ICSU Regional Office for Africa

AFRICA SCIENCE PLAN

Natural and Human-induced Hazards and Disasters

Strengthening international science
for the benefit of society

INTERNATIONAL COUNCIL FOR SCIENCE
REGIONAL OFFICE FOR AFRICA


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Preamble

This Africa Science Plan for Natural and Human-induced Hazards and Disasters is the first review since the original plan was published in 2007. It is a joint effort of African scientists in this field, coordinated by the International Council for Science Regional Office for Africa (ICSU ROA). The review was made necessary by the many changes in the landscape that have taken place since the first plan was published. Most of all, the revised plan takes cognisance of the new Future Earth initiative, in which ICSU is a key partner, as well as the newly published Sendai Framework for Disaster Risk Reduction 2015–2030, which requires nations to have plans in place to tackle disaster risk reduction issues. Africa is one of the developing regions where ICSU is making efforts to facilitate the involvement of scientists in global scientific issues, and the Science Plan is Africa's prioritisation of key hazards and disaster issues that need attention.

The main objective of the proposed programme is to build and implement innovative and collaborative interdisciplinary research on natural and human-induced hazards and disasters in Africa that would contribute to improved risk reduction and assist in building a culture of prevention. This has far-reaching consequences in that it communicates an intent to improve the quality of life for peoples of Africa by reducing the negative impact of natural and human-induced hazards and disasters. The programme aims to achieve this objective by strengthening the knowledge base and human and institutional capacities at universities, research institutions and policy platforms on the continent. Examples are the African Platform for Disaster Risk Reduction (DRR); the university-based platform of Partners Enhancing Resilience for People Exposed to Risks (Periperi U); and universities with disaster risk and hazard mitigation programmes, such as in Mauritius and the University of South Africa (UNISA).

Dissemination of scientific data, reports, publications and skills can be done through existing networks such as the Africa Union/New Partnership for Africa's Development (AU/NEPAD), Southern African Development Community (SADC), Economic Community of West African States (ECOWAS), Inter-Governmental Authority on Development (IGAD), Clean Energy Manufacturing Analysis Center (CEMAC), Intergovernmental Oceanographic Commission (IOC), and other Pan-African structures and establishments. Further structures are the United Nations International Strategy for Disaster Reduction's (UNISDR) Africa Outreach Programme, the United Nations Environment Programme's (UNEP) Global Environment Outlook (GEO) project, the United Nations Educational, Scientific and Cultural Organisation's (UNESCO) International Geoscience Programme (IGCP), and some projects of the International Geosphere–Biosphere Programme (IGBP), the United Nations (UN) Platform for Space-based Information for Disaster Management and Emergency Response (SPIDER), the World Meteorological Organization's (WMO) THORPEX Research Programme, and the United Nations University (UNU)/Information Technology Coordinated University Network for Disaster Risk Reduction in Africa (UNEDRA).

The Science Plan describes in detail areas where urgent action and investment are needed to ensure that Africa suffers, if at all, minimal risk as the result of natural disasters that are identified as common on the continent. Climatological natural hazards have been described in much more depth, leaving the biological hazards mainly to be dealt with by another consortium that has worked on an Africa Science Plan for Health and Human Well-being. This is an important distinction which recognises that biological hazards are not only climatic in nature, but form part of the whole spectrum of issues related to health and human well-being.

The Science Plan also addresses human-induced hazards and disasters, which acknowledges the negative role played by humans in causing certain hazards and disasters by their actions that lead to the undermining and degradation of the earth system, including natural assets on which society depends. The Science Plan further proposes a research capacity building programme, the objective of which is to develop a truly regional and interdisciplinary research programme for the understanding, assessment, prediction and mitigation of hazards and disasters in Africa. This is considered important in aiding the implementation of the Science Plan, and ensuring a sustainable critical mass of experts in all skills areas to deal effectively with issues of hazards and disasters.

The implementation of the first plan, as with others, has been the most challenging and has taken many years. To date, questions remain on whether the implementation of the revised plan will be fully realised, judging from the scarcity of research funding that has dwindled even further over the past few years. The recent grant awarded by the Swedish International Development Agency (Sida) to ICSU is perhaps one tangible step towards having research projects undertaken on hazards and disasters on the continent. However, much remains to be done to place Africa's hazards and disaster research on a more solid footing.

The updated Science Plan will no doubt serve as a useful tool for African decision makers in public and private spheres, as well as academics and scientists, in seeking sustainable solutions that will reduce the risk of hazards and disasters, including human vulnerability to these. As such, ICSU ROA hopes that this Science Plan will stimulate discussion in all stakeholder forums to use synergies to address all issues at stake. The time is propitious for Africa's scientific frameworks to be in alignment with the rest of the world in this field to ensure their relevance. In today's interconnected world, Africa's prosperity is important to all, and investments in research and development in priority areas will ensure that Africa is on a par with other parts of the world, and that its own issues come to the fore and therefore contribute to promoting inclusive and sustainable globalisation.

Dr Daniel Nyanganyura
Regional Director, ICSU Regional Office for Africa

Executive Summary

Africa as a developing region is most vulnerable to natural and human-induced hazards and disasters with severe impacts on lives and livelihoods. In consequence, hundreds of thousands of people are killed and millions affected. According to the International Emergency Events Database (EM-DAT), the occurrences of recorded natural disasters rose markedly from about 100 in the decade of the 1960s to nearly 2 800 during the 2000s. The interaction of several factors contributes to Africa's high vulnerability to disasters. These involve the high rate of population growth, food insecurity, high levels of poverty, inappropriate use of natural resources, degradation of the environment, uncontrolled urbanisation, low adaptive capacities, and the failure of policy and institutional frameworks. These are exacerbated by human-induced hazards such as climate change and conflicts. In 2007, ICSU ROA drafted a Science Plan on hazards and disasters in Africa, which was evaluated and endorsed by a broad scientific community from Africa and beyond at the Regional Consultative Forum held in Boksburg, South Africa, September 2006. However, the need for an improved understanding of natural and human-induced hazards and disasters, and for stronger research coordination, necessitated its revision. This revised Africa Science Plan aims at re-focussing research based on the current state of the science, through addressing emerging challenges in disaster risk. These challenges concern how to: build research capacity in order to prevent hazards from becoming disasters; enable informed decisions on actions to reduce their impacts; and link disaster risk reduction to poverty reduction and the improved well-being of all people in Africa.

Underlying the efforts of this Science Plan is a concern that research in Africa on hazards and disasters is fragmented and insufficiently integrated and developed, at all levels. Thus, the Science Plan aims to bring together African scientists from a number of institutions in a coordinated effort of interdisciplinary research and outreach to address the impact of natural and human-induced hazards and disasters on African society. This involves building a truly regional and interdisciplinary research capacity to enable understanding, assessment, prediction and the mitigation of hazards and disasters, through the collaborative effort of the African scientific community. To that end, the hazards and disasters research programme has been using a networking approach for the implementation of the Science Plan. This has proved cost-effective and successful, as exemplified by the publication of a book on hazards and disasters in Africa (Mulugeta and Simelane (eds.), 2016). However, research, capacity building, training, and funding are challenging in most settings and attempts have been made to develop an international hazards and disasters consortium to facilitate regular workshops, teacher and student exchange programmes, and outreach activities.

At present, ICSU ROA is developing and implementing two overarching research objectives, supported by capacity building and outreach activities. These concern:

1.) Characterising, identifying and forecasting the impact of hazards and disasters; and
2.) Assessing societal vulnerability and risk for curbing losses and impact.

Based on these overarching research objectives, a number of research themes on disaster impacts and exposure, as well as the socio-economic factors that contribute to disaster risk and vulnerability, have been developed by a consortium of African scientists. In the long-term, the challenge for a successful Science Plan remains how better to anticipate and then to manage and reduce risks from natural and human-induced hazards and disasters by integrating the potential threats into planning and policies. It is a major challenge for the continent's scientific community to develop a truly regional and global partnership to minimise the impact of hazards and disasters.

ICSU ROA is keen to develop both long- and short term research through the necessary integration of natural, health, social and human and sciences in an interdisciplinary framework. We sincerely hope that the revised Science Plan will attract critical attention and provide a firm basis for understanding the causes, interrelationships and remedies of hazards and disasters for Africa's sustainability.

Source: http://www.thenewsminute.com/article/seven-spectacular-weather-events-%E2%80%93-and-what-causes-them-36087

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Source: http://maxpixel.freegreatpicture.com/Cracked-Earth-Clay-Floor-Dehydrated-Cracks-Drought-1675729

1. Introduction

Africa is a continent prone to a wide variety of natural and human-induced hazards and disasters. Phenomena such as floods, hurricanes, earthquakes, tsunamis, droughts, wildfires, pest plagues, and air and water pollution cause extensive losses to livelihoods and property, and claim many lives. Africa's population, estimated at one billion in 2014, is growing at a rate of 2–4% per annum, which means that the number of people exposed to natural and human-induced hazards and disasters will continue to increase. While reducing disaster risk through preventive measures is a central concern for Africa's sustainable development, the fact that most African countries do not invest in disaster risk reduction makes this continent a region least equipped and prepared to cope with the impact of hazards and disasters. It is therefore vitally important that African countries adopt cost-effective policies to lower risk and allocate appropriate resources for hazard and disaster mitigation. Africa is, in many ways, the continent most in need of scientific knowledge to provide solutions and to assist its socio-economic development.

However, investment in science, technology and innovation (STI) is frequently a low priority for decision- and policy makers, and a further constraint is that scientific institutions often have relatively weak infrastructures. Adaptation and mitigation measures against hazards and disasters often pale into insignificance when compared to other pressing issues such as poverty and HIV/AIDS. Through this revised Science Plan, ICSU ROA seeks to revitalise efforts to address the impact of natural and human induced hazards and disasters on African communities. It is a major challenge for the continent's scientific community to develop a truly regional and global partnership to minimise disaster risk through investing in managing risks rather than responding to crises when these arise.

ICSU ROA's overall objective is to contribute to improved risk management and to assist in building a culture of prevention, and to do so by improving public awareness and facilitating access to disaster information through joint initiatives for the sustainable socio-economic development of Africa.

2. Objectives

The main objective of the ICSU ROA hazards and disasters programme is to build and implement innovative and collaborative interdisciplinary research on natural and human-induced hazards and disasters in Africa that would contribute to improved risk reduction, and to assist in building a culture of prevention. The goal is to improve the quality of life for people in Africa by reducing the negative impact of natural and human-induced hazards and disasters. In particular, the hazards and disasters research and capacity building programme aims to strengthen the knowledge base, and human and institutional capacities, at universities on the continent. The proposed research, capacity building and outreach programmes are, therefore, aimed at enhancing the scientific potential of African universities and research institutions. Furthermore, ICSU ROA proposes to work towards advocacy for incorporating research findings into policies, and to facilitate research and training activities at all levels in society.

In the long term, ICSU ROA aims to mainstream disaster risk reduction practices into knowledge management so as to reduce vulnerability to future hazards and disasters through undertaking the following measures:

- Building research capacity on natural and human-induced hazards and disasters, through the initiation and execution of interdisciplinary research projects and the training of researchers. The challenge is how to provide relevant education at different levels (communities, schools and tertiary institutions) to facilitate the mitigation of hazards. A gender perspective is also essential in disaster risk management policies, and in plans and decision-making processes, including those related to risk assessment, education and training.

- Arranging yearly regular short courses and workshops to strengthen the capabilities of researchers on natural and human-induced hazards and disasters. In this respect, the workshops and short courses should also provide professional development opportunities and resources.
- Promoting outreach activities so as to strengthen the link between science and society in the field of natural and human-induced hazards and disasters.

3. Background

Since the publication of the ICSU ROA Science Plan on hazards and disasters in 2007, both the science and science policy environments have developed rapidly across the continent. This necessitated the revision of the Science Plan, which evolved in two phases: an electronic consultation phase where input was gathered from a wide spectrum of scientists and stakeholders from across Africa and beyond, followed by review workshops. The Pretoria workshop held in March 2012 aimed at the implementation of the Science Plan by fostering research consortia. The workshop carried out a SWOT (Strength, Weakness, Opportunities and Threats) analysis of the projects that had been undertaken. In turn, the Kuala Lumpur workshop in September 2012 emphasised the need for integrating the outcomes of research on hazards and disasters across the ICSU network of science institutions. At the Dakar workshop in September 2012, ICSU ROA identified three overarching research themes as central to reducing the risks and vulnerabilities:

- Reducing risk from geo-hazards, such as seismic (earthquake), volcanic and landslide hazards;
- Reducing risk from hydro-meteorological hazards, such as floods/droughts, fires (including bushfires), heat waves, cyclones and dust storms; and
- Undertaking integrated assessments of vulnerabilities to hazards and disasters, including coastal hazards and the forensic investigation of hazards.

Furthermore, the decision was that each research proposal should be developed to facilitate interdisciplinary research collaboration. The Pretoria workshop in September 2013 aimed at drafting a consolidated proposal on ‘Reducing risk to natural and human-induced hazards and disasters’, based on the three research proposals outlined at the earlier Dakar workshop. Other proposed activities included: arranging regular consortium workshops to broaden and consolidate the consortium; establishing regular teacher and student training programmes; and publishing a book on hazards and disasters in Africa.

In October 2014, ICSU ROA, in collaboration with the Sustainable Africa University Network (SAUNET) at Uppsala University, organised a Swedish/Africa consortium-building workshop titled, ‘Reducing the risk of natural and human-induced hazards and disasters for Africa’s sustainability’. In June 2015 a workshop was organised in Pretoria to review the ICSU ROA Science Plan on hazards and disasters. At this workshop, inputs were gathered from a scoping exercise undertaken by a group of African scientists, aimed at building on the research priorities and activities outlined in the 2007 Science Plan. The workshop provided a platform for the scientists to consolidate ideas and inputs generated through electronic consultations since the start of the review process earlier in the year. This review process built on the outcomes of previous workshops to facilitate the implementation of the Science Plan.

During the review process, participants considered a number of pertinent questions and issues essential for producing targeted outputs and deliverables. These included:

- Identifying what has worked and what not in the implementation of the original Science Plan
- The efficacy of the mode of design/co-design of the revised Science Plan

- The sustainability of implementation and how best to ensure that the reviewed Science Plan will address that which needs to be achieved
- The factors that hindered the implementation
- The alignment of the revised Science Plan with the Strategic Plan of ICSU
- How the revised Science Plan can ensure that the implementation reaches the communities it intends to serve.

It was noted that ICSU ROA, as an intermediary between scientists and funders, should move with speed to make things happen. In particular, ICSU ROA should increasingly source funding from African organisations, such as the African Development Bank and others, for the implementation of its Science Plans. This revised Science Plan has been developed within the context of the current ICSU Strategic Plan of 2012–2017, as well as new developments in the global research agenda. These include, in particular, the post Rio+20 Agenda, the Sustainable Development Goals (SDGs), the Sendai Framework for Disaster Risk Reduction (DRR), and the Science, Technology and Innovation Strategy for Africa 2024 (AUC, 2014), as well as the parallel and subsequent processes that were leading towards the expected 2015 agreements on Climate Change Adaptation and on the SDGs.

4. The International Context

The year 2016 and beyond are critical years for building synergies among three ongoing international processes that will set the global agenda for sustainable development. These are the Sendai framework for disaster risk reduction; global agreement on climate change; and the adoption of the Sustainable Development Goals (SDGs), each of which is briefly described below.

The Sendai Framework for Disaster Risk Reduction

The Sendai Framework for Disaster Risk Reduction 2015–2030 is the first major agreement of the post–2015 development agenda, organised by the United Nations International Strategy for Disaster Reduction (UNISDR). It was adopted by United Nations (UN) Member States on 18 March 2015 at the third UN world conference on Disaster Risk Reduction in Sendai City, Miyagi Prefecture, Japan. The goal of the Sendai Framework is a substantial reduction of disaster risk, and losses in lives, livelihoods and health, including other economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. This all-encompassing goal is necessary as previous efforts under the Hyogo Framework for Action (HFA) 2005–2015 had limited success in reducing disaster losses. In fact, during that period disaster risks increased substantially in Africa. The Sendai framework provides a global framework for action with the objective of reducing human, social, economic and environmental losses due to natural hazards and related technological and environmental phenomena. In Sendai, Africa was represented by Heads of State, ministers, civil society, academic organisations and development partners. There was agreement to work together towards substantial reductions in disaster losses, mortality and economic damage over the coming 15 years.

However, implementation of the framework needs to address three key challenges, and has remained a major challenge:

- How best to integrate DRR into sustainable development.
- How to strengthen Africa’s capacity to prevent and address natural and climate-induced disasters.
- Defining the roles that civil society would play in the implementation of the Sendai Framework for Disaster Risk Reduction in Africa.

Framework Convention on Climate Change

Africa is most vulnerable to the adverse effects of climate change, despite it contributing the least to global greenhouse gas (GHG) emissions. For example, climate change is a key trigger for the occurrence of extreme events such as droughts, floods, storms and other hydro-meteorological hazards, and is creating pressure on water availability, food insecurity and other associated livelihood impacts. Moreover, climate variability and change could result in low-lying lands being inundated, with resultant impacts on coastal settlements. In December 2015, parties to the UN Framework Convention on Climate Change (UNFCCC) reached an important agreement in Paris, France. [1] The new agreement provides a common framework that commits all countries in the region to strengthening their efforts in combatting climate change in the years ahead. The Intergovernmental Panel on Climate Change (IPCC) report on managing the risks of extreme events and disasters to advance climate change adaptation noted that the character and severity of impacts from climate extremes depend not only on the extremes themselves but also on exposure and vulnerability, and that key challenges remained (IPCC, 2001). The IPCC also clearly points out the need for scenarios at regional and local levels, to enable appropriate action.

The Sustainable Development Goals. On 25 September, 2015 as part of a new sustainable development agenda, countries adopted a set of global Sustainable Development Goals (SGDs) aimed at ending poverty**,** protecting the planet, and ensuring prosperity for all. Each goal has specific targets to be achieved over the next 15 years. Reduction in vulnerabilities to disasters is essential to achieving the SDGs. There are several challenges in Africa related to the global agenda for sustainable development, which include the following:

- Child mortality is still high in Africa, in spite of having declined five times faster during 2005–2013, compared to the period 1990–1995.
- 70% of Africa's population still suffer from a lack of access to improved sanitation facilities, 41% of its inhabitants still live with less than $1.25 a day, and out of the 57 million of global out-of-school children of primary school-going age in 2015, 33 million are in Africa.
- Gender inequality persists.
- Climate change and environmental degradation undermine some of the progress achieved, and poor people suffer the most as a result of climate change.
- Conflicts continue to undermine security and sustainable human development.
- Hazards and disasters pose a major threat to achieving sustainable development.

ICSU ROA is committed to contribute to Africa's achievement of the SDGs by 2030, through improving understanding of the causes of risk, and by enhancing knowledge on the linkages between sustainable development, disaster risk reduction and climate change. The importance of aligning the ICSU ROA hazards and disasters programme and activities from the outset with the post-2015 Framework for Disaster Risk Reduction must be underscored, and the implementation would need to involve governments, private and civil society organisations, as well as scientists from across the region. In the revised Science Plan, ICSU ROA and its collaborating scientists have ensured that the principles of planning and implementation, as outlined by the Science and Technology Major Group of UNISDR, are adhered to and that the four pillars of implementation – assessment, synthesis, scientific advice, and monitoring and review – are supported by two cross-cutting themes: communication and capacity-building.

[1] https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf;http://

5. Natural Hazards

According to the International Emergency Events Database (EM-DAT, Guha-Sapir *et al.*, 2016), as many as 479 million people have been affected in Africa by five major hazards, and nearly a million have lost their lives in the period 1960–2015 (Table 1). In the revised Science Plan, hazards are classified into two broad overlapping categories:

- Natural, such as climatological, hydrological, meteorological, geophysical, biological hazards; and
- Human-induced, such as environmental pollution, waste-disposal and conflict hazards.

A 'hazard', by definition, is any event, phenomenon, or human activity that may cause loss. Natural and human-induced factors may act together to create a compound hazard. For example, earthquakes are normally considered to be natural hazards, but they can also be triggered by mining activities or the impoundment of large dams. A landslide can be caused by a combination of heavy rains, light earth tremors, and deforestation. A 'disaster' is defined as an event that causes serious disruption, leading to widespread human, material or economic losses beyond the coping capacity of a given society. Thus, disaster management requires a set of actions and processes that are designed to lessen hazardous events before they become disasters.
A disaster event recorded in the EM-DAT database can affect one or several countries. In the latter case, the event would result in several country-level disaster occurrences being entered into the database. In consequence, the more the number of occurrences increases, the more countries are affected by the same hazard. Deaths denote the number of people killed due to the disaster event. Among the five major hazards recorded in the database (Table 1), hydro-meteorological events account for most of the disaster occurrences and they have an impact on nearly every country. These constituted 61% of the total number of the major natural disasters that occurred in Africa in the period 1960–2015, with hydrological hazards (floods plus flash floods) accounting for 38.2%, climatological (droughts and wildfires) 12.5 %, meteorological (storms, extreme temperatures) 10%, biological hazards (epidemic, insect infestation and animal accidents) 36%, and geophysical hazards 0.35%.

With respect to the terminology used by EM-DAT, 'affected' denotes people requiring immediate assistance during a period of emergency. An alarming trend is the increasing number of people affected by natural hazards of climatological and hydro-meteorological origin, with drought, flooding and storms accounting for 97% of the total number of people affected, and 79% of deaths (Figure 1). By comparison, the EM-DAT database contains far fewer entries on disaster damages, especially for sub-Saharan Africa. It shows, for example, that almost 45% of disaster damages are caused by geophysical hazards, which is surprising, given the fact that only 0.35% of disaster deaths are caused by such hazards. These damages and losses are often incurred by poor rural communities without insurance, and lacking the financial resources needed to regain lost livelihoods.

Table 1. African disaster victims and losses by hazard type

Hazard Type	Biological	Climatological	Geophysical	Hydrological	Meteorological	Total
Occurrences	862	303	85	925	244	2419
Deaths	164 763	697 418	32 114	24 734	5 191	914 220
Affected	15 698 034	373 440 132	2 202 201	69 844 718	17 585 306	478 770 391
Damage ('000 $)	5 200	3 424 593	12 355 949	7 528 723	4 329 827	27 644 292

Global climate change is expected to alter the risks posed by hydro-meteorological hazards. It is forecast that many regions in Africa might suffer from the effects of droughts, floods, storms and epidemics with higher frequency and intensity due to climate change. However, questions on how climate change can directly impact on risk patterns remain largely unanswered, as current climate models are unable to target specific areas essential for predicting local alterations in weather patterns, storm severity or habitat degradation. This would, in turn, suggest that more monitoring stations are required as they are essential to the design of adaptation and mitigation measures to withstand and cope with climate change.

At present, African disaster losses are not recorded with sufficient detail to understand the full spectrum of disaster risk. Moreover, little or no damage assessment is made to determine the direct and indirect losses per disaster event, and these are not followed by detailed evaluations. Overall, the majority of African countries have not yet established mechanisms for loss accounting, even with the Hyogo Framework for Action, 2005–2015 (ISDR, 2005) stating as one of the priorities the compilation of information on disaster risk and impact at all scales. For example, there is very little economic data available on potential costs to governments in the region arising from natural hazards. By comparison, in developed countries, estimates of losses normally reflect insured losses of physical infrastructure.

In Africa, most hazards and disasters (with a few exceptions, such as the Mozambique floods of 1999–2000), are relatively silent and insidious encroachments on life and livelihood that increase the social, economic and environmental vulnerability, even to mild events. For example, recurrent drought, deforestation, and progressive land degradation and desertification result in incalculable human, crop, livestock and environmental losses, which are not easily measured by conventional disaster-loss tracking systems (Holloway, 1999). In consequence, the losses caused by African disasters are often underestimated, and it is the cumulative effect of these phenomena that lead to disasters.

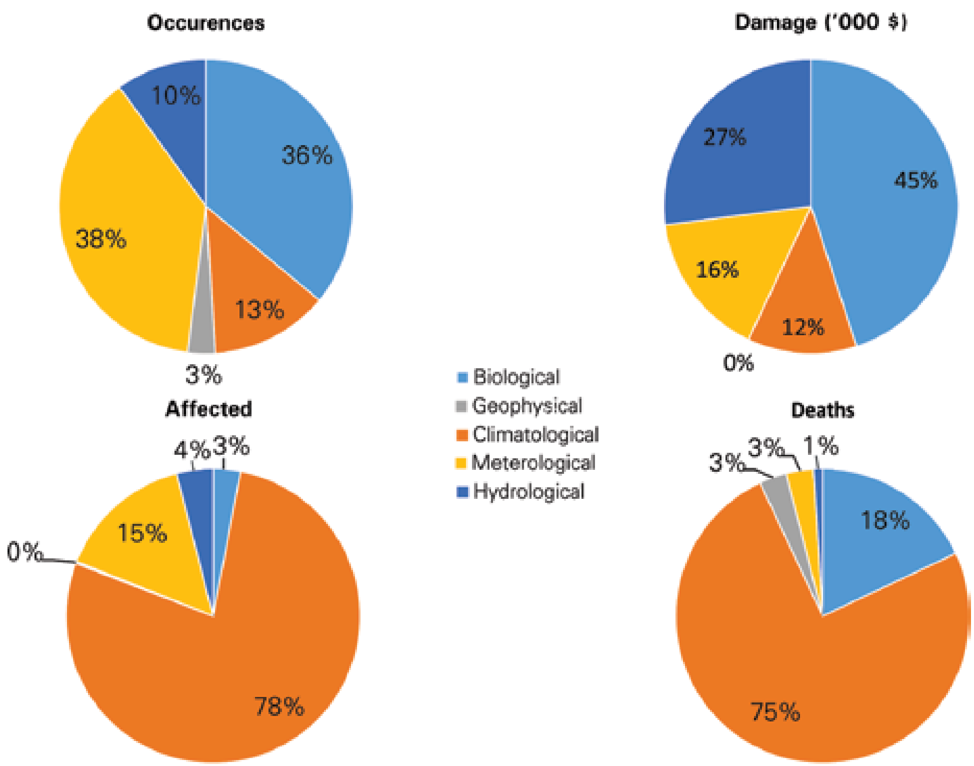

Figure 1. Disaster occurrences, damages, victims and mortality by hazard type (based on Table 1 data)

5.1 Climatological Hazards

Drought

A large part of Africa is susceptible to drought and has experienced several drought episodes; such as the extreme droughts of 1972–1973, 1983–1984, 1991–1992, 2001–2003, 2010–2011, and 2015-16. Studies based on instrumental records indicate that droughts have become more frequent, intense and widespread over the past 50 years (Masih *et al.*, 2014), continental in nature, and stand unique in the available records. The study conducted by the Earth Institute at Columbia University (USA) to assess the effect of natural disasters, as well as the risks to human populations and economic activity, shows that drought and combinations of drought and hydro-meteorological hazards are the main causes of mortality and economic losses in Africa (Dilley *et al.*, 2005). In no other continent does drought appear to be as severe a risk as in Africa. Future projections show a net overall global drying trend, and the proportion of the land surface affected by extreme drought is predicted to increase from 1% at present to 30% by the end of the 21st century. The drying trend is related to anthropogenic emissions of greenhouse gasses and sulphate aerosols into the atmosphere (Burke *et al.*, 2006). Although droughts under current climate conditions affect many parts of the globe, they are a particular concern in Africa.

Starting from the late 1960s, the Sahel with an annual rainfall of 150–600 mm experienced devastating and prolonged droughts that have lasted up to 30 years, the causes of which remain a subject of debate. Initial studies blamed the persistence of the drought on poor land use and the resulting desertification, but recent work indicates that the three decade-long drought might have been due to complex interactions between the atmosphere, land and ocean (Nicholson, 2001; Foley *et al.*, 2003). The 1970–1974 droughts in the Sahel region caused unprecedented losses of human life and livestock as well as environmental damage. The drought was equally devastating in the Horn of Africa, and Ethiopia suffered heavily – an estimated 250 000 human lives were lost and 50% of the livestock perished in the Tigray and Wello regions. The widespread droughts of 1984–1985 were the most catastrophic: about 8 million people were affected, 1 million died, and large numbers of livestock were lost in the Horn of Africa (Webb *et al.*, 1991). In the 2000 drought, nearly 100 000 people died in the same region. The most severely affected were the 16 million nomadic pastoralists whose range straddles the borderlands between Kenya, Somalia and Ethiopia. In 2006, United Nations International Children's Emergency Fund (UNICEF UK) reported that over 8 million people were on the brink of starvation in the Horn of Africa (Kenya, Djibouti, Ethiopia, Eritrea and Somalia) due to severe drought, crop failure and loss of livestock. Signs of vegetation recovery in the Sahel from the late 1980s to 2003 were revealed by remote sensing data, although most rainfall stations have remained below the long term mean (Nicholson, 2005; Anyamba and Tucker, 2005). The interpretation of the observed recovery sparked further speculation about the causes of this green-up, that it could, for example, have been caused by CO_2 fertilisation and the resulting increase in water use efficiency by plants in the region, rather than by the recovering rainfall (Herrman *et al.*, 2005).

El Niño/Southern Oscillation (ENSO) has caused severe droughts and flooding episodes across Africa. ENSO refers to periods of unusually warm or cool sea surface temperature in the tropical eastern Pacific Ocean. Some drought years in Africa have been linked to the El Niño phenomena. Historically, these happened in 1882–1883, 1915–1916, 1997–1998, 2002–2003. Nearly all climate change projections signal greater chances of severe droughts over southern Africa, particularly in the central and western areas (IPCC, 2001; Scholes and Biggs, 2004). In this respect, countries or regions with a Famine Early Warning System (FEWS) can and do benefit from ENSO forecasts, which are essential for mitigating the impact of drought; they can also be useful in agricultural planning. The El Niño of 2015–2016 has already had significant impact in Africa. For example, southern and eastern Africa are suffering from the current drought. In Ethiopia, the drought is threatening the livelihood of more than 7.5 million people. Zimbabwe has also experienced the brunt of the drought through crop failures, disruption of hydropower production and water rationing in some areas.

The factors which influence ENSO events are not well understood but are linked to climate change. Moreover, El Niño is forecast to come more frequently. Thus, successful ENSO predictions, coupled with implementation strategies on the part of policy makers, can help reduce the human and economic toll of disasters on vulnerable populations. In addition, uncontrolled population growth and economies dependent on rain fed agriculture make affected African countries most vulnerable to drought. Thus, there is a clear need for drought risk management, as the situation is likely to worsen in the future due to climate change.

Drought is also exacerbated by deforestation. Deforestation rates in the Congo Basin Rainforest, for example, were estimated at 0.6% per year in the period 1980–1990, whereas rates for the whole of Africa varied from 0.1–0.7% (Scholes and Biggs, 2004). Deforestation leads to land degradation and eventually desertification, thus increasing the vulnerability of populations to drought (Timberlake, 1994). The most serious result of drought is famine. Drought and famine are not sudden events, however, but rather the end result of long-term degradation of the environment due to poor land use and irrational exploitation of natural resources.
There are a few organisations that operate to combat drought in Africa. The Economic Community of West African States (ECOWAS) is developing programmes in environment and natural resource management, including the management of desertification and water resources. SADC, through its SADC Water Sector coordinating unit, has approved a strategic approach to managing droughts and floods. The key institutional player is the SADC Drought-monitoring Centre in Harare, Zimbabwe. The SADC Regional Early Warning Unit (REWU) develops information on weather threats and conditions as well as drought, and works closely with the African Centre of Meteorological Application for Development (ACMAD). ACMAD's mission is to provide weather and climate information to member countries through weather prediction, climate monitoring, technology transfer (telecommunications, computing and rural communication) and research. The Inter-Governmental Authority on Development (IGAD) operates a Regional Early Warning System (REWS) as a key component of national drought and flood preparedness in the Horn of Africa. The IGAD Climate Prediction and Applications Centre (ICPAC) in Nairobi, Kenya, is responsible for the Great Horn of Africa Climate Outlook Forum (GACOF), a participatory consensus mechanism for deriving seasonal forecasts. In the SADC region, the same process is known as SARCOF – Southern African Regional Climate Outlook Forum. The regional Centre for Training and Applications in Agro-hydrology and Meteorology (AGRHRYMET) in Niger is a specialised centre for training and applications in agro-meteorology and operational hydrology. The services of these few technical institutions are limited, however, due to resource and capacity constraints.

Wildfires

Much of Africa is susceptible to wildfires, which destroy pastures, crops, buildings and infrastructure. Wildfires may be ignited naturally by lightning or by the spontaneous combustion of coal (e.g., Zimbabwe) and peat (e.g., Okavango Delta and Lesotho highlands). People, however, are responsible for igniting most of the wildfires. About 168 million hectares burn annually south of the equator, accounting for 37% of the dry biomass burnt globally. It is estimated, for example, that more than 60 million hectares are burnt annually in Sudan (Goldammer and de Ronde, 2004; Pyne *et al.*, 2004). The large area affected by wildfires has implications for short-term productivity and long-term land degradation processes, which eventually contribute to famine during drought periods. Fires caused by people are becoming more frequent in Africa. Combined with intense drought, these fires destroy biodiversity and reduce the regeneration capacity of the vegetation. Although fires cause few deaths, valuable resources are lost, thereby contributing to poverty. Pasture is destroyed, and animals have to be moved, or funds allocated to purchase their feed. According to the Air Pollution Information Network for Africa (APINA), fires also affect air quality and generate greenhouse gases. In addition, they can affect hydrological processes such as run-off and may lead to soil erosion. Examples of recently reported fire incidents include a fire threat to fuel storage tanks at an airport in Botswana during the dry season of 2005; and a wildfire in the Kruger National Park, South Africa, that led to the death of animals and about 20 people. In many African

countries, fires are used to clear forest for agricultural purposes. In Mauritius, sugar-cane fields are burnt prior to mechanised harvesting. These fires sometimes get out of control, causing ecological disaster. In the Borana zone in Ethiopia, over 32 000 hectares were burnt by 96 fires in March 2000. About 80 000 firefighters were mobilised to extinguish these fires (www.fire.uni-freiburg.de/current/ archive/archive.htm).
Fire prevention and mitigation requires the following: knowledge about the weather, ecology and terrain of an area; infrastructure for monitoring, such as the availability of satellite images, for example; the ability to mobilise and train human resources; and appropriate communication and road networks, all of which are scarce in most African countries A few African countries, such as Ethiopia and South Africa, have fire danger warning systems. Most research in Africa, however, is based on ecological field studies. From the late 1980s, some African countries have introduced the use of satellite data to monitor burnt areas for purposes of estimating biomass-related greenhouse gases. The Southern Africa Fire Network (SAFNet) provides a framework for exchanging fire management information and for capacity building, with the emphasis on the use of geo-spatial information technologies. The Global Fire Monitoring Centre (GFMC) also covers fires in Africa. In addition, the University of Maryland (USA) and the National Aeronautics and Space Administration (NASA) provide near-real-time information on active fires detected by the MODIS satellite. In southern Africa, this service is provided through collaboration with the South African Satellite Application Centre (SAC).

5.2 Hydrological Hazards

Floods and flash floods

Floods are among the most devastating hazards, whereas flash floods are among the greatest hazards arising from tropical cyclones and severe storms. Floods and flash floods cause loss of life, damage to property, and promote the spread of diseases such as malaria, dengue fever, cholera and chikungunya. From 1900 to 2006, floods in Africa killed nearly 20 000 people and affected nearly 40 million more, and caused damage estimated at about US$4 billion. While the primary cause of flooding is abnormally high rainfall (e.g., due to tropical cyclones), there are many human-induced contributory causes such as: land degradation; deforestation of catchment areas; increased population density along riverbanks; poor land use planning, zoning and control of flood plain development; inadequate drainage, particularly in cities; and inadequate management of discharges from river reservoirs. Flooding can also be caused by the failure of dams, both constructed and natural. It has been suggested, for example, that a seismic event could cause the pyroclastic dam retaining Lake Nyos in Cameroon to collapse.

The floods that occurred in Mozambique in February 2000 are a recent example of a flood disaster. Rainfall accompanying tropical cyclone Eline caused excessive flows in rivers, such as the Limpopo, with catchments in other countries. These floods affected a total of about 4.5 million people and caused 700 deaths. Losses were estimated at US$500 million, and the GDP growth rate decreased from 10% to 2%. In Ethiopia, the most serious floods occurred in May 1968, August 1994, and May 2005, causing damage estimated at US$0.9, 3.5, 1.2 and 3.5 million, respectively (OFDA/CRED, 2002). In the period from 2004 to 2006, flooding afflicted several areas of eastern and southern Ethiopia, Somalia and Kenya, killing and displacing hundreds of people. The Shabelle and Juba Rivers in the region have both flooded their banks, affecting towns and villages in an area stretching across hundreds of kilometres. Floods in the Horn of Africa normally follow the June–September rainy season. According to the UN, the 2006 floods, which followed droughts in 2005, affected 1.8 million people and were the worst in the region for 50 years. In August 2006, the overflow of the Dechatu River killed more than 300 people in Dire Dawa (a town in south-eastern Ethiopia), displaced thousands more, and caused extensive damage to homes and markets (BBC News, 6 August 2006).

Among some of the notable floods with a region-wide scope include those in the 1997–1998, 2005, 2007, 2009 and 2010–2011. For example, the 2007 floods that extended from Mauritania in the west to Kenya in the east were of continental scope and were among the worst in decades. At minimum, an estimated 1.5 million people were affected. Among the countries with the highest mortality included Angola, Algeria, Burkina Faso, Ghana, Mozambique, Nigeria, Sudan, Uganda and Zaire. The 2015 floods in East Africa (Kenya and Tanzania), which have killed hundreds of people and left thousands homeless, have also been linked to El Niño.

Flood defence is essential to protect communities. Self-help for long-term mitigation should be encouraged. At present, the accuracy and lead times of flood forecasts in Africa are limited or questionable. Thus, training and research should place emphasis on the prevention of floods. New research and collaborative efforts are needed to advance flood management in the future.

5.3 Meteorological Hazards

Tropical cyclones and hurricanes

Weather systems characterised by severe winds and rainfall, known as 'tropical cyclones' in the Indian Ocean and 'hurricanes' in the Atlantic Ocean, are generated between latitudes 5 and 20 when sea temperatures are sufficiently warm. Cyclones or hurricanes are capable of annihilating coastal areas through sustained winds with speeds of 250 km/h or higher, through heavy rainfall, and, most devastating of all, through storm surges that cause the ocean level to rise by as much as 10 metres. As a cyclone approaches land, a dome of ocean water, 80–160 km in diameter, sweeps over the shoreline, causing coastal flooding and damage to coral reefs, mangroves, and fisheries. In most low-income countries, the mortality rates associated with cyclones are 3 to 20 times higher than those associated with floods. Tropical cyclones can cause huge economic losses, especially in island states, by damaging dwellings, infrastructure (power, telecommunications, roads), and fisheries. Heavy rainfall can cause floods that damage infrastructure and crops, trigger landslides, and spread disease. The impact of these storms on coastal communities is exacerbated by the destruction of natural barriers such as mangrove swamps.

In Africa, the areas most often affected by cyclones are the Indian Ocean islands and the coastal areas of eastern and southern Africa. Cyclones can penetrate as far as over 1 000 km inland, for example, up to Botswana from the eastern and southern Africa coastal areas. Countries such as Mauritius are well prepared for cyclones, while others, such as Madagascar, Comoros and Mozambique, are more vulnerable. Typically, 12 cyclones occur annually in the south-western Indian Ocean. A very severe cyclone occurs about once a decade. There is concern that Atlantic Ocean hurricanes could affect West African countries such as Senegal, although there has been no recorded instance of this happening. Further research is needed to assess the risk.

The World Meteorological Organisation (WMO) Regional Specialised Meteorological Centre in Reunion serves the sub-region with information concerning cyclone disasters, especially the members of the South West Indian Ocean Cyclone Committee (SWIO). Cyclone warnings are broadcast on radio and television and published in the press. Warnings are also disseminated locally through, for example, schools, religious networks, and government and traditional establishments. In this way it has been possible for countries such as Mauritius to reduce the number of people killed by cyclones.

Severe storms

Tornadoes are violent rotating columns of air extending from thunderstorms, and they are among the most severe and destructive of all weather phenomena. Hailstorms are associated with thunderstorm activity caused by intense convection and occur in areas such as the South African Highveld, causing damage to property, crops and livestock. The forecasting of tornadoes and hailstorms is challenging as their effects are localised, and as they last on average less than 30 minutes. Currently, there are no warning systems for tornadoes and hailstorms anywhere in Africa. Losses due to these events in Africa are limited, compared to those caused by other types of hazard, and little research has been conducted.

Heat waves

Depending on the average weather in a particular area, a heat wave is a prolonged period of excessively hot weather, which may be accompanied by high humidity. However, there is no universal or standard definition of a heat wave (Robinson, 2001), and there is generally little reporting, particularly in Africa, on the health effects of extraordinarily hot conditions. In Europe and North America, heat waves are increasingly considered to be a major cause of weather-related deaths annually, rather than more energetic natural hazards such as floods, hurricanes and tornadoes. Severe heat waves can lead to deaths from hyperthermia (or heat stroke). The elderly, very young children, and people who are ill or overweight, are at a higher risk of heat-related illness. Increased demand for cooling in cities during a heat wave often leads to electricity spikes that can create power failures, further exacerbating the problem. Heat waves can lead to damage of infrastructure, causing ruptured water lines and buckled roads, for instance. Where the heat wave occurs during a drought, it can trigger hazards such as bushfires, which threaten livelihoods and the security of people and animals.

Studies on climate change reveal that Africa, like the rest of the world, became warmer over the past century, and temperatures are expected to continue rising in the future. Extreme events such as heat waves are predicted to be among the hazards that will be associated with climate change (Díaz *et al.*, 2004). For example, the North West province of South Africa was hit by a heat wave in January 2016, where temperatures reached the highest at 45 degrees Celsius. South African health officials say 11 people have died of heatstroke after a week-long heat wave across the country. Climate change studies focusing on heat wave trends in Africa are lacking. However, indications for other parts of the world, such as North America and Europe, are that global warming will lead to more intense, frequent, and longer lasting heat waves during the 21st century (Meehl and Tebaldi, 2004). The problem of hazards such as heat waves in Africa will be exacerbated by changes in lifestyle, linked to urbanisation and a general lack of preparedness for such events.

Dust storms

The Sahel region is one of the largest sources of dust storms in the world. Summer storms are due to gusts associated with convective rain-bearing storm systems, whereas winter storms are associated with the Harmattan winds. The dust alters air quality, affecting animals, plants and the weather. Scientists in the Niger-based Centre de Recherché Médicale et Sanitaire (CERMES) have found that dust storms blowing across the Sahel might be linked to lethal meningitis outbreaks that often hit this region and its 300 million inhabitants. The Caribbean Basin receives enormous quantities of African dust every year. In addition to its impact on air quality, it affects hurricane activity.

5.4 Geophysical Hazards

Earthquakes

Africa is largely a stable intra-plate region characterised by relatively low levels of seismic activity, with earthquakes randomly distributed in space and time. The only parts of Africa that do not display the characteristics of an intra-plate region are the East African Rift System (and its continuations into Botswana and Mozambique), and the Africa-Eurasia collision zone.

Potentially damaging earthquakes with magnitudes greater than 5.5 occur almost annually in the East African Rift. The 22 February 2006 Mozambican M_w7 earthquake was the largest ever recorded in southern Africa. Shocks were felt as far away as Zimbabwe and South Africa. Four people were killed, 27 injured, and at least 160 buildings damaged. On 3 February 2008, a M_w5.9 earthquake struck the Lake Kivu region of the Democratic Republic of Congo and neighbouring Rwanda. Numerous buildings collapsed or were seriously damaged. At least 40 people died and more than 400 were injured. The Cameroon Volcanic Line experiences earthquakes associated with volcanoes and fault movements. They do not exceed a magnitude of 6 on the Richter scale, and so far have caused no casualties.

Several deadly earthquakes have struck north African countries in the last century. For example, the M_w5.7 earthquake that struck Agadir, Morocco on 29 February 1960 killed about 15 000 people, approximately one-third of the town's population; the M_w7.1 earthquake that struck El Asnam, Algeria on 10 October 1980 killed more than 5 000 people; the M_w5.8 earthquake that struck Cairo, Egypt on 12 October 1992 killed more than 500 people; and the M_w6.8 earthquake that struck Boumerdès-Zemmouri, Algeria on 21 May 2003 killed more than 200 people.

While most earthquakes happen near plate boundaries, it should be noted that a damaging earthquake could occur anywhere. A low rate of seismicity does not mean that the maximum possible size of an earthquake is small, just that earthquakes are less frequent. Although Ghana is remote from present day plate boundaries, it has experienced several destructive earthquakes in historical times, notably a M_L6.4 event that struck Accra on 22 June 1939. The reported death toll ranged between 17 and 22. On 22 December 1983, a M_w6.3 earthquake struck Guinea, a region previously thought to be essentially aseismic, and killed at least 275 people, injured more than 1000, and left 18 000 people homeless.

Earthquakes also occur occasionally in the Cape Fold Belt, South Africa. The most destructive earthquake to occur in recorded history was a M_L6.3 event that took place on 29 September 1969 in the Ceres–Tulbagh region of the Western Cape, killing 12 people. Aftershock activity had virtually ceased when a M_L5.7 event occurred on 14 April 1970, causing further damage in the towns of Ceres and Wolseley.

Earthquakes are also triggered by the impoundment of reservoirs. Kariba Dam was built from 1955–1959. The reservoir is located in a tectonically-active branch of the East African Rift System. An Ms6.0 earthquake occurred in the region in 1910. The filling of Lake Kariba and subsequent fluctuations of the water level have been accompanied by seismicity. The largest event (M_L6.1) occurred in 1963 and caused damage to the dam structure and some property in nearby settlements. No casualties were reported. Since 1963 there has been a general decline in seismic activity. Seismicity has also been associated with the Aswan Dam (Egypt), the Gariep Dam (South Africa), and the Katse Dam (Lesotho).

In recent decades there have been significant on-shore discoveries of oil and gas in many sub-Saharan countries (e.g., South Sudan, Kenya, Uganda and Tanzania). The Karoo Basin of South Africa is thought to contain significant deposits of shale gas. The injection of fluids into the shale to fracture the rock and liberate gas ('fracking') and the extraction of oil and gas may trigger earthquakes. The events may range in size from micro seismic events ($M<0$) associated with fracking, to large events ($M>5$) that may alarm residents and cause damage to vulnerable structures.

Mining-related earthquakes pose a significant hazard to mineworkers in the gold and platinum mining districts of South Africa. Thousands of mineworkers have perished during the last century as a result of rock bursting. A M_L5.3 event on 9 March 2005 caused serious damage to buildings in Stilfontein and caused minor injuries to fifty-eight people. The underground workings were severely damaged: two mine workers died and 3 200 were evacuated under difficult circumstances. The largest earthquake to occur in a mining district in South Africa was a M_L5.5 event that occurred on 5 August 2014 near Klerksdorp. One person was killed by a collapsed wall and more than 600 houses were damaged.

The 2004 Indian Ocean undersea earthquake, known as the Sumatra–Andaman earthquake, that occurred at 00:58:53 Coordinated Universal Time (UTC) (07:58:53 local time) on 26 December 2004 triggered a series of lethal tsunamis that spread throughout the Indian Ocean, killing large numbers of people and devastating coastal communities across South and South East Asia, including those in parts of Indonesia, Sri Lanka, India and Thailand. The number of casualties is estimated at 186 980 dead and 42 880 missing. The impact on coastal fishing communities was devastating, with high losses of income earners as well as boats and fishing gear. Beyond the heavy toll on human lives, the tsunami had an enormous environmental impact that will affect the region for many years to come. For example, severe damage was inflicted on ecosystems such as mangroves, coral reefs, forests, coastal wetlands, vegetation, sand dunes and rock formations, biodiversity and groundwater. The destruction was exacerbated by the spread of solid and liquid waste and industrial chemicals, water pollution, and the destruction of sewage collection and treatment systems. Soil and freshwater contamination with infiltrated salt water and salt layer deposits on arable land also took their toll.

Although not as severely affected as Asia, African countries also suffered losses (UNESCO-IOC *et al.*, 2005). In Somalia, 176 people were killed, 136 went missing, and 50 000 were displaced. One person drowned in Kenya. In Madagascar, 1 000 people were left homeless. No casualties were reported in Mauritius, but a village in the northern island was submerged. In the Seychelles, three people died and seven went missing. In Tanzania, there were 10 deaths, an oil pipeline was destroyed, and an oil tanker ran aground. The disaster created an awareness of the need for a tsunami warning system for the Indian Ocean. Before the event of 26 December 2004, little research had been done to address the risk of tsunamis in the region. No historical records of past tsunamis existed for the affected areas. A survey conducted by UNESCO's Intergovernmental Oceanographic Commission (IOC), WMO, and the International Strategy for Disaster Reduction (UN/ISDR, 2004) showed that least developed countries have limited capacity to implement mitigation measures for tsunamis effectively. The UN started working on an Indian Ocean Tsunami Warning System, and by 2005 had the first monitoring facility in place.

Volcanoes and explosive crater lakes

Active volcanoes

Active volcanoes pose a serious threat to life and property in parts of Africa. The continent has about 140 volcanoes that have erupted during the past 10 000 years, of which 25 are active (that is, they have erupted during recent historic time, c. 500 years). The distribution of dormant and active volcanoes on the continent is centred within two major zones, namely the East African Rift Valley System and the Cameroon Volcanic Line in Central Africa. Many tens of millions of lives have also been disrupted as a result of volcanic activity through direct death, enforced evacuation, starvation, disease, damage to the local environment, and disruption of the social and economic fabric of communities.

The rapid population growth where most active volcanoes are located has ensured an increase in the vulnerability of the populations and their property. Hazard and disaster perspectives of the active volcanoes are indicative of increasing vulnerability of the populations around these volcanoes, especially those who have settled to cultivate the fertile volcanic soils on the flanks of the active volcanoes. Vulnerability is also related to the past frequencies of eruptions of the volcanoes, such as Mount Nyamulagira which erupted 30 times in the last century, Mount Cameroon which has a quiescence period of about 16 years, and volcanoes in Ethiopia with return periods of explosive eruptions of seven to 100 years, and Mount Karthala in the Comoros which erupts in a cycle of approximately 11 years. The most disastrous volcanic eruption on record in Africa occurred at Mount Nyiragongo in the Democratic Republic of Congo in January 2002. It killed 147 people and caused significant damage to Goma, a town with over half a million inhabitants. The eruption of Mount Karthala (Comoros, April 2006) caused more than 10 000 villagers to flee their homes. Other active volcanoes that have recently erupted include Mount Fogo (Cape Verde, 2000), Mount Oldoinyo Lengai (Tanzania, 1994, 2006 and 2007), and Mount Fournaise (Réunion).

Since human responses to the volcanic threats are influenced by many factors such as culture and belief systems, education, awareness, trust (or lack of trust) in experts and authorities, indigenous knowledge and past experiences, approaches to risk reduction will have to be limited to improvement in scientific knowledge regarding the physical hazards, monitoring capacity, ability to give early warning, and human behaviour and controls regarding societal resilience during disasters.

Africa's preparedness for monitoring proximal volcanic hazards, and for responding to future disasters, is inadequate. Systems have been installed to monitor seismic, thermal and gas emissions on some volcanoes and these need to be complemented with satellite-based monitoring systems. Remote sensing data obtained from a combination of complementary multi-parameter techniques, including volcano-seismic networks, ground deformation, temperature, gas emissions, and readily-accessible remotely-sensed data (temperature, gases, geodetic, infrared), as well as telemetered monitoring of magnetic and electric fields, gases and temperature are essential in so far as monitoring of these volcanoes is concerned. The technology for most of these techniques is yet to be installed around active volcanoes on the African continent.

Improvements in eruption forecasting are critical for reducing the loss of life and property. However, basic information about the character of past volcanic activity is lacking for most of these active volcanoes where priority is most often given to alleviating poverty and combating disease, rather than monitoring, forecasting and mitigating adverse impacts of the volcanic activity aimed at reducing the risks. There is accordingly an urgent need for action at two levels: firstly, ensuring adequate investment in hazard assessment and monitoring in order to characterise and address volcanic risks; and secondly, constant monitoring, using contemporary and successful approaches of eruption detection. This two-fold action would greatly reduce the vulnerability of populations to these hazards, especially if local scientists, policy makers and local communities work in synergy towards disaster risk reduction from these active volcanoes.

Explosive crater lakes

The worst recorded disaster from an explosive crater lake occurred in Lake Nyos, Cameroon in 1986, where a carbon dioxide emission killed 1 876 people and over 3 000 livestock (Lockwood and Rubin, 1989). A similar event took place in Lake Monoun (Cameroon, 1984), killing 37 people. It was the first time in recorded history where a lake degassed, asphyxiating people and animals on such a scale in a single and brief non-direct volcanic event. Such eruptions from crater lakes that release gases are termed 'limnic eruptions', a term first coined by J-C Sabroux at a UNESCO Conference on the Lake Nyos disaster (Yaoundé, Cameroon, 1987) for describing such a violent overturn.

Carbon dioxide is one of the major magmatic gases released during volcanic activity. It is colourless, odourless, and 1.5 times denser than air, thus it can accumulate in low-lying places and depressions without being detected when released into the atmosphere. It is equally highly soluble in water and, if released at the bottom of a deep quiet lake free of overturning, high concentrations can build up because its solubility increases with hydrostatic pressure. The bottoms of deep crater lakes and low-lying depressions are accordingly suitable environments for the build-up of concentrations of CO_2 gas which kills by asphyxiation when its proportion and concentration in the atmosphere reaches 15 % and >350 ppm, respectively.

Studies carried out from these lakes place the CO_2 source to be from magmatic origin and the result of an absence of significant amounts of hydrogen sulphide and halogens, which are typical of high-temperature volcanic gas emissions, which suggests that the direct injection of volcanic gases into these lakes is not the source of the CO_2. The CO_2 is apparently derived from the slow degassing of magma at depth and then diffuses along fracture zones into the bottoms of the lakes. The mantle and paleo-lacustrine environments have been identified as the sources of this gas where it is formed through a mechanism of passive degassing, after which groundwater conveys and accumulates the gas at the bottom of the lakes. Any disturbance upsets the density stratification of the lakes' water column, thus triggering an overturn of the lake, and thereby releasing the carbon dioxide gas into the atmosphere. Investigations of the physics and chemistry of the water in both lakes revealed that they still contained huge amounts of dissolved CO_2. Although degassing systems installed in Lake Monoun from 2003 has removed almost all the gas, and about 32% of the gas in Lake Nyos, it is still uncertain whether the gas will rebuild when degassing stops.

Another peculiar hazard associated to Mounts Nyiragongo and Nyamulagira in the Democratic Republic of Congo is the *mazukus*. This word means 'evil wind' in Swahili and corresponds to areas with depressions where CO_2, being heavier than air, accumulates in high concentrations, often at a lethal level of 15% in the atmosphere. Mazukus are abundant in Goma and its vicinity, and more generally in the south of Nyiragongo and Nyamulagira volcanoes. From field observations, its source could be from a link between the CO_2 source and a network of fractures allowing the gas to reach the surface or a depression in which the gas accumulates by gravity. Even though these mazukus have been known for a long time, their mode of formation has never been studied and is still a subject of debate. According to local inhabitants in this area, people are killed by mazukus every year. Due to the current population growth, the risks associated with mazukus are increasing. Attempts to reduce the risks from this gas have included prevention campaigns and signposts installed in some of these depression areas.

The only other lakes known to contain gas-rich bottom waters are Lake Kivu, Democratic Republic of Congo, and Lake Tanganyika in Tanzania. Lake Kivu contains enormous amounts of dissolved CO_2 (250 km STP) and methane (60 km STP) in its deep waters, and the CO_2 here poses a threat to the communities living near this lake if it was to be triggered to outgas by lava flow into the lake from the neighbouring active Nyiragongo volcano. However, the concentrations of these gases are presently below 60% saturation and an extraordinary event will be required to trigger a 'limnic eruption', although the release of only a fraction of these gases could have catastrophic consequences for the densely populated region.

Further research and, in particular, an assessment of the risks and vulnerability of the communities within these volcanic regions, will be essential and could include a systematic mapping exercise involving the testing of the already existing hypothesis on mazukus formation in depressions. The northern border of Lake Nyos is confined by a 40 m high natural dam made up of unconsolidated pyroclastic deposits. If the dam were to fail, it has been calculated that a devastating flood could affect over 10,000 people along the valley of the River Katsina-Ala to as far as Nigeria. In order to reduce the disaster risks in these cases, it will be necessary to use the results of such research to sensitise policy makers and the vulnerable populations living in these areas.

Mass movements, erosion and siltation

Mass movements

Mass movements, erosion, siltation and associated hazards are among the major development and environmental challenges in many parts of Africa. Mass movements are defined as the downslope movement of soil and rock under the influence of gravity. The hilly and mountainous terrains of many African countries (especially the western, eastern, central and southern Africa), which are characterised by variable topographical, geological, hydrological and land-use conditions, are frequently affected by mass movements of various types and sizes. The factors that influence the initiations of mass movements include soil/rock types, topography, land use, vegetation cover and erosion processes. The triggering factor could be heavy rainfalls or earthquakes. Human factors that contribute to mass movements include deforestation and poor land management practices, coupled with migration of people to marginally unstable terrains due to population pressure.

Mass movements cause considerable loss of life, and damage to croplands, dwelling houses and infrastructure such as highways, railways and pipelines. In many of the hilly areas of Africa (e.g., Ethiopia, Kenya, Uganda, Tanzania, Cameroon, Democratic Republic of Congo, South Africa) such hazards have been causing major economic, environmental and social problems. The El Niño weather phenomenon in 1997–1998 caused widespread landslides and floods in parts of Kenya (Ngecu and Mathu, 1999); the national economic loss due to landslides was estimated at 1 billion US$. In Réunion, a landslide triggered by heavy rainfall and unstable ground overran a busy coastal road in March 2006; a key transport route was destroyed, which disrupted economic activity, and vehicles were buried, causing several deaths. Landslides are also common along the Cameroon Volcanic Line, with most triggered due to heavy rainfall, although some by earthquakes. Recent events in Cameroon include the Limbe landslides in 2001 and the Wabane landslides in 2003, where 21 and 23 people were killed, respectively. Heavy economic and infrastructural damage was also caused. In Ethiopia, in the years 1998 to 2003, 135 human lives were lost, about 3 500 people were displaced and property valued at an estimated 1.5million US$ was damaged in the highlands of Ethiopia. With the increase in population and effects of climate change, mass movements are expected to cause huge economic, social and environmental costs, unless given due considerations.

There is, therefore, a need for several actions, including the need to: identify institutions that could play a leading role; develop policies and guidelines on mass movement hazard management and risk management; initiate and promote capacity building programmes; initiate and promote collaborative mass movement hazard mapping, loss assessment and research; initiate and promote mass movement hazard forecasting and monitoring; and adopt feasible and multi-purpose remedial measures which are context specific.

Erosion and siltation

Erosion is the process by which the surface of the earth is worn away by, for example, the action of water, glaciers, winds and waves, while siltation is the undesirable increase in the concentration and/or deposition of water-borne silt in a body of water. These two processes are the results of land degradation and poor land management practices. In many parts of Africa, erosion and siltation are among the major environmental concerns. Erosion may degrade arable land, and, consequently, reduce agricultural production. Siltation of rivers and dams results in shallow waters, which affects irrigation schemes severely and, as a consequence, reduces agricultural production, as has been the case in Zimbabwe. In Mauritius, deforestation has accelerated erosion. The consequent siltation has a significant impact on coastal economic activities, such as fishing and tourism. In many of the highlands of Ethiopia, erosion and siltation remain among the major factors causing the silting-up of water reservoirs. Evaluations of the drivers of erosion and siltation, and the development of appropriate strategies to address such problems, are critically important for Africa.

5.5 Biological Hazards

In recent decades, biological hazards have become increasingly severe on the African continent, due to the steady and continuous increase in the population. A study of EM-DAT statistics shows that biological hazards account for 3% of all hazard victims and 18% of deaths, for the period 1960–2015 (Figure 1). As noted earlier, biological hazards are discussed in detail by the ICSU ROA Consortium on Health and Human Well-being. This Science Plan, therefore, makes only brief mention of health hazards that are associated with environmental phenomena.

Epidemics

In the EM-DAT database, an epidemic is defined as an unusual increase in the number of cases of an infectious disease, or the appearance of an infection previously absent from a region. It can also refer to the appearance of a significant number of cases of an infectious disease in a region or population that is usually free from that disease. Epidemics may also be a consequence of disasters of other kinds, such as tropical storms, floods, earthquakes and droughts. Epidemics may also attack animals, causing local economic disasters (www.ifrc.org).

It has been estimated that almost 60% of deaths caused by infectious diseases are among the poorest 20% of the world's population (www.ifrc.org). Epidemics most associated with environmental phenomena include malaria, cholera, meningitis, leishmaniosis, dengue fever, Rift Valley fever, yellow fever and West Nile fever. Malaria kills over 1.5 million people in Africa every year. According to World Bank reports, mosquito-borne diseases are the leading killer of African children. Epidemic malaria in the highlands of eastern Africa is closely associated with climatic hazards such as the El Niño phenomenon. A series of cholera outbreaks occurred in April–July 2005 in Burkina Faso, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Senegal, and the Democratic Republic of Congo near the eastern border with Rwanda and Burundi. 30 977 cases of cholera outbreak were reported in 2016, including 849 deaths, with a fatality rate of 2.7%. The majority of cases were from the Congo River basin (Democratic Republic of Congo, Central African Republic, and Congo Brazzaville). [2] According to the UN Office for the Coordination of Humanitarian Affairs, there were over 24 000 cases of cholera in West Africa in 2005 (Quinn, August 2005). Chikungunya and dengue fever are associated with environmental phenomena such as flooding and drought. In the East African Rift System, landslides can cause outbreaks of Rift Valley fever by releasing a soil fungus into the air that may be inhaled.

Pest infestations

Pests such as locusts, grain-eating birds, and African armyworm cause great agricultural losses, contributing to poverty and famine (Mengech *et al.*, 1995). The large grain borer, Prostephanus truncates, has spread through parts of Africa and is causing value and weight losses in stored maize approaching 60% of harvests. About 10 million square kilometres of Africa is affected by animal *trypanosomiasis* (also known as *nagana* or sleeping sickness), spread by tsetse flies (*Glossina* spp.), which seriously limits farming activities.

Locusts, armyworm, fruit flies, banana diseases, cassava diseases and wheat rusts are among the most destructive transboundary plant pests and diseases. A fall armyworm outbreak is causing considerable crop damage in southern African countries. Reports from the Zambia Disaster Management and Mitigation Unit indicate that as of 9 January 2017, close to 130,000 ha planted maize had been affected by a severe outbreak of the *Fall Armyworm*, which is new to the southern African region (http://reliefweb.int/disaster/2017-000019-zmb). Outbreaks follow crippling El Niño-triggered drought which scorched much of the region in 2016, severely affecting crop production and leaving millions in need of food aid.

2 http://reliefweb.int/report/democratic-republic-congo/cholera-outbreaks-central-and-west-africa-2016-regional-update-7


Source: https://pixabay.com/en/forest-fire-blaze-smoke-


Source: https://pixabay.com/en/smoke-building-chimney-air-654072/

6. Human-Induced Hazards

The challenge for Africa is to improve the quality of life of its population without over-harvesting resources and accumulating waste, which inevitably leads to the degradation of the natural assets on which society depends. However, the ecological footprint of most African countries is relatively low, and so is the human development index (Swiss ADC, 2006: http://hdr.undp.org).

Environmental pollution

Environmental pollution in Africa is reaching proportions that are of worldwide concern. Urbanisation and industrialisation, along with economic development, have led to increasing pollution and waste discharges. Onyemaechi and Sanders (2009) reviewed evidence of human exposure to and health effects from modern environmental health hazards, to highlight the growing significance of these hazards as African countries experience urbanisation, industrial growth and development. Some of the sources of these hazard exposures are linked to mining and processing, automobile exhaust and lead and pesticides, such as *p,p'-dichlorodiphenyltrichloroethane* (DDT), and organophosphates.

Linked to environmental pollution is air pollution, which is increasingly becoming a serious environmental problem in Africa. In the past 25 years, Africa has experienced the world's most rapid rate of urbanisation at nearly 5% per annum. This, alongside tax regimes that encourage the use of dirty fuels, a sharp rise in the importation of old and outdated cars, and inefficient industrial plants, are seriously affecting air quality on the continent. The high rate of urbanisation, which is expected to continue for the next decade, combined with low-income solutions to daily commuting, has resulted in the rapid increase in pollutants emitted by motorised vehicles. The available information suggests that the concentrations of toxic metals in many ecosystems are reaching unprecedented levels. The 2012 World Health Organisation (WHO) estimate suggest s176 000 deaths per year in Africa from outdoor pollution, and 600 000 deaths per year from household air pollution (http://www.unep.org). Because of the heavy load of contaminated dusts in the air of highly populated cities, the ambient concentrations of toxic metals are now among the highest in the world. Lead pollution from the rising number of automobiles and cottage industries represents a major health hazard, and it is estimated that 15–30% of infants in some urban areas may already be suffering from lead poisoning (Nriagu, 2004).

According to the Africa Environment Outlook (AEO) report (UNEP, 2002), the use of biomass fuel, besides degrading the environment, also raises the risk to health of women and children, who mostly do the cooking in African families. In Tanzania, for example, children under five years of age who die from acute respiratory infections are three times more likely to have been exposed to the burning of such fuels. To address the issues related to air pollution, APINA, a regional network of scientists, policy-makers, and non-governmental organisations (NGOs), has been established and currently covers the southern Africa region. Their activities form part of a Programme on Atmospheric Environment Issues in Developing Countries, coordinated by the Stockholm Environment Institute (SEI) and funded by the Swedish International Development Cooperation Agency (Sida) under a project titled, Regional Air Pollution in Developing Countries (RAPIDC).

Water pollution (e.g., contamination in rivers and lakes) is also a serious hazard in Africa. About 66% of Africa is arid or semi-arid and over 300 million people do not have access to clean and safe water, and over 500 million live without adequate sanitation. The African population without access to sanitation increased by 153 million, from 430 million in 1990 to 583 million in 2006. The increases in coverage are not keeping pace with population growth (http://www.wssinfo.org). Up to 90% of wastewater in developing countries flows untreated into rivers, lakes and highly productive coastal zones, threatening health, food security and access to safe drinking and bathing water (http://www.unwater.org). In addition, low-income urban dwellers have to pay high prices for water, sometimes up to 50 times the price paid by higher income groups. This problem has been worsened by high rates of uncontrolled urbanisation and industrial activity.

An investigation by the Nigerian Environmental Society in 1985 revealed that, between 1970 and 1983, offshore and on-shore oil spillage amounted to 1 711 354 barrels (Aguiyi-Ironsi, 1988). According to Kadafa (2012), the oil spillages ongoing for several decades have resulted in an area characterised by contaminated rivers, stream and forest, resources which constitute the major income source for the majority of the local population inhabiting the region, and who are mainly dependent on ecosystem services.

Gas flaring

Gas flaring is a serious health hazard in southern Nigeria and in other parts of Africa where there are oil refineries. In Nigeria, almost two million cubic feet of natural gas is burnt every day in the production of crude oil, more than any gas flare reported from elsewhere in the world. Not only does gas flaring cause major environmental pollution in the Niger River Delta, where most of Nigeria's oil is produced, but it also wastes a valuable resource. According to a World Bank report (Svensson and Djumena, 2002), gas flares in Africa could produce approximately 50% of the continent's current power supply. Gas flaring in Nigeria has impoverished the communities where it is practiced, with attendant environmental, economic and health challenges (Ajugwo, 2013).

Artisanal and small-scale mining

While both large-scale and artisanal or small-scale mining can adversely affect the environment, the latter is not properly regulated. The mine operators often have only limited access to technology. It is estimated that over five million people are involved in artisanal or small-scale mining in Africa. This type of mining practice has made a valuable contribution to some African countries, providing employment to significant numbers of people, especially in rural areas, and adding to foreign exchange earnings. At the same time, however, it has adversely affected the environment. While the basic environmental impacts of intensive mining operations include the accumulation of sediments in rivers, lakes and water pipes; deforestation and erosion; as well as dust and pollution (including heavy metals such as lead, arsenic, and cadmium), the most serious are pollution from mercury and land degradation (Hilson, 2002). Mercury is used for gold amalgamation in artisanal mining. It is typically released into the atmosphere and waterways, where it is converted by microbes into toxic methyl mercury and poses a threat to the health of animals and humans. Toxic mercury hotspots have been identified in several areas on the continent. These include the Victoria Fields in Tanzania, and Obuasi and Kumasi in Ghana (Hilson, 2002). The main causes of health hazards among miners include: inhaling large amounts of siliceous dust, careless handling of mercury during gold panning, gold/mercury (Au/Hg) amalgam processing, the existence of water-logged pits and trenches, and the sharing of poor quality air in the mines by large numbers of individuals. Since 2010, ongoing, widespread, acute lead poisoning and gold mining has killed at least 400 children in Nigeria's Zamfara State (https://www.hrw.org/).

The use of pressure burners to weaken the reef is a deadly mining procedure, as hot particles of lead, arsenic, and other sulphide minerals burn the body and, when the burns become septic, death can apparently follow within 2–3 years. Health problems of gold miners who have worked underground include increased frequency of cancers of the trachea, bronchus, lung, stomach and liver; increased frequency of pulmonary tuberculosis (PTB), silicosis and pleural diseases; increased frequency of insect-borne diseases, such as malaria and dengue fever; noise-induced hearing loss; increased prevalence of certain bacterial and viral diseases; and diseases of the blood, skin and musculoskeletal system.

Toxic waste disposal

For the past three decades, African countries have been used as dumping sites for hazardous toxic waste materials from developed countries. Such wastes include raw sewage, sludge, incinerated ashes, contaminated oil, nuclear materials, acids and poisonous solvents ejected by chemical, pharmaceutical and fertiliser-producing plants in the industrialised world (www.american.edu/TED/ oauwaste.htm). The dumping of toxic waste materials poses a grave environmental threat to African people, many of whom are not aware of the dangers and are not equipped to handle the ensuing consequences. In August 2006, for example, hundreds of tons of chemical slops were dumped in open-air sites in Abidjan, Côte D'Ivoire. Ten people were reported to have died, and thousands more were reported to have fallen ill with vomiting, diarrhoea, nosebleeds and breathing difficulties (BNW, 2007). Recently in was reported that millions of tonnes of the world's e-waste ends up in Africa where it is dumped in landfills, such as at Agbogbloshie in Ghana's capital, Accra. The mountains of 'e-waste' that build up in landfill sites such as Agbogbloshie pollutes the local water and harms the health of the scavengers whose livelihoods depend on these broken goods (Akbar, 2015)

Conflict-related hazards

Ongoing conflicts in Africa exacerbate other hazards. Fragile and degraded environments can fuel conflict and war, and *vice versa*. Conflicts aggravate the effects of natural hazards, such as famine and epidemics, by increasing the vulnerability of societies and ecosystems already under stress. In turn, the type, onset and intensity of conflicts are also influenced by natural environmental hazards. Both are linked but the relationship is complex. These issues, therefore, need to be integrated in disaster risk reduction interventions. In 1985, almost all drought-affected African countries (such as Ethiopia, Sudan, Chad and Mozambique) were also wracked by civil wars (Timberlake, 1994). In such times, governments allocate resources to war and give low priority to long-term environmental concerns. Today, landmines and unexploded ordinance affect 30 of Africa's 54 countries (Human Rights Watch, 1993 and 1994). The severely mine-affected sub-Saharan African countries include Angola, Chad, Eritrea, Ethiopia, Somalia, Mozambique and Zimbabwe. Conflict and land degradation can cause large numbers of people to move within the borders of a country or across international borders. Fragile and conflict ridden states experience shocks and stresses related to the combined effect of natural hazards and the challenges of conflict and fragility. In this respect, the Sendai Framework must do more to support effective disaster risk reduction in these complex contexts by being explicit about the need to support governance strengthening as a starting point to building disaster resilience (https://www.unisdr.org/).

7. Research and Capacity Building

The main objective of the research and capacity building programme is the development of a truly regional and interdisciplinary research programme for the understanding, assessment, prediction and mitigation of hazards and disasters in Africa. Underlying the efforts of this proposal is a concern that research in Africa on hazards and disasters is fragmented and insufficiently integrated and developed, at all levels. Thus, the project aims to bring together African scientists from a number of institutions in a coordinated effort of interdisciplinary research and outreach to address the impact of natural and human induced hazards and disasters on African communities. The immediate objective of this proposal is to facilitate the implementation of the ICSU ROA Africa Science Plan on Natural and Human-induced Hazards and Disasters.

There are several challenges to be considered, the first is the need for interdisciplinary research and recognising the difficulties related to implementation. Defined as a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts and/or theories from two or more disciplines to solve complex or 'the grand challenges' facing society, it requires research capacity at multiple levels. Some of the questions and challenges that need to be considered, include:

- How to prevent hazards from becoming disasters.
- How to linking disaster risk reduction to climate change adaptation as a means of achieving sustainable development.
- How to analyse and address the social, economic and institutional factors that contribute to risk.
- How to use research and the knowledge generated on disasters and vulnerability to improve the understanding of the causes of risk. For example, do the mounting disaster losses in Africa reflect the inadequacy of knowledge, despite accumulating research, or is it because existing knowledge is not used to curb disaster losses?

There is a need, therefore, to address the gaps in knowledge, methodologies and types of information that are preventing the effective application of science to avert disasters and reduce risks. In the revised Science Plan, an integrated and multi-hazard approach is proposed to deal effectively with natural and human-induced hazards, where each proposed research programme is intended to facilitate interdisciplinary research by linking hazards and vulnerabilities. For this purpose, ICSU ROA has identified two overarching research objectives, based on the outcomes of the workshops mentioned earlier:

1.) Characterising, identifying and forecasting hazards and disasters, and
2.) Assessing risk and societal vulnerability in order to curb losses.

The first research objective requires building research capacity to forecast hazardous events using an integrated approach. The primary focus of the first research objective is on activities leading to the reduction and control of disaster trigger events, through early warning, adaptation and mitigation, and facilitating efficient communication strategies for timely information on the occurrence of events. The second research objective concerns assessing societal vulnerability for curbing losses, through knowledge-based actions. The second research objective would require the integration of outputs from the first research objective, and can only be achieved through implementing informed risk reduction measures; for example, how early warning systems and seasonal forecasts can be used to enhance the resilience of vulnerable communities and to improve societal capacity to cope with current and future hazards and disasters. Compared to the developed world, several countries in Africa often lack data, information, knowledge, skills and human resources in this field. Furthermore, there are many other competing claims to limited resources, and the proportion of GDP devoted to scientific research lags far behind that of developed regions.

Governments in Africa tend to rely on international donors rather than on building science and research capacity. There is therefore a need for training and to build interdisciplinary research capacity so as to facilitate the better use of research results in policy- and decision making. A review of recent work on natural and human-induced hazards and disasters indicates that there is a good deal of research activity on hazards and disasters in Africa. For most countries, however, there are gaps in the availability and quality of scientific data, information and skills, and where these are available, they are often insufficiently shared.

Furthermore, the purpose of the proposed research is to:

- Enable enhanced understanding and evaluation of the impact and vulnerability to compounded hazards and disasters (e.g., drought, floods, and cyclones);

- Make better assessments of losses and to minimise the costs of hazards; and
- Provide tools to enable the prediction of the effects of climate change on hazards and disasters, especially floods and droughts.

8. The Research Proposals

As a first step in the implementation of the research objectives outlined above, some targeted project proposals have been developed by a consortium of African scientist. It needs to be noted, however, that these are generic proposals that need to be tailored to the criteria of potential funders, in the process of implementation. Also, the research programme will be developed in line with other ICSU ROA Science Plans and the Integrated Research on Disaster Risk (IRDR).

In addition, each of the proposed research activities should incorporate elements of the research objectives outlined above, and further, needs to address the risks posed by geophysical and hydro-meteorological hazards, and vulnerabilities to these, in an interdisciplinary framework.

Changes in climate due to global warming are widely expected to exacerbate the impact of hydro-meteorological hazards in the coming decades. Rising temperatures will affect weather and precipitation patterns, sea levels may rise, and the average maximum wind speed of tropical cyclones is likely to increase. The expected increase in frequency of climate extremes will, in turn, increase hazard exposure and the risk of events such as droughts, floods and storm surges affecting different regions of Africa in different ways.

Research is needed on how to communicate warnings of impending disasters effectively, and how to disseminate knowledge to help communities to improve their resilience. Related, there is an urgent need to transmit scientific knowledge on hazards to support early warning and preparedness (ISDR, 2006).

All communities, and rural communities in particular, have developed specific coping strategies. These indigenous knowledge systems should be investigated, validated, and formalised as they are often site-specific. Traditional knowledge in one region might not be applicable in another region, and climate change may result in hazards beyond the knowledge bank of indigenous systems. It is essential to identify best practices for reducing hazards and disasters that can be used as models for people living elsewhere.

Africa is the continent where urban areas are growing fastest and where millions of poor people are living in slums on hazardous sites, such as flood plains and steep slopes. In coastal regions, the informal settlements of the poor are in danger from tsunamis and storm surges along the shoreline. They are also likely to bear the brunt of rising sea levels. Detailed information on present and future risks of population exposure to coastal hazards is essential for mitigation technologies that address vulnerability and risk assessment as an integral component of disaster management.

People in urban areas are directly susceptible to hydro-meteorological hazards such as drought, floods, fires, and disease epidemics. In particular, low-income groups are vulnerable because of their strong link to rural food supplies. Coastal areas are increasingly being developed for shipping, security zones, recreation and tourism, fishing and agriculture, habitation and job opportunities. Small island states are particularly vulnerable to damage in natural ecosystems (coral reefs, wetlands, freshwater resources, marine resources, forests and soils) because of the small land area, limited resources, and fragile ocean-based economies. Detailed information on present and future risks of population exposure to coastal hazards is essential for mitigation technologies.

The proposed research activities needed to mitigate the risks posed by geophysical, hydro-meteorological and other hazards are described below. In what follows, seven proposed research projects are briefly outlined.

Proposal 1: Assessing and mitigating earthquake risk in Africa

Some progress has been made to address the risk posed by earthquakes since the first ICSU ROA Science Plan was published in 2007. In brief, the following:

The Africa Array programme is a Pan-African research and capacity building programme launched in July 2004. It has deployed a 'backbone' network of 50 broadband seismographs and 25 geodetic stations in Africa, as well as several temporary seismograph arrays along the East African Rift System and in Madagascar and Namibia. The US Office for Foreign Disaster Assistance (OFDA) has commissioned a pilot study to determine how AfricaArray data and Global Earthquake Model (GEM) products (such as a harmonised catalogue), as well as open source tools (such as the Open Quake Computational Engine and the Hazard Modellers Toolkit) can be combined. The project is completed, a report delivered to USAid, and a paper submitted to the Bulletin of Earthquake Engineering is in review.

The UNESCO International Geological Correlation Program (IGCP) sponsored the compilation of a seismotectonic map for Africa, which was released at the International Geological Congress in Cape Town in September 2016.

At the launch of the African Seismological Commission (AfSC) in 2011, researchers noted that they had found that a 'laissez-faire attitude' towards disaster risk reduction prevailed. The pressure of development had overwhelmed planners and building inspectors, and poor quality building materials were often used (Allotey *et al.*, 2010). More recently, building codes in Africa were reviewed, and opportunities for improvement were identified (Worku, 2014).

The researchers proposed the establishment of a three-phase disaster management programme: the pre-disaster phase, involving prevention and mitigation; disaster or emergency response; and post-disaster recovery efforts.

Activities proposed:

1. Expand the human and physical capacity for seismic monitoring, hazard assessment and risk mitigation in Africa by:

   - Linking African seismologists, geologists, structural engineers, town planners and disaster management practitioners with one another and with the international community through common projects.
   - Training a new generation of researchers and practitioners through postgraduate projects that address African problems.
   - Providing advanced and specialised training for seismic network operators and analysts.
   - Expanding the backbone network of permanent seismic and geodetic stations.

- Creating a pool of seismographs that can be used for rapid temporary deployments to monitor aftershocks.
- Establishing and equipping a scientific rapid response team that can be mobilised to conduct forensic investigations following earthquakes (i.e. map geological phenomena, monitor aftershocks, assess damage), and evaluate disaster response.

2. Enlarge and update the public domain catalogue of African earthquakes by delivering data to the International Seismological Centre by:

- Compiling and regularly updating the seismotectonic map of Africa by analysing seismicity data, determining earthquake source mechanisms, and mapping active faults.
- Assessing the seismic hazard in Africa, with a focus on large cities and critical lifeline infrastructure.
- Executing pilot projects; for example–

    Integrated seismic hazard and earthquake risk assessments (involving seismic monitoring, geodesy, remote sensing, paleoseismology, neotectonics, vulnerability and exposure, disaster preparedness).

    Integrated geohazards studies (earthquakes, volcanic eruptions, landslides, crater lake eruption, and disaster preparedness). Mounts Cameroon (Cameroon) and Nyiragonga (DRC) are possible sites.

Expected outcomes would include:

- An enlarged cadre of highly-trained African seismologists, geologists, structural engineers, town and regional planners and disaster managers.
- Improved seismograph and geodetic networks to monitor seismicity and strain.
- An expanded and homogenised catalogue of African earthquakes.
- A seismotectonic map of Africa that incorporates the latest seismic, geodetic and neotectonic information.
- An updated Probabilistic Seismic Hazard Assessment for Africa.
- Integrated geohazard assessments (earthquakes, volcanic eruptions, landslides) for high-risk areas.

http://www.cqsisu.com/group/earthquake-wallpapers/

Proposal 2: Monitoring Hazards from Volcanoes and Explosive Crater Lakes

Active volcanoes pose a serious threat to life and property in parts of Africa, yet there is abundant evidence that Africa's preparedness for monitoring proximal volcanic hazards and for responding to future disasters is inadequate. Systems have been installed to monitor seismic, thermal and gas emissions. These need to be complemented with satellite-based monitoring systems, such as global navigation satellite systems and radar imagery for better mitigation strategies. Remote sensing data (temperature, gases, geodetic, infrared), as well as telemetered monitoring of magnetic and electric fields, gases and temperature are essential with respect to the monitoring of volcanoes. The technology for most of these techniques is yet to be installed around active volcanoes on the African continent.

An ongoing project at the Royal Museum of Central Africa in Tervuren, Belgium (SAMAAV) is studying and monitoring African active volcanoes, using radar interferometry to examine the recent evolution and assess the risks associated with four active volcanoes (Mount Nyiragongo, Mount Cameroon, Mount Fogo and Mount Oldoinyo Lengai). This work is being done in collaboration with African volcanologists, including those in Cameroon, the Democratic Republic of Congo and Tanzania. Rapid population growth where most active volcanoes are located has resulted in an increase in the vulnerability of the populations and their property, especially those who have settled to cultivate the fertile volcanic soils on the flanks of the active volcanoes. Vulnerability is also related to the past frequencies of eruptions of the volcanoes, such as Mount Nyamulagira which erupted 30 times during the last century, Mount Cameroon which has a quiescence period of about 16 years, and volcanoes in Ethiopia with return periods of explosive eruptions of seven to 100 years, and Mount Karthala in the Comoros which erupts in a cycle of approximately 11 years.

As noted earlier, the most disastrous volcanic eruption on record in Africa occurred at Mount Nyiragongo in the Democratic Republic of Congo in January 2002. It killed 147 people and destroyed Goma, a town with over half a million inhabitants. The eruption of Mount Karthala (Comoros, April 2006) caused more than 10 000 villagers to flee their homes. Other active volcanoes that have recently erupted include Mount Fogo (Cape Verde, 2000), and Mount Oldoinyo Lengai (Tanzania, 1994, 2006, and 2007) and Mount Fournaise (Réunion). Since human responses to the volcanic threats are influenced by many factors, such as culture, belief systems, education, awareness, trust (or lack of trust) in experts and authorities, indigenous knowledge and past experiences, approaches to risk reduction will have to be limited to improvement in scientific knowledge regarding the physical hazards, monitoring capacity, ability to give early warning, and human behaviour and controls regarding societal resilience during disasters.

Further, improvements in eruption forecasting are critical for reducing the loss of life and property. However, basic information about the character of past volcanic activity is lacking for most of these active volcanoes, as priority is most often given to alleviating poverty and combating disease, rather than monitoring, forecasting and mitigating adverse impacts of the volcanic activity aimed at reducing the risks. There is accordingly an urgent need for investment in hazard assessment and monitoring in order to characterise and address volcanic risks, and for the constant monitoring using contemporary and successful approaches of eruption detection. Such an approach would greatly reduce the vulnerability of populations to these hazards, especially if local scientists, policy makers, and communities work in synergy towards disaster risk reduction from these active volcanoes. Research and, in particular, an assessment of the risks and vulnerability of the communities within these volcanic regions, will accordingly be essential and could include a systematic mapping exercise involving the testing of the already existing hypothesis on *mazukus* formation in depressions. In order to reduce the disaster risks in these cases, it will be necessary to use the results of such research to sensitise policy makers and the vulnerable populations living in these areas.

In response to the research needs outlined above, a project on monitoring hazards from volcanoes and explosive crater lakes in Africa, using remote sensing and ground-truthing techniques has been developed and submitted to ICSU ROA.

Proposed activities for this project would include:

- Identifying the most active volcanoes, reviewing their past and current status, and characterising their behaviours, based on the synthesis of published information which will then be compiled into a book.
- Designing methods of monitoring the active volcanoes, especially those with high population densities on their flanks, using appropriate Remote Sensing (RS) techniques, and relevant ground-truthing studies.
- Assessing and documenting the locations and periodicities and impacts of CO2 outgassing from crater lakes within volcanically active regions
- Establishing structural and morphological links between such crater lakes and nearby active volcanoes where appropriate, using RS imagery techniques and ground-truthing studies.
- Predicting volcano eruption cycles and monitoring the physico-chemical characteristics of water in identified explosive crater lakes, as well as the types of gaseous emissions from such lakes using appropriate RS and ground-truthing techniques.
- Strengthening human resource capacity and infrastructure development in countries prone to hazards from active volcanoes and explosive crater lakes, and integrating experts, policy- and decision makers, and communities in all stages of the execution of this project.
- Developing hazard zonation maps and conceiving appropriate approaches of education and raising of public awareness for the communities exposed to these hazards.

Expected outcomes (who would benefit from the research):

- Communities vulnerable to volcanic hazards.
- The governments of countries in which these volcanoes are found, in relation to improving sustainable economic development within risk zones. This will lead to improving people's lives and hopefully reduce poverty.
- The younger generation will also benefit through capacity building in hazard monitoring and sensitisation approaches.

Proposal 3: Causes, failure mechanisms and mitigation options of landslides in Africa

This proposed project would focus on understanding the causes, failure mechanisms and mitigation options of landslides in Africa. Despite the impact of landslides in many parts of Africa, to date such hazards remain overlooked and research in the area remains insignificant. Further, the causes and failure mechanisms of such hazards remain poorly understood, and the triggering mechanisms (e.g., hydrological, earthquake) are not well studied. Mitigation options which are applicable to the African realities need to be devised. These aspects call for comprehensive landslide hazard mapping and loss assessment on the continent which include compiling and evaluating information on the economic impacts of landslides, and delineating susceptible area to landslides for development planning.

As landslides are mainly triggered by heavy rainfalls and earthquakes, there is, in the case of rainfall-triggered landslide hazard assessment, a strong link with hydro-meteorological factors.

The following have been identified as priority activities:

- Undertaking a comprehensive landslide hazard mapping and loss assessment exercise;
- Compiling and evaluating information on the economic impacts of landslides; and
- Delineating susceptible areas to landslides for development planning.

Expected outcomes:

- An evidence-based understanding of the causes and failure mechanisms of landslides in Africa, and the possible linking with hydro-meteorological hazards.
- The development of appropriate mitigation options in Africa.

Proposal 4: Sea/level change and pollution hazards in coastal areas of Africa

Coastal erosion and seawater intrusion into coastal aquifers are key global hazards associated with eustatic sea level rise. Coastal erosion is a widespread phenomenon along Africa's coastlines, and in many cases has attained alarming and disaster dimensions. Although primarily driven by oceanographic and meteorological factors, coastal erosion in many locations has had escalating effects as a result of human activities. These include: the noncompliance with regulations, or the non-existence of setback or buffer zones limiting spatial development, beach sand mining, and the lack of mitigating approaches and interventions. Often the fragility of shore systems and the flow-substrata are ignored, or inappropriately evaluated.

It is well established that for virtually all the coastal states of Africa, human population and economic activities are most concentrated within the coastal region. The immediate effect is coastal ecosystem pollution, notably from crude oil spills and gas flares, the discharge of toxic ballast waters and industrial effluents, as well as domestic waste dumping. These lethal substances in coastal waters over a prolonged period can dramatically deplete stocks of sea foods and plants, and also undermine biological productivity of coastal wetlands, thereby accentuating poverty and health deteriorating issues for communities whose livelihoods depend largely on exploiting and harnessing these coastal resources.

The inability to curtail and contain the current rates of coastal erosion and pollution spells doom, given the diverse resources human, ecologic and infrastructure that are at risk. The combined effect has meant major setbacks with respect to the attainment of the Millennium Development Goals (MDGs), including poverty reduction and environmental sustainability, and more recently, the non-alignment with the Sustainable Development Goals (SDGs). The current socio/economic conditions of coastal communities are predicted to worsen, given the existing indices of sea levels.

Activities:

- The first component of this project aims at an accurate diagnosis of coastal erosion along critical and oceanographic-distinct regions of the coastal states of Africa.
- The approach would be to use first-order principles of surf zone flow and beach profile interaction over the short term, and historical chart analyses of coastline changes, over the long term.
- As follow up, models for coherent erosion abatement approaches would be proposed.

The outcomes of the research should benefit the coastal states that directly experience this hazard, but also those with comparable coastal conditions where pertinent coastline change models can be beneficially applied.

The deliverables of the research will necessarily include a report detailing the following:

- Coastline retreat rates and patterns
- Mechanics of coastal sediment transport
- Coastal sediment budget analysis
- Littoral processes data evaluation
- Anthropogenic impacts on coastline retreat
- Coastline dynamic models
- Coastal erosion abatement strategies and policies.

The second component of the project aims to:

- Map pollution hotspots in representative African states in coastal groundwater systems and coastal ecosystems, lagoons, coastal lakes, tidal rivers and estuaries, tidal flats, swamps and associated creeks, as well as the beach and near shore regions
- Identify pollutant dispersal patterns and depositional trends
- Assess the impact of pollutants on ecosystems
- Evaluate the self-flushing potentials of the ecosystems for discharged pollutants.

The deliverables of this coastal pollution component will include:

- The mechanics of sea level rise-induced coastal aquifer salinisation
- The deterioration levels and dynamics in coastal groundwater quality
- A pollution vulnerability ranking of coastal ecosystems and contingency planning modalities.

Proposal 5: Drought and desertification in the Sahel

The project proposes to address the environmental and social impact of drought and desertification in the Sahel, and aims to set up a long-term warning and monitoring system of climatic change, drought and desertification. The output will provide effective tools for decision makers to enable them better to develop mitigation and adaptation strategies. The project must incorporate a regional outreach dimension since desertification is not a local phenomenon. Rural and urban populations, as well as national research centres, would be involved in the project.

There is a need for the multi-dimensional assessment of future vulnerability to drought, spatial and temporal trends of drought on the continent, the relation between drought and land degradation, and the relation between fire and drought. A pilot study of a region vulnerable to drought (e.g., SADC, East, West and Central Africa, the Sahel region) that includes several settings (e.g., both rural and densely populated areas), will be important. In summary, the following activities and outcomes are envisaged:

Activities:

- Setting up a long-term warning and monitoring system of climate change, drought and desertification.
- Providing effective tools for decision makers to develop mitigation and adaptation strategies.

Proposal 6: Dust events and related hazards

The focus of this proposal is dust storms, identified by researchers as one of the hazards that affect several millions of people in Africa. The frequency of dust storms is found to be increasing due to change in land use and land cover that is also related to population growth. The latest estimates put global dust emissions at about 2,000–3,000 million tons each year with half emitted from Africa, where in some parts, annual dust production has increased tenfold in the last 50 years. Dust events are common in Africa where they originate from the desert regions and are transported to the mid-Atlantic region, affecting the east coast of the United States of America. Dust storms transport large amounts of material over long distances and their increasing frequency have serious consequences for the environment as the deposition of dust could affect climate change, marine ecology, and air quality, and contribute to air pollution. It exposes populations to airborne diseases, poses hazards for aviation and highway traffic, and damages crops, according to the World Meteorological Organization (WMO).

Early warning of dust events in the dust affected region will save millions of people from related health hazards. Dust storms that blow across the Sahel region of sub-Saharan Africa are likely to be linked with the lethal meningitis outbreaks that often hit this region where 300 million inhabitants, mostly children and young adults, live. Recent studies have shown that continuous dust loading enhances water vapour, carbon monoxide and meteorological parameters, resulting in further warm-up of the troposphere, with a consequent adverse impact on the climate, monsoon and snow.

Proposal 7: Anthropogenic fires in African savannahs

Biomass burning (BB) is a global occurrence that is a typical feature of the African continent, and as a result of its spatio-temporal extent and intensity, has a wide reaching impact in a number of domains at local, regional and global scales. In particular, BB is used as a farm management practice to prepare farms for the growing season.

For a region where over 70% of the population is involved in subsistence agriculture for their livelihood, about 80% of the West African savannah is burnt annually for agricultural purposes. The resulting bushfire-induced land use change brings with it threshold changes in surface energy fluxes and impacts on the climatology (hydrological cycle) of the region. BB also exposes soils to the weather and enhances erosion, and destroys soil nutrients through heating. Additionally, BB in Africa is a major source of (greenhouse) gases and particles in regional and global atmospheric chemistry and biogeochemical cycles. This is particularly true for the extended BB latitudinal belt spanning the continent from Ethiopia to the Atlantic Ocean, within which hot spots appear (e.g., in Ivory Coast and Ghana), subject to high seasonal and inter-annual variability in location and intensity. This ancestral agricultural practice has extended connections and deep impact at several levels; to list a few:

- Agronomy, ecology, more generally land-use data, including such aspects as crop yields, altered photosynthesis (aerosols modifying radiative transfer), nutrients/toxics inputs by wet/dry deposition to vegetation covers and soils, deforestation, desertification and overgrazing.
- Climate changes induced at all scales (local to continental) by BB gas and aerosol emissions (radiative and cloud condensation nuclei effects on precipitation); and, most generally, all induced socio-economic repercussions to the populations in terms of income, health, water resources, carbon cycle, agricultural production for local markets/industrial (e.g., cocoa, coffee), air and water quality.

9. Implementation of the Science Plan

The revised Science Plan presents the impact of a multitude of hazards and disasters in Africa, and outlines the measures that need to be taken to reduce the risks in a coordinated manner across different hazard types. The emphasis is on coordinated research within an interdisciplinary framework, where impact and vulnerability related to the various hazards are combined to analyse risk. It is clear, however, that implementing the Science Plan will depend on the resources available. The interdependence of the many components of this Plan is critical and the interdisciplinary approach needs to maintain a balance between the various research components, within the constraints of the resources that are available.

The research programme needs to be developed in line with the Science Plans of the other ICSU Regional Offices and the Integrated Research on Disaster Risk (IRDR). This is necessary to avoid the duplication of efforts and to enhance synergies. Furthermore, ICSU ROA recognises that to achieve its objectives it must coordinate research and capacity-building activities with other groups active in Africa, such as the African Platform for DRR, Periperi U, and several other entities, and also to involve policy- and decision makers. In Africa, there are many competing claims to the limited resources available, and the proportion of GDP devoted to scientific research lags far behind that of the developed world. Moreover, governments tend to rely on international donors rather than to build and strengthen research capacity which could be used to facilitate the better use of research outcomes in policy-and decision making.

Working Groups

ICSU ROA has established three working groups for the implementation of the proposals, by drawing on a pool of scientists already engaged in developing research proposals. The ICSU network is as follows:

- Geo-hazards working group*:* This working group would deal with geo-hazards (such as seismic, volcanic and landslide hazards).
- Hydro-meteorological hazards working group: This working group would focus on hydro-meteorological hazards (such as drought, flooding, dust events, anthropogenic fires).
- Vulnerability and resilience working group: This working group would involve both social and natural scientists, and focus on issues of vulnerability and resilience.

Management

ICSU ROA and its task teams will be responsible for the administration, execution, and assessment of the programme. A management team identified by ICSU ROA will be responsible for the scientific organisational structure, and the financial performance of the programme. An internationally appointed Panel of Science Advisors will guide the research, capacity building and outreach agenda. Furthermore, it is suggested that a Steering Committee, comprising experts from the region should guide and support ICSU ROA in managing the regional programme and overseeing its activities.

Budget and fundraising

As mentioned earlier, ICSU ROA has developed various research proposals, several of which still require funding support. It is thus necessary to seek funds from various sources such as the European Union, UNESCO, UNEP, development partners of Africa, and the National Members and Scientific Unions of ICSU. There are limited financial resources in organisations such as SADC, ECOWAS and EAC, and these could assist in soliciting funds for ICSU ROA projects. It is also strongly recommended that African governments be urged to provide financial and material support for these projects.

Networking, capacity building and outreach

The revised Science Plan recognises the need for building research capacity in interdisciplinary research on the science of natural and human-induced hazards and disasters, through a networking approach. The mobilisation of Africa's intellectual resources will undoubtedly be the critical factor in ensuring implementation of the revised Science Plan. In this respect, ICSU ROA can serve as a bridge between African institutions and the international scientific community, as well as local communities.

At the outset, it is essential to prepare an inventory of the research performed and currently carried out by universities and other institutions in the continent. This is necessary to identify gaps and research needs, as well as to avoid the unnecessary duplication of efforts. The proposed inventory might also identify what is missing in existing programmes. Universities that have disaster risk and hazard mitigation programmes can also be identified and urged to contribute to the implementation of the programme.

The proposed interdisciplinary research should develop a long-term programme, through facilitating regular workshops, teacher and student exchange programmes, and outreach activities. In the long term, it is also essential to introduce key research findings into school and tertiary curricula by developing teaching aids (e.g., DVDs, CDs and posters). On-line computer-aided interactive learning modules should be developed, for example, case histories with real data and tutorial exercises (an on-line module is being developed by universities in Mauritius, Malta, and the South Pacific dealing with the vulnerability of islands to natural disasters). Mulungushi University in Zambia has a Disaster Management Training Centre, and the University of South Africa (UNISA), a distance learning institution, offers a module in Disaster Management. Periperi U is a partnership of African universities that spans across the continent and is committed to local disaster risk-related capacity. Established in 2006 with five original members, the partnership has grown to include twelve universities in Algeria, Cameroon, Ethiopia, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, Tanzania and Uganda (http://www.riskreductionafrica.org/).

Strategic partners

This Science Plan needs the support of African scientific institutions as well as regional and international partners for its successful implementation. Several organisations and institutions carry out disaster mitigation in Africa. It is necessary to link and work together with these bodies so that the activities of ICSU ROA complement (not duplicate) existing activities in the region. The African Diaspora should be involved in the implementation of the four Science Plans of ICSU ROA. Work should be done by ICSU ROA to strengthen national, regional and international institutional frameworks to facilitate disaster risk-related information management and sharing. Information regarding research activities (including scientific data, reports and publications) should be disseminated and skills shared through existing networks such as AU/NEPAD, SADC, ECOWAS, IGAD, CEMAC, IOC and other Pan-African structures and establishments.

Some of the institutions that conduct research and capacity building activities are listed below:

- The UNISDR Nairobi office launched the Africa Outreach Programme in October 2002 (UN-ISDR Geneva).
- There is strong emphasis in UNEP on the interaction between natural disasters and the environment. Through its Global Environment Outlook (GEO) project, UNEP has carried out scientific assessments on vulnerability to natural disasters for many regions of the world (UNEP, 2007). For example, UNEP assesses the impact of deforestation on vulnerability to natural disasters. Furthermore, UNEP, in collaboration with the global fire-monitoring centre, coordinates actions to combat large international forest fire emergencies.

- The UN Educational, Scientific and Cultural Organisation (UNESCO) is involved in various programmes related to hazards, including the International Geoscience Programme (IGCP) and some projects of the International Geosphere–Biosphere Programme (IGBP). During the Kobe Conference, UNESCO organised sessions on education for sustainable development, floods and landslides, cultural heritage management, and tsunami mitigation and early warning in the Indian Ocean. It also compiled 90 case studies on good practice in disaster risk reduction.
- Space-based Information for Disaster Management and Emergency Response (SPIDER) is designed to be a gateway to space information for disaster management support; a bridge to connect disaster management and space communities; and a facilitator of capacity building and institutional strengthening. The SPIDER platform will contribute to ensuring that all countries have access to and can use all types of space-based information to support the full disaster management cycle.
- Other relevant UN-related activities include the WMO THORPEX research programme and the UNU/IT Coordinated University Network for Disaster Risk Reduction in Africa (UNEDRA).
- The New Partnership for Africa's Development (NEPAD) promotes food security, poverty reduction and sustainable development, as well as actions that seek to reduce the impact of disasters and other threats, particularly those affecting the environment, agriculture, and health. Concerning Africa, the plan developed at the World Summit on Sustainable Development (WSSD), held in Johannesburg in 2002, urged action at all levels to support Africa in dealing effectively with natural disasters and conflicts.

The ICSU family has several relevant programmes and projects dealing with hazards and disasters. For example: The International Geographical Union (IGU) has a number of commissions on hazards and risks. It focuses particularly on the vulnerability of ecosystems, such as land degradation and desertification, land use change, and population and vulnerability. The International Lithosphere Programme (ILP) promotes themes that include evaluation of seismic exposure, impact on society, economic consequences, and preparedness and emergency response capabilities. The projects of the International Union of Geodesy and Geophysics (IUGG) include a series of activities on geo-hazards, addressing risks in cities, and exploring scientific issues while raising awareness among policy- makers. The International Union of Geological Sciences (IUGS) Programme for Environmental Management deals mostly with urban hazards. IUGS funds the IGCP projects jointly with UNESCO. Geo-Sciences in Africa (GIA), which seeks to promote basic and applied research in geosciences that will improve the quality of life in Africa, was initiated by the IUGG, is supported by the other ICSU Geo-unions such as IUGS, and works closely with the ICSU ROA. The International Union of Pure and Applied Chemistry (IUPAC) has organised meetings on water quality and is deeply concerned with appropriate applications of chemistry in the region.

The International Federation for Information Processing (IFIP) is an affiliate member of ICSU. Among its various technical committees is a special Working Group on Critical Information Infrastructures, which could make an important contribution to projects dealing with vulnerability of IT systems to natural disasters.

10. Way Forward

The mobilisation of Africa's intellectual resources will undoubtedly be the critical factor in ensuring the implementation of this revised Science Plan. Unfortunately, there is a great shortfall in current research on how science is used to shape social and political decision-making in the context of hazards and disasters. Many research projects have failed in Africa because they are not based on local needs, initiatives and material resources. Addressing this problem would require an approach that integrates research and policy-making across all hazards, disciplines and geographic regions. The need for African scientists to work with local communities in evaluating risks and finding ways to respond to risks cannot be overemphasised. In this respect, integrated and co-designed research projects are needed to tap the knowledge base of rural communities and hence foster disaster resilience.

There is also a need to establish dialogue among scientists, and policy- and decision makers. As DRR is not only a technical/scientific problem, any discussion of DRR should involve policy- and decision makers. Research is needed on how to translate research results into policies that minimise the human and economic cost of hazards. In this respect, ICSU ROA can play an important role in promoting and linking scientific research and capacity building to policy and decision makers and society.

We suggest that the programme identifies some initial steps that need to be addressed during the implementation of the revised Science Plan, including steps to develop interdisciplinary science capacity that is currently lacking, and to improve linkages between the production and implementation of knowledge and its use**.** At the outset, it may be necessary to collate African data (e.g., an inventory of research and training programmes, facilitating/inhibiting policies and structures in the process of implementing the revised Science Plan). Hazards and disasters research is highly interdisciplinary which means that during the implementation process, it may face new opportunities (as well as challenges) for further development. Major challenges include working through institutional barriers that make it difficult to facilitate interdisciplinary research and interaction. Although universities may be poised for interdisciplinary research, strategies for faculty preparation and support are lacking. Institutions embracing the concept of team and interdisciplinary science must focus not only on the structural barriers and facilitators, but also on direct support to faculty. Developing interdisciplinary research programmes requires capacity-building through synthesis workshops and developing teaching and training programmes, as well as collaborative communication among researchers during the implementation of the revised Science Plan.

In the framework of an interdisciplinary programme, a database and set of analytical tools for the prediction and mitigation of environmental hazards, risk reduction and disaster management should also be developed. ICSU ROA should ensure the establishment of mechanisms to monitor progress of activities in Africa with regard to hazard preparedness and mitigation. The effects of climate change on various hazards (such as floods and wildfire, for instance) should be addressed through research targeted at hazard early warning, and at the vulnerability/resilience of socioeconomic systems.

In its enabling role, ICSU ROA should leverage the gains of past and ongoing research activities of several development partners such as the World Bank, Sida/SAREC (Sweden), DFID (UK), and CIDA (Canada), in capacity building and needs assessment.

As a way forward, major future activities should also take into account the recommendations of the African scientific community at the review workshop of June 2015, held in Pretoria, South Africa. These included:

1. The identification of what has worked, and what not, in the original Science Plan:
   - There is a need for a change in strategy in the implementation of project proposals. For example, the lack of sustainable funding is a major constraint. What has worked is the implementation of project proposals through networking. This needs to be developed through regular thematic workshops aimed at long-term and sustainable research capacity building.

2. The mode of co-design adopted in the revised Science Plan, as opposed to a design along disciplinary lines:
   - There is a need to develop interdisciplinary research proposals through the interaction of the various components of disaster science. It is also essential, at the outset, to involve policy-makers and stakeholders from civil society in the design or co-design of projects.

3. Sustainability and how to ensure that the revised Science Plan will address what needs to be done:
   - There is no guarantee but, as discussed at the workshop, a dedicated ICSU ROA is a prerequisite for the long-term sustainability of implementation. This, in turn, requires a dedicated interdisciplinary team of researchers. It is also essential to learn from successful projects in Africa through case studies. Further, the active participation of ICSU ROA in African fora is important.

4. Factors that hindered implementation of the original Science Plan:
   - A number of factors might have hindered successful implementation, with funding considered a major constraint. ICSU ROA Projects were proposed without acquiring the necessary and supportive funding, which resulted in a lack of responsiveness by researchers in Africa to new calls for research proposals.

5. The alignment between the revised Science Plan and the Strategic Plan of ICSU:
   - The revised Science Plan was developed within the framework of the ICSU Strategic Plan of 2012–2017, as well as in the context of new developments in the global research agenda; for example, the post Rio+20 Agenda, the Sustainable Development Goals (SDGs), the Sendai Framework for Disaster Risk Reduction (SFDRR), and the Science, Technology and Innovation Strategy for Africa 2024 (STISA 2024), as well as the parallel and subsequent processes that were leading towards the 2015 agreements on Climate Change Adaptation and the Sustainable Development Goals (SDGs).

6. The implementation of the Science Plan at the level of communities:
   - This is a major challenge with no easy solution, but one strategy may be through developing targeted outreach projects in cooperation with local communities. There is also a need to improve effective transfer of information and data from scientists to policy-makers, and to communities, in order to facilitate informed decisions based on scientific evidence.

11. Conclusion

This Science Plan highlights the major challenges, as well as actions that need to be taken to curb disaster losses, and to reduce the extent of damage caused by natural and human-induced hazards and disasters that affect African communities. The successful implementation of the proposed Science Plan will result in better scientific knowledge and understanding of hazards and disasters in Africa, and will provide adequate scientific evidence and skills to guide disaster management policies. However, effective implementation of this Science Plan will require substantial mobilisation of human and financial resources, and of research facilities for training and outreach, as well as extensive regional and international collaboration, partnerships and networking. ICSU ROA offers the opportunity to promote, facilitate and coordinate activities aimed at addressing the challenges facing the African continent, as highlighted in this Science Plan.

Source: https://pixabay.com/en/ashes-eruption-landscape-outdoors-1867440/

Source: https://pixabay.com/en/earthquake-rubble-collapse-disaster-1665890/

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Definition of Terms

Source: http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

Affected	People who are affected, either directly or indirectly, by a hazardous event. Directly affected are those who have suffered injury, illness or other health effects; who were evacuated, displaced, relocated or have suffered direct damage to their livelihoods, economic, physical, social, cultural and environmental assets. Indirectly affected are people who have suffered consequences, other than or in addition to direct effects, over time, due to disruption or changes in economy, critical infrastructure, basic services, commerce or work, or social, health and psychological consequences.
Build back better	The use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment.
Building code	A set of ordinances or regulations and associated standards intended to regulate aspects of the design, construction, materials, alteration and occupancy of structures which are necessary to ensure human safety and welfare, including resistance to collapse and damage.
Capacity	The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience.
Contingency planning	A management process that analyses disaster risks and establishes arrangements in advance to enable timely, effective and appropriate responses.
Critical infrastructure	The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society
Disaster	A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.
Disaster loss database	A set of systematically collected records about disaster occurrence, damages, losses and impacts, compliant with the Sendai Framework for Disaster Risk Reduction 2015-2030 monitoring minimum requirements.
Disaster management	The organization, planning and application of measures preparing for, responding to and recovering from disasters.
Disaster risk	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Disaster risk assessment	A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment o n which they depend.
Disaster risk governance	The system of institutions, mechanisms, policy and legal frameworks and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy.
Disaster risk information	Comprehensive information on all dimensions of disaster risk, including hazards, exposure, vulnerability and capacity, related to persons, communities, organizations and countries and their assets.
Disaster risk management	Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.
Disaster risk reduction	Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.
Early warning system	An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of haz ardous events.
Economic loss	Total economic impact that consists of direct economic loss and indirect economic loss: – Direct economic loss: the monetary value of total or partial destruction of physical assets existing in the affected area. Direct economic loss is nearly equivalent to physical damage. – Indirect economic loss: a decline in economic value added as a consequence of direct economic loss and/or human and environmental impacts.
Evacuation	Moving people and assets temporarily to safer places before, during or after the occurrence of a hazardous event in order to protect them.
Exposure	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard -prone areas.
Extensive disaster risk	The risk of low-severity, high-frequency hazardous events and disasters, mainly but not exclusively associated with highly localized hazards.
Hazard	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

Hazardous event	The manifestation of a hazard in a particular place during a particular period of time.
Intensive disaster risk	The risk of high-severity, mid- to low-frequency disasters, mainly associated with major hazards.
Mitigation	The lessening or minimizing of the adverse impacts of a hazardous event.
National platform for disaster risk reduction	A generic term for national mechanisms for coordination and policy guidance on disaster risk reduction that are multisectoral and interdisciplinary in nature, with public, private and civil society participation involving all concerned entities within a country.
Preparedness	The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.
Prevention	Activities and measures to avoid existing and new disaster risks.
Reconstruction	The medium- and long-term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community or a society affected by a disaster, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk.
Recovery	The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster – affected community or society, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk.
Rehabilitation	The restoration of basic services and facilities for the functioning of a community or a society affected by a disaster.
Residual risk	The disaster risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained.
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.
Response	Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.
Retrofitting	Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards.

Risk transfer	The process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.
Structural and non-structural measures	Structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Non -structural measures are measures not involving physical construction which use knowledge , practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education.
Underlying disaster risk drivers	Processes or conditions, often development -related, that influence the level of disaster risk by increasing levels of exposure and vulnerability or reducing capacity.
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

Acronymns and Abbreviations

ACMAD	African Centre of Meteorological Application for Development
AEO	Africa Environment Outlook
AfSC	African Seismological Commission
AGRHRYMET	Centre for Training and Applications in Agro-hydrology and Meteorology
APINA	Air Pollution Information Network for Africa
AU	African Union
AVU	African Virtual University
BB	Biomass Burning
BBC	British Broadcasting Corporation
CCN	Cloud condensation nuclei
CEMAC	Clean Energy Manufacturing Analysis Center
CERMES	Centre de Recherché Médicale et Sanitaire
CIDA	Canadian International Development Agency
CRED	Centre for Regional Economic Development
DDT	Dichlorodiphenyltrichloroethane
DFID	Department for International Development
DRC	Democratic Republic of Congo
DRR	Disaster Risk Reduction
EAC	East African Community
ECOWAS	Economic Community of West African States
EM-DAT	Emergency Events Database
ENSO	El Niño/Southern Oscillation
FEWS	Famine Early Warning System
GACOF	Great Horn of Africa Climate Outlook Forum
GDP	Gross Domestic Product
GEM	Global Earthquake Model
GEO	Global Environment Outlook
GFMC	Global Fire Monitoring Centre
GHG	Greenhouse gas (emissions)
GIA	Geo-Sciences in Africa
HFA	Hyogo Framework for Action
HIV/AIDS	Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome
ICPAC	IGAD Climate Prediction and Applications Centre
ICSU	International Council for Science
ICSU ROA	International Council for Science Regional Office for Africa

IFIP	International Federation for Information Processing
IGAD	Inter-Governmental Authority on Development
IGBP	International Geosphere–Biosphere Programme
IGCP	International Geological Correlation Program
IGU	International Geographical Union
ILP	International Lithosphere Programme
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IRDR	Integrated Research on Disaster Risk
ISDR	International Strategy for Disaster Reduction
IT	Information Technology
IUGG	International Union of Geodesy and Geophysics
IUGS	International Union of Geological Sciences
IUPAC	International Union of Pure and Applied Chemistry
MODIS	Moderate-Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NEPAD	New Partnership for Africa's Development
NGOs	Non-Governmental Organizations
OFDA	Office for Foreign Disaster Assistance
Periperi U	The university-based platform of Partners Enhancing Resilience for People Exposed to Risks
PTB	Pulmonary Tuberculosis
RAPIDC	Regional Air Pollution in Developing Countries
REWS	Regional Early Warning System
REWU	Regional Early Warning Unit
RS	Remote Sensing
SAC	Satellite Application Centre
SADC	Southern African Development Community
SAFNet	Southern Africa Fire Network
SAMAAV	Studying and Monitoring African Active Volcanoes
SAREC	Swedish Agency for Research Cooperation with Developing Countries
SAUNET	Sustainable Africa University Network
SARCOF	Southern African Regional Climate Outlook Forum
SDGs	Sustainable Development Goals
SEI	Stockholm Environment Institute
SFDRR	Sendai Framework for Disaster Risk Reduction
Sida	Swedish International Development Agency

SPIDER	Space-based Information for Disaster Management and Emergency Response
SREX	Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
SSA	sub-Saharan Africa
STI	Science, Technology and Innovation
STISA	Science and Technology and Innovation Strategy for Africa (STISA-2024)
SWIO	South West Indian Ocean
SWOT	Strength, Weakness, Opportunities and Threats
THORPEX	The Observing System Research and Predictability Experiment
UK	United Kingdom
UN	United Nations
UNEDRA	University Network for Disaster Risk Reduction in Africa
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNISA	University of South Africa
UNISDR	United Nations International Strategy for Disaster Reduction
UNU	United Nations University
USA	United States of America
UTC	Coordinated Universal Time
WHO	World Health Organisation
WMO	World Meteorological Organization
WSSD	World Summit on Sustainable Development

  

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