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Can insurance catalyse government planning on climate? Emergent evidence from Sub-Saharan Africa

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ABSTRACT

This paper explores how climate risk information produced in the context of insurance-related activities can support public climate adaptation planning. The central contribution is to outline how relevant climate risk information can translate into behaviour change, and the drivers and barriers that influence this in Sub-Saharan Africa. The insurance industry has the potential to catalyse greater use of climate information, either through existing insurance transactions or through capacity building and investment in data sharing and collaboration. We investigate the interplay of climate risk information and insurance processes from two angles: the use of climate risk data by those who provide insurance – with information as an input to the underwriting process; and the catalyst role of insurance for governments to move towards anticipatory climate risk management. We apply a multi-method approach, combining insights from a survey of 40 insurance experts with key informant interviews and document analysis from three complementary case studies: indemnity-based insurance of private assets in South Africa; parametric sovereign risk pool in Malawi; and collaboration on risk analytics and risk management advice (no insurance) in Tanzania. The analysis offers a new perspective on the catalyst role of insurance by focusing on the ways in which political economy factors, particularly incentives and relationships, influence this process. Overall, there appears to be clear scope for a dynamic interaction between insurers and governments where symbiotic use and generation of climate risk information can advance mutual goals. However, that ambition faces many challenges that go beyond availability and suitability of data. Limited trust, unclear risk ownership and/or lack of incentives are key barriers, even if there is risk awareness and overall motivation to manage climate risks. The three cases show the importance of sustained cross-sectoral collaboration and capacity building to increase awareness and utilization of insurance-related climate risk information.

1. Introduction

Climate change is already negatively impacting life on earth and a wide range of human activities. Nowhere is this more pronounced than in Sub-Saharan Africa, where countries will experience some of the greatest exposure globally while having less adaptive capacity compared with other parts of the world (IPCC, 2014). While global efforts to limit the causes of climate change are essential, there is also an urgent need to enhance the adaptive capacity to respond to current and future climate change risks in these countries (IPCC, 2018). To achieve holistic climate risk management that combines immediate crisis responses with long-term adaptation the right enabling factors are needed. These enabling factors include a supportive policy environment, adequate funding, political will, the technical capacity of decision-makers, buy-in from key stakeholders and climate awareness (Pardoe et al., 2018; Vincent et al., 2020).

Enabling factors for climate risk management are underpinned by appropriate information on current and future climate risk. It thus follows logically that accessible and useable information should help improve outcomes of planning and policy (Clarke & Dercon, 2016). In an urban context, climate information might influence buildings and infrastructure, while in a rural context it can inform the choice of crop and timing of planting. An understanding of likelihood and effect of impacts is the starting point for strategic climate risk management and is therefore central to national and local government planning, as well as to private enterprise.

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The application of climate risk information[1] to enable adaptation to climate change is at the heart of what is commonly called 'climate services'. Climate services are activities aimed at translating climate risk information into customized products such as projections, trends, or economic analyses, and tailoring these for different user communities and decision contests/making (Haigh et al., 2014; Soares & Dessai, 2016; Vaughan & Dessai, 2014). The literature points to a rising scientific understanding of climate risks and their impact and a growing provision of climate services in a developing country context (e.g., (Dinku et al., 2018; Singh et al., 2018; Golding et al., 2017). However, data availability remains poor in many parts of the world, and lack of climate risk information continues to be mentioned as a key barrier for real action on implementing National Adaptation Plans (NAPs) and achieving the Sustainable Development Goals (SDGs) (Goddard, 2016; Hewitt et al., 2017; Hewitt et al., 2020).

Where climate data does exist, it tends to stay siloed within one organization and often lacks comparability because of methodological challenges (Dinku, 2018). As a result, it is often not used by those who make planning or policy decisions (Tall et al., 2018; Wall et al., 2017). There are various reasons for the lack of uptake of climate information. Some are technical, related to the appropriateness of information, whilst others are related to political economy and the structures which shape access to, and control of, information (Carr et al., 2019; Goddard et al., 2010; Gumucio et al., 2020; Kirchhoff et al., 2013; Lemos et al., 2012; Vincent et al., 2016). Motivation and political will is also important. Decision-makers often face the trade-off between short-term costs and longer-term gains (Surminski & Tanner, 2016). There are also limited obvious rewards for government officials to consult risk information for planning purposes or to engage in anticipatory action based on risk information. Moreover, risk information may sometimes be seen as a hindrance – for example when risk models indicate why certain parts of a city should not be developed due to their risk exposure, or when risk data shows that a newly purchased crop is likely to be unsuitable in future climate conditions. As such, the use of climate risk information for decision-making is not neutral but construed as a source of power, necessitating interrogation of the politics of adaptation and climate risk management (Eriksen et al., 2015; Tanner & Allouche, 2011).

One potential catalyst for the use of climate risk information for wider decision-making planning and adaptation action is insurance (Haile et al. 2020; Clarke and Dercon, 2016; Linnerooth-Bayer et.al. 2018; Surminski et.al. 2016; Vincent et.al. 2018). This financial instrument comes in different forms and shapes, such as micro-level insurance products for farmers, property insurance policies for homeowners, business insurance for companies, and sovereign risk insurance as protection of public budgets. All of these depend to some extent on availability and use of risk information, particularly for the actuarial pricing of risks, for decisions about coverage levels and terms, as well as for solvency considerations to ensure that insurers can meet possible claims. Risk information is therefore an essential ingredient to designing and implementing insurance schemes. Importantly, climate risk information and insurance have a dual relationship. Those who provide insurance rely on risk information while they also generate new information as part of the underwriting process which could be of use to other stakeholders. Indeed, climate risk information generated for or by insurance could be used to encourage risk-based planning and decision-making – either by those insured or by those who make decisions about risk creation and risk management, including governments, planners, or individuals. As such, some industry leaders are promoting their role as supporting 'an organizing framework for risk management that allows decision-makers to compare the cost of different risk mitigation programs and assess the economic and social trade-offs' with the objective of reducing risks through better planning (Moody et al., 2020). This appears particularly relevant in the context of climate change, which poses a threat to the sustainability of many risk transfer products due to its influence on risks, implying a material interest of insurers in sharing risk information to keep risk levels manageable and insurable (Surminski et al., 2016).

This paper explores how climate risk information produced in the context of insurance- related activities can support public climate adaptation planning. We investigate the interplay of climate risk information and insurance processes from two angles. First, we look at the use of climate risk data by those who provide insurance – with information as an input to the underwriting process. Second, we look at the catalyst role of insurance for governments to move towards anticipatory climate risk management, including loss prevention and adaptation. We investigate this in developing country contexts, which are characterized by low insurance penetration and relatively low levels of government planning. Building on the climate services literature, our analysis is focused on three research aspects:

- Temporal: To what extent does the risk information also relate to future risks, therefore increasing the ability to plan and implement adaptation measures beyond short-term risk management?
- Process: What are the drivers, enablers, and barriers in the data translation process?
- Relationship: What role does the nature of the relationship between decision-makers and insurers play, considering contexts that are product-focused and transactional, or advisory, or a mix of both?

We apply a multi-method approach, combining insights from a survey with case study data from South Africa, Malawi, and Tanzania to test how the analytical thinking that emerges from the climate service literature can be applied to the insurance context. We conclude with a discussion about the potential catalytic role that insurance can play for the use of climate risk information. The central contribution of this paper is to outline the conditions under which climate risk information can translate from being relevant to triggering a behaviour change, and to explore the drivers and barriers that influence this process in the context of insurance-related climate risk information in Sub-Saharan Africa.

2. The role of climate risk information and the insurance context

There is an established need to bring science and policymakers together around climate change planning, yet utilization of existing climate data for decision-making remains limited (Goddard et al., 2010; Kirchhoff et al., 2013; Lemos et al., 2012; Moser and Dilling, 2011; Vincent et al., 2016). In response, the development of a full climate information system has been advanced by the World Meteorological Organisation (WMO) and more recently by the WMO's Global Framework for Climate Services (GFCS) as well as being taken up by a variety of international donors (Hewitt et al., 2020; Trenberth, 2008). Improving the availability of climate information requires recognition of data access and technical capacity including that of National Meteorological and Hydrological Services (Ziervogel & Zermoglio, 2009; Mahon et al., 2019).

[1] We define climate risk information in this paper as weather and climate information services (including forecasts, projections and advisories) that can help decision makers to adapt to current and future risks associated with both slow-onset climate impacts as well as increased variability, frequency and intensity of extreme events.

However, improving the utilisation of climate data for decision-making is not merely about improving data quality or dissemination (Findlater et al., 2021). It also requires an understanding of the decision contexts in which the information is intended to be used, so that the resulting information can be decision-relevant and useable (Jones et al., 2015; Taylor et al., 2021). Underlying this is an understanding of the different ways knowledge is produced and shared in the science-policy interface (Dilling & Lemos, 2011; Dilling et al., 2021). While availability of, and access to, climate risk information is important for this process, it also depends on political economy factors. This includes trust in risk information and incentives to internalize and act upon it, as well as the processes through which ideas, power and resources are negotiated, conceptualized, and implemented (Tanner & Allouche, 2011).

Several frameworks have attempted to conceptualise this catalytic process, centring on involvement, translation and dissemination at the national level (Miles et al., 2006). Similarly, Cash et al. develop a framework to translate climate information into a real-life context that depends upon salience, credibility and legitimacy (Cash et al., 2003). Prokopy et al. (2017) investigate how information moves from 'useful to useable' by reflecting on a multi-year project that sought to enhance the uptake of climate information in the Midwestern United States via co-production with farmers. Vincent et al. (Vincent et al., 2020) highlights the critical role of the enabling environment in determining whether useful information is being used.

Earlier studies show that interaction between stakeholders is key, and that collaboration between scientists and others can advance common goals and optimise data provision (Golding et al., 2017; Haigh et al., 2014; Miles et al., 2006). However, this also points to a common tension. This tension is the need to balance the provision of useful information with the need for scientific robustness (Kalafatis et al., 2015; Kirchhoff et al., 2013), which is often reinforced by lack of engagement between producers and consumers of data (Golding et al., 2017; Miles et al., 2006). In addition, there is the challenge that where climate risk information is used there may not be enough understanding of its purpose and limitations. The growing awareness of climate and environmental issues has led to a "climate intelligence arms race in financial markets" with many black-box solutions obscuring limitations, purpose, and value of risk analytics (Keenan, 2019).

The rush for climate risk information has also occurred in the insurance sector. Risk information is a fundamental part of the insurance business-model, as products rely on risk information, data, and insights from past events to develop hazard, exposure, and vulnerability models to inform underwriting decisions. Countries with disaster and climate risk insurance markets have seen the development of catastrophe modelling as one of the main tools that insurers are using for underwriting purposes, and these have rapidly developed in scope and granularity, in line with improved earth observations and climate systems modelling capabilities. However many companies, particularly smaller ones, rely on external catastrophe models and have only very limited in-house modelling capacities (Surminski, 2017).

As climate and environmental risk analytics have become commodities, the question about accessibility of data and sharing of skills needed for understanding and utilizing this data is more and more important. This includes when exploring the catalyst function of data across sectors and applications. While the main purpose of insurance-related risk information is to serve industry's understanding and pricing of risks, there is the possibility that the use of insurance can instil a risk perspective into planning and decision-making processes when shared with those responsible for managing risks, particularly at government level (Clarke & Dercon, 2016; Linnerooth et al., 2018; Surminski et al., 2016). In this context, data generated or collected during the insurance process can be of use to wider decision-making and climate risk management.

During the process of designing and implementing insurance schemes, a range of risk information including disaster and climate risk data is collected or generated. The content of that climate risk information is prima facie relevant to many other actors and can play an important role in mitigating losses incurred (Surminski et al., 2016). It can also help to transform the efficacy and impact of disaster response by removing ambiguity about who owns the risk, who needs to respond, and how it is financed (Clarke & Dercon, 2016).

The insurance sector is claiming a role in advising society about risk, urging its customers to manage risk to keep impacts and costs of risks low. Companies such as Lloyds of London argue that "we have to create a world in which it is unacceptable not to have planned in advance" (Lloyds of London, 2017). This role expands beyond the traditional view of risk transfer as a financial service, where increased insurance uptake is considered an important stimulus for fiscal resilience in the face of shocks (ILO, 2016; Kunreuther, 2015) , and focuses on government planning and ex-ante climate risk management supported by better risk information. In other words, insurance becomes a 'climate information system' and can be the source of data as well as incentivising others to use it.

Observation models, datasets and forecasting tools are often developed by or at the request of insurers, which could be more widely used for social benefits beyond insurance, particularly with regard to reducing current and future risks through risk-based planning and decision-making (ACRI, 2017; The Geneva Association, 2016). However, there are several challenges that can hamper the flow of risk information during insurance processes: not all information is open and freely available and there is often lack of transparency due to the commercial sensitivity of insurers' internal processes. This is a well-known challenge in existing insurance markets. Surminski (2017) lists the example of data sharing initiatives from the insurance sector. However, she also notes that data is often "not readily available and accessible for risk modelling purposes owing to a number of factors, such as restrictive national data policies, institutional ownership of data, prohibitive costs for hardware and software, and a lack of staff who understand the limits of models (computerized simulations of the impact of catastrophes, combining statistical datasets with science, technology and engineering knowledge)" (ibid., p. 13). Accessibility and useability of this data is another challenge. While in some countries the public dissemination of some data through online platforms is available, such as in Germany through the ZUERS dataset, "these approaches are often limited in their application, and it remains unclear how and to what effect they are used in decision-making." (ibid., p. 13).

Overall, there are ongoing efforts to strengthen the open availability of scientific data to be used by the climate risk management community. The greatest area of improvement so far has been on computational processing power. There has been an increase in the availability of supercomputing capabilities for hazard modelling, such as the ESA Copernicus, a high-resolution satellite that is publicly open.

The kind of data use for insurance purposes depends highly on the type of insurance policy in question, that is, the type of risk being covered. Property & Casualty type of insurance is increasingly relying on technological smart devices to gather data (WTW, 2018). This applies also for climate risk insurance, where technologies to obtain hazard related data, such satellite images (for hurricane cover for example), rain level (used for flood insurance), soil moisture (key for drought insurance) and seismic activity (pillar of earthquake cover) are technologically developing fast (UNDRR, 2019a,b).

The use of this data can vary from pricing and underwriting, when historical data is key, to risk calculation, new business development, steering strategy and claims management when instantaneous data is needed. Data is particularly relevant in the context of agricultural insurance, where usually three types of data are used: weather station, satellite data and yield (GFDRR, 2013). Those can be used for several key metrics, such as predictions of rainfall, soil moisture and temperature oscillations. Although the first two are the cheapest ones to implement, yield data offers the lowest base risk and can capture crop perils that the other two ones cannot (Ibarra and Skees, 2007).

Particularly in countries with no or nascent insurance markets closing this data and analytics gap can be seen as an important enabling condition for insurance market development. At the same time, it can help to build risk management and planning capacity prior to any product-focused transactional activities (Vivid, 2018). This argument is illustrated in Fig. 1 where collection of climate risk information forms the basis of further cross-sectoral engagement, education, and capacity building, eventually create the conditions for introduction of insurance products.

The strategy for the sequencing of interventions was originally proposed for development partners contemplating investments in climate resilience and insurance mechanisms. However, it could also involve insurers in steps 1–3 as advisors and facilitators, before moving to the transactional provision of insurance in step 4. In this context, steps 1–3 are investments in capacity building. This can include the development of models, collection of data, and engagement with prospective clients to identify risks and risk management strategies. However, for private sector insurers this can be a somewhat risky strategy, as product transactions (e.g., selling insurance policies) may never be achieved or may take very long to materialize. Because of this, delivering these initial steps often falls to development partners (e.g. multilateral development banks), or it is supported by sector initiatives (e.g. the United Nations Environment Programme Finance InitiativeUNEP FI, or ClimateWise) rather than individual insurers.

What remains unclear is how this data is being utilized beyond insurance. This has recently been investigated by the Risk Modelling Steering Group of the Insurance Development Forum. In its report 'The Development Impact of Risk Analytics' (Moody et.al., 2020) the group makes the case for risk analytics to support government planning and climate risks management. This is an option particularly in vulnerable countries where the absence of risk analytics can hamper risk understanding and risk-informed decisions. One example of an initiative working to address this is the OASIS loss modelling platform which aims to increase in-country risk information capacity using catastrophe risk models and climate analysis as the basis for new climate change adaptation mechanisms, including but not limited to insurance (International Climate Initiative, 2021).

While most of the data sharing and risk modelling efforts described above focus on current risks, the question about integrating climate trends and future risk levels presents a key temporal challenge for those involved in insurance processes. Risk data collected and analysed in the context of insurance tends to focus on the insurance period - usually 12 months or determined by next harvest seasons, with less focus on future risk trends (Surminski, 2017; Botzen, 2013; Linnerooth et al., 2018). While recent developments such as forecast based finance attempt to instil a more forward-looking perspective, the norm is still very much framed around current risks. For insurers, the drive for greater climate risk disclosure (for example via the Financial Stability Board's Task Force on Climate-related Disclosure recommendations) might lead to a greater incorporation of forward-looking risk information into decision-processes – with regulators and investors growing concerned about sustainability of business models in the light of climate change. However, for most insurers this still presents technical challenges, particularly in developing countries, where the lack of risk information about current and future conditions has been identified as one of the key barriers to the development of insurance markets (see for example (IDF, 2020). This highlights the role of climate data and information as an input to insurance processes.

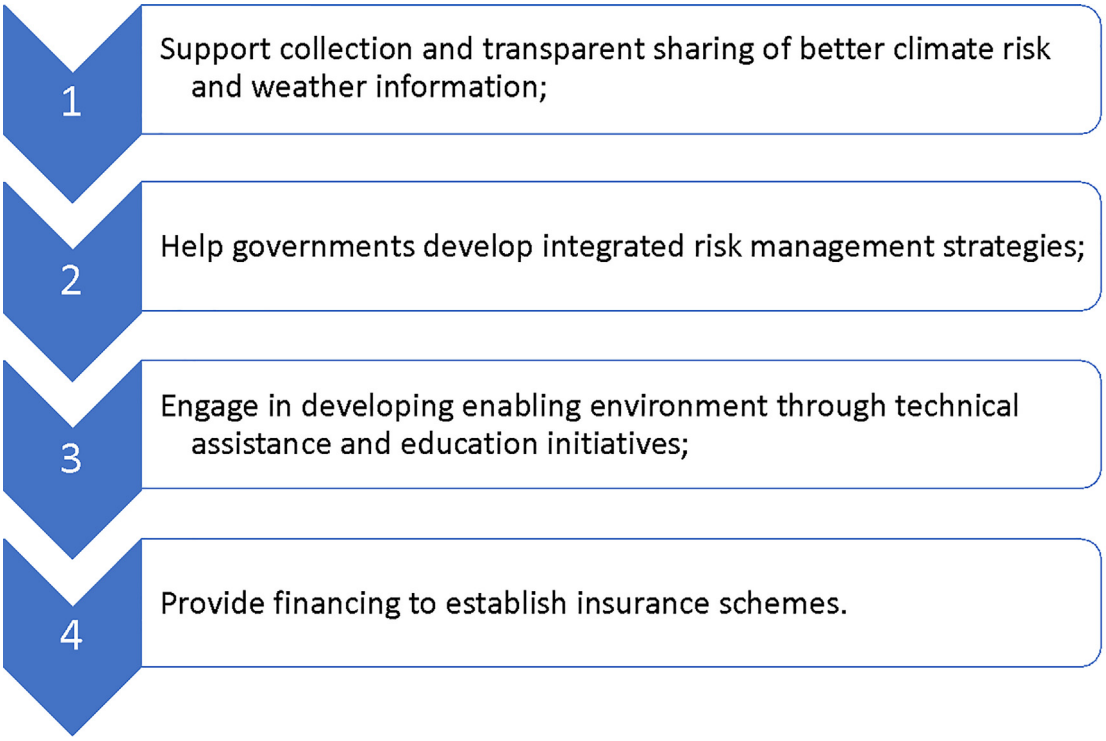

Fig. 1. Sequencing of interventions to support insurance development.

3. Analytical approach and evidence base

Building on the climate services literature, our analysis is based on the hypothesis that insurance has the potential to be a catalyst for greater use of climate information by relevant actors. It can do this through existing insurance transactions (where products are already available and customer relationships exist), or through capacity building and investment in data sharing and engagement with decision-makers (where products are lacking or are only emerging, and little or no customer relationships exist) or a combination of both. This perspective brings together climate risk information and the actors that produce, facilitate, and eventually use it. For example, risk information can provide a picture or a narrative for stakeholders to congregate around and to find solutions. In this context, catalysis refers to an acceleration towards a desired outcome or outcomes. Fostering improved outcomes via behaviour change is the objective of a data-driven approach to development, with the outcome being anticipatory planning and adaptation action. The extent to which climate risk information can perform such a catalysing role and move through this process depends on a range of factors, including supply and demand for that information: There is an opportunity for catalysis whenever an actor produces information that is relevant to another. In this view, climate risk information can have a catalytic effect if it sufficiently aligns supply and demand between producers and users, leading to it being utilised for a specified purpose.

We employ a dynamic concept of the information process (Figure 2) to explore the production and use of climate risk information. This highlights the potential for insurance to help catalyse the use of climate risk information to create a more anticipatory approach when dealing with climate risks. The process is centred on a producer and a potential consumer of climate risk information. However, importantly we note that insurers are also requiring climate risk information for their own purposes as risk information is a key ingredient to any insurance transaction.

This concept builds on the assumption that actors must work together, reflexively, with the climate risk information and collaboratively refine it to ensure that the information can pass through the stages as indicated in Figure 2. This process is dynamic and complex, containing feedback loops. For example, a behaviour that is changed based on any type of information could lead to a significant alteration in perception of general usefulness of that type of information. Alternatively, data being useable might lead actors to identify other opportunities where data is relevant.

The concept outlined in Figure 2 distinguishes five different statuses of climate information based on the different stages of creating end-user-friendly climate risk information (Table 1).

We interrogate the characteristics of this process in the context of three insurance-related case studies. The associated political economy lens is applied to provide insight into the drivers, incentives, barriers, and constraints to this process, and can lead to suggested changes and inputs to facilitate progress. The end goal is to have climate risk information that is intelligible and operable. This then meets a demand and is readily taken up, leading to a behaviour change in response to the risk information. Such behaviour changes can vary and might include moving the site for a bridge to avoid risks of landslide or tidal surges; planning an irrigation system that considers longer-term trends in river water levels; to investing in agricultural innovation to make farmers more climate resilient.

Our evidence (Table 2) is based on a variety of sources and includes findings from a literature review, several years of field interviews and close interactions with decision-makers in the three case study countries enabled through a climate information research project. The key informant interviews were undertaken between June 2015 and May 2019, and an insurance survey was conducted in April 2019. The insurance market data comes from industry reports (Deloitte, Swiss Re) and from the Grantham Research Institute Insurance Database (2012–2019). Qualitative content analysis was conducted on interview notes and transcripts, and quantitative analysis conducted on survey findings. In addition, secondary literature that provides insights from across different insurance projects was reviewed to recognize the wider context (Actionaid, 2017; CISONECC, 2016; Hirsch and Schäfer, 2017). Sections 4 and 5 present the findings from surveys, interviews, and the secondary literature analysis.

4. The insurance and case study context examined

Overall, the use of insurance across Africa is very low, particularly for non-life risks. Penetration levels - premium volume as a percentage of gross domestic product - are 1.08% in Malawi, 0.79% in Tanzania and 2.7% in South Africa, which is close to the world average penetration rate of 2.8% (Swiss Re Sigma – 2013

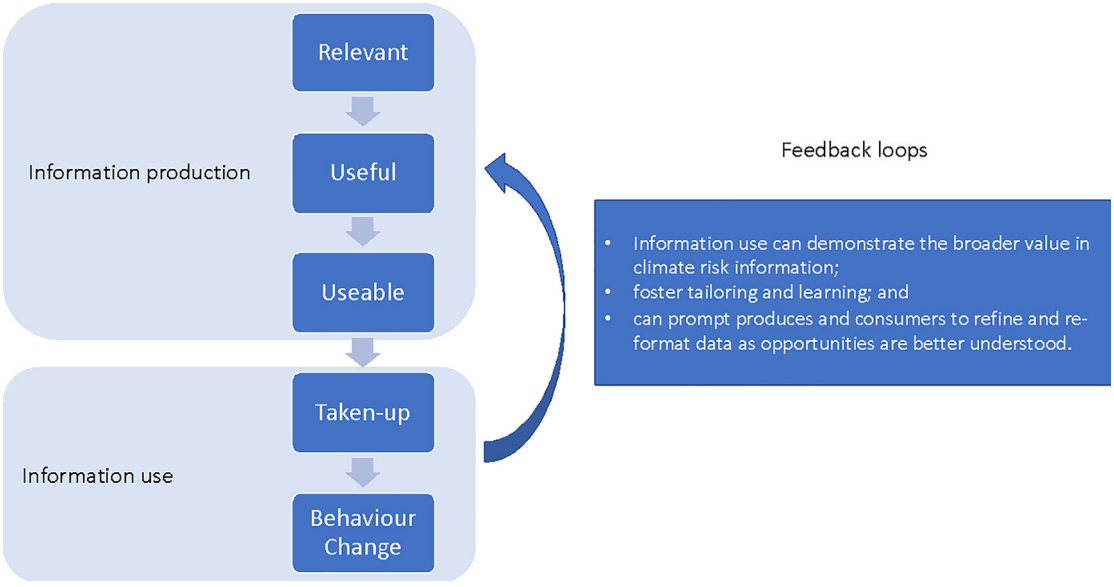

Fig. 2. Stages in creating end-user-friendly climate risk information.

Table 1
Definitions of the five stages of the risk information process.

Status of information	Definition
Information is relevant	Information is relevant when it refers to an adaptation issue, problem, outcome or end use that is identifiable.
Information produced is useful	Information is useful when it responds to a user's need or demand.
Information is useable	Information is useable when it is accessible to a user who can incorporate it into decision processes.
Information is taken up	Information is taken-up when it is incorporated by an end-user into a decision-making process. This occurs when there is sufficient incentive and no barrier to use such as lack of trust or limited credibility of the information.
Information leads to behaviour change	This final stage considers the action or decision that is shaped by the risk information. An example is a government acting on an early warning or advice about harvest timing, another example is a change to planning regulation based on flood risk data.

and 2018). Overall Africa remains the continent with the lowest penetration level of around 0.8%, compared to Asia's average of 1.8%, Europe at 2.7% and North America at 4.1% (Deloitte, 2019; see also Swiss Re: Sigma Explorer, 2021).

Using the Grantham Research Institute database[2] provides a snapshot of the current use of disaster and climate risk insurance across the continent, and shows 36 active schemes. Figure 3 shows that these insurance applications spread from micro to macro level, with the most common being micro insurance schemes that benefit individuals, usually farmers. However, the reach (number of insured or beneficiaries) of micro insurance schemes is more limited when compared to sovereign risk schemes, which cover governments and their budget. As a result, sovereign insurance potentially has a wider impact on government activities and larger parts of the population.

While traditional areas of insurance, such as motor or funeral cover, are more widespread, products for climate–related hazards are still relatively uncommon for private insurers, and many of the pilots or products on offer now rely on significant support from donors or government. Figure 4 shows the role of public and private players in delivering the existing 36 insurance schemes across Africa.

For Sub-Saharan Africa the database shows 21 disaster and climate risk insurance schemes (2019 data), compared to 8 in 2012, with most of them (16) offering agricultural micro-insurance. All these insurance schemes are framed in the context of current risks: either through indemnity-based structures, where pay-outs occur after a loss; or, as common in the context of agricultural insurance, in form of parametric products that are linked to pre-defined meteorological events, such as number of days without rainfall. Overall, the data suggests that the type of trigger seems to be shifting towards parametric insurance types - with 18 of the 21 schemes identified as parametric type and only three as indemnity-based insurance types. However, there is likely to be some reporting bias as the database only considers data that is publicly available and might not include some indemnity-based property insurance is available through the private market. It is therefore worth noting that this is a snapshot based on publicly available data with a possible bias towards public or Public Private Partnership schemes, as purely private insurance is often not featured publicly, with little data about type, coverage, and penetration available.

Table 2
Evidence base for this study.

African insurance sector	Document analysis of industry reports. Market data from Grantham Research Institute Insurance Database: 2012–2019, to describe the landscape of insurance for natural disasters and perils in Sub-Saharan Africa. This data has been developed over many years, with the original version compiled for ClimateWise (2012), and an update for the United Kingdom's Department for International Development in 2016. In the database, each scheme is defined by two key properties: (i) the transfer of risk away from entities in low- or middle-income countries, and (ii) the use of one or more ex ante risk transfer instruments. For 2019 the database recorded 21 insurance schemes for Sub-Saharan Africa (2012:8). Survey of 30 insurance experts conducted across attendees of the UNEP Finance Initiative (FI) Africa market meeting in Lagos in April 2019. The UNEP-FI Principles for Sustainable Insurance (PSI)- Africa initiative works with domestic insurance companies, reinsurers, and brokers to explore opportunities for innovation and transformation of sustainability-focused insurance solutions. The second PSI market event hosted in Africa took place at the end of April 2019 in Lagos, Nigeria and was attended by around 60 representatives of African insurers, technical experts, and donor organisations. The Survey responses were from 15 insurers underwriting business in Africa, 5 reinsurers underwriting business in Africa, 2 insurance brokers operating in Africa, 2 consultants advising insurance projects in Africa, 1 academic researching insurance in Africa, 3 international organizations involved in insurance schemes in Africa, 2 NGOs involved in placing insurance in Africa. 8 key informant interviews with representatives from the insurance (4) and reinsurance (2) industry, development organizations (1) and NGO (1) conducted at the UNEP Finance Initiative (FI) Africa market meeting in Lagos in April 2019.
Malawi	Document analysis on climate information usage in Malawi. Key informant interviews with government staff and international donors connected to the African Risk Capacity (ARC) sovereign drought insurance scheme (16 interviews in total).
Tanzania	Document analysis on climate information usage in Tanzania. Key informant interviews with participants in the City Innovation Platform for African Infrastructure Risk and Resilience (CIP AIRR) in Dar es Salaam (six interviews in total).
South Africa	Document analysis on climate information usage in South Africa. Key informant interviews with insurance staff members and local government experts in South Africa (six interviews in total).

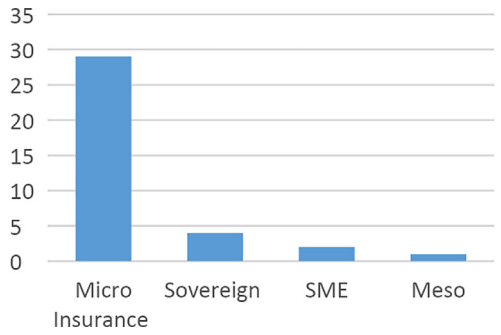

Fig. 3. Number of disaster and climate risk insurance schemes in Africa by type.

[2] This analysis is based on an empirical assessment of schemes in Africa—based on data from the *Grantham Research Institute on Climate Change and the Environment's Disaster Risk Transfer Scheme Database* (2012–2018). (formerly known as the Climate Wise Compendium on Disaster Risk Transfer Schemes in emerging and developing countries) http://www.lse.ac.uk/GranthamInstitute/evaluating-the-resilience-impact-of-climate-insurance-erici/

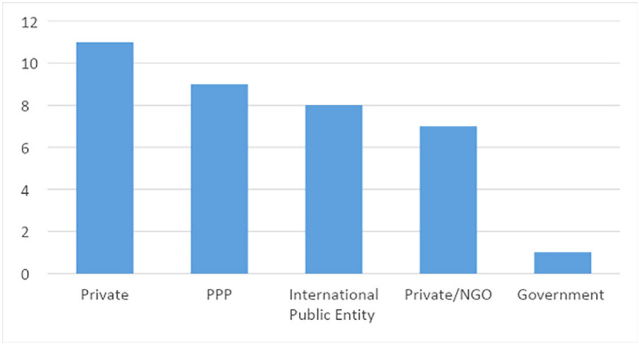

Fig. 4. Number of disaster and climate risk insurance schemes in Africa and who provides them.

The type of risk information generated for insurance purposes depends on hazard covered, design of insurance mechanism and who the insured and the insurers are. In this paper we focus on the insurer-government relationship, with government actors as the potential end-users of insurance risk information, based on the hypothesis that insurance can instil a risk perspective into planning and decision-making processes, particularly at government level (Clarke & Dercon, 2016).

Our case studies (Table 3) have been selected to illustrate three different types of contexts and relationships: differentiating between indemnity-based private market products for property insurance (South Africa), advisory-service focused on infrastructure and property risks but without direct insurance transactions (Tanzania), and a combination of product and advisory in the context of parametric drought insurance linked to donor-funded data and analytics provision (Malawi).

The South Africa example is of an existing insurance product provided to private asset owners who have the capacity to act and a city with an established planning system – factors that seem conducive to the use of risk information. In the case study, a domestic private insurer (Santam) shares flood risk information with officials responsible for land use and planning in an area where Santam is underwriting indemnity-based insurance for private asset owners. Flooding is one of the key climate hazards to which South Africa is exposed (Department of Environmental Affairs, 2018). Whilst there are national level policies, implementation takes place at municipality level. Significant efforts have been made to assess the nature of risk at local level in South Africa, through initiatives such as the South African Risk and Vulnerability Atlas (Mambo & Faccer, 2017) and the Green Book with its presentation of municipal risk profiles (CSIR, 2019). In the case study, insurer and city officials share risk information about current and future risk to improve land-use and planning and secure insurability of private assets. While the focus is on local level government, the collaboration between insurer and municipality was triggered by the 'Business Adopt a Municipality' initiative set up by the national government.

In contrast, in Malawi and Tanzania the overall insurance coverage is minimal and the balance of barriers, incentives, and motivations for use of risk information appear more complex. Furthermore, neither Malawi nor Tanzania has comparable institutions nor the extent of established property insurance as in South Africa. Nonetheless there has been sustained interest from the international community and insurers in crop and livestock insurance products.

The adaptation and development agendas are closely linked and high priorities in both Malawi and Tanzania. Their vulnerability to climate change impacts is acute and both countries have national policy documents that stress this and the need for targeted intervention in key sectors and vulnerable populations (GOM, 2013; GOM, 2016; GOM, 2017; GOM, 2021, 2012; URT, 2011; URT, 2012a; URT. 2012b; URT, 2016). In Tanzania, floods and erratic rainfall pose a risk to life, infrastructure and Tanzania's economy depends heavily on natural resource-based sectors like tourism (mostly nature-based), agriculture and fisheries World Bank (2018) Under the UNDP's Climate Information for Resilient Devel-

Table 3
Overview of the cases.

Case study context	Risk	Details of insurer/ end-user relationship	End-user of risk information
South Africa - municipal level: Vaal River municipality; property insurance	Flood risk	An existing insurer (Santam) underwrites private assets located across the municipality through an indemnity-based insurance product and engages with government officials to share risk data for government planning and to improve insurer's own risk knowledge. This is a private market solution, and the insurance premium is not subsidized; purchase of cover is voluntary for asset owners. The insurer's collaboration with the municipal government was incentivised through the 'Business Adopt a Municipality initiative' of the national government.	Municipality and district governments, private asset owners who are insured and live in the municipality.
Malawi – national level: Government participation in the multi-country sovereign risk pool African Risk Capacity (ARC) offering parametric drought insurance	Drought risk	The national government purchases sovereign drought insurance through the ARC pool, a parametric insurance scheme. The transaction is based on risk information from the Africa RiskView (ARV) tool, which represents an effort by ARC, and the international community, to make climate related information more useable for governments. The capitalization of the pool, the technical assistance and modelling through ARV are donor-funded, participation is voluntary but subject to government submitting drought management plans to ARC. Government insurance premium was donor-funded.	National government line ministries.
Tanzania – city level: Dar es Salaam, advisory service focused on infrastructure and property risks	Various climate risks to public infrastructure	Insurers, brokers, and risk experts (represented by ClimateWise) launch the City Innovation Platform for African Infrastructure Risk and Resilience (CIP AIRR) and test this in Dar es Salaam with officials from the city government. No underlying insurance product or product design – focus on risk advise and analytics.	City authorities.

opment in Africa project there is a target to increase national coverage of the hydrometeorological network from 50% to 75% (UNDP, 2016) to strengthen the capacity for evidence-based decision-making. Tanzanian institutions are relatively well set-up to develop and deliver climate services, but at present the services rendered are being under-sold to private actors. Improvements in accuracy could lead to an opening-up of new markets. The City Innovation Platform for African Infrastructure Risk and Resilience (CIP AIRR) was developed by insurers, brokers, and risk experts (represented by the international ClimateWise industry initiative) and launched and tested in Dar es Salaam with officials from the city government. The focus of the initiative was on improving risk knowledge for public infrastructure development projects, without a direct insurance transaction.

Malawi has a high degree of vulnerability to climate change as its economy is dependent on rain-fed agricultural production dominated by smallholder farming. Agriculture accounts for a third of GDP and supports the livelihoods of two thirds of the population World Bank (2018). Natural hazards, such as floods and droughts, regularly disrupt food production and accessibility, leading to hunger, malnutrition, and famine. Recognising the imperative for information and early warning, several development partners have invested in climate service provision in Malawi, especially regarding weather data. At present, Malawi's meteorological forecasts are disseminated via radio, television, websites, emails, and text messages. Private weather agencies also provide meteorological information so there is scope for private sector collaboration especially regarding communication.

Malawi has had several experiences with sovereign insurance. Between 2008 and 2011, Swiss Re provided Malawi drought insurance. The premiums for the first 2 years were paid by the UK's Department for International Development (DFID), and then in the 3rd year by the World Bank. The pay-out trigger was based on a single index (the Malawi Maize Index), providing average conditions across the country, and therefore disguising the existence of droughts in parts (which is not uncommon because of Malawi spanning a wide range of latitude). Malawi then joined the second risk pool of ARC for sovereign drought insurance in 2015–16. ARC comprises a specialised agency, which provides capacity building and overseas contingency planning and implementation, and a financial affiliate – ARC Insurance Company Ltd – which conducts the commercial insurance functions of risk pooling and risk transfer. ARC offers sovereign drought insurance to individual countries upon payment of a premium, with the intention of rapid release of funds for response, by using the diversity of weather risk across the continent within the risk pool. An important feature is Africa RiskView (ARV) which is funded through donors to measure and quantify disaster risk in the relevant region to provide modelling input to ARC for insurance purposes, but also aims to be a financial early warning tool, supporting government decision-makers with cost estimates before and during a drought season (Linnerooth et al. 2018).

5. Findings

Our paper investigates the interplay of climate risk information and insurance processes from two angles. The first is the use of climate risk data by those who provide insurance – with information as an input to the underwriting process. The second is the catalyst role of insurance for using climate risk data for government planning and decision-making. For both aspects the analysis reveals insights across three dimensions: temporal, process, and relationships.

5.1. Temporal considerations: Current or future climate risk information?

The survey of insurers underlines that there is a clear distinction between use of data about current risk versus data about future risks. 50% of respondents state that their company uses meteorological data capturing historic trends and near-term forecasts for transactional purposes (i.e. underwriting) and 27% use it for strategic planning (Figure 5). Lack of available data is the main reason for non-use (21%), followed by costs (9%) and data considered as irrelevant (4%).

In contrast, future climate data including climate change scenarios and projections are only used by 26% for underwriting and 26% for strategic planning, with 36% responding that this type of information is not available to them (Figure 6).

The lower application of data for future risks is not surprising, given the traditional short-term underwriting periods that rely on current risk information. However, overall both Figure 5 and figure 6 indicate that there are significant barriers facing the industry in terms of using both current and future data and show that use of risk information by insurers is not as widespread as often assumed. One explanation might be the fact that not all companies who participated in the survey are currently actively underwriting climate risks. In the absence of existing insurance products, they might be

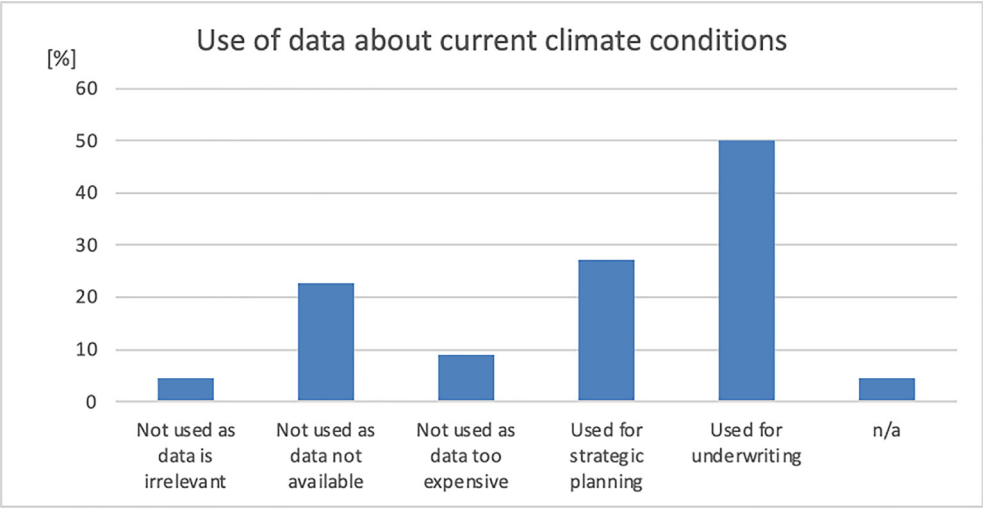

Fig. 5. Use of data about current climate conditions by insurers in Africa and reasons for non-use.

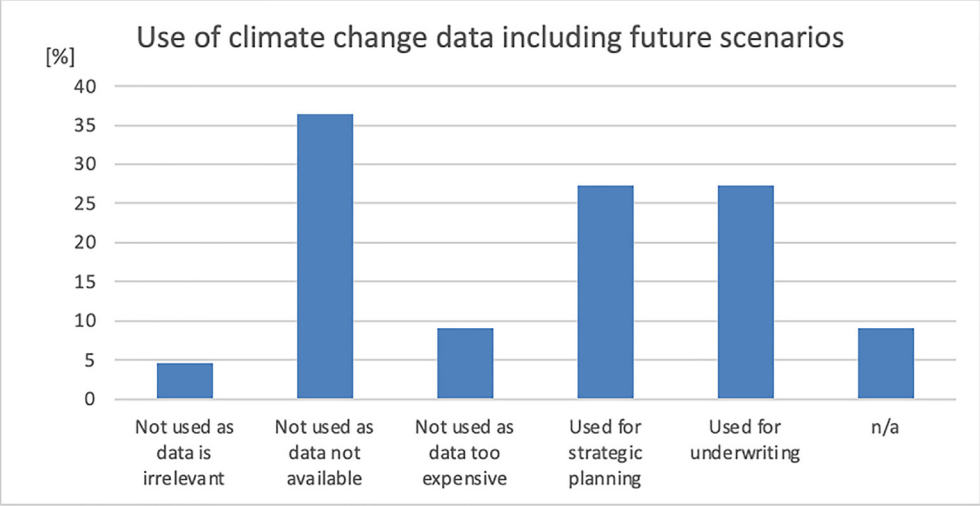

Fig. 6. Use of data about future climate change by insurers in Africa and reasons for non-use.

involved in discussions as consultants and risk experts and use the risk data in this context. This is also highlighted by a discussion of insurers' views on the role of insurance in supporting adaptation in section 5.3.

In the three case studies, climate risk information predominantly focuses on current risks, but also offers an opportunity to integrate with climate change projections and modelled future risks trends. In the South African case study, the collaboration between insurer and municipality leads to the production of geographic information system (GIS) data relating to current flood risk along a major South African river. This is then used by the insurer in the modelling of future flood risk and associated damages to private property, which helps inform the municipality's approach to flood risk management and the insurer's own strategy.

The Malawi case study focuses primarily on the ARV, which is a technical product associated with the ARC sovereign insurance programme developed by the United Nations World Food Programme. It estimates crop losses and the impact on populations' food security from past and future droughts for sub-Saharan African countries. It also provides the weather index that is used as a trigger for ARC products. ARV is designed as a platform and can, according to ARC, use "climate change scenarios as an input in order to evaluate the future impact of climate variability and changes on critical issues such as food security and the overall performance of an envisaged risk management system, such as ARC."[3]

In the Tanzania case, the climate risk information introduced to city governmental actors in Dar es Salaam during the collaboration with insurers took the form of catastrophe risk models for planned urban infrastructure projects. This offers planners and technical specialists a greater understanding of how to factor both slow and fast-onset climatic threats into city planning and individual infrastructure projects, allowing a glimpse into the future. This can show, for example, how individual buildings might be at risk from flood or other hazards in the short-term and how rising sea-levels or projected flooding might manifest in the longer-term under climate change.

In summary, we note a difference in the perception of relevance of climate risk information between current risk information for underwriting and future risk information for planning and strategy. While this is not surprising, it does raise the question of how the influence of climate change and other risk drivers such as urbanization and land-use are reflected in current risk assessment and at what point those will be deemed material for the underwriting processes.

5.2. Stages in creating end-user-friendly climate risk information in the case studies

The results from our analysis of the information translation process are summarised in Table 4, distilling empirical observations about the data at different stages of the process and translation between these from the three case studies. In addition, there are several barriers and enablers which apply across the whole process. Personnel can change at any time which can derail progress, whilst unclear mandates and limited inter-sectoral collaboration can also halt or delay the risk information process. Trust - within organisations and between partners - is an important enabler, as are clear mandates and risk ownership. Local power dynamics must be understood and observed throughout, while fears of corruption can be a barrier. Furthermore, human and technical capacity issues, especially relating to use of information technology and risk finance, can prevent progress.

The following sections discuss the findings for each of the stages.

5.2.1. From relevant to useful

In the South African case, the risk information shared was directly relevant to the city officials and the insurer. By bringing in private sector partners to improve the capacity and capability of its staff, the municipality was able to generate new GIS data relevant to the city's decision-making tools. For the insurer, there was the incentive of accessing risk information that is relevant to their own underwriting as well as creating a collaborative relationship with the municipality, and to support the future aim of selling more insurance products in the city. The data is only indirectly relevant to asset owners who will encounter this in the form of insurance quotes and planning decisions from the municipality.

In Dar es Salaam one of the objectives of the workshop was to demonstrate relevance of risk information to city governmental administrators, but there appeared some initial misunderstandings in terms of focus and approach. Participants in the CIP AIRR process initially expecting a focus on insurance products or an insurance sales pitch rather than a collaboration on data and risk information. At the outset city officials expressed their reservations and reported that insurance was "just an additional cost" that did not help their work. Another barrier was limited risk and insurance literacy at the level of individual actors. As the workshop progressed actors from different backgrounds worked together to develop shared understandings of where and how risk information could

Table 4
The drivers and barriers in the insurance-related climate risk information process.

Transition between levels	Barriers	Enablers	Main observations from the case studies
From Relevance to Usefulness	No visible or immediate recognition of how risk information matters to individuals or institutions. Low insurance literacy can lead to misconceptions and wrong expectations when engaging with insurers.	Insurance and financial literacy can prompt actors to frame climate risk information in terms of savings rather than costs. Risk awareness and experience with using risk information.	In South Africa the insurance data responded to a need of the municipality to improve risk management and planning while also starting a data -sharing process that supports the underwriting efforts of the insurer and its longer-term strategic aims. In Dar es Salaam the CIP AIRR meeting overcame negative perceptions of insurance and convinced city governmental staff that collaboration could be useful. Data produced through ARC/ARV was relevant for multiple national government ministries in Malawi, but low understanding and challenges in identifying and making connections with the appropriate actors.
From Usefulness to Useability	Limited tailoring of data. Incentives to focus on disaster response ex-post rather than invest time and effort in risk understanding and risk reduction. Data protection regulation might restrict use of data or personalization of data. Private funding is often necessary to foster data collection, but can hinder transparency and open access to data	Actors have the space and resources to proactively pursue innovative options. Climate risk information addresses specific needs and is presented in appropriate format to end-user. Systems and technology must be adequate and compatible across insurer and end-user. Technical ability to identify and address gaps supports progress to next level.	City governmental staff in Dar es Salaam have competing priorities and no clear incentives for using data. Inter-Ministerial collaboration was disincentivized in Malawi; different actors were protective of data ; and little incentive for actors to seek improvements of policies through better data. The ARV model appears to have been inadequately ground-truthed (tested in local context, acknowledging local know-how and needs) prior to use, making it less useable. Information gaps and opportunities arising from sharing data were clearly identified in the South African example and formalised in the insurer-municipality partnership to ensure useability of the data.
From Useability to Uptake	Policies, legislation, and regulation can be cumbersome or temporally out of sync with implementation practices. Competition and secrecy leading to mistrust. Framing of risk reduction as a cost lessens any political capital linked to uptake.	Adequate funding for technology and data infrastructure including licensing. Transparency and close collaboration between insurers and government motivates and incentivises uptake. Clear regulation of related insurance and planning processes helps actors to know when and what information to take up.	Good useability and partnership approach enabled uptake in the South Africa case. Consistency in personnel is also central to uptake. Technical issues, including access to internet and software, prevented actors in Malawi from incorporating useable data. Donor-led processes, including the paying of premiums, can lead to a lack of buy-in amongst end-users and prevent uptake. Limited trust and competition between national and city governments undermined the uptake of data in Dar es Salaam.
From Uptake to Behaviour change	Climate risk information that is not sufficiently reflective of end-user need and demand can be taken-up but not lead to a behaviour change. Disconnect between those who take-up information and those whose behaviour determines risk levels.	Actor seniority key to empowered use of information. Clear feedback from climate risk information to financial performance incentivises action.	Data offered tangible benefited to both the insurer and the municipality in South Africa, leading to behaviour change. The improvements in underwriting in turn incentivized behaviour change in policy holders.

contribute to planning and budgeting. Respondents agreed that the CIP AIRR workshop saw climate risk information move from being relevant to being useful in the minds of city governmental actors. However, a shift in personnel after the local elections in 2017 meant that the understanding and trust that had been built previously was lost.

The Malawi case reiterates the importance of targeting those who have ownership of the issue and demonstrate benefits of risk information to them. While different ministries and agencies held responsibility to address drought risk, there was limited understanding of which domestic actor should use climate risk information from ARC. In addition, the reliance on donor funds for ARC and ARV risk information may have created a disincentive. The key informant interviews show a lack of clarity around which institutional actors can benefit from climate risk information which appears to have frustrated progress and lack of prioritization from government. A donor representative argued that since the government was not directly investing in the premium or the risk data, there was limited incentive to ensure appropriate understanding of the insurance product and the ARV software that triggered pay-outs. Limited ad-hoc funds appear to undermine the structures and institutions responsible for risk reduction, with coordination exacerbated by rushed political decision-making.

5.2.2. From useful to useable

In the Dar es Salaam case it appears that, in principle, individual technical staff at city level saw a possible use for the climate risk information. Their time was often diverted, however, towards completing other more immediate tasks including ex-post responses to climate risk events. Until such actors have time and space to think about ex-ante risk reduction there will remain a disconnect between the use of risk information and their information requirements. A lack of clear incentives to apply the risk information can be a key barrier. Addressing this would require collaboration beyond the initial risk information sharing exercise and would require sustained management and resources to support applications.

In Malawi, the ARV has been designed with government use in mind but aligning this with incentive structures and interests within different parts of government has proven challenging. The poor uptake of the ARV can be traced back to two issues: disincentivised inter-ministerial collaboration and limited awareness of ARV information (Pardoe et al., 2020). A staff member from the Ministry of Agriculture, Irrigation and Water Development stated that "the ARC operational plan should be made public, but government is not sharing, so no one knows about it". A representative of a multilateral donor added that, after the 2015–16 season, "there were clearly problems with ARV because, although the customisation was meant to avoid the whole-country-treated-the-same issue, it included the local variety of maize which no one plants, and the model averaged out the drought, which was mainly in January-February (core germination time) with a lot of rain in March." Indeed, the ex-post response to food shocks is an important political tool at the highest level, further undermining progress towards risk reduction and ex-ante planning.

The South Africa example indicates the importance of active collaboration and buy-in prior to the sharing of risk information, including Memoranda of Understanding and clear governance arrangements that provide a stable framework for the collaboration. Data gaps in the planning and underwriting processes were identified at the outset, creating a workable basis for developing useful risk information to plug those gaps. Actors had a good awareness of the direct and indirect benefits of the data to their individual mandates. The South African case demonstrates that useability can be a design-feature: municipalities and the insurer brought their own decision-support tools into the collaboration and ensured that risk information is formatted and packaged to fit into those systems. This reflects that financial and performance incentives can drive useability.

The need for more transparent and accessible data can be an important enabling condition to close the current resilience gap in countries where the insurance market is underdeveloped. The more responsive a policy aims to be, such as some parametric covers, the more up to date and detailed the data must be. During extreme events, for example, higher-resolution imagery is required, what is usually easier to obtain with the private sector support, for example when public data providers partner with space agencies (UNDRR, 2019b). The nature of this partnership is beneficial for both parties, as the public sector can stimulate the sharing of information.

For accessible data, the government plays an important role, not only in funding data that will be open for the public, but also in guaranteeing an enabling environment in terms of legislation and incentives for the provision of open data. However, what happens frequently is that private data providers release a previous version of their data for free, keeping the most recent set privately (UNDRR, 2019a). Another challenge can arise when data is not publicly available but part of commercial offerings, for example in the context of developing new indices for parametric products, such as insurers using the VanderSat database to develop a Soil Moisture Deficit Index for parametric crop insurance to farmers (Swiss Re, 2020), or the World Bank incentivising micro-finance providers, insurers, banks to use specific satellite services to build low-cost accurate credit scores for farmers (World Bank, 2021). In this case acquiring the ready-to-use service can largely decrease transition costs of managing complex data in house for those providers, but it raises questions about transparency and scrutiny of the underlying data, which is often not publicly available.

5.2.3. From useable to uptake

Sustained collaboration between individuals can lead to shared production and uptake of climate risk information. Useable information is thus more likely to be taken-up when collaboration builds mutual understanding and commensurability between organisations rather than actors, especially those linked to the political cycle. The capacity building and sensitisation with city government representatives during the CIP AIRR workshop in Tanzania was hampered by change in personal and political priorities during election processes. Furthermore, the technical capacity of those targeting the appropriate level of seniority and experience is also relevant.

There were few technical issues in Dar es Salaam. Informants reported that the technical requirements to use the climate risk information "is not especially onerous", reflecting high capacity among municipal workers. While the CIP AIRR process brought together insurers, the NGO ICLEI-Local Governments for Sustainability and municipal workers, there was an inherently strained trust between municipal and national government. This national-municipal disjuncture was considered an impediment to municipal employees having either the time or the resources to do activities outside of the core requirements of their roles, particularly those considered adding expense.

Lack of experience with risk information can also hinder uptake. In Malawi, ARV risk information was considered in the context of sovereign risk insurance. Our key informant interviews show that tensions between the World Bank, WFP and various Malawi agencies culminated in a poorly calibrated cover. The Government of Malawi did not adequately invest in the process technically. Poor understanding of the trigger mechanism then led to frustration and anger when the pay-out did not come in 2016-17. Challenges with the underlying product impacted trust and uptake of risk information for other purposes.

In the South African case, both the insurer and the municipality took up climate risk information, having each established the value of data for their own individual purposes. As such both sides were driven by different incentives but worked together to understand their respective data-gaps, seeking out the climate risk information that each could offer. Enhanced GIS capacity in the municipality improved the insurance companies modelling output, which in turn was shared with the municipality and used for planning purposes.

5.2.4. From uptake to behaviour change

In Malawi and Tanzania this stage was not reached as the data was never fully taken-up by those who could change drought risk management processes or infrastructure investment plans.

In South Africa the municipality and the insurer both saw value in risk information for influencing their own behaviour and that of others, mainly asset owners and developers. The municipality used this risk information to undertake more proactive planning in terms of new building permissions, requiring consideration of risk and resilience during the planning process. The insurer used newly gained risk information to reflect on risk in its underwriting process, passing on savings to low risk policyholders whilst increasing costs to high risk asset holders and incentivising others to address their risk exposure ex ante to reduce their insurance costs. The interviews indicate that these behaviour changes occurred, but evidence remains anecdotal and is not tracked over time – e.g., the municipality might disregard the information if pressure to accelerate development increases. Similarly, the options to act among asset owners are relatively limited and contingent on socioeconomic status. For example, people could move expensive assets such as boats away from the river during expected bad weather and look to purchase more expensive cover for immovable assets such as boat-houses – but these options tend to be only available for a small group of wealthy asset owners rather than to the wider population at risk of flooding.

5.3. The relationship between insurers and those at risk: Product transaction or risk advisory?

The final aspect of our analysis considers the nature of the relationship between insurers and those at risk and what implications this might have for the catalyst role. Overall, this relationship can take different forms. It can be based on contractual transactions, on broader risk management collaboration, or on a combination of the two. When asked about what role insurers see for insurance companies in supporting climate change adaptation in Africa, the dominant roles expressed reveal a focus on risk communication and risk management advice: 'risk awareness' (mentioned by 19 participants), ' risk management' (17), 'engagement with clients and government'(13), 'data analysis'(9) and 'public outreach' (6) are the top categories identified. In contrast, insurers seem to see less potential through their product-based transactional activities, as low responses on 'closing the protection gap'(4), 'product innovation'(2), and 'recovery'(2).

These results are not surprising given the low insurance penetration rates across Africa which means that there are currently not many products or underwriting relationships that could be utilised for adaptation. It also aligns with the recognition of existing barriers to insurance across many countries and customer segments (Linnerooth et al., 2018; Hillier, 2018). At the same time, the responses underline the potential for risk advice and information to help pave the way for future risk transfer transactions. This line of argument follows the view that the protection gap that exists in the developing world is a symptom of wider disaster risk reduction issues. Closing it will only work if at the same time adaptation and resilience gaps as well as risk information gaps are addressed (UNISDR, 2013; Panda and Surminski, 2020).

The case studies show that the catalyst role of insurance is possible in either a transactional or risk advisory relationship, or in a mix of both:

5.3.1. Indemnity based insurance cover

In the South African example, the insurer Santam and local authorities collaborate without having a direct insurer-customer relationship. That direct relationship exists between Santam and private asset owners in the Vaal River area, who take out indemnity-based property insurance. Success seems to be driven by three main factors: 1) willingness of the insurer to invest time in this process; 2) the municipality identifying a clear benefit from sharing risk data with the insurer; and 3) asset owners having financial options to take risk reduction action and see this rewarded through lower premiums. In this example the different partners have common monetary incentives and see the value added of sharing information in the context of an already existing insurance transaction. This leads to collaboration, and eventually to use of risk information: by Santam to improve its underwriting process and incentivise its customers to reduce their risks, and by the city to factor this information into planning decisions, which can be expected to help reduce future risks. The results appear to indicate a capacity and willingness to use the risk information and to change behaviour accordingly. However, the political economy could easily derail this, for example should there be a push back from elected officials out of concern about lost tax revenue due to planning restrictions; or if asset owners decide to not insure at all or move to a different insurer.

5.3.2. Parametric insurance cover

The Malawi case shows a direct customer relationship for parametric sovereign risk between the national government and ARC, with ARV providing data and risk information, including in the context of trigger points for the insurance product, which offers pay-outs in case of drought. Here, trust and use of information also depend on experience and understanding of the technical nature of the parametric insurance instrument: if that works well then there is a greater chance for using the risk information more broadly. Our analysis shows a degree of disconnect between a product-focused 'transactional' relationship (Ministry of Finance) and those ministries involved in adaptation and risk management who are not directly linked to or in some cases not even aware of the insurance transaction. Furthermore, the Malawi case shows that the transactional insurance context can also hamper the wider use of risk information if there are misunderstandings, as highlighted by the trigger point controversy in Malawi. This is also relevant in a more general agriculture insurance context, as a study by the International Association of Insurance Supervisors (IAIS, 2017) found: "The distribution and intake of agricultural insurance associated with climate information faces difficulties that hamper its broader dissemination. Challenges such as small farmer's low understanding and demand for insurance, high transaction costs for running the schemes and scarcity of reliable data for parametric purposes can drive claims up and restrict the success of those insurance programmes. The high reliance on data for both operating the product and serving as an information system is a barrier to be passed by the insurance industry" (IAIS, 2017).

5.3.3. Risk advice

In the Tanzania case the industry consortium and city officials interacted in the context of risk advice without a direct customer relationship, although there was a preconception on the side of government participants that the interaction with insurers was ultimately aimed at developing insurance products against damages to public assets. Transparency about aim and objective are essential, but trust and mutual understanding are not easily established and require longer-term commitment and collaboration. This is a significant investment of time and effort for both sides, with uncertain benefits, particularly if undertaken as a pilot or one-off exercise and not embedded into a long-term plan with solid political and industry support.

6. Concluding discussion: The catalyst effect of insurance?

In this study we have explored how climate risk information emanating from insurance processes can support a move towards anticipatory climate risk management, which includes loss prevention and adaptation to climate change. Our analysis offers a new perspective on the catalyst role of insurance by focusing on the underpinning political economy factors, particularly incentives and relationships, which influence this process. An important aspect underpinned by the analysis is the challenge around open data accessibility and sharing.

Several of the findings are distinctively shaped by the specific circumstances in each of the cases investigated, and this study is therefore not exhaustive nor representative of the entire range of insurance products and audiences that have emerged across developing countries. For example, we have not considered the case of agricultural micro-insurance and the potential influence on farmer behaviour. However, our case-study specific findings are confirmed by recent investigations, such as the work on insurance risk analytics in developing countries (IDF, 2020) or UNEP FI's collaboration between local insurers and city officials in Lagos, Nigeria (Fi, 2019).

Overall, there appears to be a clear scope for a dynamic interaction between insurers and other actors such as governments, planners, property developers, investors, farmers, or individuals where symbiotic use and generation of climate risk information can advance mutual goals. In an urban context this might influence building practices and infrastructure planning, while in an agricultural context this might influence the choice of crop and timing of

planting. However, that ambition can face many challenges that go beyond availability and suitability of data. These include:

6.1. Technical capacity

All three cases show the importance of sustained collaboration across sectors and capacity building to increase awareness of the role of insurance-related climate risk information and its potential benefits and uses. This includes technical capacity. The municipality in the South African case had the staff, hardware, and software to operate GIS technology to utilise risk information in their planning, but this is not the norm. Investing in this capacity building would be an important first step towards scaling up of the South African case. However, providing training and technical resources can also be challenging, even when done in the context of an insurance transaction, as seen in the Malawi case. Difficulties around the users' understanding of the ARV software for the trigger validation became a barrier for using the risk information for other purposes. This resonates with observations in other, long-established insurance markets, where often lack of trust, concern about insurance price implications or regulatory constraints prevent effective risk information sharing (Surminski, 2017). In addition, as the Malawi case shows, there is usually a disconnect in terms of departments responsible for data in insurance context (Ministry of Finance) and those departments that might use the data for other risk management purposes, such as the Ministry of Agriculture, Irrigation and Water Development.

6.2. Role of policies and regulations

Policies, regulation and legislation can either constrain or empower institutional political economy contexts. In the South Africa case the link to an existing insurance product may not have been sufficient motivation for the insurer to collaborate with the local authorities: Santam's motivation to engage was also incentivised by the national government. In South Africa, the government reached out to the private sector with a Business Adopt a Municipality initiative[4] which provided the opportunity for Santam to formally showcase its efforts in this area. This was also in part driven by Santam's response to the Black Economic Empowerment drive in South Africa post the 1994 transition to democracy. To contribute to transformation, the company created an Empowerment Trust which funds stakeholder engagement activities and which is supplemented by expert time, project management, data and corporate social investment funds through the company.

Cumbersome or unclear regulations and policies can also hamper use of risk information. In Dar es Salaam, for example, city planners reported frustration about not being able to move in time for influencing new building projects. For example, in instances where building is planned in a high risk area such as a floodplain, works might be completed before the correct regulatory processes can be enforced. This experience is not limited to a developing country context, as numerous examples of inefficient planning systems show, for example in flood contexts (Golnaraghi et.al. 2020).

On the other hand, existing regulation also presents civil servants in both Malawi and Dar es Salaam with opportunities. If urban building codes or national resilience strategies would contain a strong risk reduction rationale it could empower domestic actors to pursue ex-ante risk reduction even in instances where this incurs a short-term cost for the government. Similarly, this could bring opportunities for insurers as documented during key informant interviews in South Africa. Altering the regulatory context to include a mandate for risk reduction could lead to insurers and other potential sources of risk advisory being involved in the planning process, leading to cost-savings in the medium-term. For example, Santam's underwriting subsidiaries Emerald (property) and Mirabilis (engineering) could provide risk advisory to municipal planners during the initial stages of a project. Emerald has a wealth of risk information and risk event experience and can assess projects to advise how to build to reduce risk that will reduce subsequent premium costs and further re-insurance costs. At present, insurers are consulted at the end of the process and write a policy based on the planning, rendering their input minimal. This remains a challenge across established markets, as for example studies of the flood insurance system in Ireland and in the US show (Surminski, 2017; Golnaraghi et.al., 2020).

6.3. Targeting the right actors and clear risk ownership

A key consideration when building technical capacity is targeting the correct actors who can make decisions and have the agency to alter processes. Without due consideration of this, even relevant, useful, and useable climate risk information is unlikely to lead to behaviour change. Activities such as the CIP AIRR workshop can lead to the recognition of the usefulness of climate risk information, but the political cycle can easily undo this progress for example if there is a shift in personnel within the government agencies involved. To mitigate this, interventions should focus on developing an institutional appreciation of the relevance of such information, for example by targeting individuals with a skill or function that is removed from the election cycle, such as engineers or GIS specialists. Staff changes within private sector partners or NGOs can also have a similar disruptive influence.

Political economy challenges tend to be greater when dealing with 'official' counterparts in government, and there are already known challenges of policy coherence around risk reduction, and often unclear roles and responsibilities (England et al. 2018). Both the Dar es Salaam (city administration) and Malawi (national government) cases show existing mandates for the actors targeted, but limited or unclear risk ownership and lack of incentives to act in advance to reduce risk and increase preparedness.

6.4. Incentive structures

While economically sensible, anticipatory interventions often bring little political gain, at least compared to the usually more visible support roles that elected officials can play during or after a crisis. In addition, insurance schemes might reduce the incentive to take anticipatory action, as having insurance creates a sense of security that can lead to inaction. That can be reinforced when insurance is subsidized, as shown by (Greatrex et al., 2015), which can lead to lack of interest in understanding how the insurance mechanisms operate and how risk could be reduced. Similarly, donor support (through premium subsidies or in other forms) might be necessary to kick-start insurance pilots and generate uptake. But this can also discourage officials' interest in understanding the complexities of insurance solutions. For example, donors often subsidise the premium in early years to encourage uptake but, in so doing, can reduce the need for participants to fully understand the process.

There is a possibility that heavy reliance on development cooperation also acts as a disincentive to recognize the relevance of climate risk information for internal decision-making. For example, infrastructure planning is heavily influenced by a range of actors, including foreign investors or donors, limiting the degree of ownership and relevance shown by those officials at the city level. Furthermore, the Tanzanian national government retains a large degree of control over budgets and urban planning, which limits

[4] http://www.durban.gov.za/resource_centre/new2/documents/index_baam_z_fold_leaflet.pdf

the decision-making power of the city administration. However, the risk faced from climate risks and the potential damage and disruption is expected to directly impact the city's finances. This highlights several challenges across governance scales and those working in insurance and climate risk management need to understand and embrace this existing landscape.

The issue of cross-scalar governance is challenging even in developed markets, where unclear risk ownership, roles and responsibilities and use of insurance across local and national scales has been identified as a key issue in managing flood risk, as shown by a recent report from the Geneva Association (Golnaraghi et.al. 2020) Another example comes from the Philippines, which has a comparatively well-developed climate and disaster risk management governance system spanning across national, regional and city scales and is now piloting insurance pool solutions for cities (with the Asian Development Bank) and for regions (with the World Bank), while also developing insurance solutions at micro-and community level (Surminski et al., 2019). These complex governance and decision-structures can also limit the opportunities for risk owners to take-up climate risk information emanating from insurance and related processes if planning and operation of infrastructure sit with different actors. This appears to be the case with Dar es Salaam's Bus Rapid Transport system, funded through multilateral development banks, and supported as a large-scale, highly visible project by the National Government, whilst key informant interviews suggested that climate information was not considered, and that less expensive and more effective options might have been available.

Appropriate incentive structures are essential for the translation process of climate risk information. This applies to both insurers and governments, particularly in the context of climate change and risk information about future risks: The motivation to invest in and consider future information tends to be low on both sides. It is therefore important to not simply assume that insurers themselves use future risk information for strategic planning. Indeed, there is often a disconnect between local risk, local insurer, and global reinsurer - where risk analytics conducted by reinsurers are more advanced than at the local level, but incentives to engage with those who can change risk levels through government planning and adaptation are stronger at the local level.

6.5. Transparency and accessibility of risk information

Additionally, the perceived public good nature of risk information about current and future risks can clash with the standard insurance business model that uses risk information as a key commodity on which companies compete. Companies invest in risk models and analytics to gain a competitive advantage – and therefore sharing and collaborating with other users can be considered a risk for an insurer, with unclear commercial benefits. Similarly, data providers have an interest in maintaining ownership of the raw data. Overall, publicly funded data is expected to be open to all but with privately raised data it might be reasonable to keep some information confidential. However, to support further knowledge development and to foster a better understanding of data it is important that private sector companies and public–private partnerships who specialize in data collection and usage do not shy away from collaboration and engagement with the science community. For example making data samples rather than whole data sets available to academics would not threaten any commercial advantages but enable scientific scrutiny and ultimately lead to improved data products. This appears particularly important in the context of climate science, where academic research is driving innovation, but where a disconnect between data firms, scientists and users hampers progress (see for example (Swart, 2019; Crawford et al., 2018; Stainforth & Calel, 2020).

To support the catalyst function for climate risk information, it is also important that insurers compete only on know-how and strategy, and not on data provision and information access. This is one of the reasons why mutual insurance models, built on joint risk ownership, might be more aligned with the catalyst function for climate risk information than other forms of insurance, as recently highlighted in a study by the Cambridge Institute for Sustainability Leadership (Cambridge Institute for Sustainability Leadership, 2019). ARC, which is based on a type of mutual pool, has several structures in place to foster this risk ownership. However, as seen in the Malawi case, utilizing this for adaptive behaviour and change in government planning depends on a range of factors. Recent experience with ARC in Madagascar in the context of cyclone insurance appears to signal a more successful utilization of risk information. The work ARC completed with the government, modelling the country's exposure to tropical cyclones, enabled the government to understand future cyclonic impacts. This facilitated better preparedness, including reducing property damage risks and increasing emergency services readiness. This demonstrates the risk knowledge that is generated by insurance is an added value that can support governments and others.

This also underpins the importance of collaboration across different insurers to demonstrate the value of climate risk information for climate resilience. The Dar es Salaam case study alludes to this as it was driven by the industry initiative ClimateWise, representing several insurers, reinsurers, and others. Similarly, IDF's Risk Modelling Steering Group presented a "call to action for public and private collaboration" to improve the quality and use of risk information, including across the industry and with non-industry partners (IDF, 2020). And Surminski (2017) shows several examples where insurers have collaborated on risk information, including in Austria and Germany. Extending this to collaboration with government presents its own challenges, as shown in all three case studies. However, there are now a growing number of new initiatives testing this across government scales: One recent example of a collaborative approach between the insurance sector and local government is an agreement formed between leading Nigerian insurers and local government to explore the development of a 'city sustainable insurance roadmap' in Lagos focussing on collaborative action to improve understanding of risks (Fi, 2019).

These challenges highlight why cross-sectoral collaboration is so important for realizing the wider benefits of climate risk information for development and planning. This is at the core of the triple resilience dividend concept, which considers activities in risk information sharing as investments not as costs (Weingartner et al., 2017) One example was raised in the Dar es Salaam case study. Here insurers and modellers have the know-how and climate risk information that can improve understanding of urban flooding, which could support the case for up-stream afforestation as one simple solution that might be attractive to governments. This could be framed as a low-skilled job creation activity rather than a cost, with risk reduction, social and wider environmental benefits. Recognising and capitalising on these opportunities would further enable insurance, government, and development partners to catalyse the use of climate risk information to support greater climate adaptation and to look at solutions systemically and holistically. However, this needs to be part of ongoing capacity building efforts – both for governments and the insurance sector – without which a successful navigation through the climate risk translation process seems unlikely.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

ACRI. (2017). The role of insurance in integrated disaster & climate risk management: Evidence and lessons learned. Retrieved from http://www.climate-insurance.org/fileadmin/user_upload/ACRI__2017_Role_of_Insurance_in_ICRM_online.pdf.

Actionaid (2017). The wrong model for resilience: How G7-backed drought insurance failed Malawi, and what we must learn from it. Retrieved from: https://actionaid.org/publications/2017/wrong-model-resilience.

Botzen WJW (2013) Managing extreme climate change risks through insurance. Cambridge University Press, Cambridge

Bruno Soares, M., & Dessai, S. (2016). Barriers and enablers to the use of seasonal climate forecasts amongst organisations in Europe. *Climatic Change, 137*(1–2), 89–103.

Cambridge Institute for Sustainability Leadership. (2019). Mutual microinsurance and the Sustainable Development Goals: An impact assessment following Typhoon Haiyan. Retrieved from https://www.cisl.cam.ac.uk/resources/publication-pdfs/mutual-microinsurance-sustainable-development.pdf.

Carr, E. R., Goble, R., Rosko, H. M., Vaughan, C., & Hansen, J. (2019). Identifying climate information services users and their needs in Sub-Saharan Africa: A review and learning agenda. *Climate and Development*, 1–19. https://doi.org/10.1080/17565529.2019.1596061.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences, 100*(14), 8086–8091 http://www.pnas.org/content/100/14/8086.abstract.

Green Book: Adapting South African settlements to climate change. Available at: www.greenbook.co.za.

CISONECC. (2016). Dialogue meeting on the national drought insurance policy. Retrieved from https://www.cisoneccmw.org/wp-content/uploads/2020/01/CISONECC_Dought-Insurance-Meeting_Report_.pdf.

Clarke, D. J., & Dercon, S. (2016). *Dull disasters? How planning ahead will make a difference*. Oxford University Press.

Crawford, M.H., Crowley, K., Potter, S.H., Saunders, W.S.A. and Johnston, D.M. (2018) Risk modelling as a tool to support natural hazard risk management in New Zealand local government. International Journal of Disaster Risk Reduction 28, 610-619.

Deloitte. (2019) Emerging Markets Growing insurance & challenges with a focus on Africa . Retrieved from https://www2.deloitte.com/content/dam/Deloitte/za/Documents/financialservices/za_2019_03_Deloitte_Emerging_Markets_Growing_insurance%20_challenges_with_a_focus_on_Africa_presentation.pdf.

Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change, 21*(2), 680–689.

Dilling, L., Lemos, M. C., & Singh, N. (2021). Commentary: First, do no harm: Scaling usable knowledge for just and equitable outcomes. *Global Environmental Change*. https://doi.org/10.1016/j.gloenvcha.2021.102404.

Dinku, T. (2018). Overcoming challenges in the availability and use of climate data in Africa. *ICT Update, 87*, 14.

Dinku, T., Thomson, M. C., Cousin, R., del Corral, J., Ceccato, P., Hansen, J., & Connor, S. J. (2018). Enhancing national climate services (ENACTS) for development in Africa. *Climate and Development, 10*(7), 664–672. https://doi.org/10.1080/17565529.2017.1405784.

Eriksen, S. H., Nightingale, A. J., & Eakin, H. (2015). Reframing adaptation: The political nature of climate change adaptation. *Global Environmental Change, 35*, 523–533. https://doi.org/10.1016/j.gloenvcha.2015.09.014.

Findlater, K., Webber, S., Kandlikar, M. & Donner, S. (2021). Climate services promise better decisions but mainly focus on better data. Nature Climate Change 11, 731–737 (2021). 10.1038/s41558-021-01125-3

GFDRR, 2013 - Global Facility for Disaster Reduction and Recovery. Innovations in agricultural data development for insurance, Disaster Risk Financing & Insurance Program (link).

Goddard, L. (2016). From science to service. *Science, 353*(6306), 1366–1367.

Goddard, L., Ait Chellouche, Y., Baethgen, W., Dettinger, M., Graham, R., Hayman, P., ... Conrad, E. (2010). Providing seasonal-to-interannual climate information for risk management and decision-making. *Procedia Environmental Sciences, 1*, 81–101. https://doi.org/10.1016/j.proenv.2010.09.007.

Golding, N., Hewitt, C., Zhang, P., Bett, P., Fang, X., Hu, H., & Nobert, S. (2017). Improving user engagement and uptake of climate services in China. *Climate Services, 5*, 39–45.

Golnaraghi, Surminski and Kousky: Building Flood Resilience in a Changing Climate: Insights from the United States, England and Germany, *Policy Paper*, Geneva Association, 2020.

GOM. (2013). National Climate Change Investment Plan 2013-18, Ministry of Environment and Climate Change Management. Lilongwe.

GOM (2016). National Climate Change Management Policy, Ministry of Natural Resources, Energy and Mining. Lilongwe.

GOM (2017). *Malawi Growth and Development Strategy III, 2017–22*. Lilongwe: Government of Malawi.

GOM (2021). *Malawi's Strategy on Climate Change Learning*. Lilongwe: Ministry of Forestry and Natural Resources.

Greatrex, H., Hansen, J., Garvin, S., Diro, R., Le Guen, M., Blakeley, S., ... Osgood, D. (2015). Scaling up index insurance for smallholder farmers: Recent evidence and insights. *CCAFS*. Report No. 14.

Gumucio, T., Hansen, J., Huyer, S., & van Huysen, T. (2020). Gender-responsive rural climate services: A review of the literature. *Climate and Development, 12*(3), 241–254. https://doi.org/10.1080/17565529.2019.1613216.

Haigh, T., Morton, L. W., Lemos, M. C., Knutson, C., Prokopy, L. S., Lo, Y. J., & Angel, J. (2014). Agricultural advisors as climate information intermediaries: exploring differences in capacity to communicate climate. *Weather, Climate, and Society, 7*(1), 83–93. https://doi.org/10.1175/WCAS-D-14-00015.1.

Hewitt, C.C., Allis, A., Mason, S.J., Muth, M., Pulwarty, R., Shumake-Guillemot, J., Bucher, A., Brunet, M., Fischer, A.M., Hama, A.M., Kolli, R.K., Lucio, F., Ndiaye, O. and Tapia, B. (2020). Making society climate-resilient: international progress under the Global Framework for Climate Services. *Bulletin of the American Meteorological Society*. https://doi.org/10.1175/BAMS-D-18-0211.1.

Hewitt, C. D., Stone, R. C., & Tait, A. B. (2017). Improving the use of climate information in decision-making. *Nature Climate Change, 7*(9), 614.

Hillier, Deborah (2018). Facing risk: options and challenges in ensuring that climate/disaster risk finance and insurance deliver for poor people. Policy Paper, Oxfam. Available at https://www.oxfam.org/en/research/facing-risk-options-and-challenges-ensuring-climatedisaster-risk-finance-and-insurance.

Hirsch, T., & Schäfer, L. (2017). Stock-take report & policy recommendations: the possible role of the African risk capacity climate risk insurance approaches for small-scale farmers in Malawi, Zimbabwe, Madagascar, Tanzania and Mozambique. Retrieved from www.climate-development-advice.de.

IAIS, 2017 - Exploring challenges in scaling up insurance as a disaster resilience strategy for smallholder farmers. Access to Insurance Initiative - International Association of Insurance Supervisors. Singapore, March 2017.

Ibarra, H., & Skees, J. (2007). Innovation in risk transfer for natural hazards impacting agriculture☆. *Environmental Hazards, 7*, 62–69. https://doi.org/10.1016/j.envhaz.2007.04.008.

IDF (2020). The Development Impact of Risk Analytics. Retrieved from: https://www.preventionweb.net/publications/view/74262.

ILO. (2016). Insurance and economic development: Growth, Stabilization and Distribution. Retrieved from http://www.impactinsurance.org/sites/default/files/MP46 final.pdf.

IPCC. (2014). IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press*. Cambridge: Alistair Woodward. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/ar5_wgII_spm_en-1.pdf.

IPCC. (2018). IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Retrieved from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf.

Jones, L., Dougill, A., Jones, R. G., Steynor, A., Watkiss, P., Kane, C., Koelle, B., Moufouma-Okia, W., Padgham, J., Ranger, N., Roux, J.-P., Suarez, P., Tanner, T., & Vincent, K. (2015). Ensuring climate information guides long-term development. *Nature Climate Change, 5*, 812–814. https://doi.org/10.1038/nclimate2701.

Kalafatis, S. E., Lemos, M. C., Lo, Y.-J., & Frank, K. A. (2015). Increasing information usability for climate adaptation: The role of knowledge networks and communities of practice. *Global Environmental Change, 32*, 30–39. https://doi.org/10.1016/j.gloenvcha.2015.02.007.

Keenan, J. (2019). A climate intelligence arms race in financial markets. In: Science. 365(6459):1

Kirchhoff, C. J., Lemos, M. C., & Dessai, S. (2013). Actionable knowledge for environmental decision making: Broadening the of climate science. *Annual Review of Environment and Resources, 38*.
Kunreuther, H. (2015). The role of insurance in reducing losses from extreme events: The need for public–private partnerships. *The Geneva Papers on Risk and Insurance-Issues and Practice, 40*(4), 741–762.
Lemos, M. C., Kirchhoff, C. J., & Ramprasad, V. (2012). Narrowing the climate information gap. *Nature Climate Change, 2*, 789. https://doi.org/10.1038/nclimate1614.
Linnerooth-Bayer, J., Surminski, S., Bouwer, L. M., Noy, I., & Mechler, R. (2018). Insurance as a Response to Loss and Damage? In *Loss and Damage from Climate Change* (pp. 483–512). Springer.
Mahon, R., Greene, C., Cox, S.-A., Guido, Z., Gerlak, A. K., Petrie, J.-A., Trotman, A., Liverman, D., Van Meerbeeck, C. J., Farrell, D., & Scott, W. (2019). Fit for purpose? Transforming National Meteorological and Hydrological Services into National Climate Service Centers. *Climate Services, 13*, 14–23.
Mambo, J., & Faccer, K. (2017). South African Risk and Vulnerability Atlas: Understanding the Social & Environmental Implications of Global Change. 2nd edition. *African Sun Media*. Retrieved from https://www.csir.co.za/sites/default/files/Documents/CSIR Global Change eBOOK.pdf.
Miles, E. L., Snover, A. K., Whitely Binder, L. C., Sarachik, E. S., Mote, P. W., & Mantua, N. (2006). An approach to designing a national climate service. *Proceedings of the National Academy of Sciences of the United States of America, 103*(52), 19616–19623. https://doi.org/10.1073/pnas.0609090103.
Moody, N., Fraser, S., Miles, K., Schneider, J., (2020). The Development Impact of Risk Analytics. Insurance Development Forum. Retrieved from https://www.insdevforum.org/wp-content/uploads/2020/12/IDF_Risk_Analytics_21Dec.pdf.
Moser, S. C., & Dilling, L. (2011). Communicating climate change: Closing the science-action gap. *The Oxford Handbook of Climate Change and Society*, 161–174.
Panda, A., Surminski, S. (2020). Climate and disaster risk insurance in low-income countries: Reflections on the importance of indicators and frameworks for monitoring the performance and impact of CDRI. Retrieved from https://www.lse.ac.uk/granthaminstitute/wpcontent/uploads/2020/09/working-paper-348-Panda-Surminski.pdf.
Pardoe, J., Vincent, K., & Conway, D. (2018). How do staff motivation and workplace environment affect capacity of governments to adapt to climate change in developing countries? *Environmental Science and Policy, 90*, 46–53.
Pardoe, J., Vincent, K., Conway, D., Archer, E., Dougill, A. J., Mkwambisi, D., & Tembo-Nhlema, D. (2020). Evolution of national climate adaptation agendas in Malawi, Tanzania and Zambia: The role of national leadership and international donors. *Regional Environmental Change., 20*, 118.
Prokopy, L. S., Carlton, J. S., Haigh, T., Lemos, M. C., Mase, A. S., & Widhalm, M. (2017). Useful to Usable: Developing usable climate science for agriculture. *Climate Risk Management, 15*, 1–7. https://doi.org/10.1016/j.crm.2016.10.004.
Singh, C., Daron, J., Bazaz, A., Ziervogel, G., Spear, D., Krishnaswamy, J., Zaroug, M., & Kituyi, E. (2018). The utility of weather and climate information for adaptation decision-making: Current uses and future prospects in Africa and India. *Climate and Development, 10*(5), 389–405. https://doi.org/10.1080/17565529.2017.1318744.
Stainforth, D.A. and Calel, R. (2020) New priorities for climate science and climate economics in the 2020s. Nature Communications 11, 3864.
Surminski S & Vivid Economics. (2018). Study on the Assessment of Tools to Support Climate and Disaster Risk Insurance. Materials on Development Finance, KfW Development Bank.
Surminski, S., Bouwer, L. M., & Linnerooth-Bayer, J. (2016). How insurance can support climate resilience. *Nature Climate Change, 6*(4), 333–334.
Surminski, S., Panda, A., Lambert, P. (2019): Disaster Insurance in Developing Asia: An Analysis of Market-Based Schemes, ADB ECONOMICS WORKING PAPER SERIES No 590.
Surminski, S., & Tanner, T. (2016). *Realising the 'triple dividend of resilience': A new business case for disaster risk management*. Springer.
Surminski, S. (2017). Fit for the future? The reform of flood insurance in Ireland: resolving the data controversy and supporting climate change adaptation. Policy Paper, The Centre for Climate Change Economics and Policy. *The Grantham Research Institute on Climate Change and the Environment.* Retrieved from https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2017/05/Fit_for_the_Future_Surminski_May2017.pdf.
Swart, R. (2019) Assessing physical climate risks for investments: A risky promise. Climate Services 14, 15-18.
Swiss Re Sigma 2013 available at https://www.swissre.com/institute/research/sigma-research/sigma-2013-03.html.
Swiss Re Sigma 2018, available at https://www.swissre.com/institute/research/sigma-research/sigma-2018-03.html.
Swiss Re, 2020 – Sustainability Report 2020.
Swiss Re: Sigma Explorer 2021, available at https://www.sigma-explorer.com/.
Tall, A., Coulibaly, J. Y., & Diop, M. (2018). Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. *Climate Services 11*, 1–12) 10.1016/j.cliser.2018.06.001.
Tanner, T., & Allouche, J. (2011). Towards a New Political Economy of Climate Change and Development. Retrieved from https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/7606/IDSB_42_3_10.1111-j.1759-5436.2011.00217.x.pdf?sequence=1.
Taylor, A., Jack, C., McClure, A., Bharwani, A., Ilunga, R. & Kavonic, J. (2021) Understanding and supporting climate-sensitive decision processes in southern African cities, Current Opinion in Environmental Sustainability, 51, 77-84, 10.1016/j.cosust.2021.03.006.
The Geneva Association. (2016). An Integrated Approach to Managing Extreme Events and Climate Risks: Towards a concerted public-private approach. Retrieved from https://www.genevaassociation.org/sites/default/files/research-topics-document-type/pdf_public//20160908_ecoben20_final.pdf.
Trenberth, K. E. (2008). Observational needs for climate prediction and adaptation.
UNDP. (2016). A NEW VISION for Weather and Climate Services in Africa. Retrieved from https://www.thegef.org/sites/default/files/publications/WeatherAndClimateServicesAfrica.pdf.
UNDRR (2019a). *Chapter 4 in Global Assessment Report on Disaster Risk Reduction*. Geneva: Switzerland, United Nations Office for Disaster Risk Reduction (UNDRR).
UNDRR (2019b). *Chapter 9 in Global Assessment Report on Disaster Risk Reduction*. Geneva: Switzerland, United Nations Office for Disaster Risk Reduction (UNDRR).
UNEP FI. (2019). African insurance industry leaders and UN Environment agree on key collaborative initiatives for sustainable development. Available: 2nd-PSI-African-market-event-outcome-document.pdf (unepfi.org).
UNISDR. (2013). Global Assessment Report on Disaster Risk Reduction. Retrieved from https://www.preventionweb.net/english/hyogo/gar/2013/en/gar-pdf/GAR2013_EN.pdf.
URT. (2011). National five year development plan 2011/2012–2015/2016. President's Office, Planning Commission. Dar es Salaam.
URT. (2012a). National Climate Change Communication Strategy (2012-2017) United Republic of Tanzania Vice President's Office, Division of Environment. Dar es Salaam.
URT. (2012b). National Climate Change Strategy. United Republic of Tanzania Vice President's Office, Division of Environment. Dar es Salaam.
URT. (2016). National five year development plan 2016/17–2020/2021. Ministry of Finance and Planning. Dar es Salaam.
Vaughan, C., & Dessai, S. (2014). Climate services for society: Origins, institutional arrangements, and design elements for an evaluation framework. *Wiley Interdisciplinary Reviews: Climate Change, 5*(5), 587–603.
Vincent, K., Besson, S., Cull, T., & Menzel, C. (2018). Sovereign insurance to incentivize the shift from disaster response to adaptation to climate change–African Risk Capacity's Extreme Climate Facility. *Climate and Development, 10*(5), 385–388.
Vincent, K., Conway, D., Dougill, A. J., Pardoe, J., Archer, E., Bhave, A. G., Henriksson, R., Mittal, N., Mkwambisi, D., Rouhaud, E., & Tembo-Nhlema, D. (2020). Re-balancing climate services to inform climate-resilient planning - A conceptual framework and illustrations from sub-Saharan Africa. *Climate Risk Management*. https://doi.org/10.1016/j.crm.2020.100242.
Vincent, K., Dougill, A. J., Dixon, J. L., Stringer, L. C., & Cull, T. (2016). Identifying climate services needs for national planning: Insights from Malawi. *Climate Policy, 17*(2), 189–202. https://doi.org/10.1080/14693062.2015.1075374.
Wall, T. U., Meadow, A. M., & Horganic, A. (2017). Developing evaluation indicators to improve the process of coproducing useable climate science. *Weather, Climate, and Society, 9*(1), 95–107.
Weingartner, L., Simonet, C., Caravani, A. (2017). "Disaster risk insurance and the triple dividend of resilience" Working Paper 515, Overseas Development Institute
World Bank (2018) Malawi Systematic Country Diagnostic: Breaking the Cycle of Low Growth and Slow Poverty Reduction December 2018. https://documents1.worldbank.org/curated/en/723781545072859945/pdf/malawi-scd-final-board-12-7-2018-12122018-636804216425880639.pdf.
World Bank, 2021 - Digital Ag Series - Scaling Satellite-Observed Soil Moisture Index Insurance Services; https://olc.worldbank.org/content/digital-ag-series-scaling-satellite-observed-soil-moisture-index-insurance-services#comments.
WTW, 2018 - Willis Towers Watson's 2018 Predictive Analytics Survey.
Ziervogel, G., & Zermoglio, F. (2009). Climate change scenarios and the development of adaptation strategies in Africa: challenges and opportunities. Climate Research, 40(2–3), 133–146.