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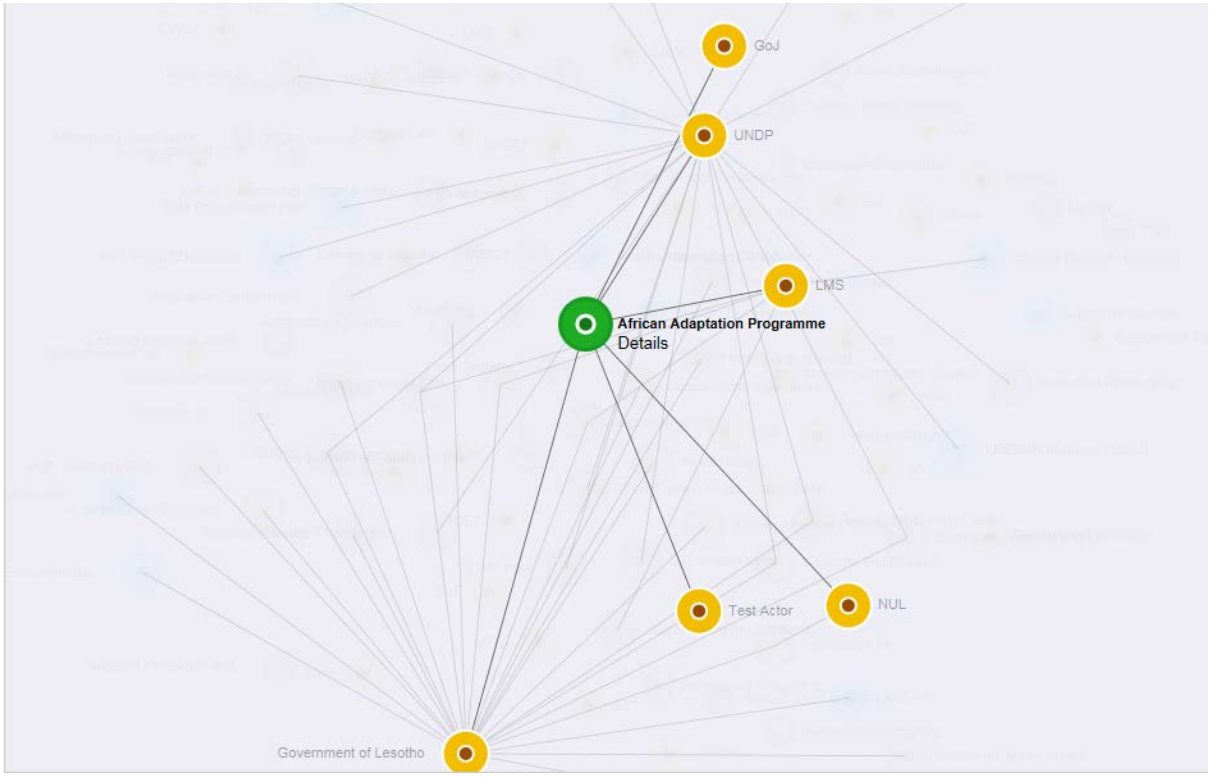
FINAL REPORT:

Climate for Development in Africa (ClimDev) – Climate Sciences and Services for Africa – Strategic Research Opportunities for ClimDev

Professor Robert Wilby

May 2014



Lesotho Meteorological Services Climate Action Intelligence stakeholder visualization tool: http://www.lesmet.org.ls/network-graph

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Executive summary

The purpose of this report is to present the ClimDev Partnership with a set of strategic research options via which the African Union Commission (AUC), African Climate Policy Centre (ACPC) and African Development Bank (AfDB) could achieve tangible development goals, and establish a defining presence in the realm of climate research and resilience planning.

A gap analysis was undertaken using different sources of evidence drawn from bibliographic metrics, previous research prioritisation exercises, peer-reviewed and grey literature, meta-analysis of web-based material, conference proceedings, ClimDev reports and proposal short-listing, an inventory of climate data requests, case studies and consultations with African experts.

The bibliographic analysis reveals accelerating output of climate change research from Africa, albeit from a low base (presently ~3% of the global share of publications). North and middle Africa are identified as regions with particularly low levels of research intensity. These regions also failed to secure any resources from the first round of the ClimDev Special Fund.

Under-represented topics include built environment, coastal zone, human health, tourism and transport. Opportunities also exist for expanding research beyond natural sciences into the social sciences, and emerging frontiers along sector boundaries, such as the water-energy or coastal-urban nexus.

A survey of web-based materials broadly supports the above findings, and shows the incidence of topics and modalities of research. Most favoured activities were web-sites and platforms intended for sharing climate science, evidence and guidance amongst a cross-disciplinary audience**.** International programmes have also contributed significant research that is pertinent to climate change in Africa (e.g., Earth observation, hazard forecasting, and groundwater systems).

An inventory of data requests submitted to the Ethiopian Meteorological Service (EMS) provides a window into user demands over the last decade. Care must be taken not to over-interpret the findings but the records suggest high demand for station-scale, daily meteorological data and monthly summaries for academic research. Large numbers of requests also originate from the construction and agricultural sectors and to a lesser extent from financial services and water. There is evidence of some cost recovery from non-academic and foreign users.

Two case studies were developed to further examine links between adaptation implementation and information needs *within* two key sectors. One explored use of hydro-meteorological data by the renewable energy sector in Lesotho. These data help to estimate resource potential, identification of prospective sites and with economic appraisal. Climate model information is used to assess future yields and potential impacts of extreme weather on infrastructure.

The second case study investigated ways in which climate information is used to manage flood-related health hazards in the rapidly expanding city of Dakar, Senegal. By combining remotely sensed rainfall and sea surface temperatures with epidemiological data causal links were established between conditions in the Atlantic, prolonged, heavy rainfall and outbreaks of water-borne disease (cholera) within flooded areas of the city. Future climate information

is needed to establish acceptable allowances for changed rainfall intensities in drainage system design.

Based on this quasi-objective analysis, six options are proposed for consideration by ClimDev. These research opportunities are summarised in Table E1 (overleaf). In each case, potential synergies with partner programmes and agencies have been identified. Ways in which Clim-Dev might facilitate the research are also suggested.

Some of the proposed options represent expansion of existing initiatives (such as [1] data rescue, [3] outreach to climate information users via climate service forums and [5] a research fellowship programme). Other activities envisage developments along [2] new research frontiers (for built environment, coastal zone, human health, transport, and tourism), or at the interface of disciplines (food-water-energy, coastal-infrastructure), or in regions that have lowest levels of research intensity (as evidenced by publication outputs).

Remaining options involving [4] transposition of climate science into practice, or [6] information exchange and mining of big data, will require considerable innovation. The latter could deliver tools that help minimise duplication of activities, as well as confusion and research fatigue within implementing agencies. These options also depend on close and sustained working relationships with non-academic partners in government ministries, NGOs and industry. Overall, operationalization of evidence of climate risks and response strategies may offer the greatest potential for developing a distinct brand identity for ClimDev.

These options point to strategic partnerships that could be developed by ClimDev (Table E1). Potential partners include: international teams working on data rescue (option 1); the European Union Horizon 2020 programme which covers some nexus themes (option 2); the Global Framework for Climate Services (GFCS) who have experience in bringing climate information suppliers and users together (option 3); the World Bank Water Anchor who are seeking to operationalize climate science for engineers (option 4); research leaders in Africa who can help to articulate ways of overcoming systemic and institutional obstacles to post-doctoral research capacity development (option 5); private sector information technology firms who are assisting AfDB and national meteorological agencies to mine/display ‘Big data’ (option 6).

New technologies in remote sensing and modelling also offer exciting possibilities for filling information gaps in data sparse regions and widening access to data across Africa. Nascent debates around the ethics of climate services point to a future of greater accountability for information providers and practitioners alike.

Table E1 Summary of research options, benefits, synergies (with partner activities) and roles (for ClimDev)

Options	Benefits	Synergies and roles
1. Expanded data rescue initiative: To locate, rescue, digitize, archive and share historic climate data in order to better estimate sustainable resources and track environmental change, to contribute to global climate modelling and evaluation efforts, and to provide a common resource for research and capacity development within Africa.	Increased availability of hydro-meteorological information to support infrastructure construction, adaptation planning (to reduce impacts of extreme events), early warning systems, mapping, spatial planning and decision making, forecast verification, routine reporting, and benchmarking environmental change. Increased access to other metrics such as sea level or sunshine duration, or ancillary data for analysing socio-economic impacts of extreme weather.	WMO data rescue activities; Atmospheric Circulation Reconstructions over the Earth (ACRE); International Environmental Data Rescue Organization (IEDRO); West African Climate Assessment and Dataset (WACA&D). **ClimDev**: Coordinates and funds a coherent data rescue strategy for Africa.
2. New frontiers research programme: To build a more holistic knowledge of climate change impacts and adaptation options for regions (north and middle Africa) and sectors (built environment, coastal zone, human health, transport, and tourism) receiving relatively little attention to date.	Enhanced research capacities and knowledge in neglected sectors and regions, thereby providing fundamental evidence to inform adaptation strategies for 'green growth'. Preliminary evidence of potential impacts on the water-energy, climate-renewable-energy, and coastal-urban systems.	EU Horizon 2020 Programme (Climate Action, Environment, Resource Efficiency and Raw Materials); alignment with national strategies for 'green growth' **ClimDev**: Leads a flagship thematic programme to address key knowledge gaps, and aligns with major funders.
3. Climate service forums: To better understand and meet the climate information needs of communities by commencing the outreach process from the starting point of information needed to achieve adaptation objectives for most vulnerable groups.	Creation of evidence with which to guide more strategic production, communication and delivery of climate information and tools needed to unlock and test adaptation potential. Opportunities to demonstrate case studies in which user-supplier approaches have yielded tangible benefits.	Global Framework for Climate Services (GFCS); Climate Services Adaptation Programme in Africa; Future Climate For Africa (FCFA) Pillar 2. **ClimDev**: ACPC expands the pilot activities of GFCS and hosts a series of national/regional climate service forums, and finances stakeholder-led needs analysis.
4. Operationalizing evidence of climate risks and response strategies*:* To pilot the implementation of climate risk	Provision of scientifically robust but practicable means of climate-proofing investments in development projects, and ensuring consistency in approach across programmes. Attendant governance and review	World Bank Water Anchor; World Bank Independent Evaluation Group (IEG); Alliance for Global Water Adaptation (AGWA); Future Climate For Africa (FCFA) Pillar 3. **ClimDev**: ACPC synthesizes

Options	Benefits	Synergies and roles
information through development of planning guidance or technical advice for practitioners.	structures are in place to enable periodic reviews of underpinning scientific evidence and update of guidelines.	evidence and pilots with partner institutions responsible for infrastructure design and planning.
5. Research fellowship and mentoring programme: To prioritise capacity building and retention especially within non-Anglophone countries in north and middle Africa. The resources would provide in situ long-term support for regional hubs that contribute to wider collaboration across Africa and improve security of tenure for early career researchers in educational facilities.	Research activity is nurtured at grass roots levels, yielding future science leaders, whilst contributing to critical mass in priority regions and topics. Incentives are in place to retain or return research capacity to Africa.	Climate Impacts Research Capacity and Leadership Enhancement (CIRCLE) in Sub-Saharan Africa; senior climate research leaders in Africa. **ClimDev**: Competitively identifies and supports post-doctoral researchers at African institutions.
6. Living data platform to support resource allocation and collaboration: To develop a knowledge-sharing web-platform to ensure that climate information and relevant studies, reports and policy documents are accessible. New technologies such as 'Big Data' are deployed to harvest information for the platform.	Creation of a powerful search engine for prospective funders (to avoid duplication) and researchers (to find potential collaborators). Big-data is used to track trends in research funding and outputs in near real-time, revealing sectors and regions that are receiving little attention relative to their need.	Major donors; private sector information technology; national meteorological agencies; stakeholder networks. **ClimDev**: Partners with AfDB and AidData to enhance existing geo-referenced data platforms such as MapAfrica, or the open risk information and analytical tools of Science for Humanitarian Emergencies and Resilience (SHEAR).

SECTION 1

Introduction

The Climate for Development in Africa (ClimDev-Africa) Programme is an initiative of the African Union Commission (AUC), the United Nations Economic Commission for Africa (UNECA) Africa Climate Policy Centre (ACPC) and the African Development Bank (AfDB). The programme is seeking to deploy climate science in ways that lead to climate resilient development.

ClimDev-Africa is contributing to this vision by supporting activities that enhance the scientific base and observational infrastructure; strengthen partnerships between government institutions, private sector, civil society and vulnerable communities; and improves frameworks for decision-making, awareness and advocacy.

The purpose of this report is to present the ClimDev Partnership with a much narrower set of strategic research options by which ACPC and AfDB in particular could establish a unique presence in the realm of climate research and resilience planning. As a result, hitherto under-represented sectors and regions would be better equipped to manage risks as well as maximise development opportunities presented by climate variability and change.

SECTION 2

Approach

This independent gap analysis was undertaken by triangulating different sources of evidence. These included:

- Bibliographic analysis of peer reviewed researched literature under the broad theme of climate change and Africa, noting sector, author affiliation, and subject preferences.
- Research priorities identified by African climate scientists, lists of topics prepared by international solicitation exercises, and by earlier options appraisal on behalf of the development community.
- ClimDev reports, including the most recent DFID Annual Review (July 2013).
- Intergovernmental Panel on Climate Change (IPCC) reports, peer-reviewed and grey literature, and conference proceedings.
- Meta-analysis of on-line materials describing climate research projects and programmes for Africa, including work supported by major donors.
- Information requests (made to the Ethiopian Meteorological Service).
- Case studies demonstrating the value-added by climate information.

Where feasible, levels of research output were normalised (by population), and priorities have been contextualised (for instance by representativeness of the advocates). Web-based materials were catalogued and counted using a quasi-objective typology (Annex 1). Further clarification or deeper analysis was obtained through consultation with key informants and experts. Potential value-added and entry-points for ClimDev were also identified.

As far as has been feasible, the following summary reflects the views of Africans. No attempt has been made to weight options. However, several criteria should be kept in mind when appraising options (Feed the Future, 2011). These considerations include: relevance to poverty alleviation (especially for most vulnerable groups); likelihood of success (i.e., risk-reward); cost-benefit and economic sustainability; natural resource implications; institutional sustainability and scope for partnership or resource leverage; time frame; scope for sectoral and/or regional integration; and alignment with ClimDev objectives.

SECTION 3

Evidence base

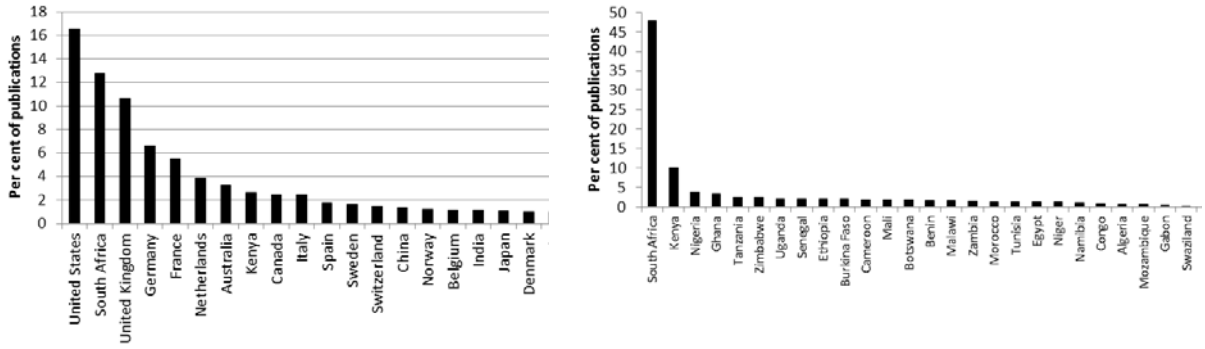
Insights gained from the gap analysis are summarised by evidence source. The following section then distils these results into a coherent set of research priorities.

3.1 Bibliographic analysis

The analysis of publication outputs was undertaken using Scopus on 4 April 2014. The number of journal articles on climate change in Africa has grown exponentially over the last decade and could exceed 400 in 2014 (Annex 2.1). The global share is also rising but is presently just 3% of all climate change research outputs.

Overall, the most prolific publishing nations to date are the United States, followed by South Africa, the UK, Germany and France (Figure 1a). Overall, these five nations account for over 50% of the total output. Within Africa, the top five publishers are South Africa, Kenya, Nigeria, Ghana and Tanzania (Figure 1b). These five nations contributed nearly 70% of the African output; 16 countries account for 90% of output.

Figure 1 Percentage of climate change publications produced by all nations (left) and African authors (right) since 1976. Scopus search date 4 April 2014.



When outputs are normalised by population (UN, 2010) the top five African nations are Botswana, South Africa, Sao Tome and Principe, Namibia and Gabon (Annex 2.1). The least represented nations, ranked by population size are the Democratic Republic of Congo, South Sudan, Somalia, Burundi and Togo (Annex 2.3). These findings are consistent with Pasgaard and Strange (2013) who found that globally author affiliations are skewed away from poorer, fragile and more vulnerable regions.

Overall, there is a clear preponderance for publications by authors in Anglophone countries, and underrepresentation of Francophone nations. When aggregated by region, southern Africa is the most prolific, whereas north and middle Africa generate the lowest volume of research papers (Figure 2a).

Preferred research topics (by decreasing rank order) are food/agriculture, extreme events (flood and drought), energy, ecosystems, water resources and livelihoods. The top four

topics account for 53% of publications (Figure 2b). There are relatively few papers on built environment, coastal zone, human health, tourism or transport.

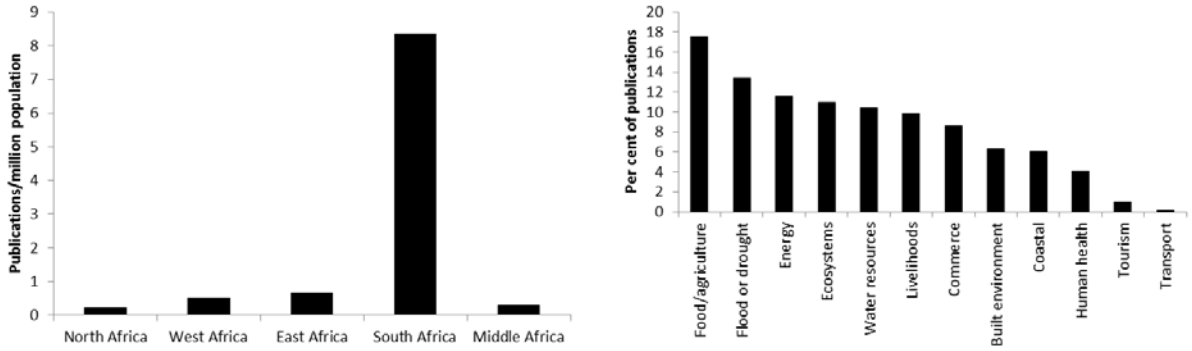
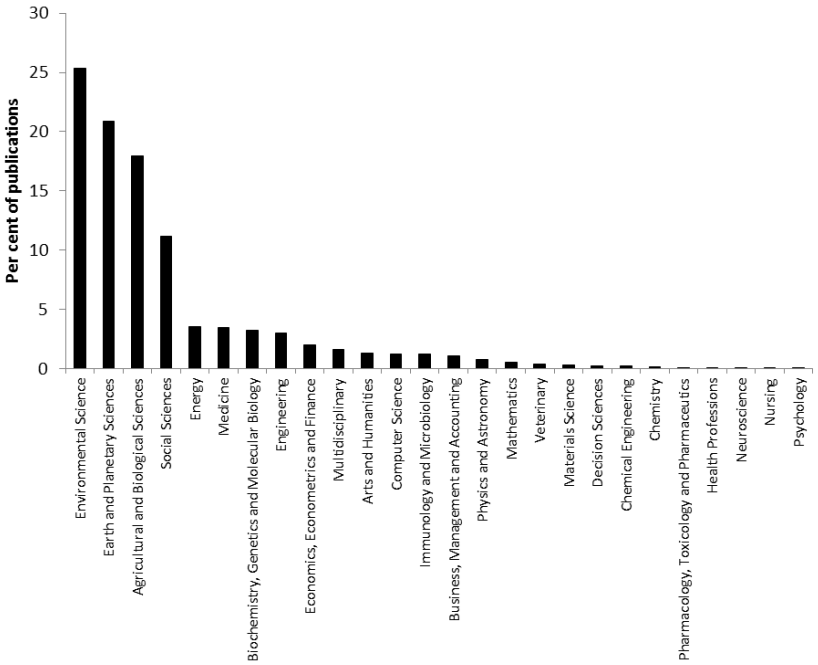


Figure 2 Research publications stratified by author region (top left), sector (top right) and subject area (bottom panel) since 1976 (*N* = 2421)



Overall, the publication profile is dominated by earth sciences: environmental, planetary and biological sciences account for ~75% of the output (Figure 2c). This is reflected in the choice of publication journal (Annex 2.4). Conversely, subject areas such as social science, decision/management, medicine and human health are relatively underrepresented.

3.2 Research prioritisation exercises

There have been many reviews of African climate science and research gaps over the last decade, as well as sector specific assessments of information needs (Box 1).

Persistent themes of the last 10 years include practical concerns about the long-term decline in weather monitoring infrastructure; limited capacity to analyse climate information; obstacles created by poor communications infrastructure, and a thinly dispersed research community. Earlier appraisals strongly advocated seasonal forecasting as a route for

improving knowledge of the African climate systems whilst having immediate utility to decision-makers (e.g., Washington et al., 2004).

Box 1 Example research options appraisal and gap analyses undertaken during the last decade

Africa Climate Conference, 2013. *African Climate Research Agenda for Climate Services and Development*. Annex 1: priorities for Climate Research in Africa. Conference Statement, Arusha, Tanzania, 15-18 October 2018.

African Climate Policy Centre, 2011. *Climate science, information, and services in Africa: Status, gaps and policy implications.* Working Paper 1. United Nations Economic Commission for Africa, Addis Ababa, Ethiopia, 26pp.

Conway, D. 2011. Adapting climate research for development in Africa. *WIRES*, **2**, 428-450.

Edwards, L. 2013. *Global problems, African solutions: African scientists' perspectives on climate change*. Centre for International Governance Innovation (CIGI) Discussion Paper 7, Africa Initiative, Ontario, Canada.

Rosenzweig, C. and Horton, R.M. 2013. Research priorities on vulnerability, impacts and adaptation: Responding to the climate change challenge. *United Nations Environment Programme*, UNON, Nairobi, Kenya, 43pp.

Thomson, M.C., Connor, J.C., Zebiak, S.E., Jancloes, M. and Mihretie, A. 2011. Africa needs climate data to fight disease. *Nature*, **471**, 440-442.

Washington, R., Harrison, M. and Conway, D. 2004. *A report commissioned by the UK Government to review African climate science, policy and options for action*. Department for International Development and University of Oxford, 45pp.

Wilby, R.L. 2007. *Options for improving climate scenarios and impact assessment capacity in Africa, Asia and Latin America*. Prepared on behalf of the Department for International Development. Lancaster University, 40pp.

Major research gaps recognised by African scientists are in urban populations and migration, built environment, clean energy, coastal zone, and mainstreaming of science into practice (Edwards, 2013). These views largely echo the findings of the bibliographic analysis of sector coverage (Figure 2b).

The research agenda emerging from the Africa Climate Conference (ACC2013) provides a snapshot of priorities drawn from a largely African constituency, dominated by academic and research institutions (Annex 3). Broadly speaking, the topics focus on data rescue and diagnosis, climate prediction (over various time-scales), process studies and field campaigns, extreme event attribution, regional impact assessment, model evaluation, decision support and science communication (Annex 1). Given the limited presence of research 'users' at the event, it is unclear whether the list genuinely meets the needs of those engaged in adaptation practice.

A researcher (rather than policy) lens was also applied in the PROVIA consultation (Annex 4). This global critique structured knowledge gaps into information needs to support policy makers, systems (such as food, water, energy) and regions (islands, mountains), and emerging topics. Again, coastal and urban environments, energy systems, and implementing adaptation stand out. There is also recognition of need for research at critical boundaries such as the food-water-energy nexus.

Other reviews paid more attention to the opportunities for strengthening human capital and the wider enabling environment for research (e.g., Wilby, 2007). The above research and information generating activities may not be realised fully without attendant infrastructure and institutional structures.

Priorities include building and retaining human capacities (via incentives, training, leadership development, career progression, project responsibility, hubs, studentships, seed corn funds, etc.); exploiting new technologies (such as cloud computing, global hazard forecasting, telemetry) or sources of information on hazards, vulnerability, exposure and loss (via crowd sourcing, smart phones, big data); communicating and translating science into practice (via coordination platforms, advice for practitioners, media strategies); and strengthening policy and institutional dimensions (by incentivising engagement, legislating and mainstreaming climate resilience, or influencing investment priorities).

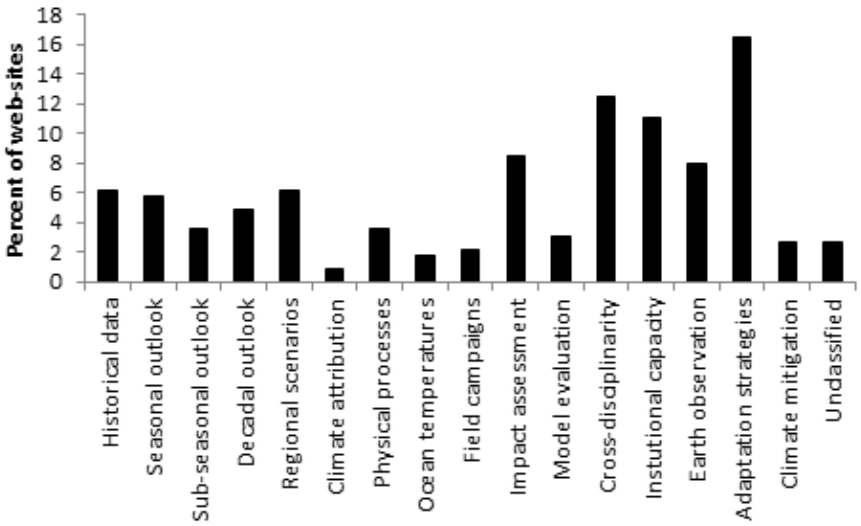
3.3 Meta-analysis of research projects and programmes

The meta-analysis of web-based materials was approached from several angles. The online presence of key funders (research councils, donors, governmental and development agencies, charitable organisations) was trawled for climate science activities. Likewise, funders behind the profiles of leading research hubs (such as the Climate Systems Analysis Group, University of Cape Town) were scrutinised. Research sponsors were also traced via acknowledgements in journal articles.

To give structure to the analysis, ACC2013 research topics (Annex 1) were used to classify the activity of each programme. Additional topics were added to those of ACC2013 to account for emergent research in Earth observation and hazard prediction, adaptation tools and technologies, and climate change mitigation. No attempt was made to weight the projects or programmes, such as by scale of investment or number of partners involved.

The resulting count shows the incidence of preferred topics across the sampled portfolio of climate research funders. More than 90 projects/programmes were registered in the inventory (Annex 5). Most favoured activities were web-sites and platforms intended for sharing climate science, evidence and guidance amongst a cross-disciplinary audience (Figure 3). The stated intent of many of these is to build institutional capacity for adaptation. Regional climate change scenarios and impact assessments are also popular topics. Conversely, relatively few research programmes address the technical challenges of climate attribution, understanding (ocean) drivers of climate variability, or the climate adaptation-mitigation nexus.

Figure 3 Meta-analysis of a portfolio of climate research projects and programmes identified for Africa, catalogued by key priorities identified by ACC2013 (see Annex 1).



International programmes such as EU Copernicus, WCRP CORDEX, EU IMPACT2 and NASA START have global coverage but offer data or knowledge that is pertinent to climate change research in Africa. The EU Framework 7 programme has also been a prominent supporter of research activity in Africa (e.g., AfriCAN Climate Portal; African Monsoon and Multidisciplinary Analyses [AMMA]; CAAST-Net Plus; ClimAfrica; Climate change and Urban Vulnerability in Africa [CLUVA]; Improved Drought Early Warning and Forecasting to strengthen preparedness and adaptation to droughts in Africa [DEWFORA]; Healthy Futures).

The forthcoming *Climate Action, Environment, Resource Efficiency and Raw Materials* theme of the EU Horizon 2020 programme could present significant opportunities for Africa-relevant climate research.

3.4 Applications to the ClimDev Special Fund

The outcome of the first call for proposals issued by the ClimDev Special Fund (CDSF) provides further insight to climate research capacities across Africa. Proposals were invited to address three areas of intervention: 1) generation and dissemination of high quality climate information to support development; 2) capacity enhancement of policy makers and policy support institutions via quality analysis and evidence of climate change; and 3) implementation of pilot adaptation projects to demonstrate the value of mainstreaming climate information in development planning practices.

Nineteen applications were received, of which 10 were compliant with the CDSF template and eligibility criteria. The single application from north Africa did not qualify. Of the 10 projects passing the initial screening, 5 originated from West Africa and 5 from East Africa. The final set of successful applications concentrate on Ethiopia, Kenya, Mali, Niger and Senegal. Four of the projects primarily address intervention 1), the other covers topic 2). The outcome of the CDSF exercise is consistent with evidence in section 3.1 that north and middle Africa have relatively low research capacities even for fundamental climate data collection.

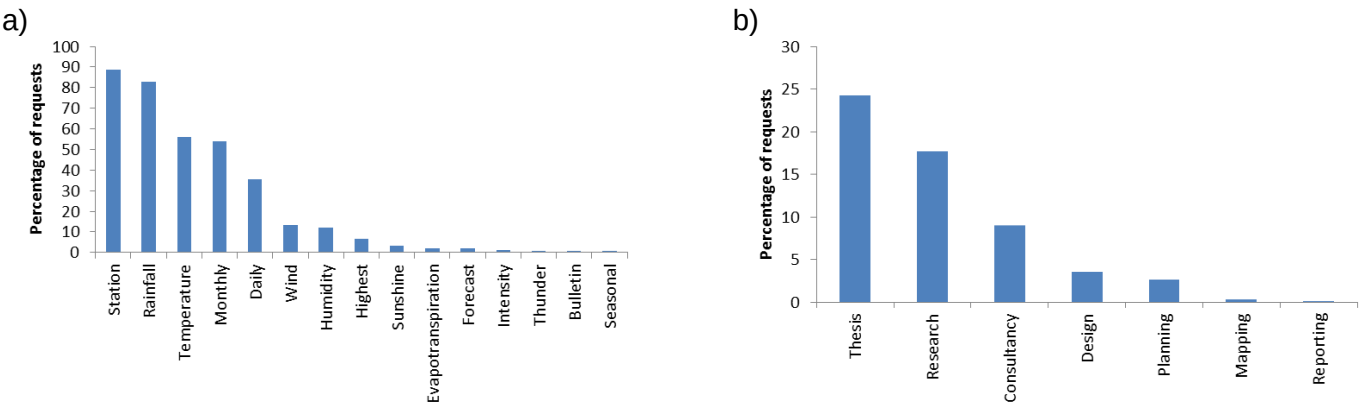
3.5 Demand for climate information/services

Uptake of climate information for risk assessment has been growing steadily since the 1990s, but there are relatively few examples of use in adaptation planning. Indeed, Wilby et al. (2009) assert that globally, scientific efforts on adaptation to climate change is trailing level of activity on impact assessment by nearly a decade. Part of the difficulty in meeting user information/service needs is that they are highly region, sector, time-scale and application specific (Clement et al., 2011). Accordingly, some agencies are concentrating on improving enabling environments by opening access and/or exchange of climate information via on-line platforms[1].

Some data demands may be driven by periodic reporting, or by work-streams emerging from National Adaptation Programmes of Action (NAPAs)[2]. National schemes such as the Productive Safety Net Programme (PSNP) of Ethiopia require regional drought indices to estimate yield reductions and livelihood impacts in order to calculate the overall cost of social protection (Conway and Schipper, 2011).

Aside from surveys of seasonal forecast uptake, characterisation of 'grass roots' demand for climate services in Africa is generally hindered by lack of empirical evidence. Nonetheless, the Ethiopian Meteorological Service (EMS) has provided detailed records of data requests since the late 1990s. Their user demand profile provides insight to the types of information requested, the intended application and sector(s) involved (Figure 4), but the findings should not be extrapolated too far.

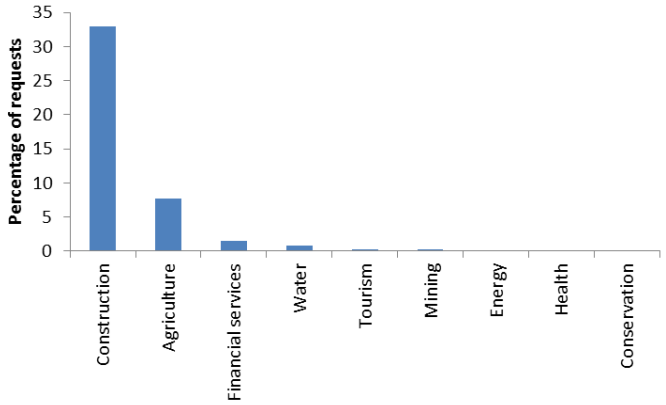
Figure 4 Analysis of data requests to the Ethiopian Meteorological Service 2005-2013 by a) information type, b) intended use, and c) sector



1 See for example the KNMI Climate Explorer: http://climexp.knmi.nl/start.cgi?id=someone@somewhere

2 http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4583.php

c)



The EMS inventory reveals that the majority of requests are for rainfall and temperature data, most likely at monthly resolution (Figure 4a). Demand for other variables (wind, humidity, sunshine, evaporation and thunder) was much lower but this may be an artefact of availability of digital records. Nearly 90% of requests are for station data, presumably reflecting the growing presence of other products (such as the Tropical Rainfall Measurement Mission [TRMM][3] or gridded weather and hazard data) in the public domain. The majority of users seek to apply the meteorological data in further study (MSc, PhD) or research projects (Figure 4b). Consultancy, design and planning applications account for at least 20% of the requests; far fewer are using data for mapping and reporting purposes. An even smaller proportion (~2%) is requesting data in the form of (seasonal) forecasts, monthly bulletins or summaries.

The most prolific users of meteorological data in Ethiopia are the construction and agricultural (including irrigation) sectors, followed by water and financial services (insurance/investment) (Figure 4c). Much lower levels of demand originate from tourism, conservation, energy and health sectors. The total number of data requests across all sectors and applications rose from ~200 per year in 1987 to ~800 per year by 2012. Most of this rise in demand has been due to research and academic study.

There is evidence of some cost recovery in the EMS meta-data, especially from overseas data users and commercial entities. For example, in 2012 three clients were charged more than $50,000 for receiving meteorological data for at least 200 weather stations. Overall income in the same year was in excess of $1.5 million. However, it is apparent that data continue to be made available free of charge to students and researchers who constitute the largest user group.

A recent study of farmers' willingness to pay for agricultural extension services in Benin showed that attitudes are determined by a range of factors including age, gender, level of education, experience in agriculture, access to credit, and farm size (Yegbemey et al., 2014). The research also showed that farmers were more willing to pay for documented climate change adaptation *strategies* than for climate change *predictions*.

The Climate and Development Knowledge Network (CDKN) (2014) scoped the information needs of three prominent African climate data users. Their findings confirmed the heterogeneity of user expectations but a few recurrent themes did emerge. Shared requirements included outlooks for the next 5-10 years, climate model information at local (provincial) scales, strengthening of early warning systems, data to support infrastructure

[3] http://trmm.gsfc.nasa.gov/

planning and design, improved capacity for domestic production of climate model information, techniques for reconciling divergent observed and modelled climate trends, and improved data rescue.

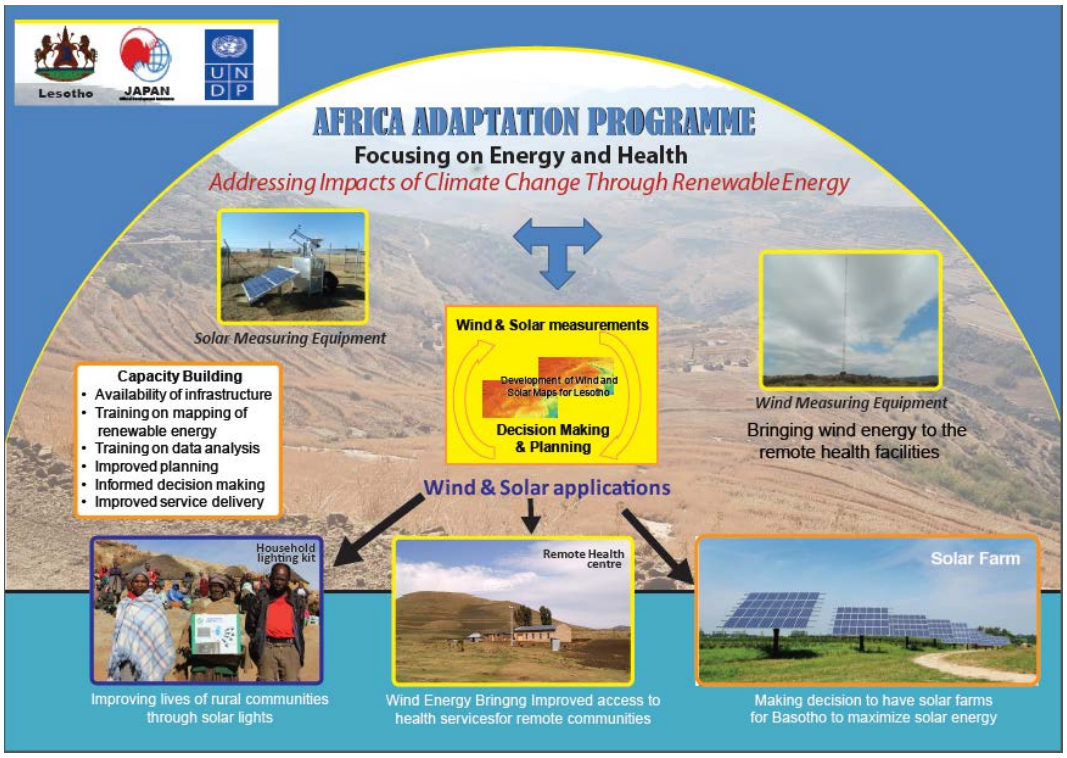
Other surveys also highlight the value of seasonal forecasts and Regional Climate Outlook Forums in enhancing preparedness and disaster response (Hansen et al., 2011). For example, Braman et al. (2013) describe how the International Federation of Red Cross and Red Crescent Societies used a seasonal forecast for West Africa in 2008 to dramatically reduce the time for relief supplies to reach flood victims. Even so, there remains a need to build data bases of sector impacts and to improve translation of forecasts into decision-relevant quantities (Aldrian et al., 2010). Others call for institutional and policy changes to treat meteorological data as a free public good (Hansen et al., 2011). However, reliability of information ultimately remains the major factor in uptake of climate forecasts across all timescales (Conway, 2011).

3.6 Case studies

Two case studies were developed to examine in greater depth the links between climate science and information needs of key sectors.

The first explored the climate information needs of the renewable energy sector in Lesotho (Annex 7; Figure 5). The country is highly dependent on energy imports and vulnerability of the nation's hydropower supply to climate change is recognised. The key objectives of the Government of Lesotho's energy policy are threefold: to improve energy security whilst reducing reliance on imported fossil fuels and electricity; to increase access to energy in rural areas; and to reduce greenhouse gas emissions and other environmental damage associated with energy production.

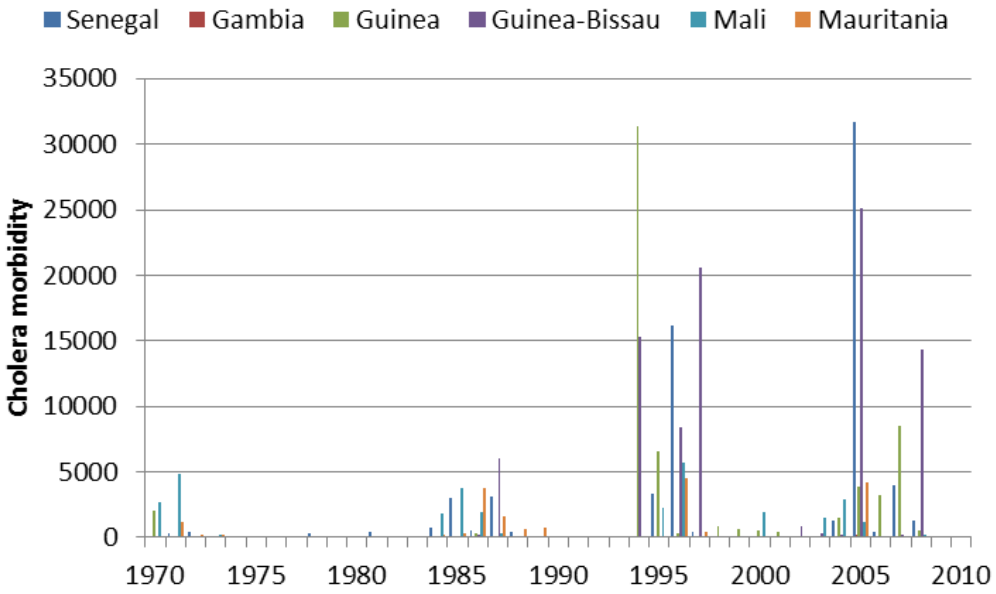
Figure 5 Africa Adaptation Programme focus on energy and health in Lesotho: http://www.undp-aap.org/sites/undp-aap.org/files/Lesotho_Poster_Renewable%20Energy.pdf



Hydrometeorological data are essential for estimating renewable energy resource potential, for identifying prospective development sites and for undertaking economic appraisal. Data to support investment in renewable energy include current wind speed, solar insolation, biomass production and river flow. Information is also needed on future resource potential (given water, wind and solar energy scenarios) as well as for assessing impacts of extreme weather (storms, lightning, cloudiness and dust) on infrastructure. Accordingly, the Africa Adaptation Programme (AAP) embarked on a campaign to strengthen observing networks as well as investments in data storage and training within the Lesotho Meteorological Services (Figure 5).

The second case study illustrates ways in which climate information is used to manage flood-related health hazards in Dakar, Senegal (Annex 8). Rapid, uncontrolled expansion of the Dakar Metropolitan Area has placed about 40% of the peri-urban population at risk from surface flooding, coastal erosion and sea level rise. A major flood episode in 2005 was followed by cholera outbreaks with significant loss of life in Dakar, across Senegal and the region as a whole (Figure 6). The event was preceded by a period of prolonged heavy rainfall which led to flooding of low-lying, poorly drained areas, contamination of untreated water supplies, and displacement of ~50,000 people by standing water.

Figure 6 Annual cholera morbidity in Senegal and neighbouring countries between 1970 and 2010. Data source: WHO (cited in de Magny et al., 2012)



Remotely sensed rainfall and sea surface temperatures (SSTs) were combined with epidemiological data to establish that the epidemic dynamics were strongly weather dependent. The correlation between SSTs and rainfall raises the prospect of seasonal predictability of water-borne disease outbreaks in Dakar (and other African cities). It also demonstrates the value of combining socio-economic and climate data.

Although the multi-decadal outlook for the West African wet season is highly uncertain, there is higher confidence in regional sea level rise projections and an expectation that daily rainfall intensities could increase under climate change. These scenarios point to increased flood risk and associated health hazards in the absence of adaptation. The Senegal Stormwater Management and Climate Change Adaptation Project (PROGEP) has responded to these challenges through investment in new infrastructure and maintenance,

institutional capacity building and stakeholder engagement. Even so, further research is needed to establish acceptable allowances for climate change in drainage system design.

SECTION 4

Research options

Based on the above gap and needs analysis, six options are proposed that could yield early wins for ClimDev by delivering quality outputs that align naturally with the affinities and strengths of ACPC/AfDB. These are loosely organised under the broad ClimDev work areas (data, fundamental science, and implementation). Anticipated benefits and synergies with partner organisations are identified, where possible.

4.1 Expanded data rescue initiative

Objective: To locate, rescue, digitize, archive and share historic climate data in order to better estimate sustainable resources and track environmental change, to contribute to global climate modelling and evaluation efforts, and to provide a common resource for research and capacity development within Africa. This activity would build on the lessons learnt from ClimDev projects to rescue meteorological data and install new equipment in Ethiopia, Gambia and Rwanda (Figure 7).

Figure 7 Hard copies of data held by the National Meteorological Agency of Ethiopia

The approach could be rolled out to other African nations, and aligned with international data rescue efforts (e.g., Atmospheric Circulation Reconstructions over the Earth [ACRE] (Allan et al., 2011), International Environmental Data Rescue Organization [IEDRO]). The remit could be expanded to other metrics such as sea level and sunshine duration, or to ancillary data needed to analyse socio-economic impacts of extreme weather (as in the Dakar case study, Annex 8).

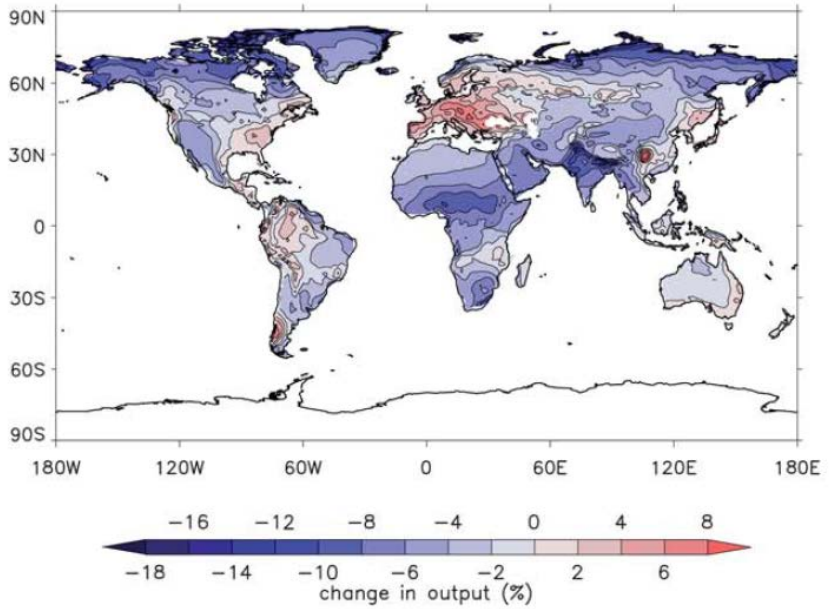
Benefits: Increased availability of hydro-meteorological information to support infrastructure design, adaptation planning (to reduce impacts of drought, floods, and storms), early warning systems, spatial planning and decision making, seasonal forecast verification, routine reporting, and benchmarking environmental change.

ClimDev role: Work with World Meteorological Organization (WMO) Expert Team Data Rescue (ET-DARE)[4] , Voluntary Cooperation Programme (VCP), and other international data rescue efforts[5] ; devise a coherent strategy for hydro-meteorological data rescue in Africa; prioritise most vulnerable assets and data sparse regions; coordinate regional data sharing and diagnostics workshops to mine the information gained (e.g., New et al., 2006).

4.2 New frontiers research programme

Objective: To build a more holistic knowledge of climate change impacts and adaptation options, especially for regions and sectors receiving relatively little attention to date. Based on bibliographic and meta-analysis as well as earlier research prioritisation exercises key gaps are identified in the following sectors: built environment, coastal zone, human health, transport, and tourism. Moreover, there is growing recognition of the need to explore potential consequences and adaptation strategies for the water-energy and climate-(renewable) energy nexus (Figure 8; see also Annex 7).

Figure 8 Percent change in photovoltaic output by 2080 according to a HadGEM1 A1B scenario.



Source: Crook et al. (2011)

Priority might be given to research into the nexus of coastal-urban given the vulnerability of some of Africa's cities to sea level rise (Hallegatte et al., 2013; see also Annex 8). The thematic programme could be used to direct resources to north and middle Africa, or to address climate loss and damage in most vulnerable and/or least research intensive countries (Annex 2.3).

Benefits: Enhanced research capacities and knowledge in neglected sectors and regions, thereby providing fundamental evidence to inform adaptation strategies for 'green growth' (such as low-carbon, diversified energy mix) and climate-resilient infrastructure.

ClimDev role: Leading a flagship thematic programme on priority topics and regions; ensuring that the commissioned research is explicitly tied to development objectives. There

4 http://www.wmo.int/pages/prog/wcp/ccl/opace/opace1/et-dare.php
5 http://www.meteobal.com/climatol/DARE/

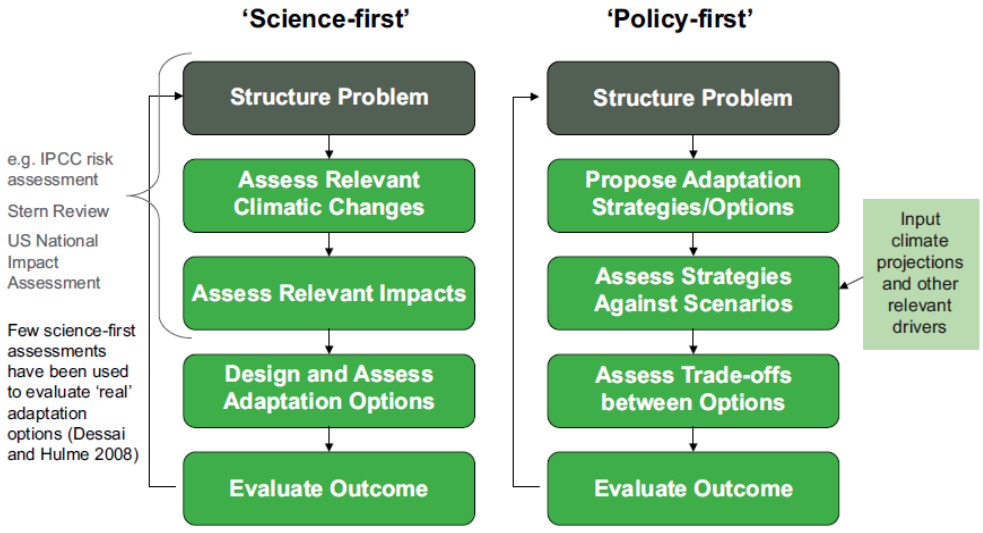
may also be potential to align and leverage resources from the *Climate Action, Environment, Resource Efficiency and Raw Materials* theme of the forthcoming EU Horizon 2020 programme.

4.3 Climate services forums

Objective: To better understand and meet the climate information needs of vulnerable communities. This activity would build on insights gained from the 2011 ACPC consultation workshop in Ethiopia, and from the 2012 Global Framework for Climate Services (GFCS) pilot projects in Burkino Faso, Chad, Mali and Niger (Tall, 2013). The participatory forums would increase opportunities for interaction between national meteorological and hydrological service providers and their user constituencies. Participation by communities (including youth representatives) would enable 'shared perceptions of urgency' to emerge (Conway and Mustelin, 2014). Where national capacities are very low, regional forums could be convened. The unifying theme would be to develop information flows that meet the needs of most vulnerable groups.

A key innovation would be to commence outreach processes from the starting point of information demand to achieve adaptation objectives (i.e., 'policy-first'), rather the more conventional initial point of climate information supply (Figure 9). The proposed forums would also create opportunities to demonstrate case studies in which user-provider partnerships have yielded tangible benefits. Other activities might include stakeholder mapping, surveys of user needs and expectations, plus research into the cognitive processes involved in the translation and uptake of climate science.

Figure 9 Comparison of stages involved in science-first and policy-first approaches to identifying and evaluating adaptation options. Note the late entry point for climate risk information in the policy-first approach.



Sources: Dessai and Hulme (2007) and Ranger et al. (2010).

Benefits: Creation of evidence with which to guide more strategic production, communication and delivery of climate information and tools needed to unlock and test adaptation potential. Over time, a catalogue of exemplar projects would be assembled that would act as a blueprint for new entrants. Roles and responsibilities of science producers, communicators and users would be clearly delineated.

ACPC role: Host national/regional forums to strengthen climate services and commissions surveys of user needs; creates a specialist working group that would convene each year at the ClimDev Annual Conference. Note that these activities map well to Pillar 2 of the Future Climate for Africa call (*researching how stakeholders interpret and use climate information and tools for decisions*).

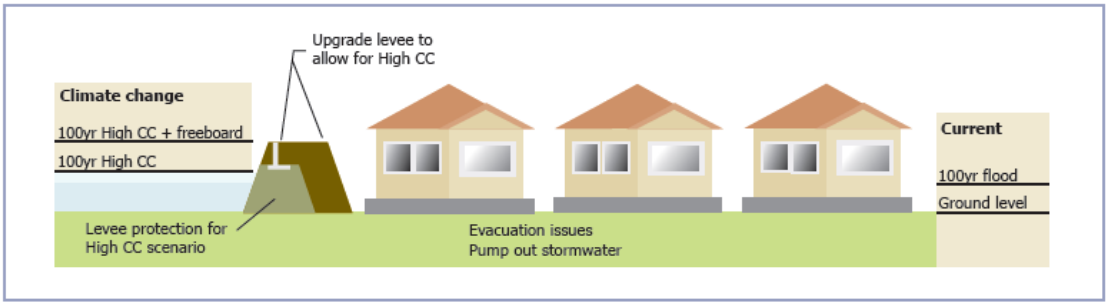
4.4 Operationalizing evidence of climate risks and response strategies

Objective: To pilot implementation of climate science through development of planning guidance or technical advice for engineers. Thus far, most examples of this kind are found in developed regions (Annex 9 and Figure 10), but the World Bank is pioneering relevant techniques in the project 'Enhancing the Climate Resilience of Africa's Infrastructure'. ClimDev would work with relevant ministries and professional bodies to co-produce the guidance.

Figure 10 Extract from *Floodplain Risk Management Guideline – Practical Consideration of Climate Change*.

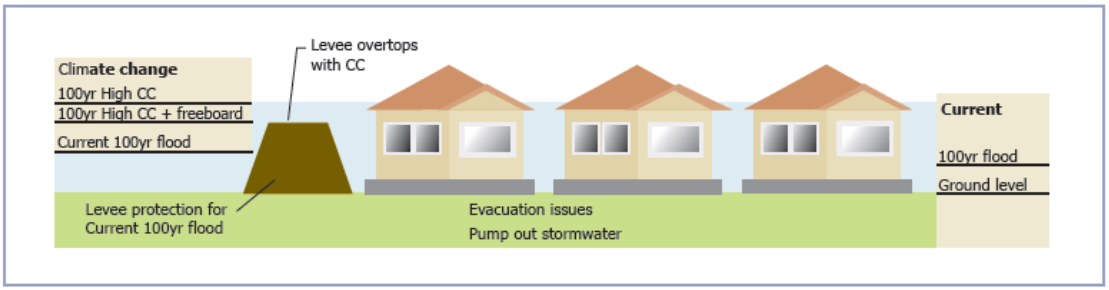
Strategy Existing 5 – Build New Levee for Existing Flood Situation but Design to Enable Upgrading for Climate Change or Examine the Ability to Upgrade an Existing Levee for Climate Change

Levee provides protection to property for high climate change impacts and existing flood risks once upgraded.



Strategy Existing 6 – Build New Levee for Existing Flood Situation Without Climate Change Allowance

Levee provides protection to property for existing flood risk but protection reduces overtime due to climate change impacts.



Source: NSW DECC (2007)

An alternative strategy is to operate at city-scale when adapting long-lived infrastructure (as in the case of flood defences in New York, or London). Wider consideration would be needed of the attendant governance and review structures (i.e., the interval between periodic reviews of underpinning scientific evidence and update of guidelines). Economic appraisal would be required to determine cost-benefit at various levels of climate proofing. The approach should be trialled in a few pilot ministries then used to showcase benefits.

Benefits: Provision of scientifically robust but practicable means of climate-proofing investments in infrastructure projects, and ensuring consistency in approach across programmes. The work could also provide a focal point for regional climate modelling and impacts research (to address recognised model deficiencies in representing extreme events e.g., heavy rainfall, tidal surge and droughts).

ClimDev role: There is potential for ACPC to pilot techniques and develop a niche activity in this area given limited implementation in Africa. There is also considerable scope to build on existing collaborations with major investors (e.g., World Bank) and NGOs (e.g., Alliance for Global Water Adaptation) who are actively exploring such ideas. Furthermore, the activity maps well to Pillar 3 of the Future Climate for Africa call (*informing specific medium-term decisions, for example, concerning a local adaptation strategy, an urban development plan, or a water infrastructure design*).

4.5 Research fellowship and mentoring programme

Objective: To prioritise capacity building and retention especially within non-Anglophone countries in north and middle Africa. Resources would build in situ, long-term support for regional hubs to stimulate international collaboration and improve security of tenure for early career researchers in educational facilities. Calls would be aimed at post-doctoral applicants and provide salary enhancements (analogous to the UK Wolfson scheme) to remain in country, with accompanying PhD studentships to build critical mass around named researchers. Ideally, investments would simultaneously address grand challenge scientific questions, make provision for mentoring and development of next generation research leaders in Africa, and link fellows by twinning teams (see Annex 6).

Benefits: Research activity is nurtured at grass roots levels, yielding future science leaders, whilst contributing critical mass in priority regions and topics. Incentives are in place to retain or return research capacity to Africa. The scheme should be carefully designed such that benefits accrue to both the fellow and host institution. The scheme would deliver an increase in internationally peer-reviewed research outputs, particularly by African women. Over the long-term, investment in local researchers (as opposed to external technical assistance provided by consultants) is more likely to result in effective engagement and delivery of adaptation projects involving communities (Conway and Mustelin, 2014).

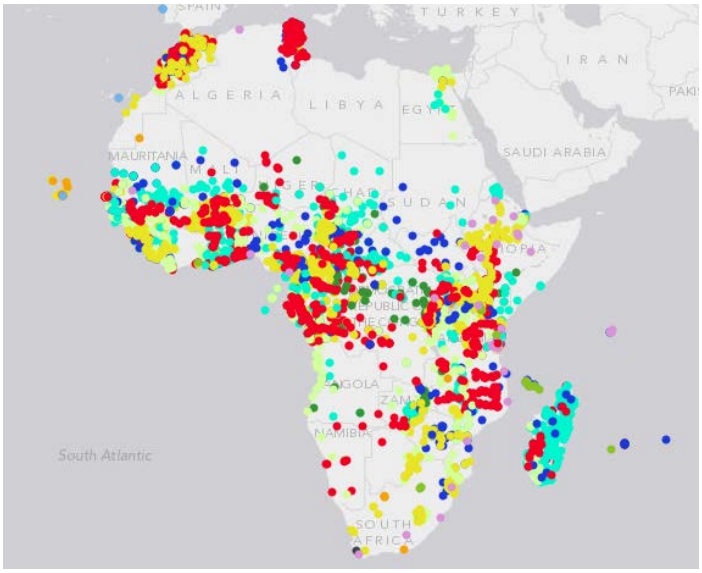
ClimDev role: Issue directed call(s) (perhaps in the priority topic areas of 4.2); screen and fund applicants; support networking events for fellows and international partners. Calls should be aligned so as to avoid duplication of priority research themes addressed by other programmes (such as Climate Impacts Research Capacity and Leadership Enhancement (CIRCLE) in Sub-Saharan Africa).

4.6 Living data platform to support resource allocation and collaboration

Objective: To develop a knowledge-sharing web-platform to ensure that climate information and relevant studies, reports and policy documents are made publicly accessible (as stated in the ClimDev 2013-2014 Work Plan). This is not a particularly novel proposition since

nearly 20 such platforms (albeit most with a single sector focus) were identified during the course of the web-based meta-analysis (Annex 5). For example, the Climate Action Intelligence platform of the Lesotho Meteorological Services helps to visualise stakeholder and research networks[6]. Likewise, AidData and AfDB have recently launched MapAfrica: a dynamic, online platform that geocodes development projects since 2002 (Figure 11).

Figure 11 MapAfrica geo-referenced development projects in Africa 2003-2013 for key sectors (agriculture, communications, finance, environment, industry, multi-sector, power, social, transport, water supply and sanitation).



Source: http://mapafrica.afdb.org/

Despite the above developments, there remains scope for a bespoke tool to provide convenient accesses to all projects and programmes that are actively engaged in climate research across Africa. New technologies and 'Big Data' could be deployed to harvest and geo-reference information, ensuring that the platform is a 'living' tool.

Benefits: If the underpinning data base was searchable this could create a powerful tool for prospective funders (to avoid duplication) and researchers (to find potential collaborators). Big-data could be used to track trends in research funding and outputs, revealing sectors and regions that are receiving little attention relative to their need (determined by metrics such as reports of extreme weather events).

ClimDev role: Coordinate the initiative and gather primary data to implement a prototype platform. Ideally, institutions identified in Annex 5 would unite behind and benefit from the service. Possibilities exist for collaborating with companies with expertise in super-computing and mining 'Big Data'[7]. One option would be for AfDB and AidData to include additional search fields for climate change within MapAfrica. There may also be synergies with the open risk information and analytical tools envisaged by the Science for Humanitarian Emergencies and Resilience (SHEAR) project.

6 http://www.lesmet.org.ls/network-graph

7 http://www.climatecentral.org/news/white-house-brings-together-big-data-and-climate-change-17194

SECTION 5

Strategic partnerships and value added by ClimDev

According to the ClimDev (2013) Annual Report "*the ClimDev-Africa Programme draws its strength and strategic value from the comparative advantage that each of the partners brings on board*". These strengths are political leverage and leadership (AUC), the policy basis for strategic investment (ACPC), development and implementing activities (AfDB). The programme also draws on other partnerships to mobilise expertise, plus extend the reach and delivery of activities.

Current funding partners include: the European Union Commission (EUC), the UK Department for International Development (DfID), the Swedish International Development Agency (SIDA), the United States Agency for International Development (USAID), the African Caribbean Pacific (ACP) 10thEDF Intra-ACP and the Nordic Development Fund (NDF).

ACPC has formalised strategic partnerships with 28 organisations. Some are internal to the ECA and intended to support implementation particularly in the realms of economic impacts, agriculture resilience and gender dimensions of climate change. ClimDev also aspires to work more closely with national meteorological and hydrological services in Africa, and has begun strengthening infrastructure in three pilot countries (Ethiopia, The Gambia and Rwanda). Agreements have been signed with 14 institutions with expertise in climate change impacts and policy responses. These partners include African universities (e.g., Bunda, Malawi; Addis Ababa, Ethiopia) and foreign institutes (e.g., IDS, IRI, ILRI, TERI).

Strategic partnerships developed by AfDB include the Global Dry Lands Alliance (GDLA), CGIAR's programme on Climate Change Agriculture and Food Security (CCAFS), plus ongoing initiatives with WMO and GCOS to strengthen observing systems.

The gap analysis and summary of research options suggests that other strategic partnerships could be developed by ClimDev (Table E1). For example, a more ambitious programme of data rescue and digitization (option 1) would benefit from the technical expertise and international forums hosted by projects such as ACRE and IEDRO. High-level discussions might be held between ClimDev and administrators of the EU Horizon 2020 programme to determine scope for alignment of research streams that fit with the 'green growth' agenda (option 2). The GFCS and parts of the FCFA programme are, like ClimDev, seeking to enhance climate services (option 3) as well as the utility of climate research to practitioners (option 4).

ACPC is well-placed to develop partnerships with African ministries leading to the co-production of technical/planning guidance for new infrastructure – an objective shared by donors such as the World Bank (option 4). To date, initiatives to grow post-graduate research capacities within Africa have tended to be piece-meal (relative to the need) and fragmented. ClimDev could draw on the experience of programmes such as the Climate Science Research Partnership (CSRP) and perspectives of senior researchers in Africa (see Annex 6) to deliver a more ambitious, better coordinated and strategic fellowship programme for the continent (option 5). Likewise, new technologies for harvesting and geo-referencing

data could be used to avoid duplication and maximise collaboration across climate research programmes (option 6). AfDB is very well placed to broker partnerships between private and public sector organisations to achieve this goal.

SECTION 6

Concluding remarks

This report has assembled evidence showing key knowledge gaps and opportunities for ClimDev to support strategic climate research in Africa. It is imperative that prioritisation of investments is African-led, and that initiatives are driven by the information needs of African decision-makers and communities. As far as possible, this review has attempted to honour these principles.

Some of the proposed options represent expansion of current activities (in data rescue, human capacity development, and outreach to climate information users). Others envisage developments along new research frontiers (for built environment, coastal zone, human health, transport, and tourism), or at the interface of disciplines (food-water-energy, coastal-infrastructure), or in regions that have lowest levels of research intensity (as evidenced by internationally peer-reviewed research output).

Remaining options involving transposition of climate science into practice, or mining of Big-data, will require technical innovation and co-production of tailored information by researchers and practitioners. This will depend on close and sustained working relationships with non-academic partners in government ministries, NGOs and private sector. However, the operationalization of climate science perhaps offers the greatest potential for developing a distinct brand identity for ClimDev.

If developing any of the options, ClimDev will need to be mindful of other conceptual and practical issues that are emerging across the wider climate science community. Not least is the debate about how to avoid "climate exceptionalism"[8] and consider a much wider set of information (beyond climate observations and scenarios) within a more holistic approach to risk governance.

At the same time, there is growing interest in the development of ethical standards and codes of conduct for climate services providers. Some are even questioning the utility of conventional, scenario-led modes of adaptation planning and are calling for a smarter approach to climate model application. These two points are related since there are tensions surrounding the production of higher resolution climate information versus the danger of perpetuating a myth that more precision equals more accuracy. Fortunately, such matters are beginning to be recognised by scientists involved, for example, in the CORDEX project.

There are also wider philosophical and economic concerns around access to data. Some regard environmental information as a public good and urge data holders to improve freedom of access to such assets. Others are concerned about the recurrent costs associated with observing networks and data management, so promote policies of cost-recovery. Discussions about the value of data and the cost-benefit of adaptation touch on the highly problematic, technical challenge of deriving counter-factuals for avoided damages. The unavoidable truth, however, is that restricted access to climate information (whether publicly or privately held) represents a significant impediment to adaptation at all levels.

8 http://www.economist.com/news/science-and-technology/21600080-new-report-ipcc-implies-climate-exceptionalism-notion

Finally, new technologies in remote sensing, hazard forecasting and mapping have the potential to overcome some of these obstacles by placing climate products on-line, in the public domain. For example, national-level early warning systems are beginning to be superseded by *global* forecasting capabilities for floods, landslides and droughts. These tools are particularly potent for transboundary hazards or in situations where neighbouring states do not cooperate with data exchange. Meanwhile, crowd sourcing techniques are creating opportunities to gather real-time, geo-referenced information on hazard extent and local consequences. Such tools offer exciting possibilities for filling information gaps in data sparse regions, and thereby reaching some of the most disadvantaged, climate-impacted communities in Africa.

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Annex 1 A typology of research topics based on the *African Climate Research Agenda for Climate Services and Development* presented in no particular order. Additional categories *N, O, P* and *U* have been added.

Code	Research topic
A	Recovering, digitizing, and analysing historical surface (climate) data*
B	Improving seasonal climate prediction through better understanding of drivers
C	Improving understanding of sources of sub-seasonal predictability
D	Improving understanding of drivers of decadal multi-decadal variability
E	Developing climate change scenarios at regional and local levels for adaptation
F	Refining methodologies for attributing climate events
G	Improving understanding of physical processes and feedbacks
H	Improving understanding and prediction of sea surface temperature variability
I	Developing short-term intensive field campaigns
J	Developing impact data bases to aid development
K	Improving the characterization and evaluation of model forecasts (all time-scales)
L	Strengthening cross-disciplinary research to better communicate projected impacts
M	Building the research capability of institutions
	Additional topics
N	Improving Earth observation and hazard prediction systems
O	Developing technologies, tools and adaptive strategies to build resilience
P	Assessing climate change mitigation options
U	Unclassified

* Taken to include climate change indicators such as bio-monitoring

Annex 2 Results of bibliographic analysis. Scopus search date 4 April 2014

Figure 2.1 Total number of climate change publications (Scopus) for Africa since 1976.

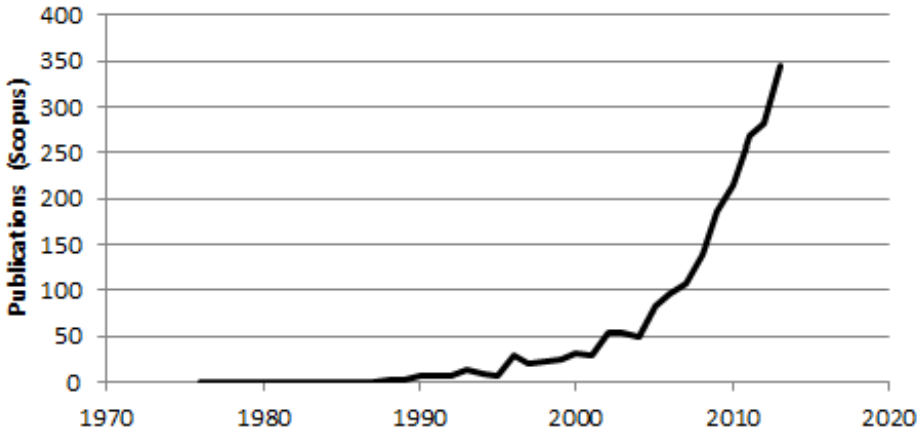
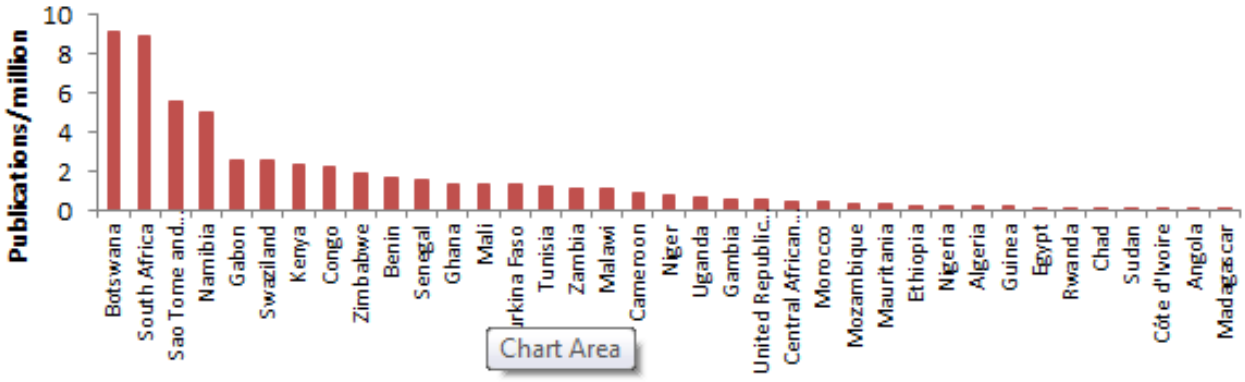


Figure 2.2 Number of publications per million population (African countries only) since 1976.



EVIDENCE ON DEMAND
CLIMATE & ENVIRONMENT
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Figure 2.3 Counties with least publications since 1976 ranked by population size (UN, 2010).

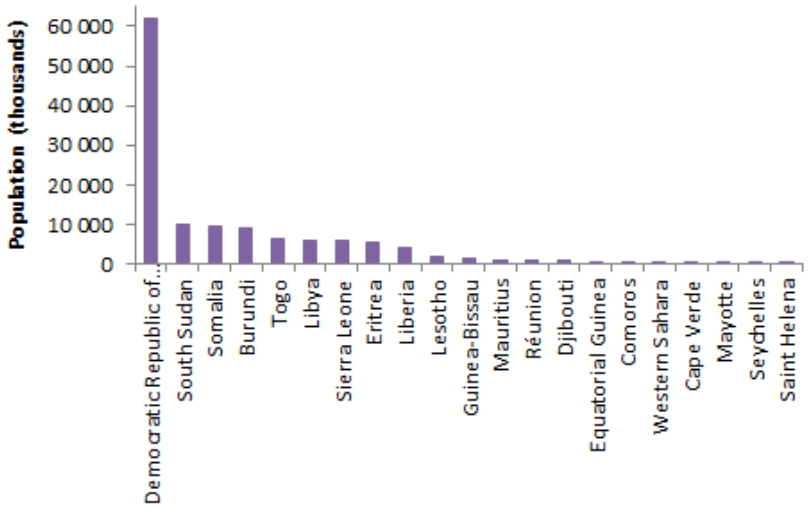
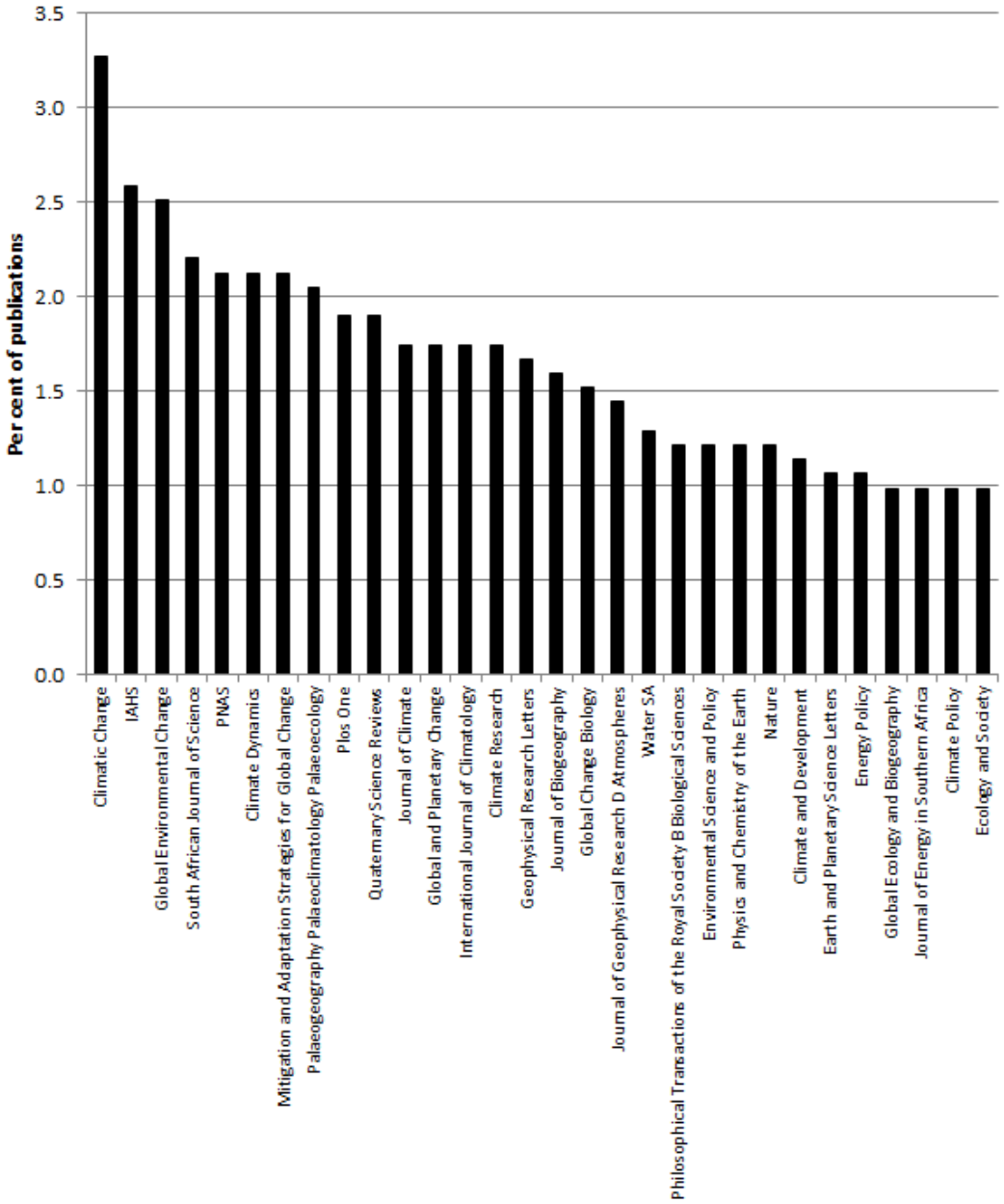
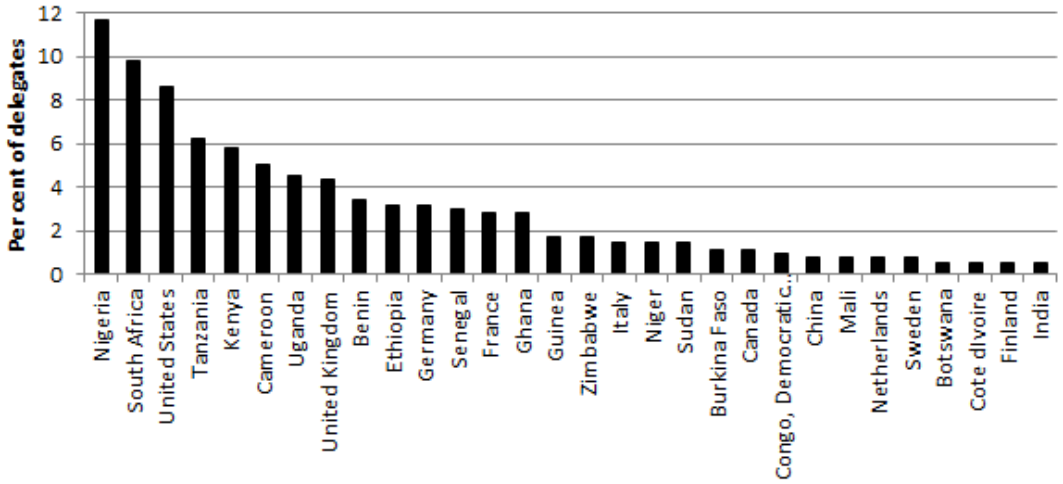
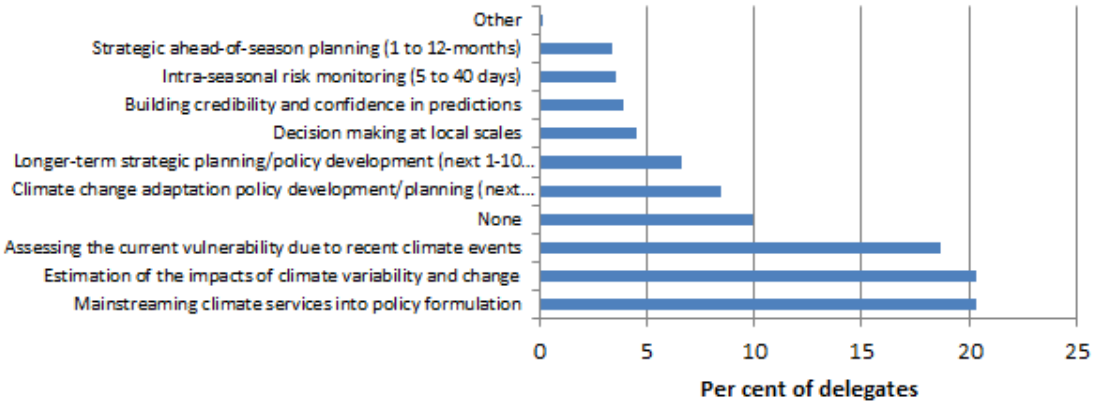


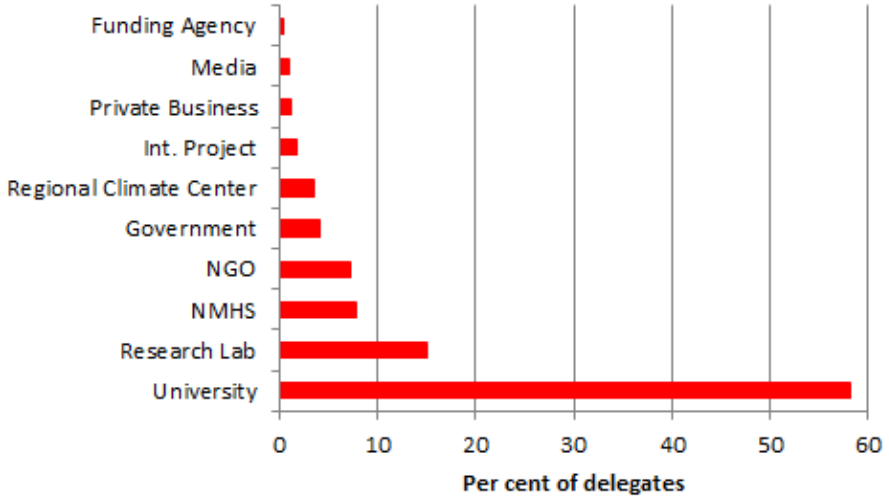
Figure 2.4 Per cent of all Africa climate change publications (Scopus) by journal since 1976.



Annex 3 Analysis of ACC2013 delegates by country of origin (top), topic area (middle), and organization type (lower panel)







Annex 4 PROVIA research priorities on vulnerability, impacts and adaptation (VIA). Highlighted options reflect the priorities of African scientists cited by Edwards (2013).

A. Information to Support Policy Maker Decisions	
A.1.1 Measure and Map Vulnerability	*Develop a robust framework to define, measure and map vulnerability and the most vulnerable groups (based on gender, age, poverty and other factors), sectors, ecosystems and places in order to determine where adaptation is most needed*
A.1.2 Develop and Strengthen Indicator and Monitoring Systems	*Formulate cost-effective indicators and monitoring for tracking impacts, changes and the crossing of thresholds related to climate, ecological and socio-economic systems*
A.1.3 Understand Risks of Extreme Climate Events, Non-Linear Impacts and Tipping Points	*Improve understanding of risks and uncertainties related to the impacts of extreme climate events (including low probability, high-impact events), non-linear impacts and tipping points*
A.2.1 Develop Integrated Solutions	*Research integrated approaches that maximize adaptation, mitigation and sustainable development benefits while minimizing economic, social, environmental and other costs*
A.2.2 Identify Factors that Support or Hinder Vulnerability Reduction and Adaptation	*Identify economic, financial, political, legal, institutional, psychological, social and cultural factors that support, or act as barriers to, vulnerability reduction and adaptation*
A.2.3 Conduct Focused Research on Implementation	*Advance understanding of the opportunities and challenges of implementing adaptation (e.g., integrating adaptation into planning frameworks and budgets, coordinating activities across agencies, the private sector and other entities)*
A.3.1 Improve Approaches for Valuing Adaptation	*Create effective and innovative approaches to measure and value the monetary and non-monetary aspects of short- and long-term adaptations and mal-adaptations and to compare these across groups, sectors, regions and timeframes*
A.3.2 Advance Criteria for Prioritizing Adaptation Strategies	*Investigate a range of evaluation criteria for prioritizing adaptation decisions*
A.4.1 Conduct Studies on Communication, Participation and Capacity Building	*Analyze how to build capacity of local communities and institutions (including government, educational and research organizations, media outlets, the private sector and other practitioners) to communicate about and participate in climate change and VIA activities*
A.4.2 Determine how Communication between the VIA Research Community and Policymakers can be more Effective	*Improve ways that VIA researchers and decision-makers interact*
A.4.3 Advance Research on Lessons Learned from Developing Country Experiences and Local and Traditional Knowledge	*Conduct research on how developing country VIA research and activities and local and traditional knowledge can inform global knowledge*
B. Systems and regions	
B.1.1 Food Systems	*Understand how food systems, including production, processing, distribution and access will be impacted by and adapt to climate change and extreme events and how these impacts and adaptation strategies interact with other stresses*
B.1.2 Water Systems	*Build greater knowledge about water use/ demand, availability and quality in relation to water use decisions, water law and governance, under changing climate and other stresses*

B.1.3 Ecosystems	*Investigate how ecosystems and their management will be affected by interactions between climate change and other ecosystem stressors including air pollution, overfishing, wildfires, loss of biodiversity, invasive species and disturbance regimes*
B.1.4 Energy Systems	*Determine how climate change will influence energy production, distribution, demand and consumption, including renewables like hydropower, wind, solar and bio-energy*
B.1.5 Infrastructure Systems and the Built Environment	*Examine the impacts of climate change on infrastructure and buildings, focusing on extreme events, multiple stresses and interactions with mitigation*
B.2.1 Human Health	*Advance research on climate change and human health, including health sector adaptation*
B.2.2 Human Security and Risk of Conflict	*Investigate how climate change modifies human security and the risk of conflict through changes in resource scarcity, likelihood of migration, capacity of the government to respond and frequency and intensity of extreme weather events*
B.3.1 Vulnerable Coastal Areas and Islands	*Increase understanding of VIA and natural processes in the most vulnerable coastal areas, which include mega deltas, coastal wetlands, islands, coral reefs and coastal cities*
B.3.2 Arid and Semi-Arid Regions	*Focus studies on VIA issues facing arid and semi-arid regions, including water quantity and quality, deforestation and fire*
B.3.3 Open Ocean	*Explore key open ocean topics in need of further research, including ocean acidification, the carbon cycle of the ocean, changes in the marine food chain and potential for regional de-oxygenation*
B.3.4 Mountain Regions and the Cryosphere	*Advance understanding of VIA issues facing mountain regions and the cryosphere (e.g., glacier retreat, changes in streamflow and runoff, loss of livelihoods and unique ecosystems and the emergence of new regional development opportunities)*
B.3.5 Urban Areas	*Investigate the VIA issues related to urban areas, including how cities are playing a leading role in early adoption of both mitigation and adaptation policies*
C. Emerging topics	
C.1 Transformative Change	*Explore the potential for, and VIA implications of, transformative change and transformative learning in social-ecological systems*
C.2 Impacts of Geoengineering	*Investigate the potential impacts of geoengineering, including implications of unilateral actions and unintended consequences*
C.3 Legal Principles and Role of Law	*Improve understanding of legal challenges related to climate change and the role of law, legal tools and legal principles in promoting or preventing adaptation*
C.4 Food-Water-Energy-Security Nexus	*Apply a systems approach to the food-water energy- security nexus that considers cross-sectoral interdependencies, transboundary impacts and adaptation tradeoffs (e.g., potential conflicts over water use in agriculture and energy generation)*
C.5 Participatory Processes for Mitigation and Adaptation Scenarios	*Create protocols that enable stakeholders to explore mitigation and adaptation decisions, such as scenario processes based on Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs)*
C.6 Integrated Impact Model	*Develop frameworks for integrated impact model*

Intercomparisons	*intercomparisons within and across sectors to advance system understanding, characterize uncertainty, test adaptation strategies and improve impact models*
C.7 Decision Theory	*Deepen decision theory research, including studies of who makes decisions and how they are made in different institutional, political, legal, historical and cultural contexts*
C.8 Risk Perception, Climate Knowledge and Behaviour	*Characterize the factors that shape risk perception, including social and cultural contexts, and study links to behaviour*
C.9 Governance, Collaborative Frameworks and Networks	*Investigate how different types of governance, collaborative frameworks and networks are effective at fostering partnerships and multi-stakeholder approaches in support of VIA*
C.10 Long-Term Planning and Design	*Examine how long-term regional planning and design can support adaptation, mitigation and sustainable development potential*

Annex 5 An inventory of climate research projects and programmes in Africa, catalogued by key priorities identified by ACC2013 (Annex 1). Projects shown in *italics* have completed since 2012. Last updated 28 May 2014

Programme	Code(s)	Activities	Partners	Sources
Africa Adaptation Programme (AAP)	*O*	*During the four years of its implementation, the programme aimed to lay foundations for an ongoing, dynamic adaptation process in harmony with each country's social, environmental and economic priorities. In each country the AAP aimed to help create an environment in which decisions and activities in support of adaptation can be evidence-based, strategic and appropriate to the goals of sustainable development. Reflections on the programme were compiled in the report* Laying the Foundations for Climate Resilient Development: Voices from Africa.	*UNDP-Japan*	*http://www.undp-aap.org/*
Africa Climate Change Resilience Alliance (ACCRA)	O	A consortium with two key objectives: 1) Governments (in Uganda, Ethiopia and Mozambique) support the resilience of citizens by adapting their decision making and effectively implementing good decisions; 2) international and national civil society to support the increase in adaptive capacity of vulnerable people through their programmes, policies and processes. Research seeks to produce solid evidence that demonstrates how to incorporate adaptive capacity into development programming to improve all types of development interventions and plans. Capacity-building activities support improved policy and practice of government actors. Advocacy activities ensure lessons learned from communities which are adapting to climate change are translated into better policy and practice globally, with a specific focus on adaptation finance.	DFID, Oxfam, ODI, Save the Children Alliance, Care International, World Vision International	http://community.eldis.org/accra/
Africa Climate exChange (ACE)	L,J	Developed by BirdLife International, the site serves as a one stop shop on information on climate change, mitigation and adaptation in Africa. Using birds and BirdLife's Important Bird Area network as entry points, it demonstrates how biodiversity in Africa is likely to respond to climate change and what can be done. Over 1,600 species distribution maps showing how birds are projected to respond to climate change are available. The portal links to various sources of information on climate change in Africa and provides a library of over 800 downloadable documents.	BirdLife International	http://www.africa-climate-exchange.org/
Africa Climate Exchange (AfClix)	L	A web-portal of the Africa Climate Exchange Project, led by the University of Reading. This knowledge transfer project facilitates the exchange of climate science and adaptation knowledge, initially between parties in Sudan, Senegal and the UK.	NERC, University of Reading	http://www.afclix.org/elgg/groups/all
Africa Initiative	L,M	A multi-year, donor-supported project undertaken by CIGI in cooperation with the	CIGI	http://www.cigionline.

Programme	Code(s)	Activities	Partners	Sources
		South African Institute of International Affairs. Launched in 2008, it creates knowledge-sharing opportunities, building capacity in Africa with a focus on five thematic areas: conflict resolution, energy, food security, health and migration, with special attention paid to the crosscutting issue of climate change. The ***research program*** supported field-based research in the social and physical sciences. It aims to inform and influence African policy making and contribute to the body of research on topics of importance to the continent. The ***exchange program*** supported short-term academic placements for African- and Canadian-based scholars undertaking research on Africa. The Africa Portal (http://www.africaportal.org/) is an online knowledge resource for policy-related issues on Africa.		org/africa-initiative
AfricaAdapt	L,M	A bilingual network (French/English) focused exclusively on Africa to facilitate the flow of climate change adaptation knowledge for sustainable livelihoods between researchers, policy makers, civil society organisations and communities who are vulnerable to climate variability and change. Activities include: An innovation fund offering small grants for new approaches to knowledge sharing; Radio-based programming and dialogues in local languages, developed with community radio broadcasters across the continent; Face-to-face meetings bringing people together to exchange ideas and overcome challenges; A CD-Rom and paper-based dissemination service for network news and resource.	IDRC, DFID, ENDA, IDS, FARA	http://www.africa-adapt.net/
AfricaInteract	L,M,O	**Aims to** provide a forum for interaction between major stakeholders particularly researchers and policy makers in climate change adaptation involving agriculture, health, and water sectors as well as urban issues. Specific objectives are to: 1) promote and support effective documentation and sharing of information to improve climate change adaptation policy; 2) identify policy gaps, support related action research, and promote the integration of climate change into development policies, strategies, programs, and projects at continental and sub-regional levels. Projects focus on: a) synthesizing and disseminating research aimed at influencing strategies and practices for adaptation; b) strengthening capacity and implementing targeted research on adaptation; c) establishing a framework for periodic discussions between stakeholders leading to the formulation of strategic recommendations or policy options related to climate change adaptation; d) contributing to strategic debates at continental and international meetings to establish an African position on adaptation.	IDRC, FARA, CORAF/WECARD, ASARECA, ENDA, FANRPAN, COMICFAC	http://africainteract.coraf.org/en/partners/
African Access Initiative	M	Eliminates archival journal fees on JSTOR across all of Africa. All not-for-profit institutions in Africa are eligible to participate, including colleges, universities,	ITHAKA	http://about.jstor.org/libraries/african-

Programme	Code(s)	Activities	Partners	Sources
		secondary schools, government and non-profit organizations, and museums.		access-initiative
African Agriculture and Climate Change Resilience Initiative	L,M,O	Aims to ensure the ability of poor and vulnerable smallholder African farmers to maintain, increase, and improve their own agricultural production despite climate change. Anticipated outcomes include: 1) creating new partnerships and networks among major stakeholders to leverage resources; 2) enabling policy frameworks are generated and implemented that allow the integration of climate information into agricultural development; 3) enhancing capacity building for African agricultural scientists and development experts to address the major climate related agricultural challenge; and 4) increasing the stability of agricultural production needed to help smallholder farmers meet their own basic food security and income needs. Eight Climate Change Units (CCUs) were established in universities and national agricultural research institutes in East and Central Africa (Tanzania, Kenya, Rwanda, Uganda and Ethiopia) to develop evidence-based climate smart agricultural practices that result in higher yields, improved resilience to climate shocks and greater carbon sequestration (e.g., **Kenya Agricultural Research Institute, KARI:** http://www.kari.org/kccu/**).**	Rockefeller	http://www.rockefellerfoundation.org/our-work/current-work/climate-change-resilience/african-agriculture-climate-change
African Centre of Meteorological Application for Development (ACMAD)	B,L,M,O	Provides weather and climate information for the promotion of sustainable development of Africa (notably within the context of national strategies for poverty eradication), in the fields of agriculture, water resources, health, public safety and renewable energy. This is achieved through capacity-building for the 53 National Meteorological Services (NMSs) of its Member States, in weather prediction, climate monitoring (extreme events), transfers of technology (telecommunications, computing and rural communication), and in research. Projects include Institutional Support to African Climate Institution Project (ISACIP).	UNECA, WMO	http://www.acmad.net/new/?q=en/home
African Climate Change Fellowship Programme (ACCFP)	*L,M*	*Supported African professionals, researchers, educators and graduate students to undertake activities that enhance their capacities for advancing and applying knowledge for climate change adaptation in Africa. Participating Fellows received small grants that enabled them to visit other institutions – "Host Institutions" – where they collaborated with mentors to implement individually-designed projects that, for example, assess and prioritize climate risks, investigate current practices for designing and implementing adaptation projects, consider approaches for integrating adaptation with planning and practice and/or develop and implement curriculum that promotes integration of climate change and climate change adaptation into graduate level education. ACCFP Fellows also participated in periodic program workshops and seminars that offered opportunities for them to*	*CCAA (IDRC, DFID)*	*http://www.accfp.org/*

Programme	Code(s)	Activities	Partners	Sources
		interact face-to-face with each other and program staff and challenge them to step "outside the box" in considering the role and potential contributions of their individual work within broader efforts to address climate change adaptation challenges in Africa.		
AfriCAN Climate Portal	L,M	A **web-based knowledge platform** for **sharing** climate change research and good practices. The portal targets a wide variety of climate change stakeholders: researchers, field practitioners, project developers, development partners, NGOs, local/national governments and farmers organisations. Scientific research, indigenous knowledge, and policies are collected in the form of articles, publications, news, project initiatives, organisational links and networks. To help practitioners on the ground, case studies of good practices are show-cased by climate change experts. In order to assess the applicability and transferability of project interventions, case studies are evaluated against **eight principles of sustainability** to assess their financial, economic, social and environmental sustainability.	EU FP7	http://africanclimate.net/en/research
African Ministerial Conference on Meteorology (AMCOMET)	L,O	A permanent forum where African ministers convene every two years to discuss matters related to the development of meteorology and its applications and its contribution to the socio-economic development in Africa. Projects include: Pilot projects under the Global Framework for Climate Services in West Africa; Mobile weather alerts for the fishing community of Kalangala and farmers in Kasese district, Uganda; Roving Seminars on Weather, Climate and Farmers for countries in West Africa (METAGRI).	WMO, Norwegian Ministry of Foreign Affairs, Government of Greece	http://www.wmo.int/amcomet/
African Monitoring of the Environment for Sustainable Development (AMESD)	*J*	*Provide decision-makers in the RECs, the AUC and at national level with full access to the environmental data and products needed to improve national and regional policy and decision-making processes. This involves extending the operational use of Earth observation technologies and data to environmental and climate monitoring applications.*	*EUMETSAT, AUC, RECs, ACP*	*http://www.eumetsat.int/website/home/AboutUs/InternationalCooperation/Africa/AfricanMonitoringoftheEnvironmentforSustainableDevelopmentAMESD/index.html*
African Monsoon and Multidisciplinary Analyses (AMMA)	*B,C,G,I,N*	***An international interdisciplinary programme dealing with the West African Monsoon (WAM), its variability and its impacts on communities in the region. Three scientific goals to:*** *1) improve understanding of the WAM and its influence on the physical, chemical and biological environment, regionally and globally; 2) provide the underpinning science that relates variability of the WAM to issues of*	*EU*	*http://www.amma-international.org/spip.php?rubrique1*

Programme	Code(s)	Activities	Partners	Sources
		health, water resources, food security and demography for West African nations and defining and implementing relevant monitoring and prediction strategies; 3) ensure that the multidisciplinary research carried out in AMMA is effectively integrated with prediction and decision making activity.		
African Plant Breeding Academy	O	To train ~250 African scientists in the latest biotechnological techniques to optimize the yield and nutritional content of 100 important but little-researched edible crops and trees native to Africa. Grown widely on farms, the improved varieties will help address the serious challenge of poor health caused by chronic malnutrition and recurrent episodes of hunger among Africa's populations, especially the rural poor.	ICRAF	http://blog.worldagroforestry.org/index.php/2013/12/10/icraf-and-partners-launch-first-african-plant-breeding-academy/
AGRHYMET	A,B,M,N	A specialized agency of the Permanent Inter-State Committee against Drought in the Sahel (CILSS). The main objective is to contribute to food security and increased agricultural production in member countries, and to help improve the management of natural resources of the Sahel and West Africa. Main activities include provision of: training of cadres of the Sahel and elsewhere; agro-meteorological and hydrological monitoring at the regional level; agricultural statistics and crop monitoring; regional data banks; management and dissemination of information on the monitoring of natural resources in the Sahel; documentation on agrometeorology, plant protection, environmental monitoring, desertification, natural resource management, etc.; maintenance of meteorological instruments and electronic equipment; strengthening interstate cooperation through the exchange of technology and methodologies.	USAID, EU, supporting nations	http://www.agrhymet.ne/eng/
Agricultural Model Intercomparison Project (AgMIP)	E,J,K,O	A global economic model inter-comparison, which harmonizes input datasets for 10 global agro-economic models to better evaluate the model results. Regional projects include: Knowledge enhancement for modeling in climate change: capacity-building in Southern, Western, and Eastern Africa; Impacts of climate variability and change on agricultural systems in Eastern Africa while enhancing the region's capacity to undertake integrated assessment of vulnerabilities to future changes in climate; Crop-livestock intensification in the face of climate change: exploring opportunities to reduce risk and increase resilience in Southern Africa using an integrated multi-modeling approach; Southern Africa Agricultural Model Inter-comparison and Improvement Project (SAAMIIP); Climate change impacts on West African Agriculture (CIWARA) — A regional assessment	DFID, USDA	http://www.agmip.org/
Agriculture Food	J,O	Five core research themes: 1) Sustainable food security under climate change,	FACCE-JPI,	http://www.faccejpi.co

Programme	Code(s)	Activities	Partners	Sources
Security and Climate Change		based on an integrated food systems perspective: modelling, benchmarking and policy research perspective; 2) Environmentally sustainable growth and intensification of agricultural systems under current and future climate and resource availability; 3) Assessing and reducing trade-offs between food production, biodiversity and ecosystem services; 4) Adaptation to climate change throughout the whole food chain, including market repercussions; 5) Greenhouse gas mitigation: nitrous oxide and methane mitigation in the agriculture and forestry sector, carbon sequestration, fossil fuel substitution and mitigating GHG emissions induced by indirect land use change.	Belmont Forum, South Africa	m/ (FACCE-JPI) http://www.igfagcr.org/food-security-and-land-use-change-call (IGFA-Belmont)
AidData	U	Collects, curates, and publishes data on more than $5.5 trillion dollars in development finance from 90 bilateral and multilateral agencies at the project level. All this information is available in a searchable database of more than one million development finance activities.	USAID, University of Texas, AfDB, ESRI, OECD	http://aiddata.org/
Atmospheric Circulation Reconstructions over the Earth (ACRE)	A	Recovering historical weather observations (e.g. from ship logs), and links to global efforts in weather and climate reconstructions. These use the very latest technology and every source of historical data available. The project has already generated global reanalyses spanning the last 140 years – the ACRE-facilitated 20th Century Reanalysis Project (20CR). It is the first historical reanalysis of its kind that assimilates only surface variables to reconstruct 4D weather variables, and can be compared with all existing reanalyses The historical weather data and the 20CR reanalyses generated from it will be made freely available to all. ACRE has an MoU with IEDRO under which both are working together to tackle various data rescue, scanning and digitisation issues, including old African surface weather observations on microfiche, and developing the propensity for a program of strip chart digitisation using new software. IEDRO are working with ACMAD in West Africa to scan all of the old microfiches of historical Africa surface weather observations from the African DARE projects involving the Belgians in the 1980s-1990s	WMO, NOAA, IEDRO, Met Office, ACMAD	http://www.met-acre.org/Home http://africaclimateconference.org/wp-content/uploads/2013/11/B4-02_Engelen.pdf
Attributing impacts of external climate drivers on extreme weather in Africa (ACE-Africa)	F	To assess the extent that climate change is already affecting the magnitude and frequency of extreme weather events in Africa, and investigate the impacts of such extreme weather events on river flow and crops. Project objectives are to: 1) demonstrate the need for and nature of the evidence base for the attribution of harm to external climate drivers; 2) demonstrate the importance of accurate attribution of any changes in weather risks for adaptation planning, to avoid 'adapting to yesterday's problems' as the balance of external drivers changes over the coming decades; 3) quantify the	NERC, Oxfam, Met Office, University of Reading	http://www.eci.ox.ac.uk/research/climate/ACEAfrica.php

Programme	Code(s)	Activities	Partners	Sources
		impact of changes in short-lived climate pollutants and regional climate forcings, in addition to the impact of warming induced by greenhouse gases, on weather extremes in Africa; 4) provide potential users of event attribution results with multi-thousand-member event-sets of regional climate model output; 5) compare the impact of changing risks of extreme weather with other impacts of anthropogenic emissions; and 6) provide members of the public with the opportunity to contribute directly to research on climate change in a vulnerable region and demonstrate the power of an evidence-based approach to climate impact attribution.		
British Council Research Links	L,M	International research collaboration is essential for the global knowledge economy, and it has been shown that internationally mobile researchers tend to be more productive. Furthermore, a shared research interest can help to build trust and relationships between people from very different backgrounds and cultures. In response to this, and taking advantage of its position as an intercultural relations organisation with global expertise in higher education, the British Council has launched the British Council Researcher Links initiative, in partnership with various research and higher education organisations from around the world. Researcher links consists of workshops and travel grants, both with a focus on early career researchers. The scheme supported a workshop on *From Climate Science to Climate Services for Society* in Cape Town, South Africa 2014.	British Council	http://www.britishcouncil.org/society/science/researcher-links
Building understanding of climate variability into planning of groundwater supplies from low storage aquifers in Africa (BRAVE)	A,D,O	The overall objective is to quantify the impacts of climatic variability and change on groundwater supplies from low storage aquifers, which can subsequently be used to benefit the poor in Africa through better informed development planning decisions. This will be achieved through **l**inking state-of-the-art climate, land surface and groundwater models, together with an assessment of user vulnerability. The project will use the River Volta Basin (RVB) as a case study and will work directly with key stakeholders in both Burkina Faso and Ghana at the project outset.	BGS, NCAS	http://gtr.rcuk.ac.uk/project/5BD6A344-E7C1-484D-AC92-6EE9F292715D
CAAST-Net Plus	L,M	A network of 25 partner organisations from all over Europe and sub-Saharan Africa, working together to support bi-regional cooperation in research and innovation. The aim is to encourage more and better bi-regional cooperation for enhanced outcomes around topics of mutual interest, and particularly in relation to the global societal challenges of climate change, food security and health. Outputs include reports and workshops on food security and water linkages; climate change and vector-borne disease; water harvesting.	EU FP7	http://www.caast-net-plus.org/

Programme	Code(s)	Activities	Partners	Sources
Capital projects and loans	N,O	Example research in support of loans to build capacity and adaptation: Coastal flooding early warning system (Sao Tome) Natural Resources Management in a Changing Climate (Mali) Stormwater Management and Climate Change Adaptation (Senegal) Water Security and Climate Resilience Project (Kenya) *Thirsty-Energy* project (global)	World Bank	http://www.worldbank.org/en/topic/climatechange
Center for Hydrometeorology and Remote Sensing (CHRS)	N	*Building global capacity for forecast and mitigation of hydrologic disasters through the development of means to extend the benefits of space and weather agencies' vast technological resources, which are untapped, into applications that can assist hydrologists and water resource managers worldwide and through equitable access to relevant information.*	NASA, NOAA, NSF, UNESCO	http://chrs.web.uci.edu/
ClimAfrica – Climate change predictions in Sub-Saharan Africa: impacts and adaptations	D,E	The main objective is to better understand and predict climate change in SSA for the next 10-20 years, analysing the expected impacts on ecosystems and population and developing adaptation strategies tailored to the African context.	EU FP7	http://www.climafrica.net/index_en.jsp
Climate Action, Environment, Resource Efficiency and Raw Materials	N,O,P	Research and collaboration opportunities between EU-Africa in the following climate-relevant themes: WASTE-4-2014/2015: Towards near-zero waste at European and global level WATER-5-2014/2015: Strengthening international R&I cooperation in the field of water SC5-13-2014/2015: Coordinating and supporting raw materials research and innovation SC5-18-2014/2015: Coordinating and supporting Earth Observation research and innovation in the EU, and in North Africa, Middle East, and Balkan region	EU Horizon 2020	http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-climate_en.pdf
Climate Action Intelligence	U	A tool that helps to visualize stakeholder and research networks, project artefacts and projects within Lesotho.	Lesotho Meteorological Services	http://www.lesmet.org.ls/network-graph
Climate and Development Knowledge Network (CDKN)	J,L,O	Supports decision-makers in designing and delivering climate compatible development. This is done by combining research, advisory services and knowledge management in support of locally owned and managed policy processes. CDKN works in partnership with decision-makers in the public, private	DFID, Dutch Ministry of Foreign Affairs	http://cdkn.org/

Programme	Code(s)	Activities	Partners	Sources
		and non-governmental sectors nationally, regionally and globally to achieve human development and environmental sustainability. CDKN supports demand-led, policy-relevant, applied research projects, led and implemented by a wide range of universities, private sector partners, NGOs and international agencies. CDKN has four main research themes: 1) Identifying impacts and vulnerabilities; 2) Exploring options for Climate-Compatible Development (CCD); 3) Decision-making on options for CCD; 4) Examination of policy processes to promote CCD.		
Climate change and Urban Vulnerability in Africa (CLUVA)	E,J,L,M,O	The overall objective of the project is to develop methods and knowledge to be applied to African cities to manage climate risks, to reduce vulnerabilities and to improve their coping capacity and resilience towards climate changes. The project will explore the issues of climate change vulnerability, resilience, risk management and adaptation in five cities in Africa (Addis Ababa, Dar es Salaam, Doula, Ouagadougou, and Saint Louis). The project will focus on the improvement of the capacity of scientific institutions, local councils and civil society to cope with climate change. It will focus on assessing the environmental, social and economic impacts and the risks of climate changed induced hazards likely to affect urban areas at various time frames, floods, sea-level rise, storm surges, droughts, heat waves, desertification, storms and fires. The project will develop and propose innovative climate change risk adaptation strategies to render cities more resilient to possible future climate-change induced hazards and risks with strong interdisciplinary components.	EU FP7	http://www.cluva.eu/
Climate Change and Water	J,O	Aims to help the world's most vulnerable people adapt to the water-related impacts of climate change. The goal: to support research that improves climate change adaptation efforts, at the policy level and in practice. Projects include: *Flooding in Cape Town under Climate Risk (FliCCR);* *Enhancing Climate Change Adaptation in Agriculture and Water Resources in the Greater Horn of Africa.*	IDRC	http://www.idrc.ca/EN/Programs/Agriculture_and_the_Environment/Climate_Change_and_Water/Pages/default.aspx
Climate Change Capacity Development (C3D)	*M,O*	*Strengthens capacities of Non-Annex I countries to address climate change through nationally appropriate measures and planning strategies.*	*UNITAR, EC, Austria, Switzerland*	*http://www.c3d-unitar.org/*
Climate Change Resilient Development (CCRD)	O,P	The Global Climate Change and Development Strategy focuses on: 1) helping countries and communities accelerate the transition to low emission development through investments in clean energy and sustainable land use; 2) helping countries and communities prepare for and respond to the impacts of climate change; 3)	USAID	http://www.usaid.gov/climate

Programme	Code(s)	Activities	Partners	Sources
		Ensuring all USAID programs and operations, from food security to disaster preparedness, take climate change into account. USAID is working in more than 30 countries to build resilience to climate-related impacts in key sectors like food security, water, and others. USAID programs are helping to ensure that vulnerable countries and populations can access climate information and take actions to manage current and future climate stresses.		
Climate Change, Agriculture and Food Security (CCAFS)	B,N,O	Research activities include: 1) Building adaptive capacity for agriculture and food systems that is more resilient to progressive climate change through the provision of agricultural technologies, agronomic practices and community- to global- level policies. Providing a portfolio of adaptation options that identify how food systems will adapt to a 2030 world and beyond. 2) Bringing promising innovations in climate risk management to bear on the challenge of protecting and enhancing food security and rural livelihoods in the face of a variable and changing climate. 3) Helping regional partners explore strategies and policies in the context of widely different but plausible future worlds.	CGIAR, CIAT, IRI	http://ccafs.cgiar.org/
Climate Impacts Research Capacity and Leadership Enhancement (CIRCLE)	U	To strengthen the capacity of African researchers in high performing African research institutions by 2018 and give greater access to funding opportunities and internationally recognized knowledge and evidence on climate change. This will result in greater support to research on climate change and its local impacts on development in Africa. CIRCLE will competitively identify 60 post-PhD and 40 post-MSc candidates from selected “home institutions” in sub-Saharan Africa to undertake structured research skills development through supervised placement in Africa-based “host research institutions”.	DFID, AAS, ACU	http://r4d.dfid.gov.uk/Project/61128/Default.aspx
Climate Research for Development (CR4D)	A,B,C,D,E,F,G,H,I,J,K,L,M	An agenda identifying four major priorities for climate research to serve development in Africa based on ACC-2013 discussions. Under each priority are clustered urgent pan-African climate research program proposals that will need to be supported and implemented to advance current knowledge frontiers, each bridging the gap between social and biophysical research, and between research and application, towards delivery of a coordinated climate research agenda for Africa that brings research outputs together with user needs. The four key priorities are: 1) co-designed multidisciplinary research for improving climate forecast skill and reliability, across temporal and spatial scales (towards operational user-relevant seamless forecast products); 2) filling the data gap tailoring for sector decision-making; 3) capacity-building, at all levels; 4) mainstreaming climate services into decision-making: linking knowledge with action.	WCRP, ACPC	Africa Climate Conference (ACC2013) Arusha declaration: http://www.clivar.org/sites/default/files/ACC2013-FINAL-Declaration.pdf

Programme	Code(s)	Activities	Partners	Sources
Climate resilience of rice and maize in the Rufiji Basin, Tanzania	J,M,O	**To** contribute critical information for climate change adaptation responses to strengthen the Feed the Future (FtF) initiative goals of reducing poverty and improving nutrition through agriculture. This project involves: field research; crop and water modelling; social and ecological vulnerability assessment of rice and maize production in the area; capacity building among key stakeholders; recommending practical and relevant climate change adaptation strategies and interventions for rice and maize production.	USAID, CCCS	http://www.cccs.udsm.ac.tz/
Climate Science Research Partnership (CSRP)	*B,C,D,E,L*	*Worked with African stakeholders to improve the understanding and practical prediction of African climate to help alleviate poverty. Five main activity areas: 1) Improved understanding and modelling of African climate and its drivers; 2) Improved application of science and climate models for early warning systems and adaptation planning; 3) Downscaling: Providing predictions at the geographical scales required for decision making using PRECIS, and developing in-country capability; 4) Strengthening African science capacity through research fellowships and knowledge transfer; 5) 'Research into use': Development of products that target demand and are accessible to users. Included 11 research fellowships.*	*DFID, Met Office Hadley Centre*	*http://www.metoffice.gov.uk/csrp/*
Climate Services Adaptation Programme in Africa	B,C,N	The first multi-agency initiative to be implemented under the Global Framework for Climate Services (GFCS). The programme intends to provide more and better seasonal climate forecasts to allow farmers to fine-tune their planting and marketing strategies; empower disaster risk managers to prepare more effectively for droughts and heavy precipitation; assist public health services to target vaccine and other prevention campaigns to limit climate-related disease outbreaks such as malaria and meningitis; and help improve the management of water resources. The main countries to benefit initially will be Malawi and the United Republic of Tanzania.	WMO, CGIAR, CICERO, CMI, IFRC, WFP, WHO	http://www.wmo.int/pages/mediacentre/press_releases/pr_982_en.html
Climate Variability and Predictability (CLIVAR)	B,C,D,G,H	Aims to describe and understand the ocean-atmosphere processes responsible for climate variability and predictability on seasonal, interannual, decadal, and centennial time-scales, through the collection and analysis of observations and the development and application of models of the coupled climate system, in cooperation with other relevant climate-research and observing activities.	WCRP	http://www.clivar.org/
Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA)	O	The program focuses on two climate change hot spots relevant to Africa: semi-arid regions; and deltas. These hot spots were chosen based on: extreme biophysical impacts of climate change, such as sea level rise in deltas, decreased precipitation in semi-arid zones; and social impacts of climate change on the livelihoods of large, poor populations, such as those living in flood plains, and farmers	DFID, IDRC	http://www.idrc.ca/EN/Programs/Agriculture_and_the_Environment/CARIAA/Pages/About.aspx

Programme	Code(s)	Activities	Partners	Sources
		dependent on precipitation for crop irrigation. CARIAA aims to build the resilience of vulnerable populations and their livelihoods by supporting collaborative research to inform adaptation policy and practice. Three initial projects relate to Africa: ***Pathways to Resilience in Semi-Arid Economies (PRISE)*** aims to spur climate-resilient development by identifying economic threats and opportunities resulting from climate change (Senegal, Tanzania); ***Adaptation at Scale in Semi-Arid Regions (ASSAR)*** aims to enable longer-term approaches to climate change adaptation-while supporting the management of current risks through transformative scenario planning (South Africa); ***Deltas, Vulnerability, and Climate Change Migration as Adaptation (DECCMA)*** will integrate climate and socio-economic data to examine migration as an adaptation option for the most vulnerable (Egypt, Ghana).		
Copernicus (European Earth Observation Programme)	N	Copernicus consists of a complex set of systems which collect data from multiple sources: earth observation satellites and *in situ* sensors such as ground stations, airborne and sea-borne sensors. It processes these data and provides users with reliable and up-to-date information through a set of services related to environmental and security issues. The service will address six thematic areas: land, marine, atmosphere, climate change, emergency management and security. They will support a wide range of applications, including environment protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection and tourism. The main users of Copernicus services will be policymakers and public authorities who need the information to develop environmental legislation and policies or to take critical decisions in the event of an emergency, such as a natural disaster or a humanitarian crisis. Considered as "public goods", a full and open access to these services will be organised. Data from the Sentinels will be free of charge to users.	EU	http://www.copernicus.eu/pages-principales/overview/
CORDEX	E,K	Aims to: 1) Quality-control data sets of Regional Climate Downscaling (RCD) based information for the recent historical past and 21st century projections, covering the majority of populated land regions on the globe. The RCD information samples uncertainties in Regional Climate Change associated with varying Global Climate Model (GCM) simulations, varying greenhouse gas (GHG) concentration scenarios, natural climate variability and different downscaling methods. The CORDEX downscaling activities are based on the latest set of GCM climate	WCRP, regional members	http://wcrp-cordex.ipsl.jussieu.fr/

Programme	Code(s)	Activities	Partners	Sources
		scenarios and predictions produced within the 5th Coupled Model Inter-comparison Project (CMIP5); 2) Build a common set of Regional Climate Model (RCM) domains for dynamical downscaling and define a standard set of variables, frequency and format for output and archival at a number of CORDEX data centres; 3) Coordinate a range of RCM simulations for the defined domains, forced by analyses of observations (currently ERA-Interim) to provide a benchmark framework for model evaluation and assessment. This exercise should include also statistical downscaling (SD) methods; 4) Develop of Regional Analysis and Evaluation Teams to: Evaluate the ensemble of RCD simulations Develop a suitable set of regional-specific metrics for RCD evaluation Collect suitable observational data to evaluate high-resolution RCD simulations Design experiments to investigate the added-value of RCDs and target future priorities in RCD research; 5) Engage with the broad RCD community in its activities and discussions; 6) Support and inform the climate impact assessment and adaptation groups interested in utilizing CORDEX RCD material in their research.		
Early Warning Systems for Climate Resilience in Africa	N	The early warning system will be implemented in 10 countries: Benin, Burkina Faso, Ethiopia, Liberia, Malawi, São Tomé and Príncipe, Sierra Leone, Tanzania, Uganda and Zambia. The initiative will enable targeted countries to take additional measures to improve existing climate information systems and adopt new and alternative technologies (e.g., installation of new observational infrastructure and strengthen capacities to collect, manage and use climate information to support decision making for farmers as well as national and sub-national planners). More generally, UNDP promotes pro-poor and pro-growth adaptation that encourages climate-resilient economic development and sustainable livelihoods in the face of climate change. Capacity development lies at the heart of the approach to climate change adaptation in three areas: 1) Integrated Policy and Planning; 2) Project Formulation, Financing and Implementation; 3) Knowledge Management and Methodology Support (e.g. the platform Adaptation Learning Mechanism.	UNDP-GEF	http://www.undp-alm.org/
Earth Observations Serving Society (SERVIR-Africa)	N	A collaborative venture to improve environmental management and climate change response by helping governments and other stakeholders integrate Earth observation and geospatial technologies into decision-making.	NASA, USAID, IRI, CSP	https://www.servirglobal.net/Africa.aspx
Ecosystem Services for Poverty Alleviation (ESPA)	I,J,L	Aims to deliver research that will deliver improved understanding of how ecosystems function, the services they provide, the full value of these services, and their potential role in achieving sustainable poverty reduction. The research will provide the evidence and tools to enable decision makers and end users to	NERC, ESRC, DFID	http://www.espa.ac.uk/

Programme	Code(s)	Activities	Partners	Sources
		manage ecosystems sustainably and in a way that contributes to poverty reduction. Projects include soil carbon (Ethiopia and Uganda); wildlife conservation (Tanzania); coastal ecosystem services (East Africa); bio-fuel production (Malawi, Mozambique and Swaziland); drivers of disease (Ghana, Kenya, Sierra Leone and Zimbabwe); and regionally coherent lake monitoring (East Africa).		
European RESPONSES to climate change	J,P	The objective of the project is to identify and assess integrated EU climate-change policy responses that achieve ambitious mitigation and environmental targets and, at the same time, reduce the Union's vulnerability to inevitable climate-change impacts. Scenario modelling was performed for five sectors: water and agriculture; biodiversity; regional development infrastructure; health and energy. The latter includes vulnerability assessment of solar energy infrastructure and output to dust exports from Africa. Other work suggests that African solar power may be diminished by cloudier conditions under climate change.	EU FP7, ICTP, IAEA	http://www.responses project.eu/index.html
Feed the Future (FtF)	J,O,P	Research to develop solutions to enhance agricultural production, with an emphasis on improving nutrition and reducing adverse impacts on natural resources and the environment. A global research portfolio to create more productive crops, sustainably intensify agricultural production systems, ensure food security, and enhance access to nutritionally improved diets. Research on climate change addresses the following research priorities: 1) Adaptation to greater climatic variability as well as longer-term climate shifts means intensifying stress tolerance while at the same time judiciously exploring and deploying genetic diversity of crop plants and livestock. Thus traits such as abiotic stress tolerance (such as drought, heat and other environmental stress) to crop and livestock disease ranges and severity (such as potato late blight and rift valley fever). 2) Advances in modelling of climates, production systems and actual or potential threats (e.g. pathogens, drought) can help guide research investments. 3) New technologies for resource use efficiency can reduce costs while also reducing greenhouse gas emissions. Here key technologies around nitrogen-use efficiency and pest resistance can increase productivity and incomes, have positive environmental impacts, and at the same time reduce emissions. 4) A number of interventions related to soil fertility and land management will have both mitigation and adaptation benefits. For example, integration of leguminous trees in agroforestry systems can both increase fertility and crop yields, as well as contribute to higher levels of carbon sequestration in soils, with accompanying increases in water-holding capacity.	USAID, USDA	http://www.feedthefuture.gov/resource/feed-future-research-strategy
Fennec Saharan	*G,I*	*An international consortium (2010-2013) aimed at developing a new understanding*	*NERC*	*http://fennec.ouce.ox.*

Programme	Code(s)	Activities	Partners	Sources
Climate System		*of the Saharan climate system and its representation in weather and climate models. A network of ground-based climate monitoring stations was deployed in the western part of the Sahara desert; in Algeria and Mauritania. For two periods, in April and June 2011, intensive measurements with the UK and French research aircraft took place over the region. The measurements are now being used to test and improve models for the Saharan weather and climate.*		*ac.uk/*
Food Security Thematic Programme (FSTP)	*L,M*	*The Food Security Thematic Programme (FSTP) aimed to improve food security in favour of the poorest and the most vulnerable under a medium and longer term perspective and to lead to sustainable solutions. Based on Article 15 of the EU Regulation establishing the Development Co-operation Instrument, it addressed food security at global, continental and regional levels. Amongst the strategic aims were: Priority 1: supporting research, innovation and information distribution in matters relating to food security, with a special focus on supporting the enhancement of capacities and scientific and technological cooperation; Priority 2: linking information and decision making in order to enhance response strategies. The programme covered all developing countries and its primary beneficiaries were: children under the age of five; communities with members suffering from HIV/AIDS or other chronic illnesses; war-affected communities and groups and internally displaced people; women; pastoralists, small farmers and fisher folk; landless and farm labourers and the urban ultra-poor. To better achieve the goal of reaching these beneficiaries in a sustainable way, the programme placed emphasis on training and capacity building for various stakeholders.*	*EU*	*http://ec.europa.eu/europeaid/how/finance/dci/food_en.htm*
Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN)	E,J,K,O	The broad objectives of the network are to: 1) Promote the development of appropriate agricultural policies in order to reduce poverty; 2) Enhance food security in Africa, and; 3) Promote sustainable agricultural development in Africa. An example project is: Strengthening Evidence-Based Climate Change Adaptation Policies (SECCAP) Project (funded by IDRC).	53 Partner Organisations	http://www.fanrpan.org/
Future Climate For Africa (FCFA)	E,L	Successor to the Climate Science Research Partnership (CSRP) with the UK Met Office Hadley Centre. Expected to launch early 2015 and bring together a wider international community of natural and social scientists and stakeholders with the aim of producing and enhancing the availability and accessibility of robust and 'decision relevant' climate information products to inform climate-resilient investment, policy and strategies across sub-Saharan Africa. Initial scoping will occur via four pilot projects in sub-Saharan Africa.	DFID, NERC	http://www.nerc.ac.uk/research/funded/programmes/fcfa/
Global Change	D,E,L,M	Advances knowledge generation and dissemination that informs policy and	NASA, various	http://start.org/

Programme	Code(s)	Activities	Partners	Sources
SysTem for Analysis, Research and Training (START)		decision-making in and across climate-sensitive sectors of the developing world by: 1) Expanding understanding of climate change and other drivers of global change at local, national and regional scales in Africa, Asia-Pacific; 2) Increasing the number and caliber of developing country scientists engaged in global change research; 3) Strengthening institutions in developing countries to advance interdisciplinary science and informed policy and decision-making; 4) Catalyzing and enhancing regional cooperation in regional and global change research; and 5) Fostering dialogue and collaboration between scientists and communities of policy and practice that enhances knowledge exchange and translation of knowledge to action.		
Global Climate Change Alliance (GCCA)	M,O,P	Aims to strengthen dialogue and cooperation on climate change between the European Union (EU) and developing countries most vulnerable to climate change, in particular Least Developed Countries (LDCs) and Small Island Developing States (SIDS), which are hardest hit by the adverse effects of climate change. The five GCCA priority areas include: (1) mainstreaming climate change into poverty reduction and development strategies; (2) adaptation, building on the National Adaptation Programmes of Action (NAPAs) and other national plans; (3) reducing emissions from deforestation and forest degradation (REDD); (4) enhancing participation in the Clean Development Mechanism (CDM); and (5) disaster risk reduction (DRR).	EU	http://www.gcca.eu/
Global Framework for Climate Services (GFCS)	A,L,M,N	Pilot projects have been established in Burkina Faso, Chad, Mali, Niger, Sudan and South Sudan with five components: (1) development of a framework of regional and national climate services through 'Early Warning – Early Action workshops'; (2) rehabilitation and upgrading of the observation network; (3) training and capacity building for the agricultural sector; (4) upgrading of climate data management systems including data rescue; (5) demonstration projects focused on development and use of customized climate information (e.g., forecasting dust storms in the Sahel for the health sector).	WMO, supporting nations	http://www.gfcs-climate.org/west-africa
GroFutures: Groundwater Futures in Sub-Saharan Africa	A,J,L	*GroFutures* is building on past research in groundwater-dependent communities of Ethiopia (Upper Awash and Shebelle Basins), Ghana (Atankwidi and Anayere Basins), Tanzania (WamiRuvu Basin) and Uganda (Aroca Basin) to pursue the following five objectives: 1) Quantify and characterise current and projected changes in groundwater demand in study areas of Ethiopia, Ghana and Tanzania resolving relationships among water demand, access and poverty; 2) Quantify and characterise current and projected changes in groundwater supply from recharge in semi-arid Tanzania and humid Uganda upscaling results to other regions of	CGIAR. UNESCO, Dutch Ministry, WMO, IAH	http://www.un-igrac.org/publications/501

Programme	Code(s)	Activities	Partners	Sources
		SSA; 3) Test a new metric of water availability to support groundwater governance; 4) Review groundwater governance structures in Ethiopia, Ghana, and Tanzania identifying potential barriers to sustainable and pro-poor management policies; and 5) Develop an interdisciplinary, pan-African consortium to carry out collaborative studies of groundwater futures and prepare a consortium research proposal for more in-depth research.		
Groundwater resilience to climate change in Africa	*A,D,O*	*The aim of the project was to improve understanding of the impacts of climate change on groundwater resources and local demand. The three key objectives were to: 1) strengthen the evidence base linking climate change, climate variability, aquifer resilience and livelihood vulnerability; 2) support local and international research agendas and programmes, including the ability to collect and interpret data, and transform data into policy-relevant information and knowledge; 3) develop evidence-based guidance on assessing how groundwater can support adaptation and build resilience to climate change.*	*DFID*	*http://www.bgs.ac.uk/GWResilience/*
Healthy Futures	J	Construction of a disease risk mapping system for three water-related, high-impact VBDs (malaria, Rift Valley fever and schistosomiasis) in eastern Africa, taking into account environmental/climatic trends and changes in socio-economic conditions to predict future risk.	EU FP7	http://www.healthyfutures.eu/
IGAD Climate Prediction and Application Centre (ICPAC)	B,N	Part of the Intergovernmental Authority on Development (IGAD) in Eastern Africa with a mission is to foster, through various programs, sub-regional and national capacity for climate information, prediction products and services, early warning, and related applications as a contribution to sustainable development in the IGAD sub-region.	WMO	http://www.icpac.net/Forecasts/forecasts.html
Improved Drought Early Warning and Forecasting to strengthen preparedness and adaptation to droughts in Africa (DEWFORA)	B,C,D,K	The programme specific objectives are to: 1) assess the existing capacities in Africa in terms of drought monitoring, forecasting and warning, and identify constraints and opportunities for improvement; 2) enhance drought monitoring methods through improved drought indicators that integrate drought hazard and vulnerability in a risk based approach, and to understand the relationship between drought hazard and vulnerability in the current climate and how this will change as a result of climate change; 3) increase the performance of methods used for forecasting droughts in Africa by implementing state-of-the-art in (seasonal) meteorological, hydrological and agricultural forecasting, and by adopting and adapting methods used in Europe, Australia and the US; 4) improve early warning of droughts through identification of appropriate thresholds for initiation of mitigation activities, and establishing mitigation and adaptation strategies to increase resilience to drought at seasonal and longer time scales.	EU FP7	http://www.dewfora.net/

Programme	Code(s)	Activities	Partners	Sources
International Environmental Data Rescue Organization (IEDRO)	A	Aim is to locate, rescue, image, digitize and share historic climate data enabling developing countries to adapt and mitigate the effects of climate change. Activities include: International Climate Data Rescue (IC-DARE) Inventory; International Data Rescue News (IDRN); Bi-monthly newsletter; On-site training - data analysis and visualization; Climate data digitization tools; Alpha-numeric data entry (workstations and crowdsourcing); Strip chart digitization application. Projects in seven African countries (Kenya, Malawi, Mozambique, Niger, Senegal, Tanzania, Zambia).	Google, ESRI, NOAA, WMO	http://www.iedro.org/
International Food Policy Research Institute (IFPRI)	E,O	Overall mission is to provide research-based policy solutions that sustainably reduce poverty and end hunger and malnutrition. Climate change falls under the 'Building resilience' research theme which focuses on key drivers of climate change and their possible evolution over time. A scenario-based framework is used to forecast how these major drivers of change will impact food and agricultural systems and food security. Based in part on these projections, IFPRI is developing adaptation and mitigation strategies, including ones that show how alternate climate policy regimes will affect agriculture, food security, and poor people. Developing countries could finance climate adaptation and mitigation strategies with offset payments from developed countries, but the impacts of these and other approaches need to be better understood. Effective adaptation and mitigation could generate income in rural areas, further increasing local capacity to adapt to climate change, but the best means of encouraging these outcomes need to be identified.	CGIAR	http://www.ifpri.org/book-775/ourwork/researcharea/climate-change/research
International Fund for Agricultural Development (IFAD)	O	Works with governments and communities in Africa to introduce sustainable practices and adaptive technologies that reduce the vulnerability of poor rural communities to climate change. This includes income diversification and sustainable crop intensification, which are production models capable of protecting the natural resources that rural communities depend on, and help them become active players in reducing carbon emissions.	UN	http://www.ifad.org/climate/regions/esa/index.htm (East Africa) http://www.ifad.org/climate/regions/wca/index.htm (West & Central Africa)
International Water Management Institute (IWMI)	E,O	IWMI Research Sub-theme 1.2 (Climate change, water and agriculture) is to: a) assess the potential impacts of climate variability, climate change and climate change mitigation measures on water availability and access, agricultural production systems, and associated livelihoods and ecosystems; b) to minimize impacts of climate change/variability on agricultural water management and; c) to enhance preparedness for floods and droughts through identification of measures that mitigate their impact and facilitate adaptation. Projects include: ***Groundwater***	CGIAR	http://www.iwmi.cgiar.org/

Programme	Code(s)	Activities	Partners	Sources
		***Governance in the Arab World: Taking Stock and Addressing the Challenges* (inc. Tunisia); *Water Management Solutions for Flood Recession and Dry Season Farming* (Nigeria); *Enhancing adaptive capacity to climate change impacts through well-managed water use* (**Mozambique, Malawi, Zambia**); *Quantifying the Impact of 2° C warming* (Nile and Niger basins)**		
Le Fonds Français pour l'Environnement Mondial (FFEM)	A,N,P	Supports mitigation projects that seek to reduce or at least limit the consumption of non-renewable fossil fuels and GHG emissions. FGEF has also been supporting projects that strengthen developing countries' capacities to adapt in the areas of surveillance, knowledge and resilience.	French Global Environment Facility	http://www.ffem.fr/lang/en/accueil/projets/projets_ffem-par-secteur/Projetschangement-climatique
Leverhulme Trust	D,U	Funded projects include: *Modelling climate change in West African Sahel rainfall* *Rapid Holocene climate change in southwestern Africa* The *Transnational Climate Governance network*	Leverhulme Trust	http://leverhulme.ac.uk/index.cfm
Livestock Climate Change Collaborative Research Support Program (LCC CRSP)	O	Supports integrated research that helps small-scale livestock holders adapt to environmental and health impacts of climate change in Sub-Saharan Africa (and South Asia).	USAID	http://lcccrsp.org/
MapAfrica	U	A dynamic online platform that enables citizens, government officials, and donors to track investments from AfDB-funded development projects. The geocoded data are an important feature of the MapAfrica platform which designed to help people visualize, at a glance, who is funding what and where and to see specific project results. Users can filter projects by country, sector and year, or can choose one project point on a map in order to view all other related locations for the project throughout the country.	AfDB	http://mapafrica.afdb.org/
Monitoring Atmospheric Composition and Climate - Interim Implementation (MAC-II)	G,O	Provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. Products include: global records of the distribution, transport, sources and sinks of greenhouse and reactive gases, and aerosols. Other global products include fire analyses for regional monitoring and forecasting systems.	EU FP7	http://www.gmes-atmosphere.eu/about/project/
Monitoring of	N	Aims to increase the information management, decision-making and planning	EUMETSAT	http://www.eumetsat.i

Programme	Code(s)	Activities	Partners	Sources
Environment and Security in Africa (MESA)		capacity of African continental, regional and national institutions mandated for environment, climate, food security and related responsibilities by enhancing access to and exploitation of relevant Earth Observation applications in Africa.		nt/website/home/AboutUs/InternationalCooperation/Africa/MonitoringofEnvironmentandSecurityinAfricaMESA/index.html
Pilot Program for Climate Resilience (PPCR)	O	Funds technical assistance and investments to support countries' efforts to integrate climate risk and resilience into core development planning and implementation. It provides incentives for scaled-up action and initiates transformational change by catalyzing a shift from "business as usual" to broad-based strategies for achieving climate resilience at the country level.	SCF, CIF, Governments of Mozambique, Niger, Zambia	https://www.climateinvestmentfunds.org/cif/node/4
Platform for Climate Smart Planning	M	Helps developing countries access climate-related datasets and toolkits and lends support to the design of climate-resilient and low-carbon development programs. The Platform also offers tools, help desk functions, including e-training, multimedia material, and 'how to' guides on the selection and use of suitable climate-smart planning tools and datasets.	World Bank	http://www.climatesmartplanning.org/
Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA)	L,U	A global scientific initiative seeking to provide direction and coherence at the international level for research on climate change vulnerability, impacts and adaptation (VIA). Launched with the support of leading scientists and decision-makers, PROVIA responds to the urgent call for a more cohesive and coordinated research approach and the critical need to harmonize, mobilize and communicate the growing knowledge-base on VIA. PROVIA also acts as a growing network of scientists, practitioners and decision-makers working towards identifying research gaps and meeting policy needs in climate change VIA research. These were published in a 2013 report *Research Priorities on Vulnerability, Impacts and Adaptation: Responding to the Climate Change Challenge*.	UNEP, WMO, UNESCO	http://www.unep.org/provia/HOME/tabid/55173/Default.aspx
Quantifying projected impacts under 2°C warming (IMPACT2)	J,L	The project applies a range of models within a multi-disciplinary international expert team to assess effects on water, energy, infrastructure, coasts, tourism, forestry, agriculture, ecosystems services, and health and air quality-climate interactions. A number of case studies will be developed for particularly vulnerable areas, subject to multiple impacts (e.g. the Mediterranean), with the focus being on cross-sectoral interactions (e.g. land use competition) and cross-cutting themes (e.g. cities). The project also assesses climate change impacts in some of the world's most vulnerable regions: Bangladesh, Africa (Nile and Niger basins), and the Maldives.	EU FP7	http://www.hzg.de/mw/impact2c/index.html.en

Programme	Code(s)	Activities	Partners	Sources
Regional Hydroclimate Project for Lake Victoria	D,J	To understand the variability of the hydrological components of the Lake Victoria Basin in order to account for the trend of decreasing water resources during the last few decades and anticipated reversal given potential increase in rainfall over the region. The information would be used by stakeholders to lay plans for hydroelectic power generation, water and agriculture,	GEWEX	http://www.gewex.org/gewexnews/hyvic_May2012.pdf
Royal Society-DFID Africa Capacity Building Initiative	M	The overall aim of the scheme is to strengthen the research capacity of universities and research institution in sub-Saharan Africa by supporting the development of sustainable research networks. The objectives are to: 1) facilitate sustainable multidisciplinary partnerships between research groups in sub-Saharan Africa and the UK; 2) strengthen research and training capacity in sub-Saharan African Institutions of Higher Education through the skill transfer between partner organisations of the research consortia; 3) produce a cadre of young, talented researchers through integrated PhD scholarships and shared supervision of post-graduate students between the UK-based and African consortia members; 4) evaluate the contributions of the Africa Initiative to supporting universities and institutions in Africa to develop sustainable research and research training capacity.	Royal Society, DFID	http://royalsociety.org/grants/schemes/africa-capacity-building/
Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)	G,K,O	The Northern Africa-Middle East-Europe (NA-ME-E) Regional Center of SDS-WAS undertakes various research activities: *Comparison of dust forecasts*: Products from different numerical prediction models are represented at a common geographical domain, which is intended to cover the main source areas, as well as the main transport routes and deposition zones in the region. *Ensemble products*: Multi-model products are generated from different prediction models. In order to produce them, the model outputs are bi-linearly interpolated to a common grid mesh of 0.5 x 0.5 degrees. *Forecast evaluation*: Comparison of model results to multiple kinds of observations to facilitate the understanding of the model capabilities, limitations, and appropriateness for the purpose for which it was designed (near real-time to annual scales).	WMO	http://sds-was.aemet.es/projects-research
Science for Humanitarian Emergencies and Resilience (SHEAR)	B,C	Evidence-based recommendations on future research priorities for risk assessments and early warning systems for weather-related hazards (e.g. cyclones, floods, droughts, landslides) for humanitarian and development purposes.	DFID	http://www.climate-services.org/sites/default/files/wysiwyg/HR_Wallingford_ICCS_3.pdf

Programme	Code(s)	Activities	Partners	Sources
Science Partnerships for the Assessment of Complex Earth System Processes (SPACES)	E,H,J,O	Research topics are expected to contribute towards advancing knowledge on the function of the Earth System and its response to natural changes and human interventions, thereby providing the necessary scientific data base for the formulation of science-based concepts and recommendations for Earth System Management strategies. It is further expected that the proposals create opportunities for young scientists and students from the Southern Africa region and Germany to participate in the research activities and, wherever appropriate, to pursue graduate and postgraduate degrees in the field of Earth System Research. Research topics include: 1) Variability of coastal current systems and its influence on land-sea-atmosphere interactions along the southern African coastal and terrestrial environments, and its impact on marine bio-geochemical cycles and resource availability; 3) Investigation of the drivers, pressures, states and appropriate interventions and responses and time and space scales for landscape evolution and hydrological changes in the southern Africa region, and their implications for the evolution of ecosystems (e.g. wetlands, dry pans, grasslands, bush encroachment, etc) and for land use changes. For example, the Limpopo Living Landscapes project aims to understand and predict the combined effects of land use and climate change processes on: (i) rangeland vegetation; (ii) unique biodiversity and; (iii) rural livelihoods and to identify farm and policy level intervention strategies that support sustainable rural livelihoods and the natural resource base on which these people depend.	BMBF	https://www.fona.de/en/14444
South African National Biodiversity Institute (SANBI)	A,G,J,L,O	Leads and co-ordinate research and communication regarding South Africa's response to the biodiversity impacts of climate change. Also provides communication and policy products to support efforts by the national Department of Environmental Affairs in climate change responses. Activities include: monitoring and understanding ecosystem and population processes as they indicate responses to a changing climate; investigating and understanding carbon dynamics, particularly in relation to environmental changes; investigating and understanding climate change impacts and vulnerability; informing and providing support for policymakers on adaptation to climate change impacts; contributing to synthesis activities that inform policy and communicate to a range of stakeholders.	South African Department of Environmental Affairs	http://www.sanbi.org/
South African Water Research Commission (Open and Directed Calls)	B,D,E,H	The WRC has five key strategic areas (KSAs) which relate to water-centred knowledge, each providing an integrating framework for investment in addressing a portfolio of key water-related needs. These KSAs allow for multidisciplinary studies and are focused on solving problems related to national needs and supporting society and the water sector. While each of the KSAs is unique and	WRC	http://www.wrc.org.za/Pages/Research_Overview.aspx

Programme	Code(s)	Activities	Partners	Sources
		mutually exclusive (minimal overlaps), they collectively attempt to cover the complete spectrum of water-related topics of strategic importance. Three themes refer to climate change: KSA1 (water resource management); KSA2 (water-linked ecosystems); KSA3 (water use and water management).		
South Africa-Norway Research Cooperation on Climate Change, the Environment and Clean Energy (SANCOOP)	L, M	The goal is enhanced knowledge–based policies and decisions for sustainable development in the area of environment, climate change and clean energy in South Africa and Norway. The aims are to contribute to expanded research opportunities and improve research cooperation based on equal partnership between South African and Norwegian researchers within the selected thematic areas. The purpose is to achieve scientific excellence, human capital development and relevance to the identified thematic areas while ensuring gender equality and redress for mutual benefit. Projects in the following broadly defined thematic areas are considered: Environment; Climate System; Climate Change Impacts on Society; Mitigation (including energy).	Research Council of Norway, South African Department of Science and Technology	http://www.forskningsradet.no/en/Funding/SANCOOP/1253986692358/p1184150364108?visAktive=true
Southern African Development Community (SADC) Climate Services Centre	A,M,N	Provides operational, regional services for monitoring and predicting extremes in climate condition. The Centre develops and disseminates **meteorological, environmental** and **hydro-meteorological** products. The Centre's products contribute to improved **disaster risk management** in the region, and help to ensure Member States are better prepared for weather and climate disasters, conservation and protection of natural resources. The Centre also provides training in climate prediction for personnel in the National Meteorological/Hydrological Services (NMHSs), and maintains partnerships with research scientists, universities, national, regional and international climate centres worldwide.	UNDP, WMO, World Bank, NOAA, USAID	http://www.sadc.int/sadc-secretariat/services-centres/climate-services-centre/
The Observing System Research and Predictability Experiment (THORPEX-Africa)	C,N	A 10-year international research and development programme to accelerate improvements in the accuracy of one-day to two-week high impact weather forecasts for the benefit of society, the economy and the environment. The programme has established an organizational framework to addresses weather research and forecast problems whose solutions will be accelerated through international collaboration among academic institutions, operational forecast centres and users of forecast products.	WWRP (WMO)	http://www.wmo.int/pages/prog/arep/wwrp/new/thorpex_new.html
Trans-African Hydro-Meteorological Observatory Project (TAHMO)	A	**Aims to install 20,000 on-the-ground sensing stations across Africa,** specifically designed to provide rainfall, temperature, and other critical data with robust redundant sensors and real-time cell-phone uplink. **Stations** will be located primarily at schools and universities, with TAHMO providing science curriculum materials and connections between schools and others in the network. Hosted by	TU Delft, OSU	http://tahmo.info/

Programme	Code(s)	Activities	Partners	Sources
		science teachers who will receive stipends for their caretaking of stations, the data collected by stations will also provide a foundation for scientific education and research grounded in environmental factors in which students can directly participate. TAHMO is based on a sustainable, self-funded model where commercial partners pay for use of these data.		
Tropical Applications of Meteorology using SATellite data and ground-based observations (TAMSAT)	A,N	Investigates the use of satellite imagery for estimating rainfall and other surface water budget components mainly in Africa. Routine products of the group are a ten-daily (dekadal), monthly and seasonal rainfall estimates for Africa derived from Meteosat thermal infra-red (TIR) channels based on the recognition of convective storm clouds and calibration against ground-based rain gauge data. This methodology is used by AGHRYMET and by a number of African Meteorological Services to provide vital, up to the minute information on the state of the rainy season. Rainfall anomalies for each month are computed relative to a10-year rainfall climatology of Africa (2000-2009). Current research is extending the spatial coverage of the dataset to entire Africa and the temporal coverage to 30 years.	JRC, University of Reading	http://www.met.reading.ac.uk/tamsat/about/
Visualising climate information for the African vulnerability, impacts and adaptation communities	L	A theoretical research base to inform the visualisation of climate information in Africa. The research aims to guide the development of climate services across the continent and feed into the development of the Climate Information Platform, hosted by CSAG	CSAG, University of Leeds	http://www.csag.uct.ac.za/2013/07/16/visualising-climate-information/
Water, Climate and Development Programme (WACDDEP-Africa)	M,O	To support the integration of water security and climate change adaptation into development planning processes and the design of financing and investment strategies. The programme has been initiated in eight countries (Burkina Faso, Burundi, Cameroon, Ghana, Mozambique, Rwanda, Tunisia, Zimbabwe) and five river basins (Kagera, Lake Chad, Limpopo, North-Western Sahara Aquifer System, Volta Basin). The capacity development initiative aims to enhance understanding of the economics of adaptation as it relates to medium- and longterm regional, transboundary, national, sub-national and sectoral development planning as well as in evaluating different adaptation investment projects.	UNDP, CDKN, Denmark, UKAid	http://www.gwp.org/en/WACDEP/
West African Science Service Center on Climate Change and	B,E,G,N,O	A program to enhance the resilience of human and environmental systems to climate change and increased variability by strengthening the research infrastructure and capacity in West Africa and by pooling the expertise with Germany. WASCAL has three components: 1) Competence Center, an institute in	BMBF, ZEF	https://icg4wascal.icg.kfa-juelich.de/

Programme	Code(s)	Activities	Partners	Sources
Adapted Land Use (WASCAL)		West Africa, that carries out research and provides science-based advice to policymakers and stakeholders on climate change impacts, mitigation, and adaptation. 2) Core Research Program complements the scientific activities of the Competence Center, implemented by a network of German and West African research institutes. 3) Graduate Research Program, involving the creation of seven graduate schools in West Africa, contributing to the education of the next generation of African scientists and policy makers in the field of climate change and land management. The Core Research Program includes: 1.1) Development of a Regional Climate Model System for West Africa; 1.2) Seasonal Climate and Regional Weather Forecasts; 1.3) Interaction between Land Surface and Regional Climate; 2.1) Remote sensing based analysis of Land Cover and Land Use Change pathways and drivers; 5.1) Risk assessment and analysis; 6.1) Development of a spatially explicit framework for land use impact modeling based on trade-off- and multi criteria analysis		
West and Central African Council for Agricultural Research and Development	L,M,O	The vision is to contribute to sustainable reduction of poverty and food insecurity in West and Central Africa achieved through agricultural led economic growth, and improving agricultural research system of the sub-region. The general objective is to improve the efficiency and effectiveness of small-scale producers and promote the agribusiness sector. For that reason, producers and end-users are at the centre of research. Example climate change projects include: Platform for Exchange between Researchers and Policy makers for Adaptation to Climate Change in Africa; Enhancing the resilience and adaptive capacity to climate change through integrated land, water, and nutrient management in semi-arid West Africa – "ENRACCA-WA" (Mali); Sustainable soil-water-nutrient management under increasing climatic change and variability (Nigeria); *West African Agriculture and Climate Change: A Comprehensive Analysis* (Book)	IRDC, WAAPP	http://www.coraf.org/en.html
Wind Atlas (for South Africa)	A,I,K,O	Work packages include an observations campaign, high resolution as well as micro-scale modeling, extreme wind climate assessment, wind climate assessment techniques as well as data dissemination. The overall objective is to generate a very high resolution wind atlas for South Africa to provide stakeholders with knowledge allowing them to make informed decisions.	RSA, UNDP, Embassy of Denmark	http://www.csag.uct.ac.za/2010/06/10/wind-atlas/

Annex 6 Re-thinking capacity building for climate science in Africa.

Source: Bruce Hewitson, UCT

This short note is a reflection – a comment intended to stimulate discussion around how we, the climate research community in Africa, might consider new approaches to developing sustainable research capacity and leadership in the areas of climate variability and change. The comment is frank, and necessarily makes generalizations where clear exceptions may be found. Yet at the same time it recognizes that the growth in scientific research capacity under the operating modalities of the last few decades is disturbingly disproportionate to the continued investment of time and money.

The challenge: Set against a slow incremental growth of self-sustaining science capacity it is perhaps timely to consider complementary alternative actions: How to build within the continent the intellectual leadership for big science founded on a sustainable critical mass of capacity.

A cynical view: African climate science is characterized by a landscape of organizations that are in many cases procedurally and administratively inflexible as they seek to protect and sustain intellectual territory in the context of notable resource constraints. Through international initiatives many of our scientists receive overseas training where "normal practice" is predicated on a mature community that has achieved a critical mass for sustainability. When (if) they return to Africa these young scientists, of necessity, often find a work situation that requires fulfilling additional roles which may be unrelated to their core expertise. Those demonstrating substantial competency may be rapidly promoted rapidly out of the research environment. Commonly there is limited or no critical mass of co-located co-workers to provide a requisite mutual support environment, and depend instead on multiple, fragile, overlapping and competing "networks" facilitated through a range of regional and continental capacity building initiatives of finite duration. The pragmatic opportunities of the private sector and/or desirable international opportunities often further draw down the growth in core research capacity. Internally to Africa, the un-coordinated dependencies of institutions on external opportunities, along with institutional inertia and administrative inefficiencies, commonly leave the Africa participants conducting science at a junior level. Where sustained activity does take place, which is rarely, it is usually under the direction of agendas determined and mandated through the power of international funding agencies external to the continent, often loosely structured under aegis of global programs. Even if consultation in such initiatives has been part of the process, understandably the interests of the investing agencies remain the priority. Further, where African participation is needed in, for example, international high level scientific committees, the shortage of capacity can sometimes result in tokenism.

Thus a legitimate question results: why does the ongoing capacity investment in developing young emerging scientists within the climate related arena so seldom give rise to those who become recognized leaders in the international community – whilst staying within the Africa continent?

Five compounding constraints may be postulated: First, the opportunities are limited for the experiential learning that is necessary to bring insight to theoretical training – limited often to large internationally led initiatives. Secondly, young scientists in Africa seldom have the chance to experience the security of tenure[9] on focused research which affords adequate for building their intellectual momentum, and the consequent productivity,

[9] While one may debate how long is long enough to build research momentum, commonly the post-doctoral opportunities within Africa are typified by fellowships of 1 to maybe 2 years duration – too short to create research career momentum of significance.

reputation and credibility within their chosen specialty. Third is that because of resource limitations, the young scientists who do find experiential learning opportunities often do so through junior partnership in internationally prioritized research programs. Fourth, by being mostly constrained to work in a non-co-located network of distance partnerships, "big science" that requires true team-based research struggles to gain traction, further constraining the opportunities to attract commensurate investment for tackling large questions. Last, the persistent institutional and disciplinary silos in research institutions and universities works against developing creative exploration of climate questions.

In contrast, where the freedom to focus within a supporting environment has been facilitated, leaders have also clearly emerged. It is perhaps no accident that South Africa, with such an above average (for Africa) GDP investment in R&D represents an exception on the continent, as evidenced in, for example, the number of senior authors in the IPCC, or the strong (albeit numerically small) role in the international community; South Africa also has a well-educated, committed and supportive leadership in the national governmental organizations, such as NRF and CSIR.

Considering alternatives: All the above argue for trying a new approach developing regional climate understanding to complement the ongoing initiatives. Current approaches are largely top-down … for example the western aid agency activities, the WMO's Global Framework for Climate Services and the complementary Future Earth initiatives, regional and national research projects, or even the shorter term contracts from development banks. Moreover, such approaches are rarely of sufficient duration for genuine institutional strengthening to occur that can create the seeds of leadership. Given this, it would suggest that an alternative exploration for bottom-up approaches may produce a different outcome.

Consider then what could be catalyzed by a small team of young, competent, motivated and enthusiastic African scientists, with the intellectual confidence to tackle frontier questions of African climate science. Enthusiasm is infectious, and enthusiasm with competence is powerful. How then to develop such a team?

Developing breakthrough science is commonly found through a mix of senior insight, apprenticeship, mutual collaboration, and critically also being given the freedom to fail, or at least define success in terms that include simple experiential learning. This allows true team work on foundational questions, and requires a small number of mentors co-located with younger inquisitive emerging scientists, with the resources of adequate duration to sustain activities. Through this such a team can articulate the foundations of a problem[10], then develop new insight that delivers a result to expand our fundamental understanding to and inform the unique needs requirements of Africa. Imagine then just one or two such teams established, appropriately resourced with security of tenure for 5 years, under the mentorship of one or two experienced scientists, together co-located at African institutions, interacting with the international community but freed of externally determined agendas, and addressing a big question for the knowledge needs of the continent. Remove the constraints

[10] A good example of a big unresolved science question of immeasurable and immediate importance to the Africa continent is found within the WCRP strategic grand challenges, and especially the CORDEX program. In an environment of raised expectations rooted in the knowledge needs of the IAV and policy communities, the CORDEX program is generating an unprecedented multi-model multi-method data product of regional scale climate variability and change. Yet the analysis of this product does not exist, and the fundamental research methods and techniques do not yet exist even in the international research community … even the IPCC AR5 remains with the principle of model averages. How to identify noise from signal? What are the scale dependencies and limits to predictability for the regions of Africa? How does one reconcile contradictions in regional projections? The questions are many -- fundamental, critical for IAV and policy, exceedingly important for development, and unresolved.

of pre-determined outcomes and burdensome administrative overload; give the freedom to fail, for otherwise little will be attempted. What might such a team produce?

Such an approach is perhaps only one of many modalities, but a central principle remains: leadership is grown through experience, not taught. But to gain that experience one must be trusted with commensurate responsibility. Of course the risk of investment is necessarily higher than one finds with traditional research projects, but building leadership is not a project, and the potential returns on the investment as measured by value to society are so much higher. Who could best fund a small initiative such as this or some other exploratory modality: perhaps foundations followed by the more traditional agencies? Would the institutional structures show the necessary flexibility and altruism to take the risk? Would there be candidates for such a “class-of-big-science”? As with all changes in a system, it depends on whether those with resources risk easing the reins of control, if only for a while to see what could be accomplished.

Annex 7 Establishing climate-resilient renewable energy policies in Lesotho

Source: Dr Danielle Gent, Loughborough University

Extreme energy vulnerability

The Kingdom of Lesotho is a relatively small (30,355 km^2) land-locked nation, completely surrounded by South Africa. Lesotho has an estimated population of just over 2 million; two-thirds of the country is sparsely inhabited, comprised of rugged mountains and deep valleys with small, dispersed villages along mountainsides (Taele et al. 2012). Over half (57%) of Lesotho's population live below the poverty line, relying primarily on subsistence agriculture and remittances from migrant labourers in South Africa (Tshelo 2012). Approximately 24% of the adult population live with HIV/AIDS. Lesotho faces serious economic and social challenges that are expected to be exacerbated by climate variability and change. The Government of Lesotho (GoL) recognises that climate change is already affecting the country. For instance, the National Strategic Development Plan highlights that 2011 saw the heaviest rains in decades, resulting not only in loss of agricultural output but also damage to key power and transport infrastructures (GoL, 2012).

Lesotho's energy sector is particularly vulnerable. The country is reliant on energy imports, and the majority of the population remain dependent on traditional sources of energy to satisfy basic energy needs. In particular, biomass is widely used to meet energy requirements for heating and cooking. Biomass is often harvested unsustainably which is leading to land degradation, and climate change may exacerbate this degradation (UNDP 2009; Taele et al. 2012; Tshelo 2012). Electricity is supplied primarily by the 72 MW 'Muela hydropower plant, which satisfies 63% of internal demand (Taele et al. 2012). The shortfall in electricity is currently met by imports from South Africa and Mozambique. In addition to the macroeconomic stresses created by Lesotho's high reliance on imported electricity, Tshelo (2012) estimates that complete dependence on externally sourced petrol, diesel, Liquefied Petroleum Gas (LPG) and coal contribute to an account deficit, which in March 2011 stood at 21% of GDP.

The dominance of hydroelectric generation capacity renders Lesotho's electricity supply system vulnerable to changes in river flow. Drawing on Global Climate Model projections and Geophysical Fluid Dynamics Laboratory models, UNDP (2009) estimate that by the year 2075 Lesotho's available water resources could be significantly reduced, falling from 5400 Mm^2 to 4504 Mm^2. This situation is more acute when considering projected growth in electricity demand, which is expected to reach 160 MW by 2020 (Taele et al. 2012). Part of this growth will be stimulated by the government's plan to scale up grid electricity access: the draft renewable energy policy envisions 75% household electrification by 2030 (GoL 2013).

Solar and wind power: adaptive measures?

For UNDP (2009) exploitation of renewable energy (RE) resources – particularly solar and wind energy – is regarded as an essential climate adaptation response for Lesotho. For instance, solar thermal and solar photovoltaic systems could be harnessed to satisfy rural householders' thermal energy demands (currently met by biomass) and electricity needs (particularly in areas beyond national grid infrastructure) with the potential to contribute to rural development (see GoL/UNDP 2006; Taele et al. 2007). Wind power is seen as a key means of diversifying the electricity generating mix, supplementing climate-sensitive hydropower. As well as presenting a key adaptation response, the exploitation of RE is seen as an important growth driver. For instance, excess RE generation could be traded within the South African Power Pool (SAPP), which is currently characterised by a severe electricity deficit (SADC, 2012).

Based on wider regional efforts to identify RE resources, it is estimated that Lesotho possesses vast solar and wind energy potential (Schäffler 2011). However, these estimates

are based on data that are at low resolutions – presenting knowledge gaps and potential barriers to investment in the sector (Parthan, 2013). For instance, an official at UNDP Lesotho (formerly employed at the Lesotho Meteorological Service, LMS) recounted that potential investors (both international and native to Lesotho) would regularly request data on the availability of RE resource - some had even purchased their own monitoring stations to conduct assessments (Peshoane, pers. comm.[11]). Reliable hydrometeorological data are, therefore, recognised as essential to estimating potential resources, prioritising development sites and driving investment in the sector.

Climate data and renewable energy policy development: the Africa Adaptation Programme in Lesotho

Funded by the Government of Japan, the Africa Adaptation Programme (AAP)[12] in Lesotho aimed to build capacity in mainstreaming climate resilient development. As part of AAP, a review of solar and wind resource monitoring systems conducted by Schäffler (2011) concluded that Lesotho's 74 climate, synoptic, rainfall and major weather stations were inadequate for determining RE resource availability. To address the need for high resolution RE resource maps, the AAP procured systems for collecting, monitoring and storing data on solar radiation and wind resource (Helmore 2013). Another critical element of this activity was the training of personnel from the LMS to interpret data (Figure 7.1). These data were integrated into models to establish potential costs/yields of various RE options – with the ultimate goal of feeding into Lesotho's first renewable energy policy with the aim of reducing overall energy vulnerability (Schäffler 2011). The data collection process was initiated in 2012 and at the time of writing, the resource maps were undergoing internal review (Monnapula, pers. comm[13]). While a draft RE policy has been developed, it is currently being debated by government, and is not yet publicly available (Monnapula, pers. comm). Three key objectives of the policy are to: 1) enhance energy security by reducing reliance on fossil fuels and imported electricity; 2) enhance access to modern energy for rural areas of Lesotho; 3) reduce GHG emissions from the energy sector and prevent other environmental damage (GoL, 2013).

Parthan (2013) identified three classes of information that are required to attract investment in the RE sector. These include information relating to energy resource, the policy and regulatory environment, and markets. The data priorities are for more information on wind speeds, solar insolation measurements, biomass availability (e.g. agricultural and forestry residues) and head of water at prospective hydropower sites. Potential private sector project developers are likely to initiate micro level resource assessments that are commercially sensitive. Parthan (2013) argues that in addition to data generation, data sharing agreements between LMS and private sector actors will be vital to regularly publishing a compendium of RE resources in Lesotho.

Although the AAP ended in late 2012, the project laid the foundations for subsequent initiatives, such as the Global Climate Change Alliance (GCCA)[14]. This EU-funded programme aims to mainstream climate change into Lesotho's National Strategic

11 Mr. Limomane Peshoane, UNDP Lesotho (29.04.14)

12 The Africa Adaptation Programme was launched in 2008 by the United Nations Development Programme (UNDP) in partnership with the United Nations Industrial Development Organization (UNIDO), the United Nations Children's Fund (UNICEF) and the World Food Programme (WFP) with US $92.1million support from the Government of Japan. AAP ran from 2008 to 2012 to support integrated, comprehensive approaches to climate change adaptation in Africa by building the capacities of 20 African countries to adjust their national development processes to incorporate the risks and opportunities of climate change (Helmore 2013).

13 Ms. Mookho Monnapula, Lesotho Meteorological Services (22.04.14)

14 The approval process for this programme is underway (Peshoane, pers. comm.). For more information see: http://www.gcca.eu/national-programmes/africa/gcca-lesotho

Development Plan; the work of the Alliance also feeds into the development of the national sustainable energy strategy.

Figure 7.1 A member of the Lesotho Meteorological Services (LMS) maintaining a high performance computer at an AAP training workshop. Improved data collection, procurement of data processing and storage hardware, and capacity building are enabling the LMS to determine RE resource potential in Lesotho

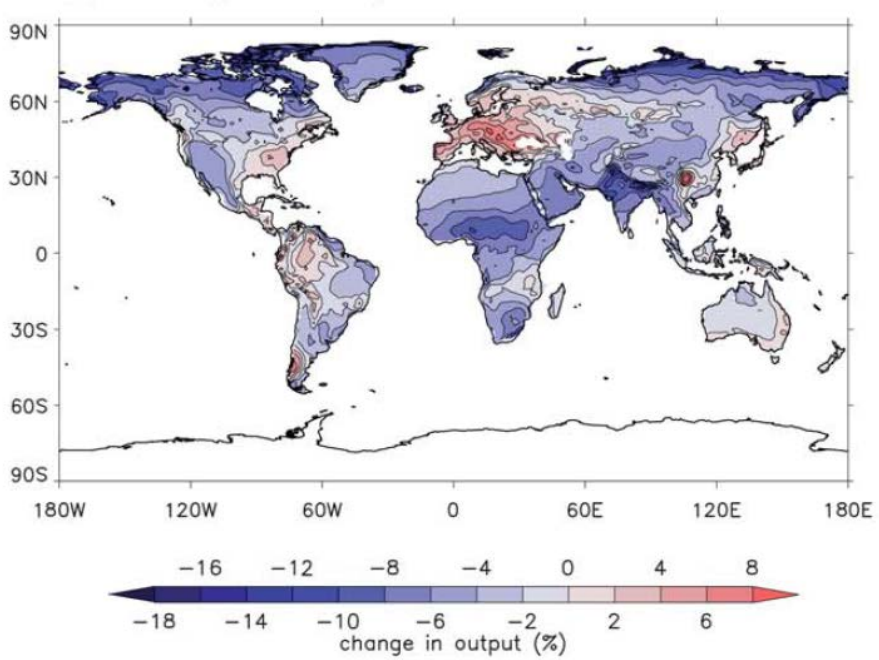
Source: Helmore, 2013

Future research opportunities

Improved availability of data on RE resource is a critical element for stimulating investment in solar and wind power developments. However, it is also important to consider other aspects that may influence future RE investments. These may relate to stable policy environments, fossil fuel subsidies, or innovative financial instruments. A further critical area relates to the impacts of extreme climatic change on future RE resource availability, or the feasibility of RE resource exploitation under different climate scenarios. While there are studies underway in Lesotho to forecast the potential impact of climate change on available water resources (Peshoane, pers. comm.), it is also important to examine changes in the distribution and variability of solar/wind resources, as well as the possible impact of climate change on extreme weather events (and hence the operating environments of renewable energy technology investments).

Crook et al. (2011) examine how changes in global temperature and solar insolation could affect the outputs of Concentrated Solar Power (CSP) and Photovoltaic (PV) installations throughout the twenty first century (Figure 7.2). They find that changes in CSP/PV output could be regionally dependent, and argue that technology outputs should be explored in more depth, and taken into account when selecting locations and technology, specifically for new large-scale interconnected plants. Similarly, Müller et al. (2014) explore global brightening and dimming trends associated with levels of air pollution, which impact on surface solar radiation. Furthermore, Patt et al. (2013) identify critical climate vulnerabilities for solar thermal, PV and CSP technologies, examining in particular the implications of increased frequency and intensity of storms, lightning, cloudiness and dust.

Figure 7.2 Per cent change in PV output by 2080 according to HadGEM1 A1B scenario.



Source: Crook et al. (2011)

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Annex 8 Managing flood-related health hazards in Dakar, Senegal

Flood hazards of Dakar

Dakar Metropolitan Area covers 550 square kilometres and in 2010 was home to an estimated 2.5 million people (~20% of the total population of Senegal). City growth has been most rapid in peri-urban segments that extend beyond the administrative reach of the Department of Dakar (Figure 8.1). Spatial analysis of settlement and hazard 'hotspots' (Figure 8.2) suggest that ~40% of the peri-urban population is situated in areas with significant exposure to urban flooding, coastal erosion, or sea level rise (Wang et al., 2009; Lo and Diop, 2000). Since 1980 more than 900,000 people have been affected by flooding in Senegal as a whole (World Bank, 2011).

Figure 8.1 Urban, per-urban and rural parts of Dakar Metropolitan Area (Wang et al, 2009)

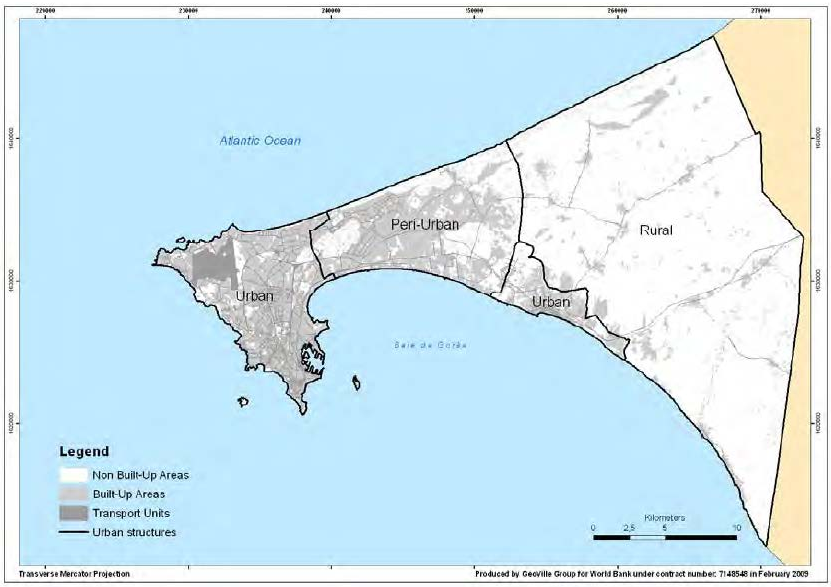
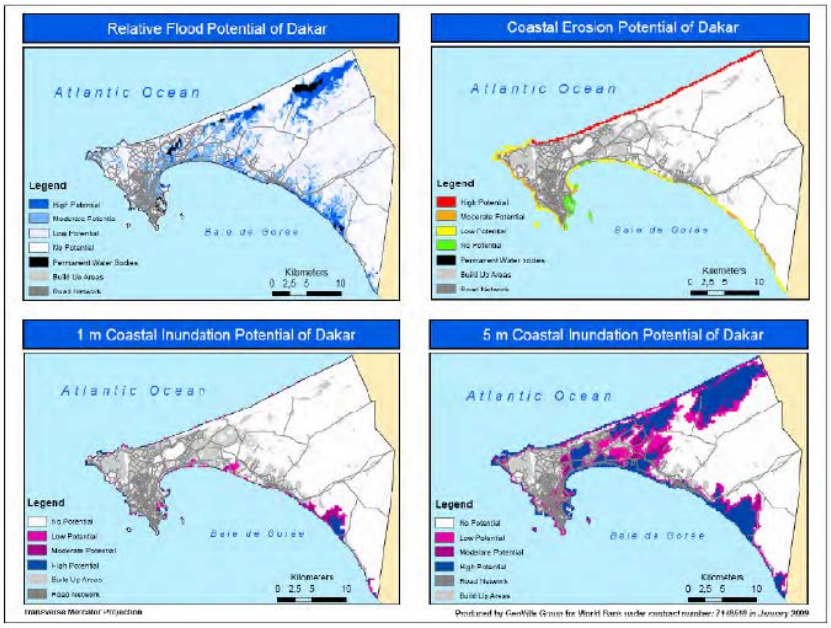


Figure 8.2 Hazard mapping of the Dakar Metropolitan Area by Wang et al. (2009)



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Photos: World Bank : http://www.worldbank.org/projects/P122841/flood-prevention-drainage-project?lang=en; *This Senegalese Life* http://thissenegaleselife.blogspot.co.uk/2012/09/endless-trash.html

Floods in 2005 and 2009 caused major damage to housing, schools, health facilities, water supply and sanitation systems in Dakar. The 2005 episode was associated with several cholera outbreaks in West Africa which led to 31,719 cases and 458 deaths in Senegal. The hardest hit areas were first the districts in Diourbel region to the east of Dakar, and then the western sector of the city (de Magny et al., 2012). The 2009 flooding impacted ~360,000 people (mainly in the districts of Pikine and Guediawaye) and caused estimated damages of US$ 103 million (equivalent to 14% of the annual average income of the affected population) (World Bank, 2011).

In 2008, Alioune Badiane of the UN-Habitat agency famously announced that St Louis is "the city most threatened by *rising sea levels* in the whole of Africa". More generally, Dennis et al. (1995) estimated that over 6000 km^2 of Senegal could be vulnerable to inundation and erosion given a 1-metre rise in sea level. The long-term sea level trend based on the fragmentary record for Dakar between 1943 and 2002 suggests a mean rise of 1.5 mm/year. Presently, the main erosion zones within Dakar include the area of Camberene-Yoff, the west and east edges of Dakar, and the bay of Hann (World Bank, 2011; Figure 8.2). Local rates of coastal erosion of 1 and 2 m per year have been reported (Niang et al., 2010).

Regional climate change

The flood hazard of Dakar arises from a combination of human and natural factors including lack of strategic planning leading to uncontrolled development and infrastructure within low-lying, flood prone coastal areas; poor maintenance of drainage systems; and concentration of heavy rainfall in boreal summer months.

Observed summer mean temperatures have risen steadily since the 1950s whereas precipitation totals fell dramatically in the late 1960s and have remained below the long-term average since (Figure 8.3). This is consistent with the widely documented reduction in wet-season (July to September) rainfall across the Sahel as a whole[15] (Balme et al., 2006; Biasutti and Giannini, 2006; Dai et al, 2004). Due to the limited number of stations plus large interannual and decadal variability it is difficult to establish with any confidence the direction of change in extreme precipitation.

Nonetheless, New et al. (2006) report regionally averaged trends for annual maximum 1-day precipitation, average wet day precipitation, maximum dry-spell duration, maximum 5-day precipitation and total precipitation on extreme days in West Africa. In short, there appears to be an increase in daily rainfall intensities, but longer duration totals have decreased. Based on a network of 31 stations with at least 50 years of data, Sarr et al. (2013) assert that there has been a return to wetter conditions in Senegal since the 1990s with 'modest to significant' increases in the average precipitation per wet day.

[15] Sahel Precipitation Index (20-10N, 20W-10E): http://jisao.washington.edu/data/sahel/

Figure 8.3 Observed annual mean summer (June-August) GISTEMP temperature (left) and GPCCv6 precipitation (right) anomalies (with respect to 1961-1990) for Senegal.

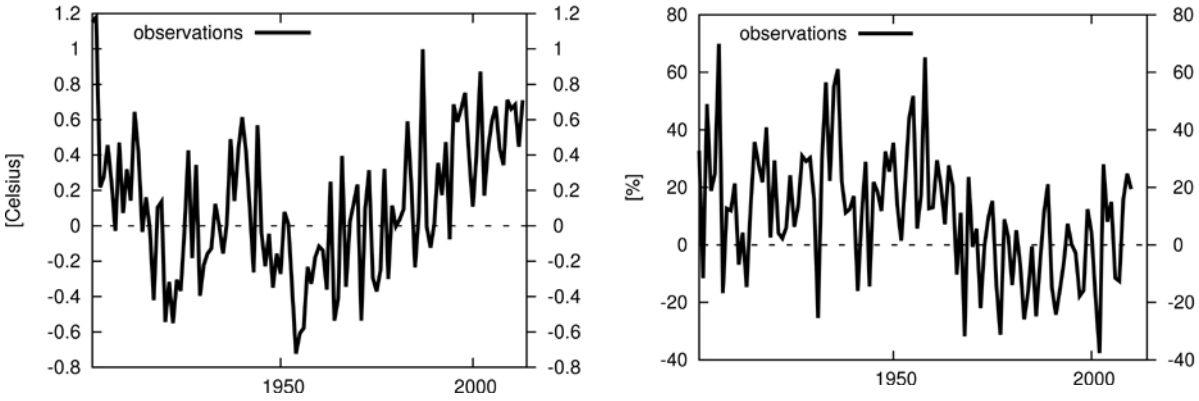
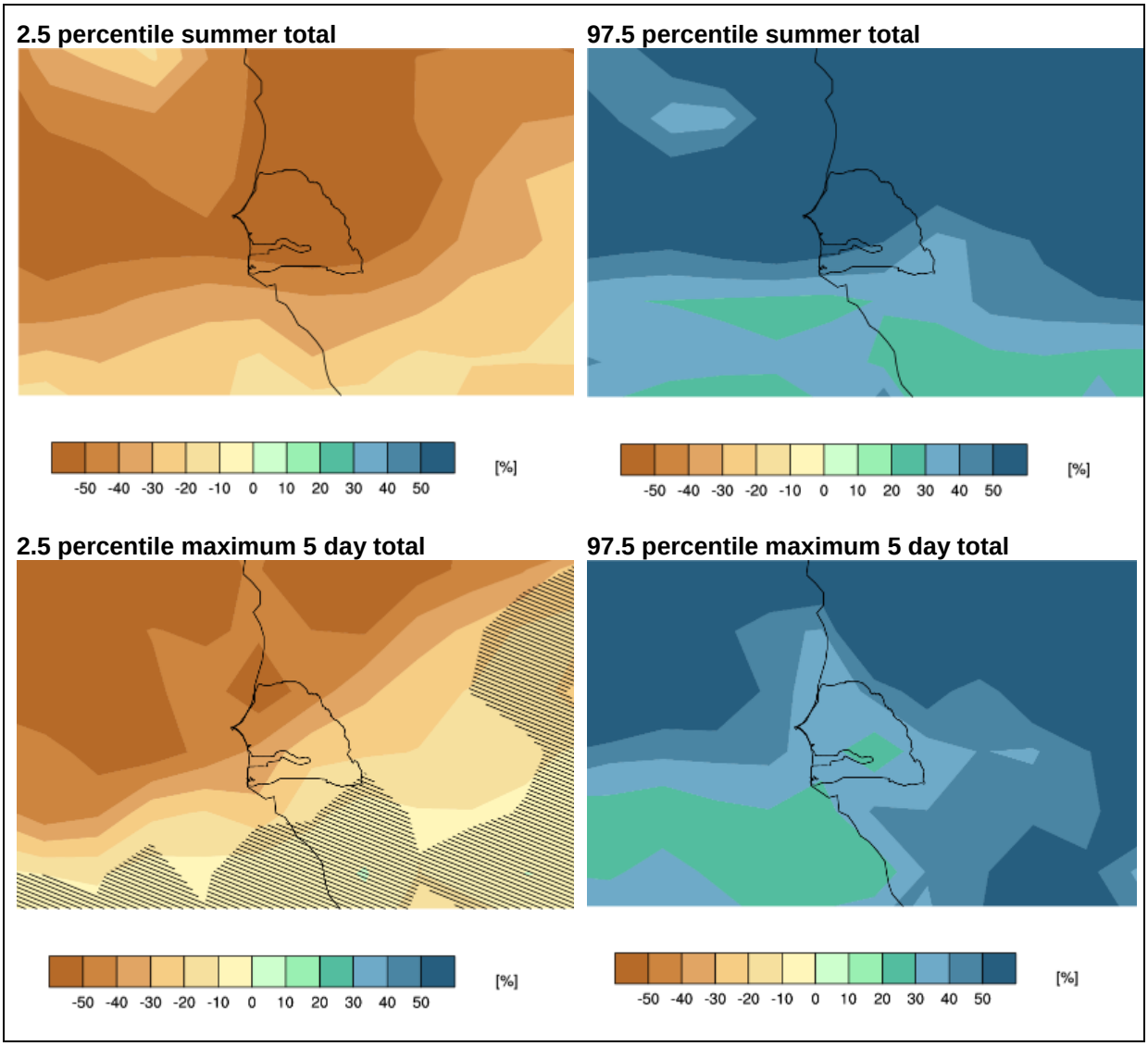


Figure 8.4 CMIP5 percent changes in summer mean (upper) and 5-day (lower) precipitation totals by 2050s under RCP8.5 for the 2.5 (left) and 97.5 (right) percentile estimates. Hatching shows where the signal is less than one standard deviation of natural variability.



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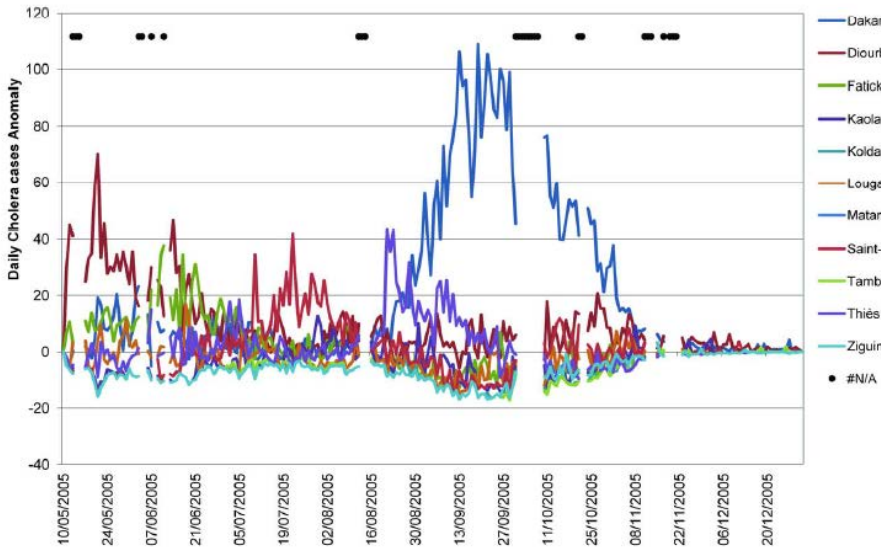
Future precipitation changes are highly uncertain. The climate model ensemble (CMIP5) used in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report suggests a range of ±50% for summer and 5-day rainfall totals across Senegal (Figure 8.4). Against this backdrop of uncertain past and projected precipitation trends, the following case study shows how climate information could improve preparedness and help to reduce flood-related epidemics in Dakar.

Climate information to forecast flood-related human health risks

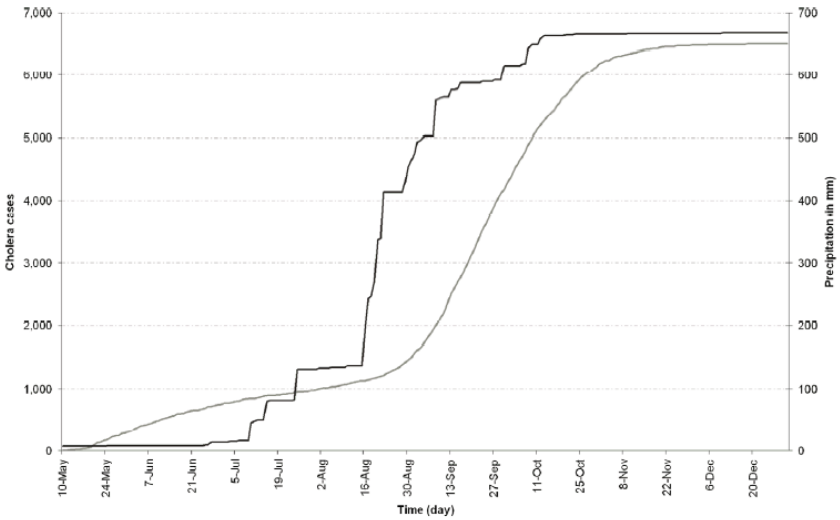
As noted above, community acquired diarrhoea occurs as widespread epidemics, with a high proportion of bacterial infections during the rainy season in Senegal (Sambe-Ba et al., 2013). Using remotely sensed daily rainfall anomalies and epidemiological data collected by the Senegal Ministry of Health between 10 May 2005 and 31 December 2005, de Magny et al. (2012) show a strong association between a specific pattern of rainfall over Dakar, and the number of cholera cases per 100,000 of population (Figure 8.5 and 8.6). Sea surface temperature (SST) data were obtained from the NCEP Climate Data Assimilation System (CDAS) and used to calculate a temperature gradient across the equator. When this gradient is strongly positive there is a northward position of the Inter Tropical Convergence Zone (ITCZ) that favours anomalously high rainfall across the region.

Figure 8.5 Daily cumulative anomaly of cholera cases observed for 11 regions of Senegal.



At the height of the epidemic there were nearly 120 new cases per day recorded in Dakar (Figure 8.5). The epidemic was preceded by a period of intense rainfall which began on 15 August 2005 (Figure 8.6). The number of new cases began to rise steeply seven days after the heavy rainfall and reached the maximum 28 days later. Cross-correlation analysis suggests that the dynamics of the cholera cases and rainfall are most strongly associated with a lag of 23 days.

Figure 8.6 Relationship between daily accumulated cholera cases (grey line) and rainfall (black line) for Dakar.



Source: de Magny (2012).

A combination of factors made conditions in 2005 conducive to a major cholera outbreak (de Magny et al., 2102). First, cholera cases were already being recorded across Senegal before the floods. Second, the flooding contaminated drinking water for those relying on untreated supplies from rivers, ponds or tube wells, and especially for populations lacking proper sanitation. Third, poor drainage in low-lying neighbourhoods led to water stagnation forcing the displacement of ~50,000 people. Fourth, the incidence was highest in regions with greatest population density (having accounted for temporary inhabitants, migrants and underreporting of cases).

Significant positive anomalies in the Atlantic SST gradient led to a 60% rainfall anomaly (relative to 1971-2000). The association between cholera transmission and flooding (and in turn between heavy rainfall and SST anomalies) raises the prospect of sub-seasonal forecasting of precursor conditions favouring epidemics in Senegal. Hence, development of a predictive framework based on rainfall forecasts could strengthen the epidemic preparedness of authorities. Moreover, there is potential to apply the same approach in other flood prone regions in Africa (see Tarhule, 2005). For example, episodes of water borne disease in Djibouti-ville are highly correlated with heavy rainfall following El Niño conditions in the Pacific (Wilby et al., 2010).

Future research opportunities

There are a range of options for reducing flood-related health hazards in Dakar (and Saint Louis) including stricter land zonation and enforcement to deter further development in hazardous areas, awareness raising and behaviour change, rehabilitation of the drainage system, enhanced artificial recharge of aquifers with storm runoff, and early warning systems to forecast prolonged, heavy rainfall (Diagne, 2007; Schmidt, 2011; Dasylva, 2012). In addition to forecasting water-borne disease outbreaks, climate information could potentially contribute to improved public health in other ways.

For example, following the 2009 floods the Government of Senegal conducted a post-disaster needs assessment and determined that an integrated approach to stormwater management was required. The *Senegal Stormwater Management and Climate Change Adaptation Project (PROGEP)* addresses these needs via three key pillars: investment in new drainage infrastructure, operation and maintenance; institutional capacity building; and

stakeholder engagement in peri-urban areas (see Table 1). A World Bank (2011:4) Project Initiation Document for PROGEP notes that:

….A decision should be taken on the acceptable level of risk: drainage systems are often designed for a 10 or 20 year return period depending on the cost of climate proofing and socio-economic importance of protected areas. This sub-component would be subject to a rigorous technical study and an environmental and social assessment during project preparation….

What remains unclear is how the design standard for "acceptable" risk will be established, and the extent to which this will be cognisant of climate change. More generally, the project touches on a wider need for guidance and technical advice for engineers on how to operationalize climate science in practice (option 4 in Table E1).

• Number of direct project beneficiaries (132,000; 2017)
• Number of female beneficiaries (65,000; 2017)
• Area protected against recurrent flooding (660 Ha; 2017)
• Capacity building programme completed (2017)
• National stormwater strategy validated (2017)
• Lessons learned from local urban plans (2017)
• Number of people reached by strategy (80,000; 2017)
• Length of primary drainage system in place (28.2 km; 2017)
• Functional stormwater management system (2017)
• Percentage of drainage channels cleaned annually (100%; 2017)
• Local flood management committee strengthened (2017)

Source: World Bank (2011)

Table 1 Performance indicators of the *Stormwater Management and Climate Change Adaptation Project for Dakar, Senegal*.

Other priorities for research (identified by the World Bank [2011]) that involve climate information include: 1) Monitoring and modelling projected changes in sea level and storm surges, particularly in the vulnerable coastal regions around Thies, Dakar, and the Senegal River delta; 2) Detailed spatial mapping of flood-related data including evolution of flood affected areas, households and neighbourhoods over time, distribution of key community assets and infrastructure, and projected future impacts (see 5th Global Forum in Urban Resilience and Adaptation, Bonn, Germany, 2014).

Finally, the epidemiological studies described before show the value of integrated assessments involving routine collection and analysis of hydro-climatic information alongside remotely sensed products, seasonal forecasting systems, and clinical data. Such studies may help to identify specific risk measures and lead to instruments for managing the multi-factor health hazards associated with rapid, unplanned urbanization and climate change in Africa.

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