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# Climate and health in Africa

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**Abstract**

This paper describes the work of the International Research Institute for Climate and Society (IRI) and its partners towards the development of climate services for the health sector in Africa; integrating research, operational applications and capacity building alongside policy development and advocacy. It follows the evolution of IRI's health work from an initial focus on the use of seasonal climate forecasts to a wider agenda serving climate and environmental information needs to a broad range of health-related users. Recognizing that climate information must be relevant to the priority policy and programming needs of national and international health stakeholders, this review highlights an approach that has centered not only on the assessment and creation of evidence, but also on knowledge transfer through engagement with decision-makers. Current opportunities and priorities identified for the routine use of climate and environmental information in health in Africa include: i) understanding mechanisms by which climate impacts on transmission and occurrence of disease; ii) mapping populations at risk both in space and by season; iii) developing early warning systems; iv) understanding the contributions of climate to trends in disease incidence v) improving the evaluation of the impacts of climate-sensitive interventions.

While traditional metrics (e.g. peer review publications) have been important in establishing evidence for policy, the IRI's role as a knowledge broker (in research and professional capacity building, facilitation of communities of practice, and engagement in policy dialogue at local and global scale) has been critical to delivery of its mission.

**Keywords:** Climate; Health; Africa; Climate services; Risk Management; Interdisciplinary; Adaptation; Early Warning System

## Introduction

Although Sub-Saharan Africa is rapidly urbanizing, the continent remains substantially reliant on rain-fed agriculture and surface water resources (McCartney et al. 2013). Despite significant economic growth in several countries, there is still a high burden of climate-sensitive diseases, food insecurity and hydro-meteorological disasters (WHO-AFRO 2011). Health and well-being therefore remain highly climate dependent.

Health has been an important focus of IRI activities through much of the institute's history. In 1999 IRI supported its first workshop on "Climate Prediction and Diseases/Health", which took place in Bamako, Mali in March/April 1999 (Tourre 1999). The objectives of the Bamako workshop were:

- To expose professionals of the climate and health sectors in Africa to state-of-the-art climate and health science.
- To explore the linkages between physical and biological mechanisms of disease transmission and epidemics relative to climate variability;
- To foster the application of regional climate prediction to preparedness and decision-making processes in the health sector;
- To provide cross-fertilization, exchange of ideas, expertise and analytical tools between climate and health researchers from other countries and continents.

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In this paper, we outline key developments and lessons learned in the health programme at IRI since the Bamako workshop.

### Development of a climate and health strategy

The initial emphasis at the IRI on *early warning systems* was a logical beginning for its health work as this emphasis provided a natural opportunity to introduce IRI's core strength in seasonal climate forecasts (Mason et al. 1999) into vector borne disease control planning. The approach taken was to drive biological models with global climate data (Hopp and Foley 2001) and then to compare the results with disease incidence (Hopp and Foley 2003). While this work provided an important starting point for the development of forecasting models, the models did not incorporate much of what is known about disease transmission dynamics (Morin et al. 2013) and were not focused on the operational needs of the health sector.

In order to better respond to potential user needs, the strategy adopted for the IRI's health programme in Africa since 2002 has been to align activities with the political, technical and economic priorities of the international health community. The overarching goal established was "to increase the well-being of people in Africa by reducing vulnerability to adverse climate impacts". The purpose was "to create the knowledge and capacity, and thus the opportunity for health organizations and their partners to predict, prevent and manage adverse climate-influenced health outcomes." To realise this knowledge and capacity, efforts were focused on diseases of major public health significance that impact the poor across the differing disease ecological strata. The choice of efforts was based on their potential to impact health policy rather than scientific curiosity. A set of *verifiable indicators* was created that included i) establishment of a coalition of partners who are able to identify and commission operational research activities ii) the provision of innovative mechanisms for health organizations to routinely access and use new knowledge to anticipate, prevent and manage climate-related adverse health outcomes; and iii) the creation of cadres of researchers focused on health – climate issues.

The following were identified as *key intermediary indicators* i) evidence on the role of climate in driving the multiple spatial and temporal determinants of health outcomes, which may include: infectious disease transmission, food security, livelihoods, poverty, disasters, socio-economic development; ii) the creation of tailored climate/environmental products that can be used both for research and operational activities, including near real-time monitoring products and downscaled climate forecasts; iii) research indicating the economic value of the use of tailored climate/environmental information in national, regional health decision-making in Africa.

An important part of the strategy to engage the global health community was the creation, in 2004, of the IRI-Pan American Health Organization-World Health Organization Collaborating Center (US 306) for "Early Warning Systems for Malaria and other Climate Sensitive Diseases." Since its inception, the collaborating center has provided a formal link with this key UN health agency. It maintains active engagement with the WHO/PAHO's Regional Offices in Africa and the Americas as well as with headquarters in Geneva, where the sponsoring department is the Global Malaria Programme (GMP).

This new strategy resulted in an explicit focus on the achievement of the Millennium Development Goals (MDGs) (UN 2013). As the MDGs became the focus of international development, scientists at IRI were concerned that climate variability and change might pose a risk to their achievement. As a result malaria was prioritized at IRI because control of this climate sensitive disease was seen as essential to the achievement of the MDGs (Gallup and Sachs 2001). The report "Sustainable Development in Africa – Is the Climate Right?" (IRI 2005) was designed to alert high-level policy-makers, involved in the Group of Eight (G8) summit at Gleneagles in 2005, to the challenge posed by climate variability and change. The report's specific objective was to link two expected outcomes of the G8 agenda: to increase overseas development assistance in support of MDG achievements in Africa, and to strengthen the continent's climate observing systems (G8 2005).

Following the IRI 2005 report, the UK Department for International Development (DFID) commissioned the Institute to undertake a "Gap Analysis for the Implementation of a Global Climate Observing System (GCOS) program in Africa" (IRI 2006). The objective was to better understand how improvements in climate data and services could have a positive impact on development outcomes – particularly on the MDGs. The "Gap Analysis" identified four major areas requiring investment in order to overcome barriers to the effective use of climate information in national decision-making for development. These were i) policy; ii) practice; iii) services; and iv) data. In short, to use climate information effectively policies need to be flexible in order to respond to changes in climatic risk, practitioners need to be able to use policy relevant climate information when and where cost-effective, the providers of climate information need to provide reliable, relevant, accurate and timely information, and the underlying observational data need to be quality-controlled, analysed and readily accessible (Connor et al. 2006).

The "Gap Analysis" was presented at a major stakeholder meeting in Addis Ababa in 2006 that launched Climate for Development in Africa (ClimDev-Africa); a multilateral initiative overseen by a Secretariat comprised of the African Union, the United Nations Economic

Commission for Africa (UNECA) and the African Development Bank. Following the Addis Ababa meeting, the IRI was invited to write its first *Climate and Society Report* to showcase examples of the effective use of climate information in development decision-making in Africa, including health (Hellmuth et al. 2007). One of the case studies focused on the development of Malaria Early Warning Systems (MEWS) in Botswana. Because much of the initiative originated from the regional health partners, this case study demonstrated the value of collaborations between climate and health sectors in the development of the MEWS.

A prerequisite to the effective use of new (in this case climate) information in health decision-making is the role of evidence (Kula et al. 2013). Evidence needs to be gathered in relation to two distinct issues. The first is the need to establish the degree to which climate is a significant driver of specific health-related outcomes (Kelly-Hope and Thomson 2008), and the second is the need to establish the utility (including cost-effectiveness) of using climate information in improving such outcomes. Demonstrating cost-effectiveness is easiest to do when a climate-informed intervention is compared with no such intervention (Worrall et al. 2008); it is much more challenging to compare the impact of a climate-informed intervention with a non-climate related intervention.

In a multi-disciplinary environment, agreeing on what constitutes evidence is not always simple since each community may approach the creation and acceptance of evidence with diverse criteria and perspectives. Getting evidence into policy and practice in the health sector is a widely identified challenge, both in the developed world (Nutley and Davies 2000; Lomas 2007) and globally (WHO 2004). Our aim has been to create policy-relevant evidence and transfer results to operational decision-making in both communities. We have used a number of approaches for knowledge transfer or 'brokering' (Ward et al. 2009) including traditional approaches for the development and diffusion of knowledge (publications, reports, presentations, conferences), fostering links between the producers and users of information (communities of practice, coalitions of partners) and targeted research and professional capacity building activities (multi-disciplinary training).

As indicated above, establishing and strengthening the evidence base for the role of climate as a significant driver of health outcomes has been a central part of IRI health work. For example, understanding the basic mechanism whereby climate affects infectious disease transmission is important for an improved scientific understanding of the disease dynamics and better targeting of interventions. In the context of malaria, the mechanisms (i.e. influences of rainfall and temperature on vector dynamics, pathogen development and human/vector interactions) are relatively well understood. Malaria is a climate-sensitive, vector-borne disease that is transmitted in Africa by mosquitoes belonging to the *Anopheles gambiae s.l.* species complex, which breeds primarily in sun lit, rain-fed puddles and other still, clear water sources (Thomson et al. 1996). Laboratory studies confirm the importance of temperature on the development rates of both the malaria parasite and its mosquito vector, but the relationship is likely more complicated than initially thought (Paaijmans et al. 2012). Mechanisms underpinning many other climate-sensitive diseases or health outcomes are not necessarily well understood. Climate-driven statistical and process-based models are increasingly being used to refine our knowledge of these relationships and predict the effects of climate variability and climate change on disease incidence. However, results are not always consistent and may be of limited operational use (Morin et al. 2013) if different components of the system are not properly elaborated.

Early on in its history, the Roll Back Malaria Partnership recognized the potential to use climate information in Malaria Early Warning Systems (MEWS) to help predict and prevent malaria epidemics (WHO 2001). The MEWS approach was designed to include elements of vulnerability assessment, seasonal climate forecasting, weather/environmental monitoring and improved case surveillance within an integrated framework that could inform malaria control planning, enable preparedness, early detection and timely response. The use of seasonal climate forecasting was explored in depth through a collaboration between IRI and the European Union funded DEMETER (Development of a European Multi-model Ensemble Forecast System for Seasonal to Inter-annual Climate Prediction) project (Palmer et al. 2004). Forecasts were developed using a multi-model system permitting forecasts to be presented to decision-makers in such a way as to indicate the level of uncertainty in the predictions (Thomson et al. 2000). Probabilistic forecasting is intended to encourage the use of forecast information in regions, seasons and years when predictability is most likely to be high (e.g. the East African short rains during El Niño-Southern Oscillation events) and ignored when predictability is insufficient for improved outcomes, e.g. during the long rains in Kenya during March-May (Thomson et al. 2003).

Initial success of the MEWS approach was demonstrated at the regional level in the Southern Africa Development Community (SADC) (DaSilva et al. 2004). The approach built on lessons learned from the food security community (Buchanan-Smith and Davies 1995; Kuhn et al. 2005) and focused on data, methodologies and tools (Grover-Kopec et al. 2005; Grover-Kopec et al. 2006) that could be readily transferred with an emphasis on political engagement with key stakeholders (DaSilva et al. 2004). Regional support for the development of MEWS came from the WHO- Southern Africa Malaria Control

(SAMC) program supported by the RBM Inter-Country Team and SADC Drought Monitoring Center (DMC) based in Harare, Zimbabwe. . Botswana was selected as an initial focus because of its long history of reliable, laboratory-confirmed epidemiological data. IRI worked with the Ministry of Health to determine the relationship between observed and forecasted rainfall and malaria incidence (Thomson et al. 2005; Thomson et al. 2006; Mason and Stephenson 2008). The strength of the observed relationship encouraged neighboring SADC countries to develop their own MEWS.

Between 2004 and 2007, the principal mechanism established for awareness-raising and information sharing between the climate and malaria control communities in Southern Africa was the seasonal Malaria Outlook Forum (MALOF), modeled on the traditional “Climate Outlook Forum” (Ogallo et al. 2008). The main purpose of the MALOF meeting was to integrate climate information into the routine planning cycle of national malaria control programmes. The meetings were timed for November, just prior to the onset of the annual rainy season when seasonal climate forecasts were of sufficient skill to enable proactive decisions to be made (DaSilva et al. 2004). The MALOF garnered great interest in its first two years of operation. The activity was considered a practical example of adaptation to climate change and the approach was seen to be applicable to other climate sensitive sectors (WMO 2007).

The impetus in this regional activity declined, however, once donor funding ended. Without the resources to enable inter-sectorial regional organization and implementation efforts, the health sector could no longer adequately support the initiative and the climate community was unable to pick up the cost. Currently, while some national level activities have continued in the SADC member states and the malaria epidemics of the past have not re-emerged at the scale seen historically, a lack of sustained, long-term investment in this regional climate service initiative has led to gaps in delivery and focus.

Despite this demise in the meetings, the MALOF has inspired continued support to malaria control from the regional meteorological agencies. In addition, there is anecdotal evidence from newspaper reports as well as ministerial, donor and non-governmental organization statements suggesting that epidemic early warning activities continue. Moving forward, early warning systems continue to be seen as a component of national malaria elimination strategies (Simon et al. 2013).

While exploring how sustainable early warning systems might be established, IRI has continued to conduct research on the various sources of environmental and climate data and products that might be incorporated into malaria risk assessments. These include rainfall, temperature, vegetation and extents of water bodies derived from remotely-sensed images. New products provided by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) have been routinely tested against field observations and new, refined products developed. For example, estimations of air temperature derived from Moderate-Resolution Imaging Spectro-radiometer (MODIS) Land Surface Temperature products (Vancutsem et al. 2010; Ceccato et al. 2010) were developed and provided to the user community to assess risks of malaria transmission in the highland regions of Africa. Maps of water bodies and vegetation using the MODIS sensor at 250 metre spatial resolution were developed and integrated into vector-borne disease risk models (Baeza et al. 2013; Ceccato et al. 2006). Additionally, a Vectorial Capacity Model (VCAP) has been designed to include the influence of rainfall and temperature variables on the potential for malaria transmission. The expanded model was tested in Eritrea and Madagascar using remote sensing data to check the viability of the approach. The analysis of climate driven VCAP and malaria incidence data in these countries showed that the model correctly tracked the risk of malaria in regions where rainfall and or temperature were the limiting factors (Ceccato et al. 2012).

In 2003, Eritrea was a primary recipient of World Bank and USAID funding for malaria control (Simon et al. 2011) and the IRI was invited to provide technical support to the Ministry of Health through the creation of a Malaria Early Warning System (MEWS) in this highly epidemic prone country. Analysis of climate and malaria data in Eritrea identified a potential limitation of the national malaria program’s impact evaluation process. A more than 60% reduction in malaria incidence observed between 1998 and 2003 was widely lauded by the World Bank and others as a result of the scale up of control efforts such as indoor residual spraying and the use of insecticide impregnated bed nets (Barat 2006). However, during the intervention period, Eritrea experienced much drier climatic conditions compared with the baseline year of 1999. Without accounting for the impact of drought on the observed decline in malaria, the Ministry of Health risked overstating the effectiveness of their control program and thereby potentially underestimating the need for future investments. A careful analysis which accounted for rainfall variability in the assessment of the impact of anti-malarial interventions in Eritrea concluded that drought contributed to approximately 40% of the total decline in cases during the period of observation (Graves et al. 2008). This analysis alerted the IRI to the value of using climate information in malaria control impact assessments (Dinku et al. 2014b; Thomson et al. 2012).

Epidemics of malaria remain a major public health issue in East Africa where both desert-fringe and highland-fringe epidemics have occurred following unusual rainfall and temperature conditions (Worrall et al. 2004). The highland areas are of particular concern due to their economic importance and dense populations. Significant epidemics in many highland regions in the 1990s prompted calls for improved epidemic early warning (Connor et al. 1999). Some considered these epidemics as evidence of climate change in the region (Patz et al. 2003). However, this perspective was strongly contested, largely on the erroneous basis that epidemics had emerged in the absence of a warming climate (Reiter et al. 2004).

The IRI's capacity to work with experts from both climate and sectorial communities has proven particularly valuable in helping to bridge the disciplinary divide at the country level. For example, in Kenya, the scientists worked closely with the Kenyan Meteorological Department to shed new light on the decade-long dispute on whether or not the highlands in Western Kenya have experienced a significant warming since the 1970's (Shanks et al. 2002; Hay et al. 2002; Pascual et al. 2006). A study by Omumbo and colleagues in 2011 using 30 years of quality-controlled daily meteorological data from a disputed highland study site (Kericho, Kenya) concluded definitively that significant warming has occurred and provided evidence that what was happening in the local climate in Kericho was intimately associated with what was happening at the regional level (Omumbo et al. 2011a). Year to year anomalies in minimum temperatures, for example, where found to be strongly correlated with equatorial land and sea surface temperatures.

Given that the climate-malaria linkages in the Kenyan highlands have been studied extensively by several research teams and that the results of different studies have been disseminated widely and cited in key reviews (Reiter 2008) and policy documents (IPCC 2007), it is disconcerting to note that it took over a decade to obtain a quality assured historical temperature record that could be used to identify these trends. This study and other observed challenges, with regard to availability and access of climate observations, spurred efforts at the IRI to overcome the policy and technical barriers to climate data that exist at the national level (Dinku et al. 2014a).

## Getting evidence into policy and practice

Early on in its development the IRI health programme identified the need for "coalitions of partners" and "communities of practice" in furthering its multi-disciplinary, research-to-practice mission. Building communities involving both researchers and policy makers and practitioners is challenging given their differing priorities (Lomas 1997). However, such communities can help researchers identify questions of direct relevance to operational needs while giving the opportunity for decision-makers to better understand the strengths and limitations of science (Sutherland et al. 2013). One such "coalition of partners" is the Meningitis Environment Risk Information Technologies (MERIT) initiative, a multi-sectorial research-to-practice consortium designed to support current and future vaccination strategies for the prevention and control of meningococcal meningitis in the Sahel.

The history of MERIT, its membership and its processes are described in detail elsewhere (Thomson et al. 2013). The research supported by MERIT has targeted identified priorities for meningococcal meningitis control and the impact of serogroup A vaccination across the African meningitis belt (Greenwood 2013). Given the make-up of the consortium membership, the most significant research outputs have been largely focused on climate/environmental drivers of meningitis incidence (Yaka et al. 2008; Abdussalam et al. 2014; Dukić et al. 2012; Perez et al. 2014). In addition considerable advances have been made in understanding and monitoring of the climate of the Sahelian dry-season (Pérez et al. 2011). Although MERIT has advanced a research for policy and practice agenda, traditional differences between research and health services worlds remain and act as a constraint on effective knowledge transfer. Differences in the incentives for researchers (grants, publications) and decision-makers (actionable information) as well as timelines for expected delivery (years versus months) pose significant hurdles to the engagement of both communities (Lomas 2007), as does the time taken to engage in meaningful discourse (Ward et al. 2009).

In 2008, a multi-agency and cross-disciplinary community of practice "Climate and Health Working Group" (CHWG) was formed in Ethiopia with support from a Google.org funded project "Building Capacity to Produce and Use Climate and Environmental Information for Improving Health in East Africa". The project was designed to facilitate the articulation of climate information needs for improved control of climate-sensitive diseases (Ghebreyesus et al. 2008). The CHWG was composed of approximately 12 agency representatives and chaired by the Ministry of Health with the National Meteorological Agency (NMA) serving as co-chair. The remaining membership was drawn from agencies that broadly supported public health development in Ethiopia including: the Ethiopian offices of UN and other international organizations, the Ethiopian Health and Nutrition Research Institute, Addis Ababa University, the Association of Schools of Public Health and the Health-Development and Anti-Malaria Association (HDAMA; previously called the Anti-Malaria Association), a local community based-organization which also acted as the CHWG secretariat.

In the control and prevention of malaria, Ethiopia provides a striking example given its large population (80 million – the second largest in Africa only after Nigeria) and the fact that 75% of its inhabitants live in areas of unstable malaria transmission where year to year and longer term changes in climate can have a major impact. It therefore provided an ideal environment to explore the use of climate information in malaria control decision-making.

In its first three years of operation, the Ethiopian CHWG, with the support of HDAMA, organized and supported cross-disciplinary training and research activities across these agencies at national and sub-national levels. These activities in turn led to elaboration of information needs and the development of operational information products designed to serve control initiatives for a number of climate-sensitive health issues (Teka 2009; Dinku 2010). This demonstration of cross-institutional facilitation from Ethiopia stimulated interest elsewhere and CHWGs (with a similar composition to Ethiopia's) were established in Madagascar with the support of the World Meteorological Organization (WMO), in Kenya with the support of WHO and in West Africa with the support of the African Center of Meteorological Applications for Development (ACMAD) and AEMET (the National Meteorological Agency of Spain). Based on these initial results, WMO has adopted CHWGs as a key strategy for the development of its engagement with the health community in Africa (Guillemot 2014).

A key outcome of the Ethiopian capacity building work has been the prioritization of improved historical and real-time climate data and information over climate forecasts. The observational data provide the basis for improved historical, current and future analyses, and since the opportunity to create useful forecast information is severely constrained where data are lacking the prioritization of the observational data is effectively unavoidable. The creation of "Enhanced National Climate Services" (ENACTS) products from quality controlled national observational data blended with appropriate satellite data (Dinku et al. 2011) has not only transformed the way the National Meteorological Agencies can serve the development community, but has focused attention on the need for robust historical information, with national coverage, to form the basis of climate-sensitive decision-making (Thomson et al. 2011). In response to demand from the national meteorological agencies and with support from WMO and regional partners, ENACTS have been developed at the regional level in West Africa and at the national level in Madagascar and Tanzania with other countries now seeking similar support. These new "gold standard" nationally owned climate resources have enabled, for the first time, detailed analyses of the impact of climate variability on malaria impact assessment by National Malaria Control Programmes (Dinku et al. 2014b).

Multi-disciplinary trainings (involving both the health and climate research and operational communities) are an important part of the capacity building portfolio of IRI and have been a central pillar of the CHWGs. Short training courses held in Ethiopia, Kenya and Madagascar have been facilitated by alumni from the Summer Institute "Climate Information for Public Health" held in New York (Mantilla et al. 2014). In Madagascar, two training courses on the use of climate information for public health were conducted in October 2009 and March 2010. These courses were implemented and funded by the Public Weather Services (PWS) program of WMO as part of its new "Learning Through Doing" (LTD) approach to the delivery of climate services. The LTD effort implemented in Madagascar offered new opportunities for multi-disciplinary research and collaboration between climate experts and public health professionals (Cibrelus et al. 2010). The content of these courses was based on the IRI Climate Information for Public Health curriculum (Cibrelus and Mantilla 2010) and the courses were delivered in the local language with materials tailored to local needs, using national disease surveillance data and examples relevant to the areas of work of the participants.

As a boundary institute (both a WHO Collaborating Center and a source of expertise for many WMO programs, projects and processes), the IRI has been present and engaged in many key inter-institutional efforts including, for example, the World Climate Conference III held in Geneva in 2009 to launch the GFCS process (Guillemot 2014; Connor et al. 2010). To facilitate inter-sectorial dialogue and processes, a US 501c3 Non-Governmental Organization, the Health and Climate Foundation (HCF 2007) was created. IRI has partnered with HCF to strengthen its engagement in the policy arena.

In April 2011, the IRI and the Health and Climate Foundation, in partnership with key regional and international organizations initiated and facilitated the "Climate and Health in Africa – 10 Years On" multi-stakeholder workshop in Addis Ababa (Omumbo et al. 2011b). The workshop was designed to reflect on achievements in climate and health research, policy and practice in Africa since the Bamako meeting of 1999 and to chart a way forward for greater impact. Steering member organizations included WMO, UNECA's African Climate Policy Center (ACPC), the United Nations Development Program (UNDP), WHO-AFRO, the Met Office, Exeter University and HDAMA. With over 100 participants, many from National Meteorological Agencies or Ministries of Health, the workshop participants developed a series of key recommendations in the areas of policy, practice, climate services and data, research and education (Table 1) building on lessons learned in the "Gap Analysis". The recommendations testify to the emergence of a mature, experience-based, discourse between diverse stakeholders.

Engagement of WHO-AFRO in the workshop highlighted the importance of linking this effort to those emerging across the continent following the Libreville Declaration

(WHO-AFRO 2008). In response to the increasing need of Ministries of Health to adapt to climate change, WHO-AFRO has recently focused its efforts on the development of an informal international consortium for public health early warning and response, under the umbrella of ClimHealth-Africa (WHO-AFRO 2011). The IRI is currently supporting this effort.

While the African health community has been focused on the development of an enabling policy environment for the better management of climate-related health risks, progress towards the creation of a Global Framework of Climate Services (GFCS) under the leadership of WMO has been underway (Hewitt et al. 2012). The GFCS further reiterated the view that climate services must fully engage the user communities and be based on accurate, relevant and reliable observational data obtained in an effective, efficient, credible and transparent manner.

## Lessons learned

Through the evolution of the IRI's strategy on climate and health over the last fifteen years, the health programme at IRI has learned many key lessons some of which are described below.

### With regard to evidence creation

Attempts to promote the application of seasonal climate forecasts within the health sector are unlikely to succeed unless the forecasts are packaged as only one component within a broader climate service system. This system should include historical and monitoring climate and environmental products as well as forecast information, which extends across timescales (from from weeks to decades). This breadth of effort enables engagement in a much wider set of climate-sensitive development challenges (Hellmuth et al. 2007; Hellmuth et al. 2011; Hellmuth et al. 2009) and provides the health community with a wide-ranging new set of products and services. With this expanded range of information products we can improve our understanding of disease drivers; map populations at risk; investigate the seasonality and timing of interventions; monitor and forecast year-to year variability and trends (including epidemics); and assess the contribution of climate as a confounder in an impact assessment of interventions.

To influence policy and practice, evidence needs to be built up in a cumulative and strategic manner so that new knowledge can be accepted by specific user communities and incorporated in their planning process. Developing sufficient evidence might require using a range of methods, repeating the analysis at multiple sites to ensure robust, locally relevant, results and ensuring that the information is presented in the 'language' of the specific community. The varying spatial and temporal uncertainty of forecast information presents a challenge to decision-makers – as policies must often be consistent across administrative regions and seasons. However, by integrating seasonal climate forecasts into an early warning system that incorporates a range of information sources (such as a historical probability of climate suitability for epidemics, recent environmental observations, early case detection etc.), decision-makers may then access actionable information even when seasonal climate forecast signals are weak (Ceccato et al. 2007; Thomson 2013).

Seasonal climate forecast verification has been an important area of research at the IRI (Mason 2012). Ensuring that practitioners are aware of the limitations as well as the opportunities of climate forecasts is critical to their effective use (Mason and Chidzambwa 2008). Recent work includes establishing a verification framework for decadal prediction (Goddard et al. 2013). Such a framework is essential to establishing the potential skill of temperature and rainfall model outputs from Coupled Model Inter-comparison Project Phase 5 (CMIP5).

Once again evidence is required to establish the strength of the relationship between forecasts and outcomes as well as the value of the information to decision-making. Even if long term assessments were shown to have predictive skill, it is not clear how such information could be used in health decision-making. This is because most policy timelines for infectious disease prevention and control are relatively short when compared to climate change timelines of decades to centuries. Planning cycles in the Ministry of Health usually follow annual and political cycles, *i.e.* normally 1–4 years. Longer time-frames associated with programme development (e.g. roll-out of the malaria elimination strategy or new vaccines for meningococcal meningitis) may be on the order of 5–20 years. While climate scientists seek to find predictability in this time-frame, very little is known about the potential for decadal forecasts to have meaningful skill (Cane 2010).

Given these decision-making constraints, current opportunities and priorities identified by IRI work for the routine use of climate and environmental information in health in Africa are focused on: i) understanding mechanisms by which climate impacts on transmission and occurrence of disease; ii) mapping populations at risk both in space and by season; iii) developing early warning systems; iv) understanding the contributions of climate to trends in disease incidence; and v) improving the evaluation of the impacts of climate-sensitive interventions.

### With regard to knowledge transfer

Knowledge transfer is complex and requires an understanding of the often misaligned agendas of research and decision-making communities (Lomas 2007; Tsui et al. 2006). Meaningful exchange can only be built on a

**Table 1 Consensus recommendations on policy from workshop held on "Climate and Health in Africa: 10 Years On" held in Addis Ababa, Ethiopia in April 2011**

| Theme 1 Policy | Theme 2 Practice | Theme 3 Services and Data | Theme 4 Research and Education |
|---|---|---|---|
| *Support effective implementation of the Joint Statement on Climate Change and Health in Africa adopted by African Ministers of Health and Environment in Luanda, 2010, as an overarching platform for addressing climate and health issues to:* | -Integrate climate health risk management into cross-sector planning and practice for adaptation to climate variability and change by developing climate services and products that address disease prevention at end-user level. | -Develop tailored services in partnerships with weather/ climate and health organisations. These should recognise that health forecasts, which are different from weather forecasts, should be well designed and understood by all. They should act as early warnings to users of differing types, that assist in the prediction of future health outcomes. | -Understand the relationships between climate and climate-sensitive diseases and health issues under different environmentalconditions through interdisciplinary, multi-sectoral and multi-centre research. |
| -Bridge the gap between policies and practices through legislation and guidelines, appropriate planning, including relevant vulnerability assessments, programmatic support and multi-sectoral and participatory processes that are gender sensitive. | -Create a human resource center/ virtual hub where expertise is shared in order to develop the capacity of African health and climate communities, institutions, practitioners and negotiators to understand/integrate climate change challenges into policy, socio-economics, planning and pro gramming by identifying institutions and organisations in Africa that can deliver training courses and conduct research on "Climate, Health and Prevention". | -Improve existing data, for example through: the digitisation of historical health and climatic data; the increased use of metadata analyses and validation tools; the inclusion of aggregated health data at appropriate spatial and temporal scales; and the enhanced awareness of, and use of, observational and processed data, appropriate satellite, and climate model data sources. | -Ensure that climate change mitigation and adaptation strategies are informed by multi-disciplinary research. |
| -Support countries to establish integrated health surveillance and climate observation and processing systems. | -Strengthen community-based organisations by liaising, in a gender-sensitive fashion, with their leaders to develop locally owned sustainable strategies for adaptation to climate change and/or variability in their communities taking account of local knowledge rooted in social history and disseminated by appropriate channels, including the mass media. | -Access and use data in a systematic manner in order to identify vulnerable groups and areas. This needs to involve: employing data strategically within and across sectors; considering trend and seasonality issues; using data to evaluate the success of interventions; and, importantly, understanding how communities cope. | -Develop capacity within Africa for the generation, interpretation and use of climate, health and other interdisciplinary data enabling informed, evidence-based decision making. |
| -Strengthen health systems using climate information tailored to decision needs at all relevant levels and time scales. | Define the different levels and needs (including learning outcomes) of health practitioners and stakeholders across different geographic scales, specifically researchers and teachers, graduate and undergraduate students, practitioners in the public health system, community opinion leaders, traditional healers, impacted communities and other special interest groups and develop appropriate curricula for adaptation to climate change and/or variability in the health sector. | -Incorporating other data into these health forecast services, for example population, rural *vs.* urban residence, migration, nutritional status, environmental and poverty data. | -Standardise and quality control data collection and storage, ensuring data are available on relevant temporal and spatial scales. |
| -Make evidence-based, sound climate-informed decisions to implement a set of preventive actions to reduce population vulnerability and lessen the additional burden imposed by climate-sensitive diseases and health issues according to their re spective epidemiological circumstances. | -Promote a gender-sensitive approach to interventions on climate and health in cross-sectoral disaster risk reduction and preventive health strategies. | -Collaboration +: new, multi-disciplinary initiatives that involve communities beyond health and climate/ weather; build upon existing initiatives and progress; aim to meet emerging challenges; and communicate with end-users in appropriate ways. | -Enhance knowledge transfer and communication of information across disciplines and communities through existing networks, encouraging the introduction of climate and health into the curriculum at all levels of education. |

**Table 1 Consensus recommendations on policy from workshop held on "Climate and Health in Africa: 10 Years On" held in Addis Ababa, Ethiopia in April 2011** *(Continued)*

| | | | |
|---|---|---|---|
| Anticipate, prepare for and respond to the health consequences of extreme weather events, particularly by strengthening the functioning of health systems and other relevant sectors. | | -Commitment at all levels that brings climate and health communities together, clarifies responsibilities, builds capacity in the climate and health sectors to achieve these services, facilitates joint initiatives and ensures resources such as data are shared in a suitable way. | -Strengthen existing partnerships and collaborations while developing new groups and building links across disciplines. |
| Multilateral partners to consider the significant co-benefits of environ ment integrity, population health and consequent economic devel opment that can result from mitiga tion and adaptation policies in the climate and health sectors and to support African countries in gaining access to resources under the various climate-related funds. | | | |

confident and trusting relationship. Approaches to increasing uptake in policy and practice must happen at a number of levels. First of all, policies must be flexible enough to respond to new information. If they are not, then opportunities to change policies should be explored. Researchers must recognize that scientific evidence is only one piece of information that is used in the pragmatic and political process of decision-making. Even when policies favour the use of new information, practitioners may not adopt it in their decision-making processes without additional support. This might come in the form of formal or informal (including web-based) training, access to decision-relevant peer-review publications (e.g. open access) and technical reports and peer-to-peer communication.

The metrics developed and described earlier in this document have acted as a guide to programme development rather than an explicit evaluation tool. Nonetheless, significant advances in the creation of evidence for policy, "support to communities of practice" and "coalitions of partners" at national and international levels have demonstrated the value of this approach.

The challenge of designing and implementing rigorous impact evaluation for in-country use of climate information remains. The effort needed to undertake significant impact evaluations, which could connect climate information to development outcomes, is not only challenging methodologically but requires resources beyond those available through conventional research funding. In addition, basic capacities in the delivery of climate information in Africa at the national level are only now emerging, making it difficult to undertake proper assessments of the value of the information in a 'real world' context.

## Opportunities going forward

IRI has long proposed the incorporation of climate information into routine epidemiological surveillance systems (Jima et al. 2012) for climate-sensitive diseases (Thomson and Mantilla 2011). To achieve this integration requires new and innovative mechanisms for strengthening observations, data management and sharing, development of relevant climate services, intersectorial collaboration, training and capacity building, all within an enabling policy environment. The premise is that improved management of health risks associated with climate variability (such as the heat early warning systems recently established in Europe and North America) increases adaptive capacity of the public health sector to longer-term climate change.

In response to this need, the IRI has invested considerable effort in training and research capacity development in the area of climate and health through its Climate Information for Public Health curriculum and associated initiatives (Mantilla et al. 2014). Going forward, a broader health agenda has to be identified, which connects climate and environmental information to the needs of communities dealing with infectious disease, public health outcomes of hydro-meteorological disasters and nutrition. Central to this strategy is a focus on availability, access and use of historical, current and forecast data at temporal and spatial scales appropriate for decision-making (Dinku et al. 2011). In addition there is an urgent need to develop research and operational capacity to use the information in decision-making.

The "Climate and Health in Africa - 10 years On" workshop held in Addis Ababa in April 2011 demonstrated the dramatic change in perception of the value of climate information in health decision-making in Africa since the Bamako workshop of 1999. This change is fostered by new resources for climate change adaptation, policy developments at the global and regional scale, donor and government requirements for more targeted health interventions and the need for better assessments of the impact of climate sensitive interventions. The specific role of IRI's contribution to mainstreaming climate information into health policy and practice in Africa cannot be fully assessed in the short term. However, we believe that the current and former staff and alumni of the IRI have played a significant role in advancing the concept and implementation of a 'climate-smart' health sector in Africa.

#### Competing interests
The authors declare that they have no competing interests.

#### Authors' contributions
All authors contributed to this review. MT was responsible for lead authorship and assumed final word on all writing. SC provided substantial contributions to conception and overview, with BP providing critical early stage revisions and content. JO, SM and GM are listed as co-authors due to their indispensable effort in reflecting on and capturing climate and health activities at IRI and launched with partners in Africa and their diligent editing advice. PC provided critical feedback on the remote sensing contributions of IRI's work to framing the health approach and new product development driven by user needs and MJ contributed to the discussions on MERIT and the broader policy implications of IRI work while AM initiated the development of Climate and Health Working Groups in Africa and reported on their development. All authors read and approved the final manuscript.

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