme, we generated reports for Nairobi and Karonga, reviewing the potential for multi-hazards. Nairobi is a large, densely populated city of 700 km^2, with 3.9 million inhabitants in 2015, and it has many different land-use types. Karonga is a small town with 42,000 inhabitants in 2008 and few land-use classifications, and is in the process of shifting from rural to urban. The two cities thus represent two different types of urban settings common in Africa. These reports can be used as templates for the assessment of multi-hazards in other African towns and cities, In these two natural hazard reports and for each of the 21 natural hazards, we:

1. Provide a **brief background** to the hazard
2. Review the **potential for this hazard to occur**, primarily based on published literature or globally available datasets
3. Specify for this natural hazard which other natural hazards **could potentially be triggered by it or could potentially trigger it**, given the local conditions, and
4. Indicate for this natural hazard the potential for it to **increase the likelihood** of other hazards occurring.

Practical Pointers

The following are practical points to consider:

- **Multi-hazards** involve two or more natural hazards impacting a region. Multi-hazards can be one hazard directly triggering another, one hazard increasing or decreasing the probability of the second hazard occurring, or two or more hazards that impact the same location and time period. Impacts can be to people, infrastructure, and the environment.
- Multi-hazards are relevant when undertaking an **urban risk assessment** as the impact of a multi-hazard event might: (i) be greater than the individual impacts from the individual hazards involved; (ii) result in unanticipated impacts; and/or (iii) overwhelm the local response mechanisms.
- A low data-cost GIS methodology called **urban texture** has been developed to assess the **potential impact of single and multi-hazards on urban infrastructure** at a coarse scale across a town or city.
- This **urban texture methodology** does not require detailed infrastructure maps and gives a view of how potential impacts from natural hazards to infrastructure might vary across different parts of the city or town chosen, using real-world case histories or scenarios.
- Working through possible **multi-hazard impact scenarios** can help multi-disciplinary teams (such as emergency response, planners, different infrastructure managers) understand potential impacts and plan suitable responses.

Figure 1: Twenty-one natural hazards

Box 1: Examples of real and hypothetical multi-hazard events

A. Observed event in Nairobi, Kenya (heavy rain, flooding, strong winds, landslide)

In April 2012, heavy rains resulted in 48 records of flooding across the city of Nairobi, identified from media reports.[3] Results of the flooding include destruction of more than 250 buildings, traffic delays, and hundreds of families becoming marooned. In addition to the flooding, the heavy rains were accompanied by strong winds, and also triggered a landslide. The strong winds blew over trees which damaged the electricity system, resulting in power outages. A large boulder that fell on ten houses in the Mathare 4A settlement killed at least eight people and necessitated a major rescue operation. The combination of four natural hazards (heavy rain, flooding, strong winds, landslides), coupled with at least four impacts to infrastructure and people (traffic delays, power outages, property destruction and fatalities) made this a complex situation for local and national authorities to plan for and respond to. This is an example of a high frequency, relatively low magnitude multi-hazard event.

B. Hypothetical event for Karonga, Malawi (earthquake, landslides, flooding)

Karonga is located near to the Livingstone Fault, which is prone to earthquakes. According to the USGS Earthquake Catalogue, from 1980 to 2018 there were 34 earthquakes within a 100 km radius of Karonga. The largest intensity earthquake recorded by sensors was in 2009 and had a magnitude of 6.0. It caused 1,557 buildings to collapse in the area.[4] The Livingstone Fault runs through steep, rocky hills on the eastern shore of Lake Malawi in Tanzania and may potentially generate stronger magnitude earthquakes (although there is considerable uncertainty around this). If strong groundshaking occurs in a high magnitude earthquake, it could trigger landslides on the Eastern shore of Lake Malawi. Should a very large landslide occur, this, which could potentially result in large waves from Lake Malawi causing flooding in Karonga (which is situated on the western shore of the lake). A large magnitude earthquake has a low likelihood of occurring and the potential scenario of this large earthquake triggering landslides and then subsequent flooding is uncertain in terms of its likelihood, without more fieldwork and computer models being conducted. Due to the potentially large impact and low-likelihood/uncertainties of this scenario, policy makers would need to decide if it was appropriate to direct resources to better understand the physical likelihood of this scenario and resilience of the area.

Box 1 provides one hypothetical and one observed example of multi-hazard events. The reports for Nairobi and Karonga are to be made available online, along with a template document that can be used for other locations.[5] Going forward, we recommend that multi-hazard case study examples be recorded within existing databases to have a better understanding of their occurrence across urban and rural areas globally.

Multi-hazard risks to infrastructure

The built environment of a town or city is comprised of many different types of infrastructure – such as roads, electricity, open spaces – and varied levels of service of each infrastructure (eg paved highways versus unpaved tracks), which comprise sub-types. Each of these sub-types may be impacted by natural hazards in different ways, for example:

- Flooding may cause:
  - temporary blockages to a highway;
  - an unpaved track to be muddy and impassable for a prolonged period.
- A drought may result in:
  - reduced power output to a hydroelectricity power plant;
  - decreased cooling capacity of a fossil fuel power plant.

As part of the Urban ARK project, we created a database of qualitative descriptions of potential impacts to infrastructure from the 21 different natural hazards as shown in Figure 1 for 13 categories of infrastructure (Figure 2), which contain 157 infrastructure sub-types).[6] For each hazard and infrastructure sub-type, a description of potential impacts is given based on existing literature or records of previous events from newspaper or responder reports. The descriptors are applicable across other African towns and cities.

Different areas of a town or city have unique infrastructure configurations and thus are impacted differently by a natural hazard. For example, the impacts to infrastructure in a town or city's central business district will differ to those in an informal settlement. Due to rapid (often informal) growth, African urban centres have the added challenge of access to homogeneous data to inform what infrastructure is present in different areas.

Different areas of a town or city have unique infrastructure configurations and thus are impacted differently by a natural hazard. Due to rapid (often informal) growth, African urban centres have the added challenge of access to homogeneous data to inform what infrastructure is present in different areas.

Urban textures

To assess at a coarse scale what types of infrastructure are present in different parts of the city, we developed a methodology called 'urban textures', which uses a low-data cost and free software technique using remote sensing and GIS.[7] Using this methodology, we divided Nairobi and Karonga into 17 'urban textures' zones (see Figure 3 for Nairobi). Each urban texture corresponds to a unique infrastructure configuration; for example, informal settlements are likely to have buildings made from wood and metal, with informal electricity connections and water taps. The methodology takes about two weeks to be applied by a non-expert to a 'new' region, and requires free data and some validation of the derived urban texture classifications from the local infrastructure in the town or city concerned.[8]

Figure 2 Categories of infrastructure considered

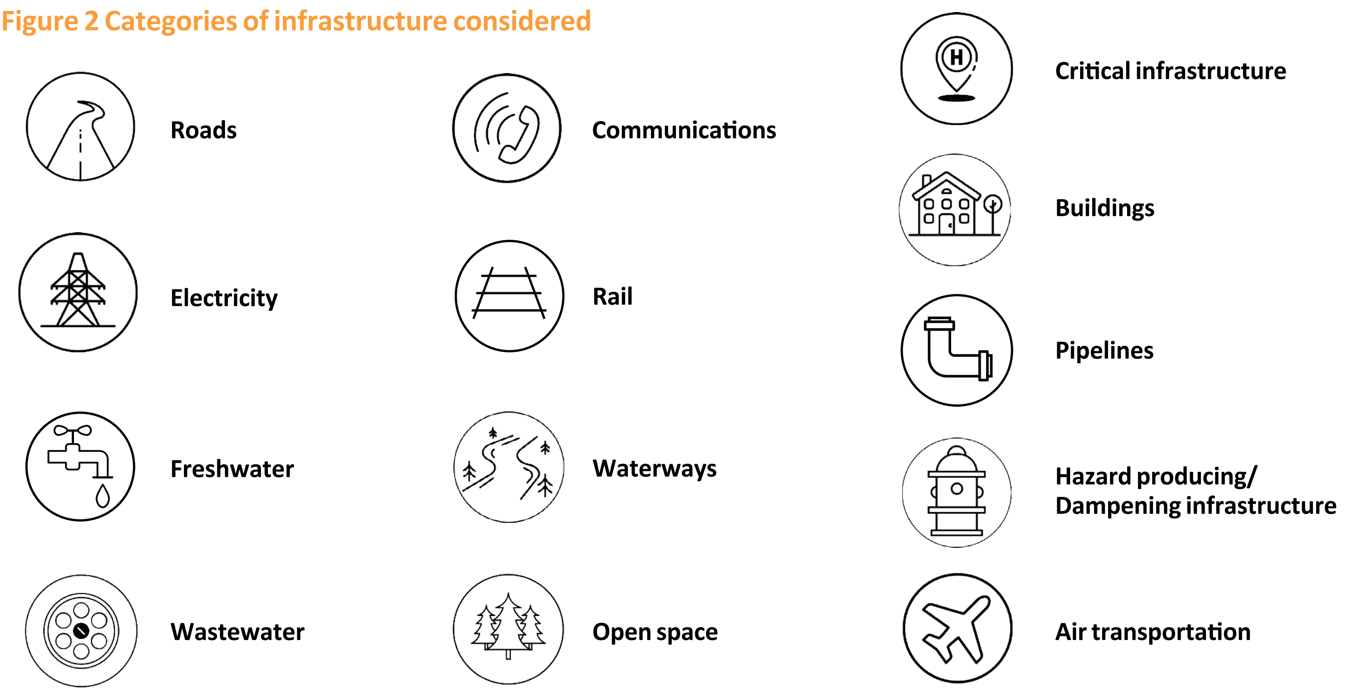
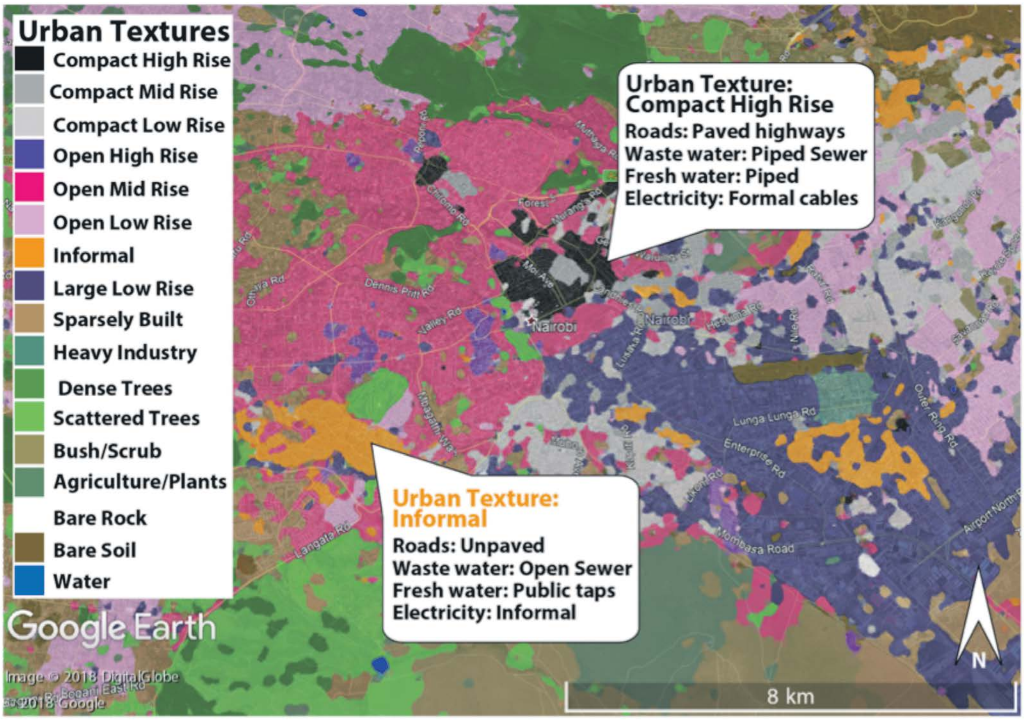


Figure 3: Urban texture infrastructure classification for Nairobi and the surrounding areas. The land cover has been split into 17 different classes (see legend on left) using free Sentinel-2 10 × 10 m resolution remote sensing imagery and free SAGA GIS software. Some descriptions of 'typical' infrastructure typology within these classes are shown in pop-up bubbles.



In combination with the multi-hazards assessments, these urban texture maps can be used by relevant end-users (eg urban planners, infrastructure managers, emergency responders) in each African urban centre to consider different scenarios of impact. This is particularly useful for considering disaggregated impacts at the sub-city scale and scenarios of change (eg future urbanisation).

The work performed here illustrates approaches to understanding multi-hazard risk that do not require considerable additional resources or capacity. It is important to carry out a first approximation of multi-hazard risk, since preparing for and responding to the complexity of multi-hazard events can be challenging.

Authors

Faith E. Taylor, University of Portsmouth, faith.taylor@port.ac.uk;
Bruce D. Malamud, King's College London;
James D.A. Millington, King's College London

Notes

1. Gill, J and Malamud, B (2014) Reviewing and visualizing the interactions of natural hazards. *Reviews of Geophysics*, 52(4), pp.680-722.
2. Sources for hazard icons used are unless otherwise stated: UN Office for the Coordination of Humanitarian Affairs (2012). All other icons from or modified from the Noun Project ((https://thenounproject.com) users: Town Icon (Made); Hole Icon (Left Martinez); Broken House Icon (Fabriaz); Hail Icon (H Alberto Gongora); Snow Icon (Adrien Coquet); Lightning icon (RULI); Sun Icon (Aybige); Asteroid (Iain Hector).
3. As an ongoing activity as part of the Urban ARK project, a database of flood events and associated impacts is being complied for Nairobi from media reports. For more information, contact bruce.malamud@kcl.ac.uk and Bernard.majani@kcl.ac.uk
4. UN Resident Coordinator for Malawi (2009) Malawi-Karonga Situation Report III [online] Available at: https://reliefweb.int/report/malawi/malawi-karonga-earthquake-unrc-situation-report-no-3 [Accessed 07/08/2018]
5. Urban ARK Work Programme 2: Hazards Assessment – http://bit.ly/WP2-UArk
6. Infrastructure Icons from the Noun Project (https://thenounproject.com). Users: Anton Gajdosik Project; Chameleon Design; rivercon; Philipp Lehmann; IYIKON; Juraj Sedlák; Lu'u Trọng Nhân; www.yugudesign.com; Dev Patel; Artem Kovyazin; Ben Davis; Srinivas Agra; Made x Made.
7. Based on Bechtel, B et al. (2015) Mapping local climate zones for a worldwide database of the form and function of cities. ISPRS International Journal of Geo-Information, 4(1), pp.199-219.
8. Training materials to apply the urban texture classification to other African towns and cities are available at http://bit.ly/WP2-UArk

Urban Africa Risk Knowledge

www.urbanark.org

Urban Africa: Risk Knowledge (Urban ARK) breaking cycles of risk accumulation in sub-Saharan Africa

A three-year programme of research and capacity building that seeks to open up an applied research and policy agenda for risk management in urban sub-Saharan Africa. Urban ARK is led by 12 policy and academic organisations* from across sub-Saharan Africa with international partnerships in the United Kingdom.

* Abdou Moumouni University; African Population and Health Research Centre; Arup; International Alert; International Institute for Environment and Development; King's College London; Mzuzu University; Save the Children; UN-Habitat; University of Cape Town; University College London; University of Ibadan; University of Portsmouth

Contact: Mark Pelling
mark.pelling@kcl.ac.uk

Urban ARK is funded by the Economic and Social Research Council (ESRC) and the UK Department for International Development (DFID) Humanitarian Innovation and Evidence Programme.

The views expressed do not necessarily reflect those of the donors.