REPORT

Global and local, public and private: How climate-vulnerable countries can have the best in understanding risk

Global Risk Modelling Alliance

Benefits of open risk tools for risk reduction and risk transfer policies

Executive Summary

A fast-track climate analysis has been conducted for Ghana and Uganda, using open risk models and freely available global data. This level of analytics demonstrates a typical low-resolution risk audit, which can be considered a first step on a country's journey of risk understanding. The analysis provides estimates of current risk at the national and subnational levels, and the amount of additional risk resulting from climate change and socio-economic development projected by 2050. This is a level of risk understanding which many countries do not possess already, and is needed to underpin the effective management of risk.

Crucially, this analysis also goes to the next step, demonstrating how to use open-source tools to assess options for managing that risk. An appraisal of four types of adaptation measures demonstrates the positive impact of investing in risk reduction, and an approach to understand which measures are most effective (and cost-effective) in different locations with different levels of risk. Adaptation measures cannot remove risk entirely and the remaining risk can still be significant. Climate and disaster risk financing and insurance (CDRFI) can provide an efficient strategy to transfer this remaining risk and fund response and recovery. This analysis illustrates the complementary nature of adaptation and CDRFI in managing risk.

Despite the valuable insights presented, they do not represent a locally-informed and locally-owned view of risk. The results demonstrate why country-specific data and local context are crucial to gain in-depth risk insight reflecting the reality within countries. This is why the Global Risk Modelling Alliance has been set up as a Public-Private Partnership the GRMA combines private sector expertise in risk analytics with public sector operational capabilities, to exchange knowledge and build countries' capabilities in risk analytics, so that they can improve on low-resolution global views of risk towards locally-owned complex views of risk to support a comprehensive risk management strategy.

Table of Contents

The power of local risk understanding

There is growing demand for 'locally owned' risk understanding to advance risk prevention and address the insurance protection gap in vulnerable countries. The needs and priorities for risk reduction and adaptation should be predicated on countries being able to identify their own risks, in line with the Sendai Framework Guiding Principle M, and countries should be able to maintain their own view of risk as it changes over time.

Co-development of risk models through collaborative, transparent and open processes leads to better understanding and ownership of the risk at the local level. It reduces reliance on global or regional data and assumptions, improving the quality of the analytics, and building greater trust in the methods and outputs. This can empower local institutions to enact disaster risk prevention, risk transfer and anticipatory actions.[1] Co-development is a mechanism for capacity building from the beginning to the end of a project, ideally providing a foundation for further development of risk analytics beyond the project.

Creates a shared understanding of climate and disaster risk for policy making

Local risk understanding can be applied in political decision making in various aspects. Building local risk understanding is the foundation for an effective risk strategy by developing an understanding of risk that is shared across sectors and agencies, for more effective policy making. That understanding of risk may range in complexity, from a low-resolution or preliminary risk audit, to complex event-based probabilistic modelling for risk financing purposes. Even a preliminary risk audit can catalyse dialogue about the risks faced, identifying regions or cities and sectors at most risk, and the 'drivers of risk' including hazards and vulnerabilities. This enables prioritisation of further analysis and data collection, consideration of potential strategies to manage risk, and inclusion of risk understanding in National Adaptation Plans, Disaster Management Plans and other policy levers. Further, in recognising the limitations in analytics with currently available information (observation data, records of disaster impacts, etc.), such analysis can catalyse investment in information that can improve the view of risk over time.

Further analysis can include benefit-cost assessment of adaptation measures, assessment of fiscal stability, and planning a disaster risk financing strategy in which the efficiency of budgetary measures, contingent risk financing and market-based risk transfer can be assessed. Risk analytics can provide information into the whole disaster risk reduction toolbox, where multiple strategies should be considered to effectively reduce risk. For example, risk transfer can address risks remaining after adaptation measures were implemented to reduce risk.

In all of these applications the confidence imparted by co-development, that best-practice analytical approaches have been ground-truthed and improved by local information, and that in-country Ministry and agency staff understand the methods and outputs can only help to embed risk understanding in those further applications and policies.

Informs implementation of climate policy

Risk analysis provides responses to key questions in managing disaster and climate risk:

[1] The IDF, 2020. The Development Impact of Risk Analytics.

- What is the present risk posed by disasters and how might that risk change into the future, with climate and socioeconomic change?
- What actions can be taken to prevent and reduce that risk, to reduce financial losses and impacts on society?
- Which potential actions are most cost effective, or provide the greatest benefit-cost ratio?

By applying insurance methodologies to communicate risk in terms of the Annual Average Loss (or cost of damages) and the maximum potential loss in a given time period, that risk can be given a 'price'. This price is used to set insurance premiums, but can also be used to compare the efficiency of different types and structures of climate and disaster risk finance and insurance (CDRFI) and investments in risk reduction and adaptation.

Investment in risk reduction measures can provide the dividends described above, but also potentially reduce the price of insurance. The reduced risk (I.e., reduced annual losses) from improving the building stock through flood or cyclone proofing, for example, can be reflected in a lower 'price' for purchasing risk financing.

The insurance sector has quantified risk in this way for decades, especially for countries with developed insurance markets. The capability to perform these complex risk analytics is therefore well-established in the insurance sector, and there has been investment in data and models in those markets that support such a level of analysis. The development of local risk understanding to apply such analytics in low- and middle-income countries can enable wider generation and use of metrics that inform climate policy, while integrating locally available information and local requirements for communicating outputs, which should, in turn, result in outputs being more relevant to the local context, than if produced remotely by international partners.

Leverages private capital for climate financing

Available resources in the development and humanitarian sectors are insufficient to meet the requirements set out in the 2030 Global Agenda. Private sector finance can assist in meeting those goals, but risk understanding is essential for enabling access to that finance. The need for greater financing of disaster risk reduction was highlighted many times at the *7th Session of the UN Global Platform on Disaster Risk Reduction* in May 2022.

Accepting risks in climate-vulnerable countries can be attractive to insurers and reinsurers, and investors in the capital markets, where they enable greater diversification of a risk portfolio. However, a lack of risk insights, can reduce confidence in what risk is being taken on. This can prevent those risks being placed in the international market or can result in a high premium being charged to cover them, to compensate for the uncertainty of that risk. Quantifying risk using established and market-accepted approaches gives entities increased confidence to accept those new risks, and at a lower cost, releasing capital into the development and humanitarian sectors.

Promoting greater risk understanding – maximising value through public-private partnerships

The public and private sectors bring complementary expertise to the question of increasing risk understanding and effective risk management in the most climate vulnerable countries. Public sector entities bring extensive networks of operational projects and staff working on the ground in many and varied local contexts. Their experience in helping communities reduce poverty, build livelihoods, prepare for disasters, and respond and recover from disasters when they happen being in-depth understanding of local operational contexts, and the need of communities who live there.

The private sector brings expertise in risk assessment and developing financial mechanisms to transfer risk to others in the insurance and capital markets. In particular, the private sector has extensive expertise in probabilistic risk analytics, critical in areas with limited historical records and where the risk is changing rapidly. Private sector catastrophe models, developed and improved over the last 30 years, have proven to be a key tool in the global insurance industry's management of extreme events.

The analysis of risk for the creation of disaster risk finance and insurance mechanisms has traditionally been solely in the domain of the private finance markets. To engage with international markets and to develop domestic insurance markets, governments and regulators need to be able to communicate in the same language of risk in use by the private sector. To enable this, partnerships between the public and private sectors can build the capacity of governments to better understand their own risk, and decide on their own risk strategy, blending global best practices with local knowledge and data. In a virtuous cycle, increasing quality of risk information can reduce the cost to governments of accessing international capital, enabling increased investment in risk prevention and preparedness, and reducing cost of residual risk transfer.

The formation of public-private partnerships like the Global Risk Modelling Alliance provide support to the public sector to develop their own capability in risk quantification for risk financing. *See Annex 1 for more details.*

The Global Risk Modelling Alliance (GRMA)

The Global Risk Modelling Alliance (GRMA) is a public-private technical assistance programme to address persistent challenges of risk understanding in the most climate-vulnerable countries. These challenges include limited access to risk analytics, a lack of knowledge exchange, and a challenge to attract investment.

The GRMA programme will assist countries in building, sharing and developing local capability in climate and disaster risk understanding, using open modelling principles and private sector knowledge to increase access to risk finance. The partnership will develop shared understanding of climate and disaster risk across ministries of finance, asset-owning ministries, disaster risk management authorities and research institutions. Through local ownership of the analysis, sovereigns and cities will be better able to develop and report strategic risk profiles, initiate climate-resilient investments, and transfer residual risk to international markets.

The GRMA programme comprises three key elements:

- An **open-source risk modelling platform** and open data standards to promote accessibility, choice, and sharing across departments and sectors.

- A **model and data component** providing a funded mechanism to fill critical gaps with data and models produced as digital public goods, with a particular emphasis on co-developing these with local knowledge and information.

- The **GRMA technical assistance team**, which provides human interaction and connects private sector experience to development needs.

The GRMA is funded by KfW on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) with EUR 11 million via the InsuResilience Solutions Fund hosting the programme. The GRMA programme is a significant contribution to the Vision 2025 of the InsuResilience Global Partnership, which aims to catalyse financial protection for 500 million vulnerable people by 2025.

Risk understanding to support climate policy

To illustrate the crucial role of risk understanding for informing climate policy, this section demonstrates the benefits of climate risk analysis that enables the impacts of adaptation measures to be understood. It then describes how the remaining risk can be addressed with climate and disaster risk financing and insurance (CDRFI). We demonstrate these for the examples of flood risk to the building stock in Ghana and Uganda.

Climate situation and historical disasters in Ghana and Uganda

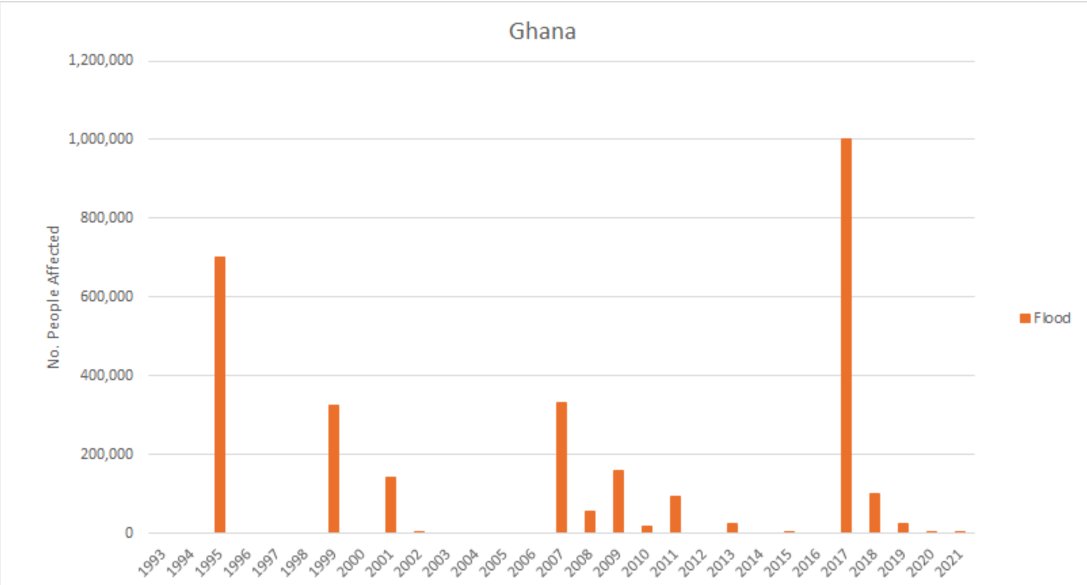
Historical data on disasters and their impacts is limited for many countries, and often inconsistent. However, the Emergency Events Database (EM-DAT) maintained by the Centre for Research on the Epidemiology of Disasters (CRED) of the Université Catholique de Louvain in Belgium provides disaster-related information on human and economic impacts[2]. This data gives an indication of the key perils that a country has faced historically. However, due to impacts of changing socio-economic conditions and climate change, as well as lack of

[2] The Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT) https://www.emdat.be/

detail and completeness in the data mean it can't be used for understanding current or future risk levels.

Ghana (population 30.9 million in 2020) is one of the most flood-prone countries in West Africa. In fact, flooding is the dominant form of disaster in the country and no other climate related disasters are recorded to have impacted the country in the last 30 years, according to the EM-DAT database Since 1990 an average of 138,000 people have been affected by flooding each year. A single extreme event can affect many more people than that, for example the biggest event in 2017 affected 1 million people when flooding affected large areas across Greater Accra, Central Region, Western Region and Eastern Region. In 1995, 700,000 people were affected by floods which caused USD 12.5 million of damage at the time.

Depending on the climate change scenario[3] , temperature in Ghana is projected to rise between 1.7 and 3.7 °C by 2080, compared to pre-industrial levels[4]. Several climate models have confirmed that temperature has already increased by 1.0°C between 1960 and 2003, at an average rate of 0.21°C per decade[5]. The rate of increase has generally been more rapid in the north than in the south. Future precipitation trends are highly uncertain and project either no change or a slight decline in mean annual precipitation amounts over the country, but future dry and wet periods are likely to become more extreme. Under a medium to high emission scenario[6], sea level is expected to rise by 39 cm by 2080. This threatens Ghana's coastal communities and may cause saline intrusion in coastal waterways and groundwater reservoirs.

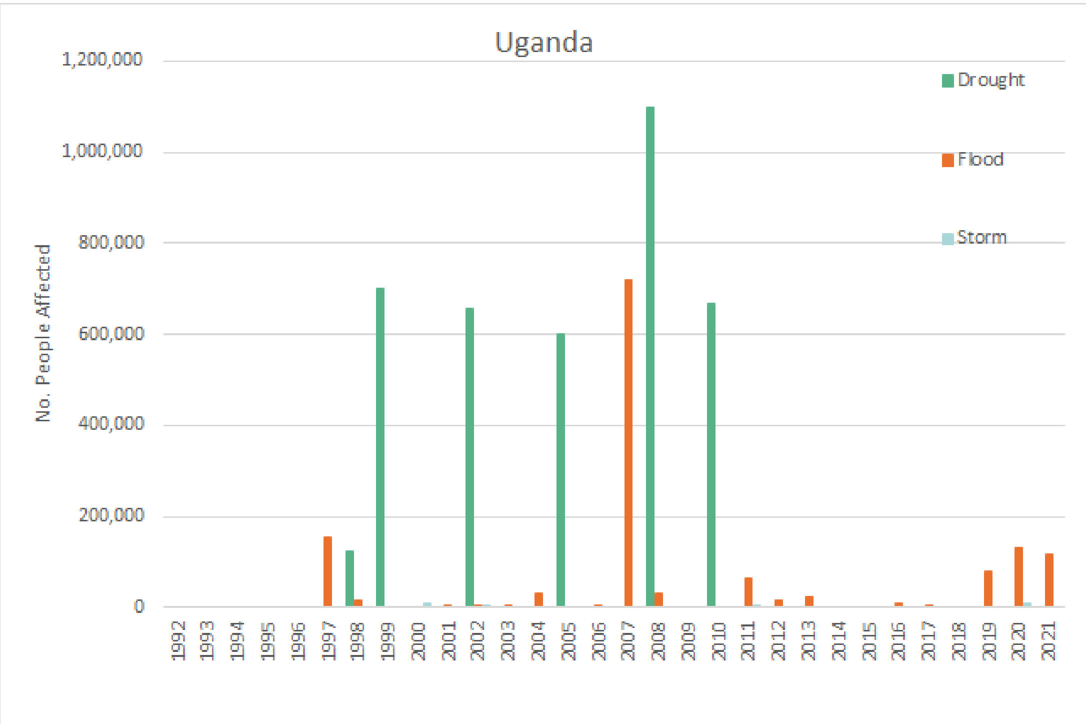


[3] as defined by Representative Concentration Pathways, RCPs, based on Fifth Assessment Report (AR5) as used in the Paris Agreement
[4] https://www.adaptationcommunity.net/publications/climate-risk-profile-ghana/
[5] World Bank, 2020
[6] Representative Concentration Pathway 6.0

Fig. 1: Number of people affected by climate related disasters since 1990 in Ghana[7], adjusted to 2020 population, floods are the dominant disaster.

Uganda (population 44.3 million in 2020) is vulnerable to multiple types of disasters, with droughts posing the greatest risk followed by flooding. According to the EM-DAT database, floods have affected 83,000 people on average each year since 1990. In one of the worst years, 2007, flooding affected 720,000 people across a number of districts in eastern and northern Uganda, destroying an estimated 80% of crops. The costliest flood event recorded was in 2013, causing an estimated 2.3mn USD estimated damage at the time, although the loss data is not always complete in the database showing the limitations of historical records only. Drought conditions in 2010 caused an estimated loss and damage value of USD 1.2 billion, equivalent to 7.5% of Uganda's 2010 gross domestic product[8].

Depending on the climate scenario, temperature in Uganda is projected to rise by between 1.5 and 3.5 °C by 2080, compared to pre-industrial levels, with higher temperatures and more temperature extremes projected for the north and east of the country[9], with increased aridity and severity/duration of the dry season (December to March). Precipitation trends are highly uncertain, but project an increase of 67 mm in annual precipitation by 2080, with much of the increase occurring through an increase in intense precipitation events. Under a moderate climate scenario median climate model projections show the number of days with heavy precipitation increases from 8 days (in 2000) to 10 days in 2080.



[7] EM-DAT, CRED / UCLouvain, Brussels, Belgium www.emdat.be
[8] The World Bank (2020). GFDRR – Uganda Country Profile. URL: https://www.gfdrr.org/en/uganda
[9] Climate Risk Profile Uganda 2021: https://www.adaptationcommunity.net/wp-content/uploads/2021/02/GIZ_Climate-risk-profile-Uganda_EN_final.pdf

Fig. 2: Number of people affected by climate related disasters since 1990 in Uganda[10], adjusted to 2020 population

Climate risk assessment and effects of adaptation measures

The following section demonstrates analysis of fluvial flood risk in Ghana and Uganda, with appraisal of benefits and costs of adaptation measures for risk reduction.

This is achieved by modelling the hazard (fluvial flood in this example), exposure data (people and assets) and vulnerability of those people and assets, in a risk modelling framework. In this example, the CLIMADA framework is used, to combine the assessment of risk with an appraisal of benefits and costs of adaptation measures. This is an example of a rapid, remote analysis intended to provide an initial risk audit to identify the areas of greatest risk and potential adaptation benefits; it is performed with global models and data, and therefore has many limitations to what the analysis can be used for. The accuracy of the numbers will be relatively low, and would need to be improved further with local risk data and knowledge before making any investment decisions. Whilst the accuracy of absolute numbers is subject to these limitations, risk relativities can help identify where to focus future efforts. The details on modelling and various parameters are provided in annex 2.

[10] EM-DAT, CRED / UCLouvain, Brussels, Belgium www.emdat.be

CLIMADA – A framework for risk modelling and appraisal of adaptation measures[11]

CLIMADA (CLIMate ADAptation) is a probabilistic natural catastrophe impact model that provides an essential instrument for comprehensive climate risk management. The open-source platform uses probabilistic risk modelling techniques, to quantify current and future climate risks from hazards including cyclones, droughts and floods. CLIMADA conducts a comprehensive mapping of climate hazards from stochastic event sets or return period hazard maps, against datasets of assets and people, and incorporates an assessment of their vulnerability at national to community scales. Based on the risk assessment CLIMADA provides analysis of the costs and benefits of adaptation measures which can include grey and green infrastructure (Nature-based Solutions), and measures to modify behaviour – for example warning systems. This analysis provides decision-makers with estimates of the reduction in risk due to different measures, to make informed decisions on which measures can most efficiently reduce climate risk.

Hazard

The hazard input to this analysis is a set of flood intensities developed from a simulation of climate between 1975 and 2005[12]. Figure 3 presents the geographic distribution of maximum flood depth over the historical period at each grid point (used as the measure of hazard intensity). Most of the flood intensity is concentrated along South-Western and North-Eastern parts of the country in Ghana along with the Volta River basin. In future the intensity of flood increases along those regions. In Uganda most of the riverine flood intensity is concentrated along western and central and parts of the country. Flood intensity is projected to also increase in these areas.

Exposure

The analysis of risk and adaptation measures includes residential and commercial buildings (loss, USD) and population (number affected). The baseline exposure data is from the UNDRR Global Assessment Report (GAR) 2015. GAR 15 provides a consistent global source of exposure data, which provides a suitable source of data for initial risk audits where more specific national data is not available. Value of the building stock in Ghana and Uganda has been trended to 2020 and 2050 using scaling based on estimates from GDP and population growth estimates[13].

The analysis of risk has also been completed for schools and hospitals, primary roads, and population (see Annex 2 for risk estimates). The total estimates of exposure/ asset values for each category are detailed in table 1, Annex 2.

Ghana **Uganda**

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[11] CLIMADA – Weather and Climate Risks | ETH Zurich

[12] Flood height and intensity is based on climate model outputwhich simulates past weather along with future projections, flooding is modelled on a 50km resolution globally available grid using a process based hydrological model (Herein it is downscaled to 5km output for both countries). Even higher resolution modelling is available for countries which have detailed terrain data, for example up to 5m in the UK. This is an example of where local data can improve the accuracy of modelled loss results if its available.

[13] Murakami, D.; Yamagata, Y. Estimation of Gridded Population and GDP Scenarios with Spatially Explicit Statistical Downscaling. Sustainability 2019, 11, 2106. https://doi.org/10.3390/su11072106

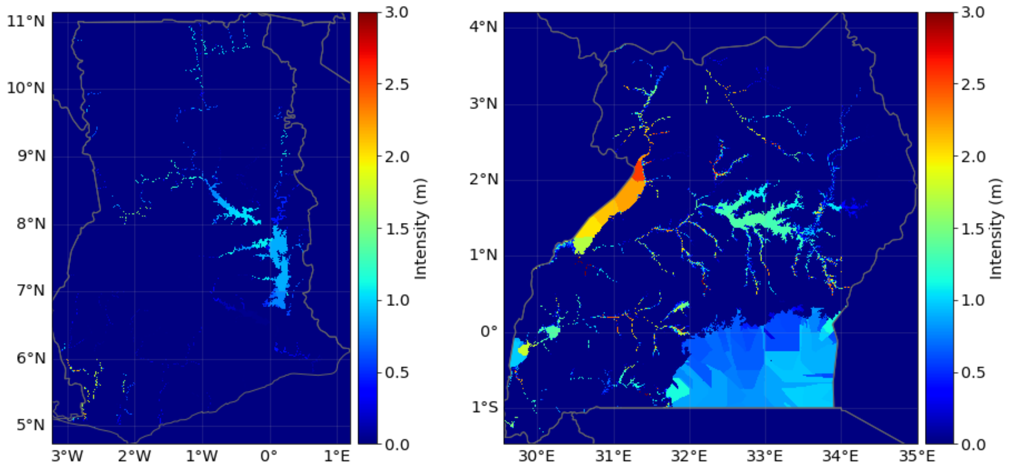

Fig. 3: Simulated maximum flood depth (metres) for each grid point over the historical period as represented by ensembles of climate model output, in each of Ghana and Uganda.

Vulnerability

CLIMADA uses vulnerability curves, which relate flood depth to a damage ratio (0-100%) for different classes of building. The damage ratio is converted to an expected loss by multiplying it by the replacement cost of that building. This enables the loss per building to be estimated based on the depth at that asset, and in turn the impact of each event to be assessed for a portfolio of buildings. In the absence of flood vulnerability curves for Ghana and Uganda developed with local information on damage in past events, this analysis uses vulnerability curves developed from literature review and global assumptions by the EU Joint Research Centre[14].

Impact (current and future climate scenarios)

Damages and losses are quantified for floods expected under current and future climate conditions, assuming different climate and socio-economic development paths in order to account for a change in exposure values in future. In the following we use 2050 as a future reference. The socio-economic direct impact of flood hazard to public infrastructure and houses is measured in terms of Average Annual Loss (AAL) representing the cost of damage to buildings and affected people expected on average every year. Affected people is defined as those located in the flooded area of each event. Figure 4 presents the AAL for buildings and people in both countries due to flood risk under current and future conditions.

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[14] Huizinga, J., De Moel, H. and Szewczyk, W., Global flood depth-damage functions: Methodology and the database with guidelines, EUR 28552 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-67781-6, doi:10.2760/16510, JRC105688.

Fig. 4: Calibrated annual average loss for current and future conditions (including climate and socio-economic growth) for Ghana and Uganda. Three future climate scenarios are shown; all use the projection based on estimates of socio-economic growth under different warming scenarios. Increase in AAL is shown as a factor relative to 2020.

The risk is estimated to increase substantially in both countries by 2050 under a future climate conditions and socio-economic growth. In Ghana climate change increases fluvial flood risk by a relatively small amount. Economic growth compounds the effects of climate change to further increase risk on national scale in Ghana and Uganda for all the asset classes and population. The effect of climate change on risk is variable within each country, and such disparities should be considered when planning adaptation practices.

Subnational analysis has been conducted for Western Region, Greater Accra, and the Upper East and North East regions of Ghana. Risk is most significant in Western Region, where the total accumulated impact between 2020 and 2050 is estimated at USD 6.4 million (Figure 5). In all three regions climate change contributes more to the increase in total risk in than socio-economic growth.

For Uganda the risk analysis was performed on two regions: Kampala and Ngora. Contrary to the Ghana analysis, socio-economic change contributes as much in Kampala compared to in the case of Ngora, to increased risk than climate change. While risk is higher in Kampala than Ngora today, in 2050 Ngora shows higher risk than Kampala, due to socio-economic growth having a greater impact on risk than in Kampala.

Adaptation

The aim of adaptation measures is to reduce the impact of individual disasters and the overall risk. They do this by reducing either the number of assets expected to be affected, the intensity of the hazard or in some cases both.

In this analysis, we assess the benefits of each measure reducing risk to the building stock, in terms of avoided damage and loss. Other potential co-benefits of adaptation[15] are not included, so in reality the benefit-cost ratio could be even higher. The expected benefit of each measure is estimated based on the reduction in flood height due to the adaptation measure implemented. The monetary cost of each measure includes the cost of installation and maintenance of the measure.

Due to a lack of local estimates cost and flood reduction estimates are adopted from other studies that have been conducted with similar measures in place[16].The results of the adaptation assessment demonstrate some notable lessons for Uganda and Ghana. First, the most effective measure in all study regions is *increasing permeable areas* followed by *drainage systems improvements*. In the studied regions of Ghana construction of *detention ponds* are expected to be more effective than *river embankments*, and vice versa in Uganda- however, in most regions the effect of these measures on avoided damages is much less than permeable areas and drainage.

Figure 5 presents the risk and adaptation for buildings for three different regions in Ghana, namely Western, Accra, and North-Upper-East wherein the top plot shows the current risk, risk due to economic growth, risk due to climate change, and finally risk in 2050 combined with increase from economic and climatic factors. The benefit-cost ratio plot shows the benefit per dollar invested (bar height) and how much of the total accumulated risk it can cover until 2050 (bar width, Net Present Value of avoided damage).

The same adaptation measures are expected to provide different benefit-cost ratios and Net Present Value of avoided damage in different regions, demonstrating that there is no "one size fit all" solution for adaptation. Adaptation measures achieve high benefit-cost ratio in regions where total accumulated impact is highest, demonstrated by the positive benefit-cost ratios in Ngora and Kampala where estimated impact is in the order of several hundred millions of dollars, and benefit-cost ratio of <1 where estimated impact is 1-3 million USD in Ghana (Greater Accra and Upper East and North East).

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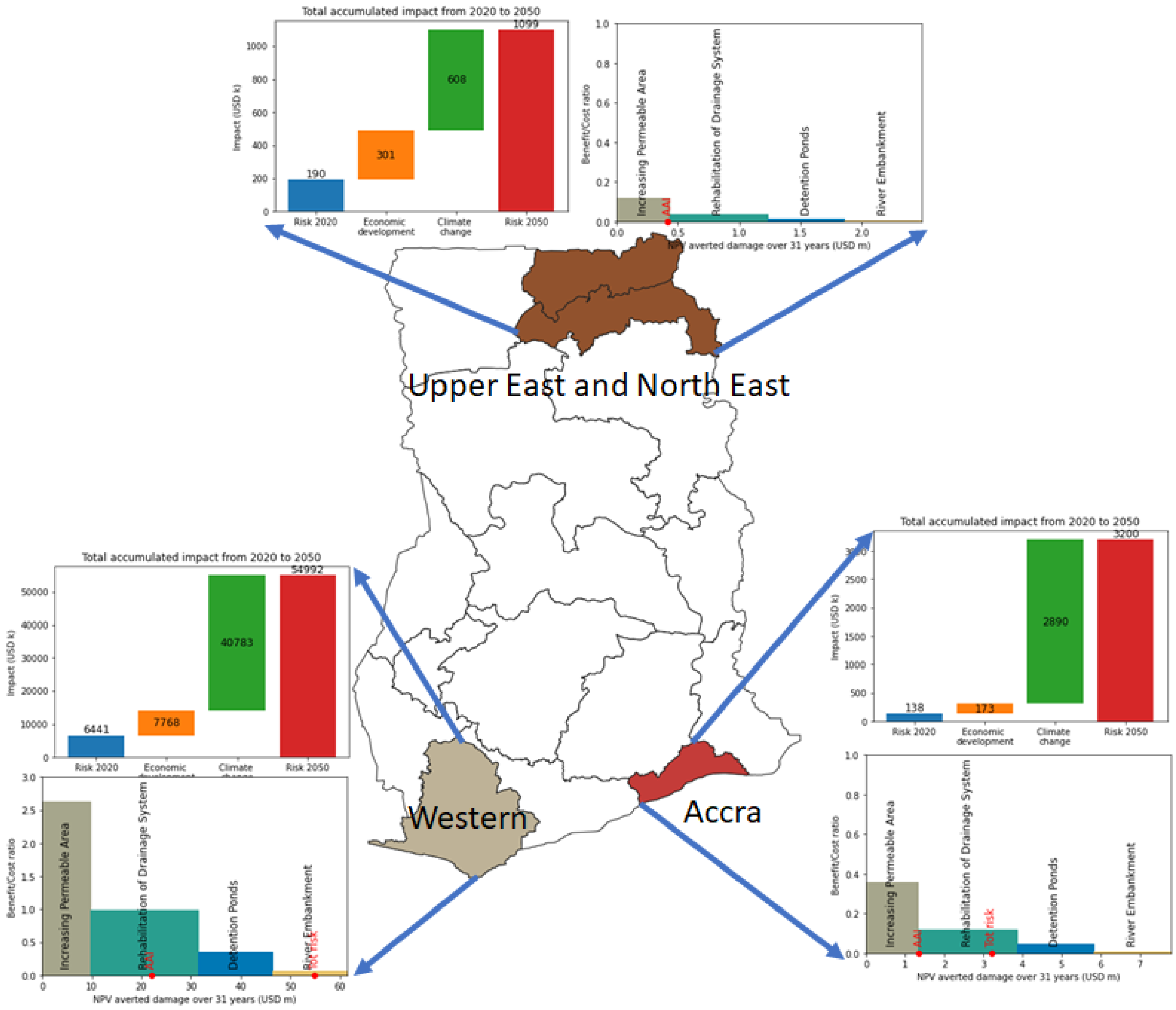
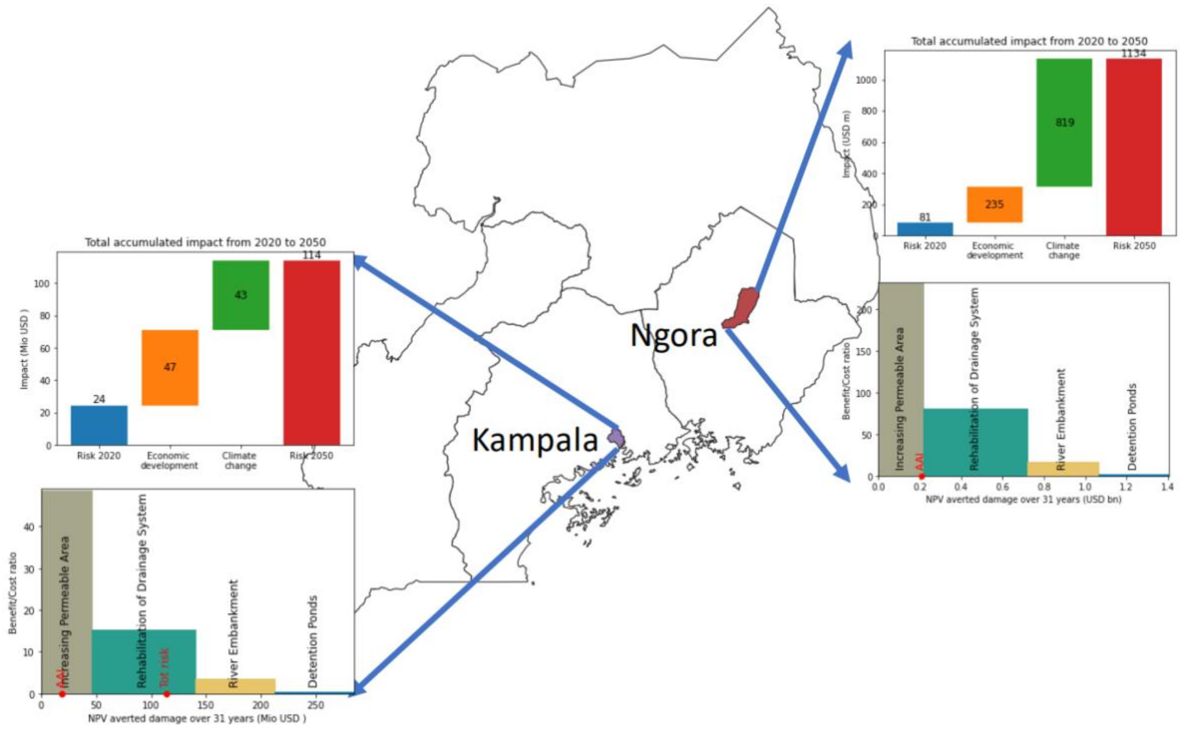
[15] See the Triple Dividend of Resilience Framework. Tanner, Thomas; Surminski, Swenja; Wilkinson, Emily; Reid, Robert; Rentschler, Jun; Rajput, Sumati. 2015. The World Bank, Overseas Development Institute and Global Facility for Disaster Reduction and Recovery.

[16] Rana, A., Qinhan, Z., Detken, A., Whalley, K., Castet, C. (2022). Strengthening climate-resilient development and transformation in Viet Nam. Climatic Change 170, 4. https://doi.org/10.1007/s10584-021-03290-y



Total accumulated impact from 2020 to 2050
Impact (USD k)
Risk 2020
Economic development
Climate change
Risk 2050
190
301
608
1099
Benefit/Cost ratio
Increasing Permeable Area
Rehabilitation of Drainage System
Detention Ponds
River Embankment
AAI
NPV averted damage over 31 years (USD m)
Upper East and North East
Total accumulated impact from 2020 to 2050
Impact (USD k)
6441
7768
40783
54992
Risk 2020
Risk 2050
Benefit/Cost ratio
Increasing Permeable Area
Rehabilitation of Drainage System
Detention Ponds
River Embankment
AAI
Tot risk
NPV averted damage over 31 years (USD m)
Western
Accra
Total accumulated impact from 2020 to 2050
Impact (USD k)
138
173
2890
3200
Risk 2020
Economic development
Climate change
Risk 2050
Benefit/Cost ratio
Increasing Permeable Area
Rehabilitation of Drainage System
Detention Ponds
River Embankment
AAI
Tot risk
NPV averted damage over 31 years (USD m)



Total accumulated impact from 2020 to 2050
Impact (USD m)
81
235
819
1134
Risk 2020
Economic development
Climate change
Risk 2050
Ngora
Benefit/Cost ratio
Increasing Permeable Area
Rehabilitation of Drainage System
River Embankment
Detention Ponds
AAI
NPV averted damage over 31 years (USD bn)
Total accumulated impact from 2020 to 2050
Impact (Mio USD)
24
47
43
114
Risk 2020
Economic development
Climate change
Risk 2050
Kampala
Benefit/Cost ratio
Increasing Permeable Area
Rehabilitation of Drainage System
River Embankment
Detention Ponds
AAI
Tot risk
NPV averted damage over 31 years (Mio USD)

Fig. 5: Accumulated risk in the current, future economic growth, climate change impacts, and combined net risk for 2020 with cost-benefit results for various adaptation measures for buildings. Top: Ghana (Accra = red; Western = light brown; North-Upper-East = dark brown), accumulated risk in thousands and NPV in million; Bottom: Uganda showing Kampala (purple) and Ngora (red), accumulated risk and NPV are in million for Kampala whereas accumulated risk is in million and NPV is in billion for Ngora.

Managing residual risk through climate and disaster risk financing and insurance

Climate and disaster risk financing and insurance (CDRFI) is useful for managing the risk that remains after the effects of adaptation measures. CDRFI can provide funds to help people, businesses and economies recover more effectively after disasters. CDRFI also provides a more efficient use of capital than holding money in budgetary reserves in case of disaster. To illustrate the benefits of CDRFI, we present a hypothetical insurance structure to show how adaptation and CDRFI investments can work together to reduce risk.

The main considerations in structuring CDRFI are the size of disaster a pay-out is desired for, and the amount needing to be covered (i.e., the upper limit of cover). The affordability of cover will also factor into the decision making. In determining their CDRFI needs, a country may consider the amount of reserve funds held by government to help with rapid disaster response and subsequent recovery, or to disburse to people who have lost their incomes and livelihoods. If the reserve fund is too small to cover the cost of extreme events, there is a *funding gap*. To close this funding gap, contingent financing or insurance can be put in place in advance of events, to provide the additional required funds, which the government can rely upon should a disaster occur. If the funding gap is not addressed, funding for the response may have to be drawn from other budget lines, reducing available funds for other sectors.

The starting point for designing a suitable CDRFI approach is understanding the risk to the portfolio being covered. Probabilistic loss modelling deployed by the insurance industry over the past 30 years are now publicly available via open-source initiatives such as the Oasis Loss Modelling Framework[17] In this study, we have generated an *exceedance probability (EP) curve*[18] derived from the 30 years simulated in the CLIMADA analysis, to understand what the more extreme risk may look like (see Fig 6 and 7).[19]

A more robust approach would be to use a full event-based catastrophe model, which developed the EP curve based on ten thousand or more years of possible events, to simulate many more physically possible events and gain a greater understanding of extreme risk and uncertainty. Using the CLIMADA analysis output from the previous section, the combined effect of climate change and socio-economic growth under a moderate climate scenario would increase the 10 year and 100-year period losses by over 16 times for the

[17] https://oasislmf.org/

[18] An Exceedance Probability curves shows the frequency and severity of potential losses. The AAL and return period losses are derived from this distribution.

A Pareto distribution has been used to generate the EP curves to 1-in-1000 years – an approach used where catastrophe models are not available.

Western Ghana region. Introducing adaptation measures would limit this increase to less than six times the amount of the current climate (Figure 6).

Illustrative thresholds for a CDRFI structure are overlaid on the EP curves (Figure 7). The amount of risk that might be retained by the government to cover frequent events themselves is the 'retention' amount (dashed line), and in this example is set to cover all losses up to the 1 in 10-year return period (i.e., would pay for response to the most frequent events). It also includes a 'limit' of insurance, set to the 1 in 100-year return period (solid horizontal line). These are shown for both the current risk, and risk at 2050 under a moderate climate change scenario with adaptation.

The EP curve provides the starting point for calculating the premium cost of that insurance. The pricing of the premium relates to the expected annual average loss, the level of uncertainty in the risk estimates, the amount of cover being purchased, and additional factors to cover costs. As we can see in each of the country analysis, adaptation measures which reduce the expected future losses also reduce the AAL and this should translate to a reduced insurance premium. Premium is also influenced by the level of uncertainty in the EP curve – greater confidence that the EP curve represents loss that could occur in reality, can result in a lower premium.

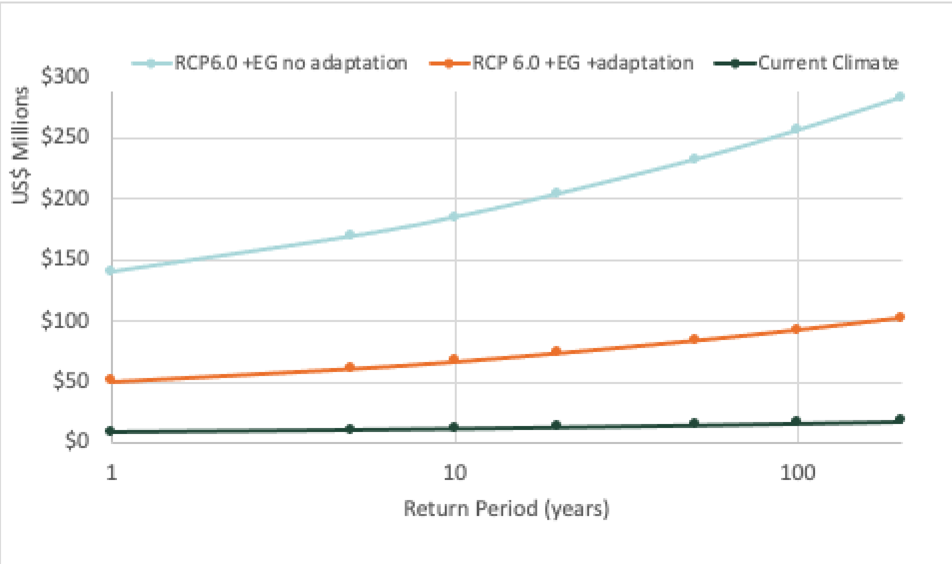


Fig. 6: EP curves for the current climate, and a moderate climate scenario including socioeconomic growth (EG) with and without adaptation (Western Region, Ghana).

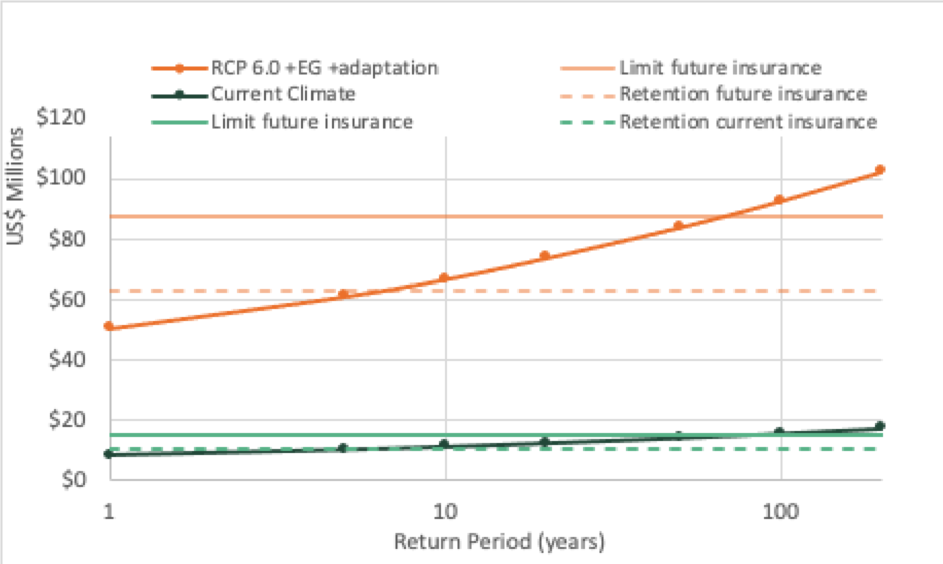


Fig. 7: Illustrative insurance structures overlain the EP curves for the current climate, and a moderate climate scenario including socioeconomic growth (EG) with adaptation (Western Region, Ghana). The dotted lines represent an illustrative government retention level set at the 1 in 10-year return period, and the solid lines the insurance cover limit set at the 1 in 100-year return period. An insurance cover would pay for losses between these amounts, with the government liable for losses below the retention level and above the cover limit.

There are many factors which influence the actual premium cost of any insurance cover. However, for the purposes of this report we apply a generalised assumption for illustrative purposes of 5%[20]. Using this assumption, the premium for this insurance could be USD 210,000, whereas in the future scenario the premium for equivalent cover would be USD 1.23 million – six times the current premium amount. Without adaptation, the premium could amount to USD 3.5 million.

Maintaining the retention amount at a 1 in 10-year loss at 2050 means that any reserve funds would have to increase from USD 10 million to USD 63 million to cover those most frequent losses. In reality, the CDRFI may have to be designed to cover even more frequent losses as well as extreme losses, which would increase future premium cost.

In either scenario the impact of adaptation is clear: reducing the risk via adaptation does not remove all risk, but it should make any complementary CDRFI cover more affordable compared to doing nothing.

Summary and recommendations

This rapid climate and insurance analysis demonstrate the potential for developing risk understanding that includes initial appraisal of adaptation measures *and* considerations for

[20] This is within the range of premium rates reviewed for regional risk pools by Munich Climate Insurance Initiative. MCII, 2019, Climate Risk Insurance Solutions: Understanding the Drivers of Cost-effectiveness.

climate and disaster risk financing and insurance. This analysis is based on global exposure data, generic vulnerability curves, and estimation of annual hazard based on climate reanalysis data. The analysis has been produced using off-the-shelf global models, in the absence of local data to demonstrate what is possible right now, with limited budget in a risk data-poor context. The model uncertainty is therefore relatively high, which would translate into challenges in accessing capital and the cost of that capital. This analysis provides a rapid assessment to catalyse dialogue and demonstrate the potential risk understanding that can be generated quickly.

The next steps after an analysis such as this, would be to improve the view of risk by co-developing more localised data and models with country partners, following the recommendations below.

The GRMA programme is designed to help countries act on these recommendations. It will enable countries to understand their own risk and design their own risk adaptation and transfer strategy to meet their needs, and to improve the quality of the risk analysis through integration of local knowledge and data. It will give risk-holders the tools they need to analyse their risk and communicate with international risk finance providers to improve the efficiency of residual risk transfer, and ultimately improve the availability and affordability of risk capital where appropriate for vulnerable countries and communities.

Recommendations

(1) The fast-track analysis should be complemented with analysis in an open catastrophe risk model framework such as Oasis Loss Modelling Framework which incorporates industry-accepted financial analysis in an open-source and transparent framework. This would enable more complete, and locally-owned, analysis of how different CDRFI could impact the loss estimates, than has been completed in this analysis.

(2) Installation and maintenance costs of adaptation measures, and their expected impact in events, should be co-developed with local experts who have knowledge about adaptation assets, to tailor the appraisal of proposed measures to the local context. For a more complete and localised appraisal, additional measures being considered locally should also be included in the CLIMADA analysis.

(3) Further analysis should apply locally informed and up-to-date information on assets and the vulnerability of the different types of buildings that make up the building stock. Exposure data should be co-developed to maximise the benefits of local expertise in the building stock, and risk analytics expertise in developing exposure datasets. Open data standards should be used, to promote re-use and sharing of data with attributes required for risk modelling and enable those data to be updated as exposure changes into the future.

(4) Catastrophe model approaches to developing a stochastic event set should be applied, to estimate the frequency and severity of hazard over a longer time period than 30

years. The use of industry-accepted approach and model, with a more complete representation of possible disasters in the analytics would streamline access to climate financing, compared to using a 30-year history in the fast-track analysis.

(5) In line with the Sendai Framework, more comprehensive disaster loss reporting should be implemented. This would not only support monitoring of progress against Sustainable Development Goals, but also enable more robust risk analytics by providing more information with which to validate the loss estimates produced. While the estimated losses presented are deemed to be within reasonable ranges based on the available information on past losses, there is currently limited potential for validating the estimated losses. The only source of past impacts is a global historical disaster database, which provides a relatively short record of loss history.

Annex 1. More on the GRMA

Globally, access to risk understanding lags far behind the demand. The unequal distribution of risk understanding is a barrier to sustainable development and macro-economic stability, especially in climate-vulnerable lower income countries. Too often, financial and legal barriers have caused lower-income countries to depend on an imported view of their risk. The problems include:

1. **Limited access to and ability to use risk analytics:** Populations expect public offices to manage risk on their behalf while simultaneously ensuring social and economic development and stability, through strengthening resilience to the impacts of climate change. Limited access to - and ability to use - risk analytics present barriers for governments of the most exposed countries and cities to developing their own strategic view of risk, especially in terms that unlock finance for the implementation of risk management and risk reduction measures. Risk science and models are mostly developed and executed by organisation in the global north, and frequently only ad hoc single-hazard / single-transaction metrics are made available to risk owners, with no lasting transfer of knowledge or building of local capability.

2. **Lack of knowledge exchange:** The predominant use of proprietary model and data formats prevents knowledge exchange across sectors such as ministries, research agencies, finance institutions and academia, and is a barrier to integration and use of local research in the analysis. Not only does this prevent use of valuable local knowledge and data, there is also reduced acceptance and trust in the imported risk insights among sovereign risk owners and populations.

3. **Challenge to attract investment:** Many countries wish to attract inward investment in physical, economic and social resilience, and transfer residual risk to international markets. However, they are at a disadvantage if they are unable to price and prioritise the risks they face as well as to identify climate-resilient investment opportunities to address them. Risk analysis must be integrated at a system level if resilience and adaptation plans are to be properly funded.

The solution is to assist countries in building local capability in risk understanding, using open modelling principles and exploiting private sector knowledge to increase access to risk finance. The IDF agreement with the V20 Group of Ministers of Finance has proven the need and demand; between them the global private, public and research sectors have the expertise and resources to make this happen. The **Global Risk Modelling Alliance (GRMA) programme** includes three key elements shown in Figure 1, to help risk decision-makers on a journey which starts with **Strategic risk assessment** or risk audit to determine resilient investment and contingent risk finance priorities, through **Operational decision-making** for adaptation, parametric risk transfer, disaster risk management/response and humanitarian anticipatory action, and eventually onto **Complex modelling** for more sophisticated risk questions, including cascading and systemic risk, and complex financial instruments.

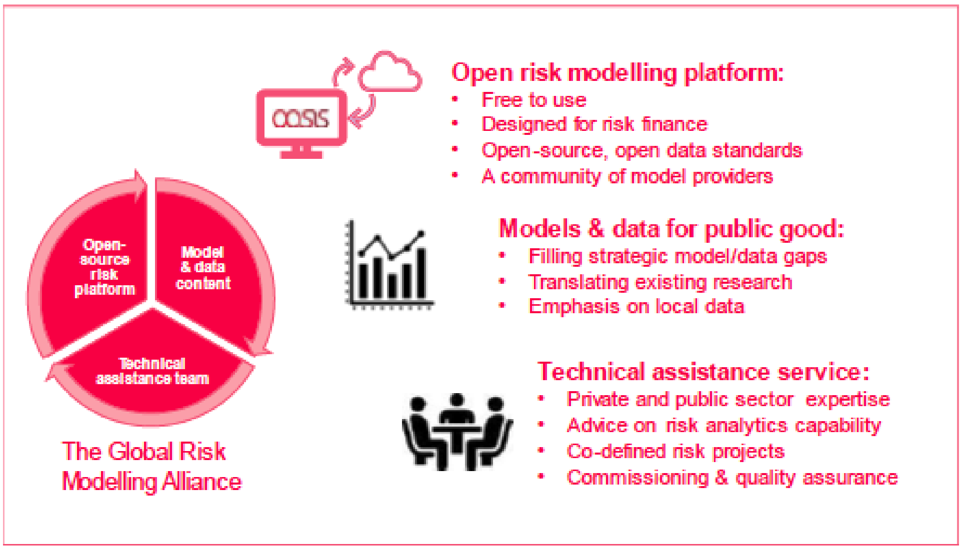


Figure 1: The three elements of the Global Risk Modelling Alliance

Annex 2. More detailed findings – CLIMADA analysis[21]

Hazard Model - The model output used herein is an ensemble of the different simulations from models under the umbrella of Inter-Sectoral Impact Model Intercomparison Project (www.isimip.org). The riverine flood model is made available under the purview of the said programme and consists of combinations of various flood models that are forced with various Global Climate Models (GCMs) to produce various simulations of riverine floods in the region of interest, encompassing the uncertainties that can be observed from various models. The GCMs also provide probable future climate simulations under various Representative Concentration Pathways (RCPs). The models were used to produce flood intensity (height, in metres) across the study region in the current (1975-2005 period for flood risk since historical simulations are available until then and 2020 exposure of the assets) and future climate scenarios (2020-2050). The flood intensity combined with information on exposure and damage functions (described below) is used with probabilistic modelling platform CLIMADA to simulate floods in current and future scenarios evaluating the damage to assets. CLIMADA is used to estimate the expected current damage for inhabitants and selected assets as well as the incremental increase due to socioeconomic growth, as well as climate change over the next decades.

Exposure – The Assessment Report on Disaster Risk Reduction (GAR 2015)[22] provides baseline information on the geographic distribution as well as value of various public assets including schools, hospitals, buildings etc. as exposure. Whereas GAR-15 dataset includes a statistical assessment of exposure, the location of the public assets (schools, hospitals and roads) across the nation was derived from Open Street Maps (OSM)[23]. The two different data layers (OSM and GAR15) were merged to calculate the exposure (economic value of the infrastructure), for current and future scenarios and geographical distribution across three countries. The baseline statistics from GAR-15 give an estimate of exposure in 2015, which is adjusted to account for the fact that the value of these assets has increased until 2020, using an economic growth rate that is determined with dataset[24] that provides population and gross domestic product (GDP) scenarios given under Shared Socioeconomic Pathways (SSPs) into 0.5-degree grids. The same procedure was adopted for projecting future changes in the exposure growth with estimates from the GDP growth numbers across the regions.

Impact Functions - An impact/damage function parametrizes the assets vulnerability (rate of damage) to a specific hazard, such as correlation of flood height to damage to houses. In this study, three impact functions were created to assess the impact of flood risk on the various exposure classes based on previous research[25] and adjusted to the African region context. The effect of flood on built structures (including schools, hospitals, and houses) has incremental

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[21] GitHub - CLIMADA-project/climada_python: Python (3.8+) version of CLIMADA

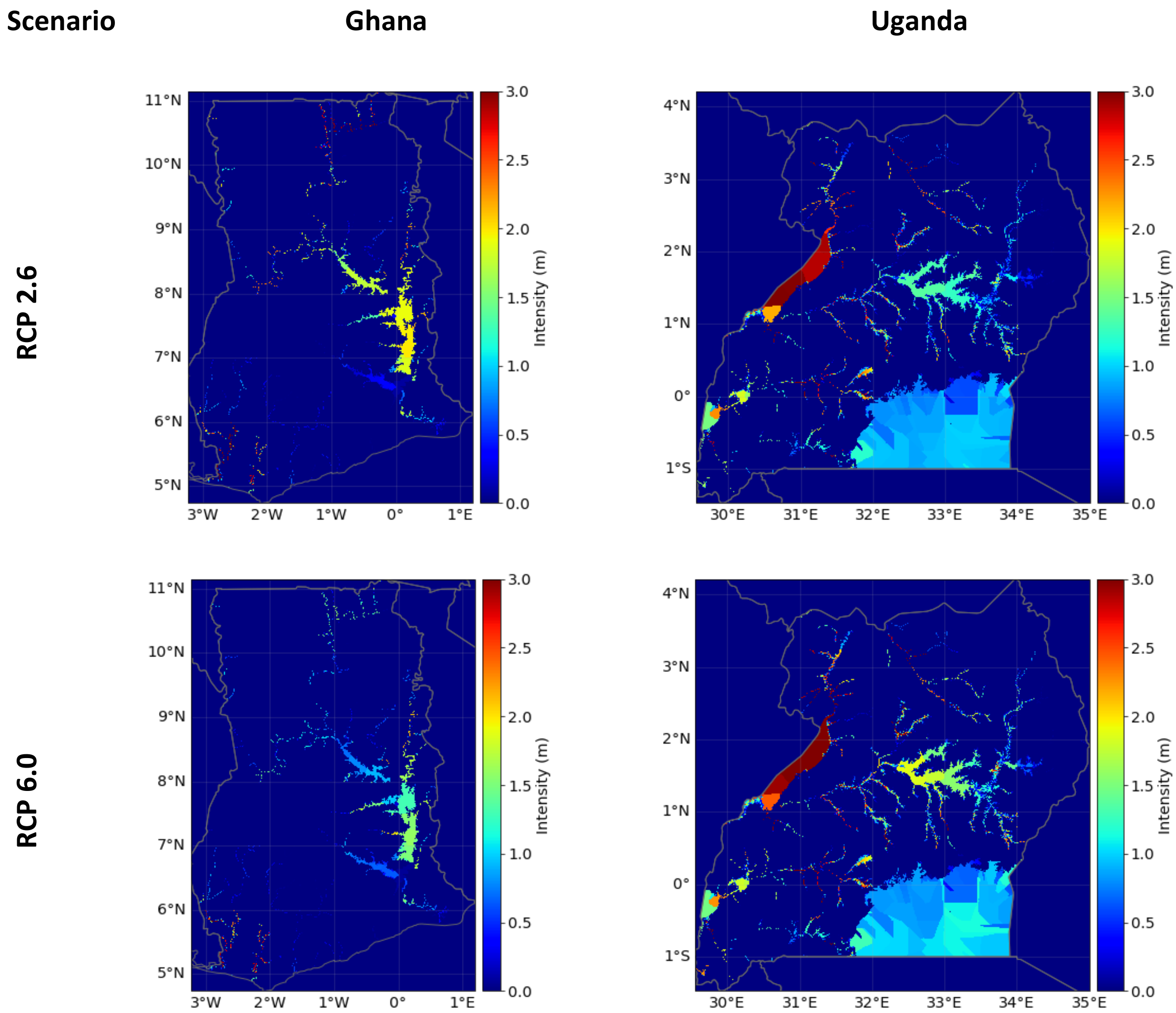
[22] United Nations Office for Disaster Risk Reduction (UNISDR), 2015. Making Development Sustainable. The Future of Disaster Risk Management, Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland.

[23] Open Street Map: https://www.openstreetmap.org

[24] Murakami, D.; Yamagata, Y. Estimation of Gridded Population and GDP Scenarios with Spatially Explicit Statistical Downscaling. Sustainability 2019, 11, 2106. https://doi.org/10.3390/su11072106

[25] Huizinga et. al., 2017. Global flood depth-damage functions. Methodology and the database with guidelines.

damage of up to 100% at a depth of 6m, roads follow a similar curve, but have 100% damage already at 3m flood height, whereas all people are considered affected at 1m water depth[26], see Figure 2 in annex here.



[26] Rana, A., Qinhan, Z., Detken, A., Whalley, K., Castet, C. (2022). Strengthening climate-resilient development and transformation in Viet Nam. Climatic Change 170, 4. https://doi.org/10.1007/s10584-021-03290-y

RCP 8.5

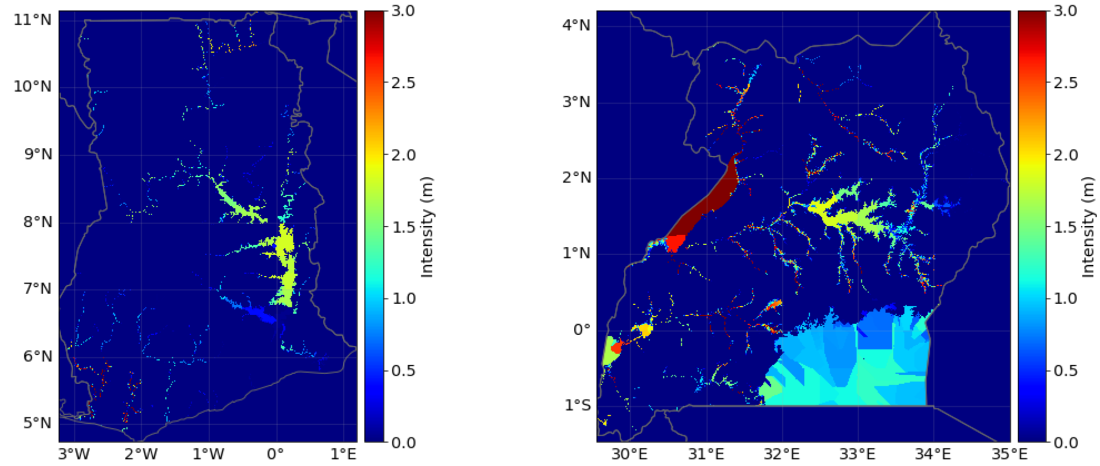
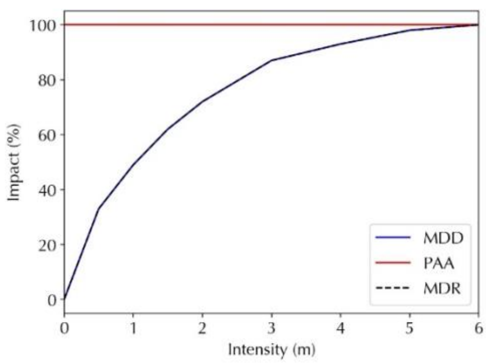


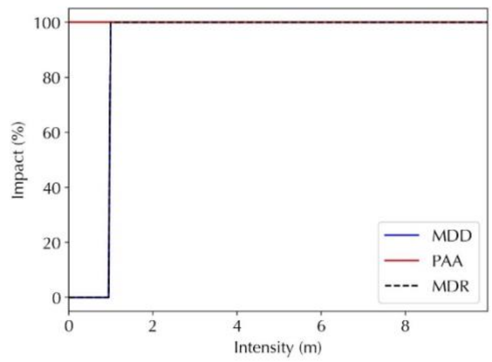
Figure 1: Spatial distribution of riverine flood as the intensity of flood in meter simulated from the ensemble of models in the historical period of 1975-2005 for three different RCPs

Asset Type	Country	Historical	Future
Buildings	Ghana	18.4	101
(USD Billion)	Uganda	111.9	904.6
Education	Ghana	14.4	74.5
(USD Billion)	Uganda	7.2	57.69
Health (USD	Ghana	29.57	152
Million)	Uganda	5.9	44.3
People	Ghana	30.6	47.1
(Million)	Uganda	44.85	95.99
	Ghana	3850	5940
Roads (KM)	Uganda	14760	31520

Table 1: Value of public infrastructure, buildings, and number of people exposed in the current and future climate scenario at national scale

Asset	**Vulnerability Function**
Buildings/ School/ Hospital	

People



Roads

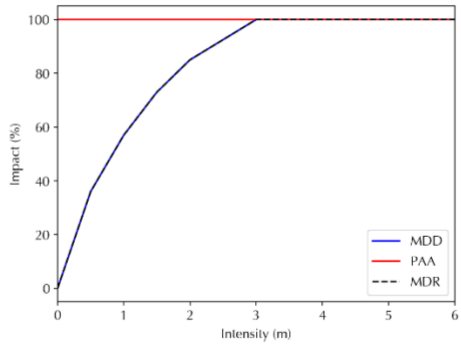
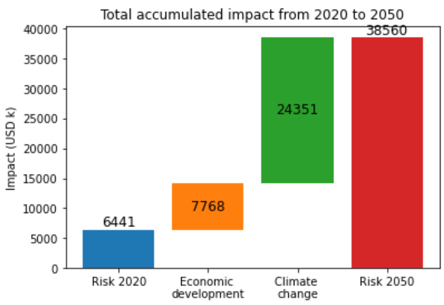
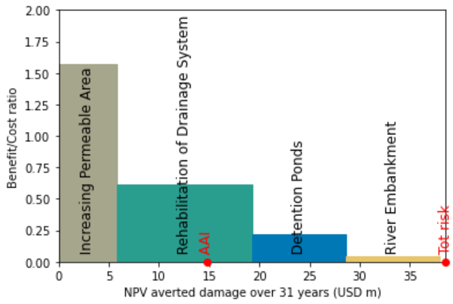
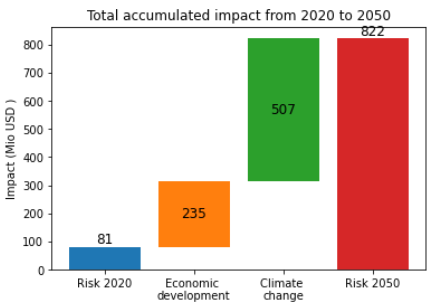
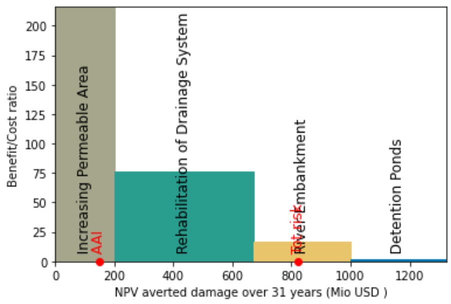


Figure 2: Impact functions for riverine flood damage for the various exposures (MDD- Mean Damage Degree; PAA-Percentage of Affected Asset; MDR- Mean Damage Ratio)

Scenario	Region	Accumulated Risk	Cost-Benefit of adaptation measures
RCP 2.6	Western Ghana		
	Ngora Uganda		

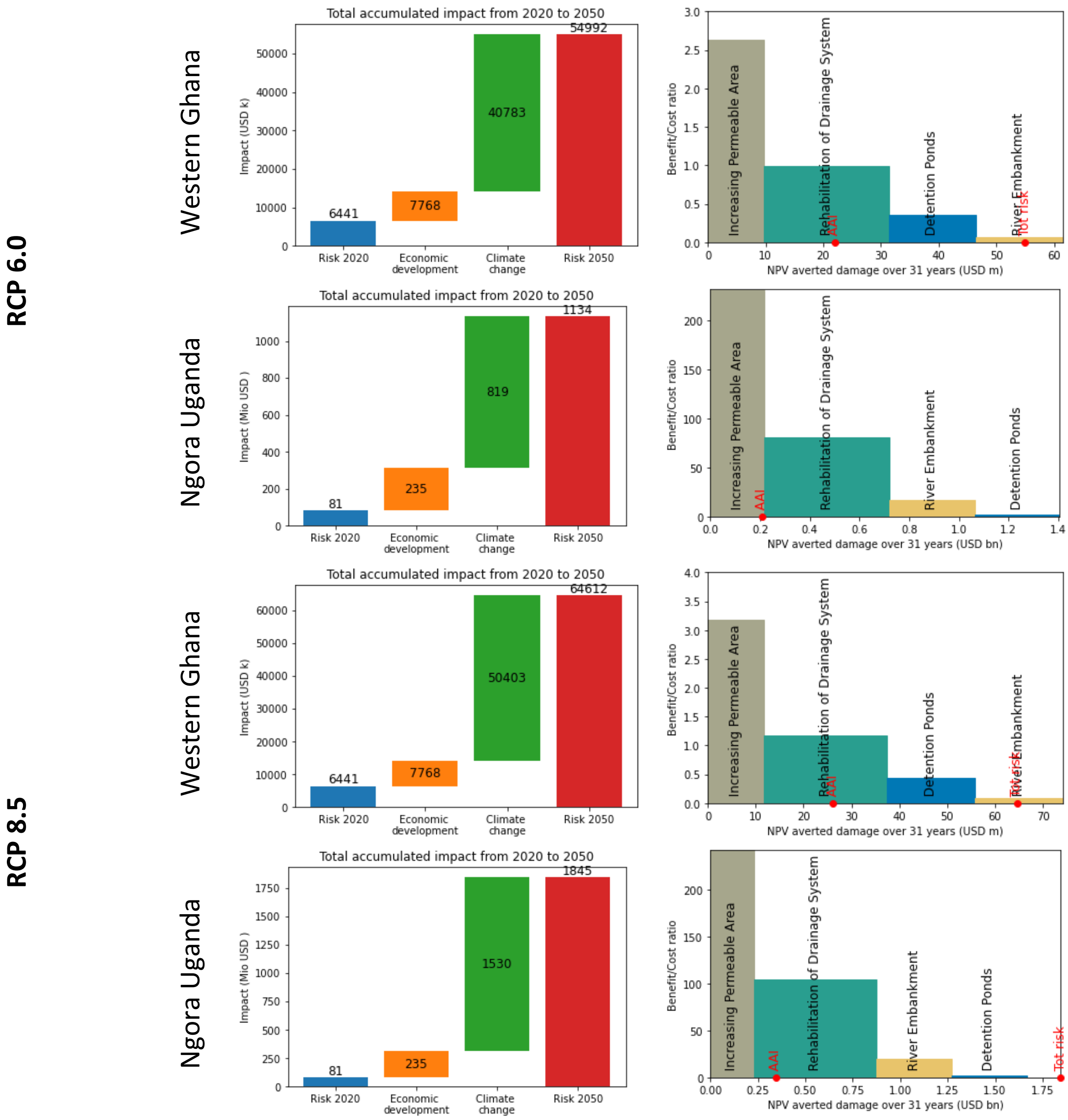


Figure 3: Total accumulated loss for buildings from 2020 to 2050 due to flood risk with economic growth and climatic change and cost-benefit ratio of implementing selected adaptation measures in the same region of the country but changing warming levels (RCPs)

S. No.	Name of Measure	Definition	Type of Measure	Cost of Measure
1	Open drainage system	A city's water drainage system is crucial to collect high quantities of water, which accumulate in large amounts on the streets and passages. All systems consist of a system of uncovered channels for discharging runoff and are designed to be of 1 m depth and 0.5 m width and are to be constructed along roads.	Grey	USD 161.5/m
2	River embankment	River embankments are generally large-scale structural investments designed to	Grey	USD 400/m

		protect against floods from significant river overflow. An embankment is an artificial ridge of soil or rock built by the side of a river and designed to try to prevent the river from flooding during times of high water. The purpose of the embankment is to protect residential areas, infrastructure and land areas from erosion and flooding. The measure is planned to be of 1 m height, constructed on one side of the river.		
3	Increased permeability of urban areas (vegetated swales)	Vegetated swales are frequently used to convey runoff and disconnect impervious areas. A vegetated swale (or bio swale, dry swale) is a broad, shallow, trapezoidal or parabolic channel, densely planted with a variety of trees, shrubs, and grasses. It is designed to attenuate and in some cases infiltrate runoff volume from adjacent impervious surfaces, allowing some pollutants to settle out in the process. This measure proposes the establishment of grass swales of parabolic form to reduce runoff from roadways and/or sidewalks by allowing water to infiltrate. It is planned to establish swales of 1 m depth and 1 m width along roads.	Green	USD 24.5/m
4	Detention ponds (Dry detention basins)	Detention ponds (also known as retention ponds) are dry vegetated depressions in the ground. They are usually designed to provide short term storage of water and remain dry outside of storm periods. Detention basins can retain flood events, reducing peak flows and limiting the risk of flooding. It is planned to establish 10 detention basins in the city's area. Each basin will be designed with a depth of 1 m, 250 m width and 270 m length to allow the multifunctional purpose of the basins.	Green	USD million 4.2/pond

Table 2: Overview list of Flood Adaptation Measures used for cost-benefit analysis in three countries (adopted in parts)[27]

[27] Rana, A., Qinhan, Z., Detken, A., Whalley, K., Castet, C. (2022). Strengthening climate-resilient development and transformation in Viet Nam. Climatic Change 170, 4. https://doi.org/10.1007/s10584-021-03290-y

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