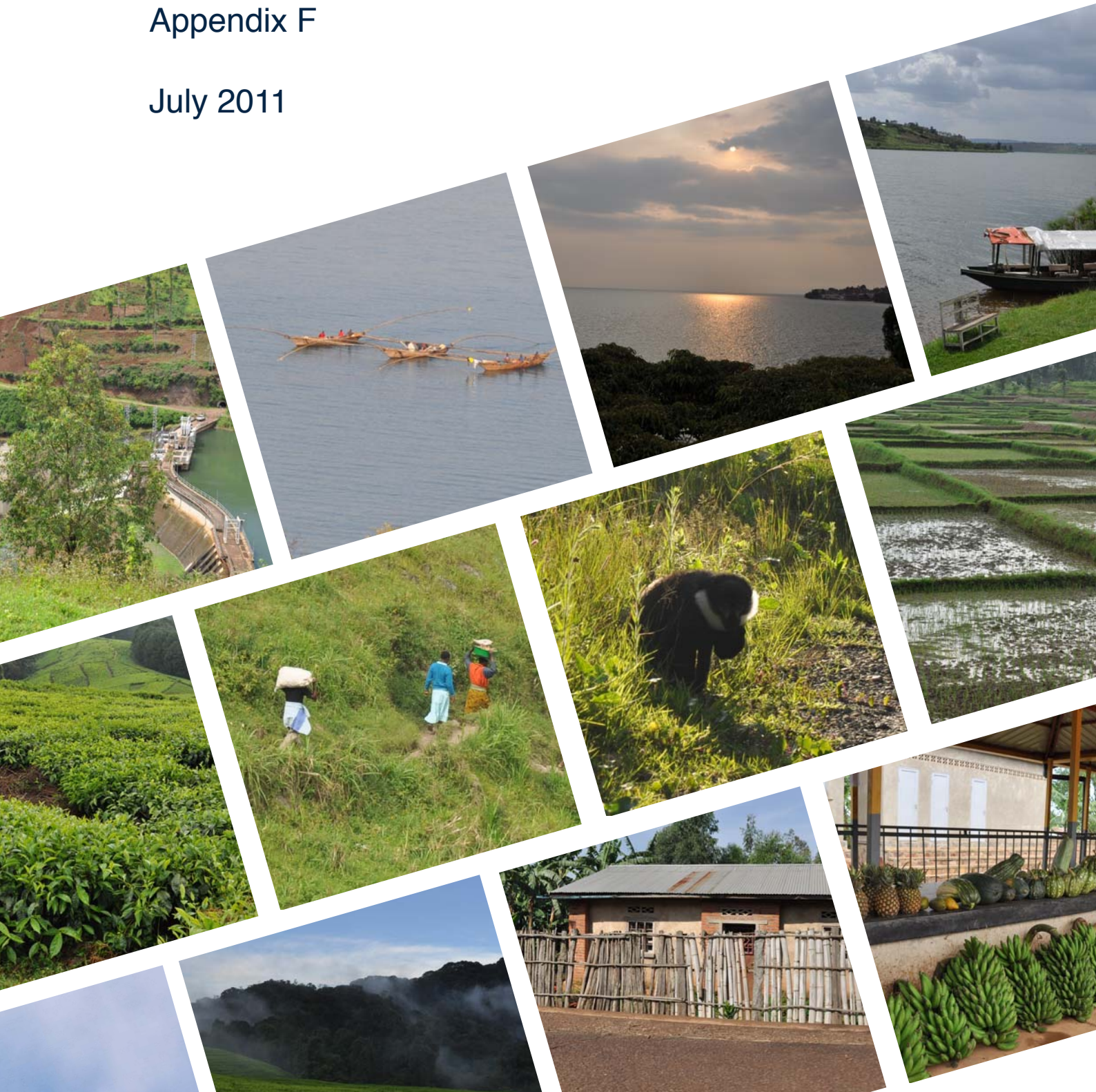
Rwanda's Centre for Climate Knowledge for Development: Proposal

Appendix F

July 2011



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Executive Summary

The establishment of a Centre for Climate Knowledge for Development in Rwanda is put forward as part of the National Strategy on Climate Change and Low Carbon Development in which the need for an institute capable of taking responsibility for generating and disseminating climate, climate variability and climate change information, and translating that information into knowledge within the overarching context of development for Rwanda, is highlighted. This is not to suggest that the programmes as presented in the Strategy would not be achievable in the absence of such an institute, but rather that such an institute would strengthen many of the actions identified in the Strategy, and would bring wider benefits to Rwanda's vision of a knowledge-based economy.

In this report, the background to, the justifications for, and some practical options are assessed for the establishment of a centre dealing with the nexus of climate and development within Rwanda. The justification is developed in this report through assessment of Rwanda's needs for climate information and of the limited resource available both within Rwanda and within the region. In the concept as developed the Centre would be focused on building resources contributing towards the introduction of a knowledge-based economy, as indicated in Vision 2020, and on informing development within the country where it is sensitive to climate variability and change. The mission statement could be:

> *"To provide the knowledge of climate, of climate variability, of climate change, and of their relationships with all components of the development of Rwanda required in the delivery of Vision 2020"*

In summary it is concluded that implementing an organisation would be in the interests of Rwanda, and the name Centre for Climate Knowledge for Development, CCKD, is put forward. Ten envisaged outcomes are outlined in this document for a Centre and the building blocks necessary to achieve them are identified (see figure1). These building blocks are discussed individually, and recommendations offered for the work that might be undertaken within each block.

The objective within this report is to offer a strategy under which a CCKD might be established; the next stage would include an implementation plan that would cover full institutional arrangements. The inter-relationships between a CCKD and other organisations within Rwanda are discussed, not least those with the Rwanda Meteorological Service (RMS), and options suggested for various possible institutional implementation arrangements for a CCKD.

The following recommendations are made, with specific recommendations covered in more detail in the full document:

- That all meteorological and observational climate data are collected, managed and distributed by the RMS, including any data from the proposed Observatory on Mount Karisimbi (with chemistry data collected according to AGAGE and GAW protocols) and from networks set up by other ministries and organisations; the CCKD should not be responsible for any

continual data collection whether for climate or for any of the other sectors involved.

- That RMS holds all responsibility for weather and climate operations and research, including predictions and projections
- That the CCKD be formed as a mainly virtual centre taking advantage of existing facilities within Rwanda, strengthened as necessary including to cover current resource gaps, using appropriate collaborative expertise such that the Centre be multi-disciplinary, including expertise in climate, in technologies in all pertinent sectors, and in policy, and in any other pertinent disciplines as appropriate, such as those related to atmospheric chemistry and to climate adaptation and mitigation
- That the Centre develop links with extant pertinent national, regional and international climate, sectorial, social and policy research and, where appropriate, implementation programmes and institutes, both to kick-start activities and to assist in capacity and resource building
- That capacity building be given highest immediate priority alongside rebuilding of the observations network and that the Centre establish training programmes and links with pertinent departments in KIST and NUR, plus any other appropriate tertiary education institutes within Rwanda, and at institutes external to Rwanda
- That within the context of the Centre options are explored for becoming linked officially under either or both of COMESA and EAC.

The structure of the document is designed for ready reference. Following the "Introduction" the section "Justification for the Centre for Climate Knowledge for Development" provides an overview of the background to climate and development in which the case for the Centre is built. The following section, "Context", provides an assessment of current capabilities, both within Rwanda and within international institutes and programmes directly relevant to a Centre. The main proposals are given in the "Recommendations" section, which includes subsections on the main proposal itself, implementation options, and an introduction to the work of a Centre in terms of its intended outcomes plus the work programme, the building blocks, seen as necessary to achieve the outcomes. In the section "Further Implementation Issues" a comparison with the parallel proposal for a Climate Observatory is given, together with preliminary details of a timeline for creation of the CCKD. The final key section is on "Possible Sources of Funding".

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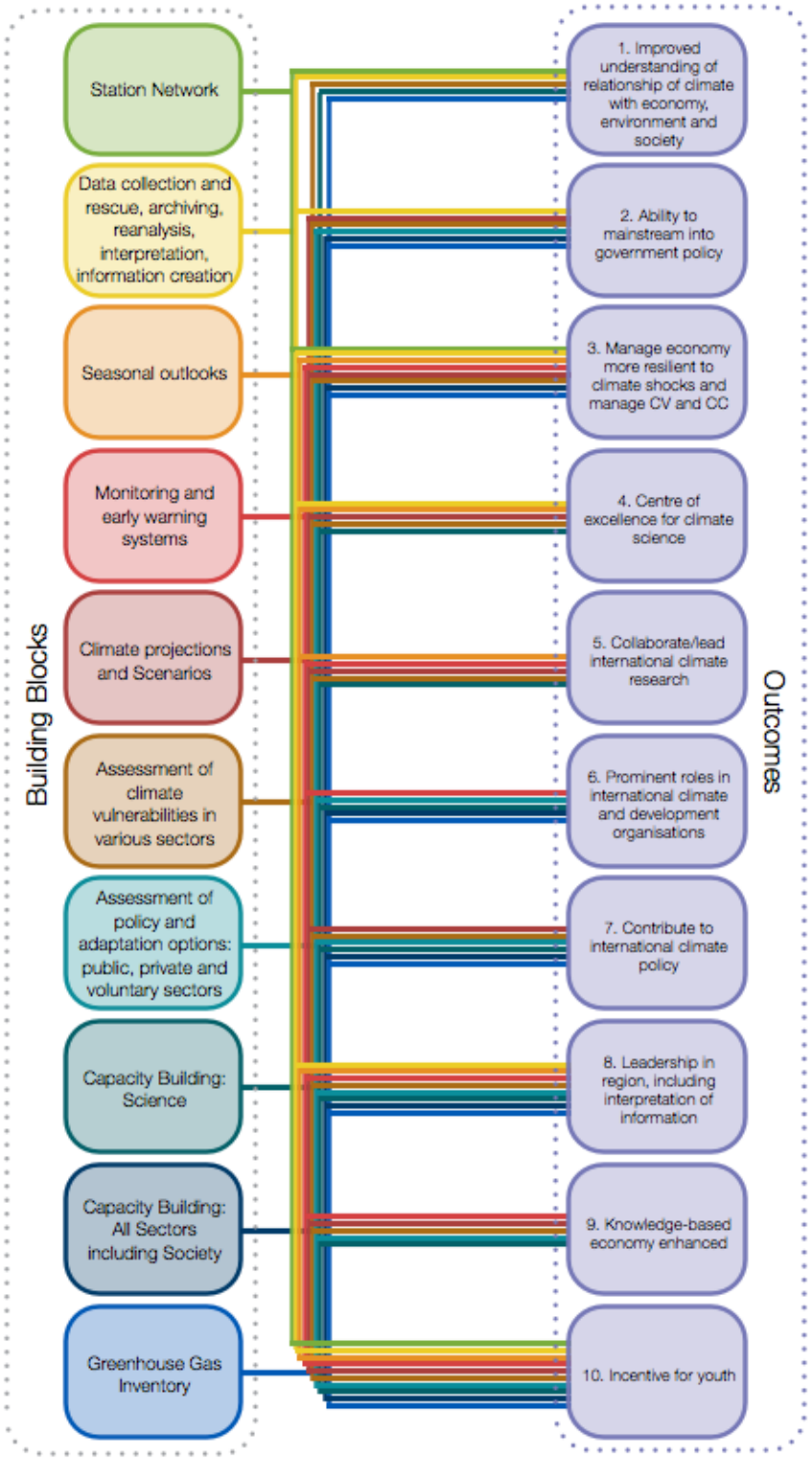

Figure 1: Schematic representation of the interrelationships between the envisaged Outcomes for a CCKD and the Building Blocks

Contents

Acronyms and Abbreviations

ACCCA	Advancing Capacity to support Climate Change Adaptation (UNITAR)
ACMAD	African Centre of Meteorological Applications for Development
ACMEN	African Ministerial Conference on the Environment
ACPC	African Climate Policy Centre (UNECA)
ADF	African Development Forum
AEWACS	African Early Warning and Climate Advisory Services (ACMAD)
AfDB	African Development Bank
AFRICANESS	African Network of Earth System Science
AGAGE	Advanced Global Atmospheric Gases Experiment
AGF	Africa Green Fund
AGRHYMET	Regional Centre for Training and Applications in Operational Agrometeorology and Hydrology
ALM	Adaptation Learning Mechanism (UNEP)
AMCOW	African Ministers' Council on Water
AMESD	African Monitoring of the Environment for Sustainable Development (EC)
AMMA	Africa Monsoon Multidisciplinary Analyses (WCRP)
AUC	African Union Commission
AWF	African Water Facility (AfDB)
AWS	Automatic Weather Station
CC	Climate Change
CCAA	Climate Change Adaptation in Africa (IDRC/DFID)
CCAFS	Climate Change: Agriculture and Food Security (CGIAR)
CCDCU	Climate Change and Desertification Control Unit (AUC)
CCKD	Centre for Climate Knowledge for Development
CCLCD	National Strategy on Climate Change and Low Carbon Development for Rwanda
CDSF	ClimDev-Africa Special Fund
CEEPA	Centre for Environmental Economics and Policy in Africa (University of Pretoria)
CGIAR	Consultative Group on International Agricultural Research
CGIS	Centre for Geographic Information Systems and Remote Sensing (NUR)
CLIPS	Climate Information and Prediction Services (WCP)
COMESA	Common Market for Eastern and Southern Africa
CORDEX	Co-ordinated Regional Climate Downscaling Experiment (WCRP)

CRED	Centre for Research on the Epidemiology of Disasters
CRIEPI	Central Research Institute of Electric Power Industry (Japan)
CRM	Climate Risk Management
CSAG	Climate Systems Analysis Group (University of Cape Town)
CV	Climate Variability
DARE	Data Rescue (WCDMP)
DFID	Department for International Development (UK Government)
DMTF	Disaster Management Task Force in Rwanda
DRR	Disaster Risk Reduction
EAC	East African Community
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EDPRS	Economic Development and Poverty Reduction Strategy (GoR)
EDS	Early Detection System
EM-DAT	Emergency Events Data Base (CRED)
ERA	ECMWF Reanalyses
ESRI	Software Company producing GIS software
EUMETCast	EUMETSAT Primary data dissemination mechanism
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EWS	Early Warning System
FAO	Food and Agriculture Organisation (UN)
FARA	Forum for Agricultural Research in Africa
FEWS	Famine Early Warning System (USAID)
GAW	Global Atmosphere Watch (WMO)
GCCA	Global Climate Change Alliance
GCCAN	Global Climate Change Adaptation Network (UNEP)
GCM	Global Climate Model
GCOS	Global Climate Observing System (WMO)
GEF	Global Environment Facility
GFCS	Global Framework for Climate Services (WMO)
GHG	Greenhouse Gas
GIEWS	Global Information and Early Warning System on Food and Agriculture (FAO)
GIS	Geographical Information System
GoR	Government of Rwanda
GPCP	Global Precipitation Climatology Programme (WCRP)
GTS	Global Telecommunication System (WMO)
HEWS	Humanitarian Early Warning System (IASC)
IASC	Inter-Agency Standing Committee (UN)
ICPAC	IGAD Prediction and Climate Applications Centre
IDRC	International Development Research Centre (Government of Canada)
IGAD	Inter-Governmental Authority on Development
IPCC	Intergovernmental Panel on Climate Change
JMA	Japan Meteorological Agency
JRA	Japanese Reanalysis Project
KIST	Kigali Institute of Science and Technology
LDCF	Least Developed Countries Fund

MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MDG	Millennium Development Goal
MEWS	Malaria Early Warning System (WHO)
MIDIMAR	Ministry for Disaster Management and Refuge Affairs (GoR)
MINEDUC	Ministry of Education (GoR)
MINAGRI	Ministry of Agriculture and Animal Resources (GoR)
MININFRA	Ministry of Infrastructure (GoR)
MINIRENA	Ministry of Natural Resources (GoR)
MIT	Massachusetts Institute of Technology
MOH	Ministry of Health (GoR)
NAPA	National Adaptation Plan of Action
NBI	Nile Basin Initiative
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction (NOAA)
NEPAD	New Partnership for Africa's Development (AU)
NGO	Non-Governmental Organisation
NM(H)S	National Meteorological (and Hydrological) Service
NOAA	National Oceanic and Atmospheric Administration
NUR	National University of Rwanda
OSS	Sahara and Sahel Observatory
PET	Potential Evapo-Transpiration
PPCR	Pilot Programme for Climate Resilience (SCF)
PRSP	Poverty Reduction Strategy Paper
RANET	Radio and Internet for the communication of hydro-meteorological information for rural development
RBO	River Basin Organisation
RCM	Regional Climate Model
RCOF	Regional Climate Outlook Forum
RDB	Rwanda Development Board (GoR)
REC	Regional Economic Community
REMA	Rwanda Environmental Management Authority (GoR)
RFE	Rainfall Estimates (NOAA)
RMS	Rwanda Meteorological Service
SADC	Southern African Development Community
SADC-CSC	SADC Climate Services Centre
SCCF	Special Climate Change Fund (UNFCCC)
SCF	Strategic Climate Fund (GEF)
START	Global Change System for Analysis, Research and Training
TAMSAT	Tropical Applications of Meteorology using Satellite data and ground-based observations (University of Reading, UK)
TARCAT	TAMSAT African Rainfall Climatology and Time-series
TECCONILE	Technical Cooperation Committee for the Promotion of the Development and Environmental Protection of the Nile Basin
TRAC Plus Control	Centre for Infectious Disease (MOH)
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme

UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
USAID	United States Agency for International Development
USGS	United States Geological Survey
WCDMP	World Climate Data and Monitoring Programme (WCP)
WCP	World Climate Programme (WMO)
WCRP	World Climate Research Programme (WMO)
WCS	Wildlife Conservation Society
WHO	World Health Organisation (UN)
WHYCOS	World Hydrological Cycle Observing System (WMO)
WMO	World Meteorological Organisation (UN)
WWW	World Weather Watch (WMO)
Z_GIS	Centre for Geoinformatics, University of Salzburg

Introduction

The climate sensitivities of numerous aspects of the Rwandan economy have been examined in the National Strategy on Climate Change and Low Carbon Development to which this report is an appendix. The need to consider and manage the issues associated with the consequences of climate variability and climate change on the social, environmental and economic development of the country are highlighted in the Strategy. That background is taken largely as read within this report in which the issue is addressed of the need for a centre of excellence within Rwanda designed to provide information enabling decision making regarding climate, climate variability and climate change within the context of development activities within the country, such as in agriculture, in water resources, in health, in energy use and generation, and so on, including within the formulation of Government policies.

It is, of course, useful to examine the background further than provided in the main Strategy from the perspectives of the provision of climate services and of the generation of the additional knowledge required to support development, and that is done within this report. Brief summaries of climate sensitivities in a number of sectors are given here, before the possibility of establishing a centre of excellence to provide climate services and knowledge related to development is covered. This is assessed within the context of equivalent services within the region and across Africa itself. In the final section of the report the case for establishing a centre of excellence is extended through the provision of recommendations that include a vision of the form an expert centre might take. That vision extends well beyond the normal concept of climate services towards a centre that produces the information required in decision making across sectors affected by climate change. Existing initiatives within Rwanda that are pertinent to all areas of work that might be undertaken within a centre of excellence have been incorporated as far as possible.

Justification for the Centre for Climate Knowledge for Development

2.1 Regional Role

Within the historical perspective of the 20th Century, the current status of meteorology and climatology within Africa may be viewed in part as an outcome of four key developments:

i. The influx of European meteorologists to support strategic services during the Second World War, with a number of these remaining in the countries of their postings to influence the later development of African meteorology

ii. The expansion during the latter half of the Century of the UN Specialised Agency, the World Meteorological Organisation (WMO) based in Geneva, to incorporate as Members the newly-independent African Weather Services, collectively called National Meteorological and Hydrological Services (NMHSs) in WMO terminology

iii. The initial priority in most African NMHSs to provide services for transport, particularly air and sea

iv. The lower priority sometimes ascribed to funding of NMHS activities in newly emerging African nations.

The cumulative effect of i), ii) and iii) above has been to introduce European, in essence mid-latitude, concepts into African meteorology, concepts widely reflected across the continent and still not fully replaced with appropriate tropical concepts; the vision of African NMHSs to match the European Services in regards to international policy issues at WMO only serves to strengthen this focus on mid-latitude issues. Development iv) has reduced capacity in African services in all regards of technical resources, including observational capacities, and human resources (see the section Lack of Resources/Infrastructure Rebuilding).

It may be argued that climate, its variability and its change, is more significant to economic and social development in Africa than day-to-day weather variability, which itself is the more critical consideration in Europe. Yet the historical background summarised above has led to the foundation of African services normally focussed on short-term weather, with climate services typically restricted to the calculation of simple statistics based on data from the often-declining number of observing stations. On a continent where longer-period events, such as the variability of rainfall totals between seasons and ultimately climate change, are more critical to development than daily weather it might be reasoned that the restricted climate services render NMHSs in part not fully fit for purpose. Indeed the need is to go beyond the mere provision of services, which is normally interpreted as the provision of climate information, often focussed for a given sector, to an interface where it may be taken up by potential users, to the development of knowledge of climate and its role in context to other drivers in numerous sectorial activities sufficient to inform high-level policies for the present and the future. As will be seen in the following, most attention to date has been focussed within services as defined above, the broader issues having received little, often no, attention.

A number of initiatives have been undertaken to address the climate resource and services issues in Africa. Foremost amongst these are the creation of regional centres of expertise to provide assistance and information to individual countries lacking the necessary national expertise and resources. Perhaps the major such initiatives have been the establishment of five climate centres, including:

i. The African Centre of Meteorological Applications for Development, ACMAD, in Niamey, with a pan-African remit.

ii. The Sahara and Sahel Observatory, OSS, in Tunis with focus on north and west Africa and a remit covering all three Rio Conventions, especially that on desertification.

iii. The Regional Centre for Training and Applications in Operational Agrometeorology and Hydrology, AGRHYMET, also in Niamey and serving West Africa.

iv. The Southern African Development Community Climate Services Centre, SADC-CSC, based in Gaborone and serving 15 southern African countries.

v. Finally, and most immediately importantly to Rwanda, the IGAD (Inter-Governmental Authority on Development) Predication and Climate Applications Centre, ICPAC, in Nairobi, with an East African remit.

A further key initiative has been development of the Regional Climate Outlook Forums, RCOFs, which have been held regularly in various parts of Africa for over ten years. Generally they are hosted by the climate centres listed above in collaboration with various international programmes, including WMO's CLIPS (Climate Information and Prediction Services). RCOFs have brought together local and international climatologists, policy makers, the media, and climate information users in numerous sectors, ahead of a rainfall season to assess existing predictions. This forms a basis to create a consensus forecast for the season, to provide capacity building and other training, and to discuss the consequences and possible responses to the prediction for each of the sectors. In addition, RCOFs have been held specifically for, or information used in, malaria and water resource predictions, and outputs from the Forums have been integrated into the Famine Early Warning System (FEWS).

A number of other initiatives have been launched aiming to improve African climate resources. Most of these initiatives originate from outside Africa, such the European Commission's (EC) African Monitoring of the Environment for Sustainable Development (AMESD) and Global Climate Change Alliance (GCCA), the World Climate Research Programme's (WCRP) Africa Monsoon Multidisciplinary Analyses (AMMA) (although this does not cover Rwanda), and the Consultative Group on International Agricultural Research's (CGIAR) Climate Change: Agriculture and Food Security (CCAFS) Programme. The full list is rather too long to be included here (but see later section Other Regional and International Programmes).

Certain other initiatives have originated largely within Africa, such as the African Network of Earth System Science (AFRICANESS), and the work undertaken by the Climate Systems Analysis Group (CSAG) at the University of Cape Town.

In addition, sector-specific research and management organisations that work with climate impacts within their sector are based in the east African region. Amongst these are CGIAR, with four Africa-based centres (including one for agroforestry and one for livestock, both in Nairobi) and a regional CCAFS project (but not including Rwanda), and the two development-focused River Basin Organisations (RBOs) for the River Nile of which Rwanda is a member, the Nile Basin Initiative (NBI) and the Technical Cooperation Committee for the Promotion of the Development and Environmental Protection of the Nile Basin (TECCONILE).

Despite the initiatives listed above, the current climate services and allied resources in Africa remain substantially below the desirable level. Climate resources overall in many countries continue at best to remain static, at worst to decline, while the focussing of expertise in a

number of regional centres has often not resulted in development of expertise at national levels. Further, numerous climate services arguably required in managing the development of individual countries are being provided only to a limited extent, if at all. In practice, deficiencies may be identified in all areas, including the production of the basic climate information required to support development, the interpretation of that information for decision making across all pertinent sectors, and the resource needed to undertake both areas of work. This analysis is by no means limited to Rwanda, with all countries in the region arguably deficient to greater or lesser extents in regards to informing and managing many aspects of climate-sensitive development. That is not to say that attempts have not be made to use the information provided; numerous, often small-scale, projects under various sponsors have been executed across the continent, particularly in regard to climate variability but also to understand the possible consequences of climate change, yet all assessments of these point to limited take-up of the information in decision making.

More specifically, ICPAC is the principal local regional climate centre that provides services and support to Rwanda. Some of the work at CSAG, such as the climate projections prepared there, are also relevant to Rwanda. Results from other projects within Africa might be migrated to Rwanda were the resource to do so available. However, as will be seen in later sections of this report, these services, scenarios and projects do not cover in full what is required to support national development in any country of the region, including Rwanda. Indeed, at present the only African initiative designed to support national climate-sensitive development across the continent is ClimDev-Africa (Climate for Development in Africa), jointly managed by the African Union Commission (AUC), the United National Economic Commission for Africa (UNECA) and the African Development Bank (AfDB). In the background philosophy to ClimDev-Africa the criticality of climate variability and change as a key driver of social, environmental and economic systems within Africa is fully acknowledged, as is the relative paucity of resource to address the consequent issues. ClimDev-Africa has not been launch formally at the time of writing, but is expected to be launched during 2011. ClimDev-Africa is anticipated, inter alia, to provide funding that will assist in improving resources at regional centres such as ICPAC. Nevertheless, there will remain substantial areas of climate services and of the onward uses of those services that will need to be covered at a national level; as such the case for the creation of a national climate centre is strong for all African countries, including Rwanda.

In summary, the position with the delivery of climate services per se, that is the creation and delivery of climate information to users, has progressed within Africa over the past decade or so, but the level of service provision remains below requirements despite initiatives such as ICPAC. Equally, perhaps more importantly the onward translation of climate information (including on basic climate, on climate variability and on climate change) into knowledge that may be merged with knowledge regarding other drivers of social, environmental and economic systems sufficient to inform and to be used in decision making at all levels has been patchy, despite numerous projects run by institutes, NGOs, etc., often in uncoordinated projects. The overall level of knowledge of climate in Africa, and more particularly the use of climate knowledge in decision making, is arguably less across Africa than any other continent, despite the well-known vulnerability of African systems to climate variability and change.

2.2 National Development

As is highlighted in the main strategy document, Rwanda's economy is strongly linked to variability in climate; by extension, so are the policies and targets for future development. In Vision 2020, Rwanda sets out the path to a transformation into a middle-income country by 2020 through focusing on three key objectives:

i. The Short Term: Promotion of macroeconomic stability and wealth creation to reduce aid dependency

ii. The Medium Term: Transforming from an agrarian to a knowledge-based economy

iii. The Long Term: Creating a productive middle class and fostering entrepreneurship.

Achieving these objectives will depend heavily on Rwanda's ability to build resilience to the impacts of climate variability and change into its economy. Rwandan development policies and actions, therefore, need to be underpinned by a thorough understanding of the consequences of and management options thereof for climate variability in the short term and the longer-term impacts of global climate change. The benefits of Rwanda developing its own capacity in climate and sectorial sciences, and in associated management, covering areas that exhibit climate sensitivities link closely to those identified in the Vision, and that can be realised over the short, medium and long-term, include:

i. The Short Term: Reducing susceptibility to climate variability and change; promoting stability in the economy through developing understanding of climate variability and the use of information thereof.

ii. The Medium Term: Enhancing the creation of a knowledge-based economy through building capacity in climate and related sciences, and then generating the knowledge base application to decision making at all levels, and advancing Rwanda's role within the region.

iii. The Long Term: Ensuring growth and development of the economy and society is resilient to the long-term impacts of climate change.

2.3 Sectorial Links

The following section highlights the needs and potential uses of climate information in the different sectors across Rwanda's society, environment and economy. This is not an exhaustive list, but provides the context on which the actions in the building blocks for a centre of excellence, as discussed later, are based. Further information for each sector is available in the Sector Working Papers and the Baseline Report, in further Appendices for the Strategy.

Agriculture

At present the Ministry of Agriculture and Animal Resources (MINAGRI) uses three forms of weather information: a decadal (10-day) weather forecast, a monthly bulletin of weather information, and a biannual seasonal forecast issued in March and August in advance of each rainy season. The seasonal forecast is based on the projections produced by ICPAC in Nairobi. A representative each from MINAGRI and the Rwanda Meteorological Service (RMS) travel to Nairobi twice a year to collect the regional forecast, which is then disseminated to farmers through each district's agronomist. MINAGRI produces a monthly Information Bulletin on Crops, which contains retrospective information on rainfall amounts across Rwanda from the US Geological Survey (USGS) and information on production levels and commodity prices[1].

There is a recognised need to provide forecasts to farmers on a continuing basis, rather than once before each of the two wet seasons, helping farmers gauge the timing for sowing seeds, applying fertilizer and harvesting. With Rwanda's complicated topography and climate, it is preferable that climate information be provided by agro-ecological zone (see Figure 2). Agriculture could also be a focus of an Early Warning System (EWS), for providing sufficient warning of extreme high or low rainfall.

As highlighted in Chapter 2 of the main Strategy document, climate change is projected to affect yields of many of Rwanda's staple crops, including

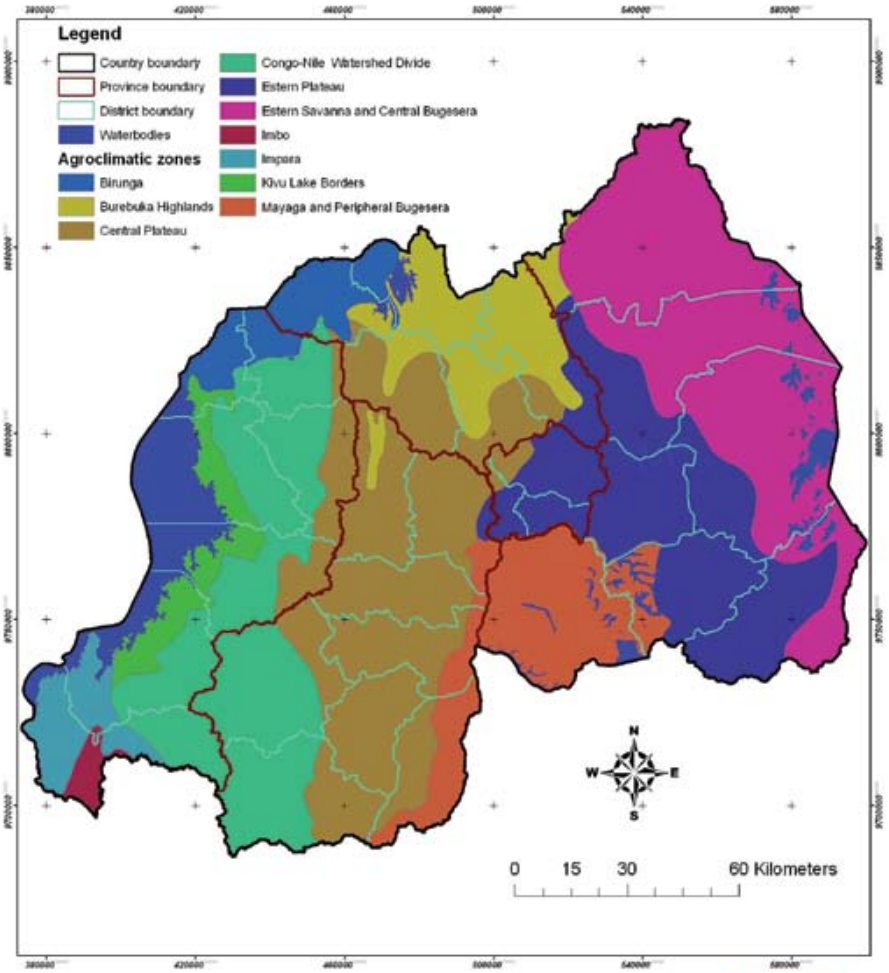

Figure 2: Rwanda's 10 agro-climatic zones, further subdivided into 38 agro-ecological zones[2]

maize and rice. Increasing temperatures may also cause a reduction in suitable land for Rwanda's production of tea, compelling farmers to switch to horticultural crops, such as cabbage, peas and passion fruit, as an alternative.

In a study in 2003 land suitability for crops was identified across Rwanda, which was subsequently used to develop Rwanda's Irrigation Master Plan[2]. The crop water requirements were calculated using FAO/WMO figures for precipitation and minimum and maximum temperature for 1960-89, from which estimates of potential evapotranspiration (PET) were calculated (see Figure 3). With climate change information specific to Rwanda, it would be possible to undertake a similar analysis, but for periods of future climate through the 21st century. Such information would allow for long-term planning of irrigation needs and crop suitability. Likewise, longer-term projections can also help provide information on the impacts on livestock and the spread of pests and diseases.

MINAGRI are currently responsible for a network of 100 rain gauges that were installed as part of an FAO project; however, there have been problems collecting data and most gauges are not maintained. MINAGRI have proposed that the gauges be incorporated into the network of stations held by RMS; however, it is not yet clear whether RMS has the capacity to collect data from and maintain further gauges.

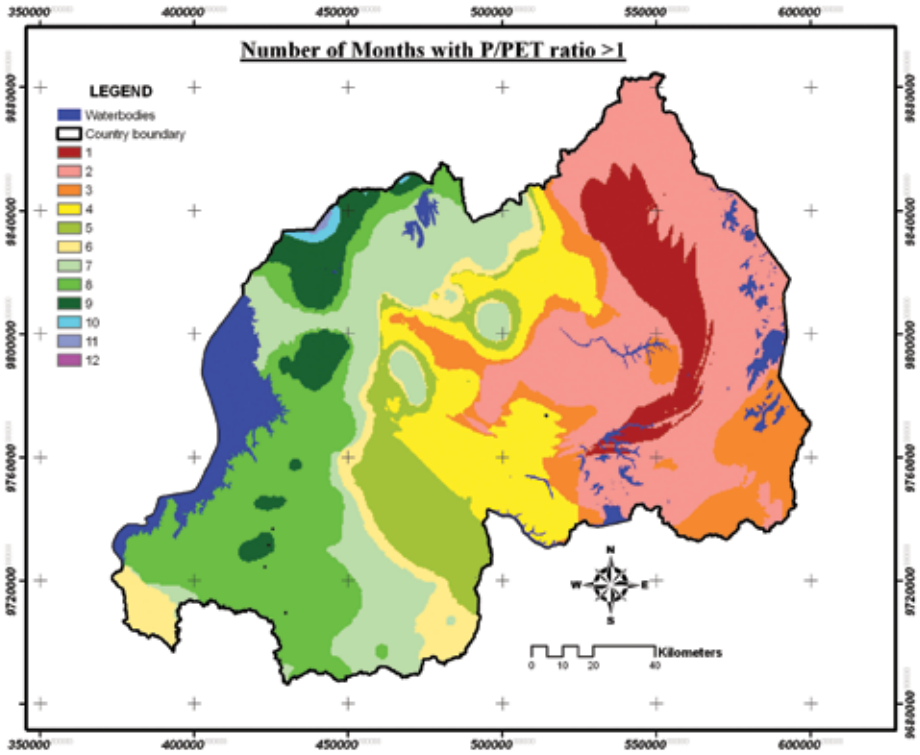

Figure 3: Distribution of total number of months where precipitation exceeds PET (using 1968-98 normalised data)[2]

So far the discussion has focussed on issues related directly to climate services, but the need for information goes more widely. The ability to convert existing forecasts on any time scale into decisions is limited within Rwanda; benefits would readily accrue were these capabilities improved. But at the higher levels are the issues of translation of climate information into policy decisions pertinent to food security, and to economic and social development, in relation to current climate variability and future climate growth, issues that extend well beyond the normal concept of a climate service.

Disaster Management

Disaster Management in Rwanda is currently limited to responding to extreme events and disasters rather than to forecasting their occurrence. Rwanda has a Disaster Management Task Force (DMTF) comprising of representatives from various ministries, the Red Cross, the police and the army, who are responsible for coordinating the response when disasters occur. The Ministry for Disaster Management and Refugee Affairs (MIDIMAR) was established in April 2010 and will provide a specific focus on disaster management.

In the next budget, MIDIMAR intends to develop a database on disasters in Rwanda, which are not currently recorded by the Ministry (although statistics on disasters are available from the Centre for Research on the Epidemiology of Disasters (CRED) EM-DAT database). MIDIMAR will also be seeking assistance on developing its capacity in disaster response.

While some warning systems do exist (e.g. for outbreaks of malaria – within the Ministry of Health), Rwanda does not have a unified warning system for natural disasters, particularly those that are weather-related. However, a proposal for an Early Warning System (EWS) has recently been developed, though it is still in its early stages.

The initial proposal has been developed by RMS, but will incorporate stakeholders such as MIDIMAR, MINALOC, other Ministries, REMA, the Red Cross and the emergency services. The next stage will be to undertake a scoping study to underpin the development of an EWS strategy.

Key issues identified in the EWS proposal include the need for further understanding of where severe weather has the most impact in Rwanda, what the triggers are for a hydro-meteorological event becoming a disaster, and the areas and communities that are most vulnerable to such events (RMS, 2011). RMS currently does not have the capacity to carry this out. Equally important is the issue of future hydro-meteorological disasters in relation to climate change, their likely impact on development within the country, and the generation of actions and policies to mitigate any threats.

Health

Incidence of disease is closely linked to climate variability in Rwanda; periods of both high and low rainfall are associated variously with outbreaks of diseases such as cholera, dysentery, and typhoid. Vector-borne diseases such as malaria and Rift Valley fever are also closely related to climatic conditions, with the range and breeding of mosquitoes dependent on temperature and rainfall. While action on the spread of disease requires social and economic interventions, the task may well be made more difficult within a changing climate. The Malaria Unit of the Ministry of Health is responsible for nine meteorological stations, with a further ten awaiting installation. However, they are not monitored regularly and – as with the rain gauges held by MINAGRI – it has been proposed that they are taken over by RMS.

Rwanda is involved in the European Commission project 'Healthy Futures', which aims to create disease risk maps of Africa for three vector-borne diseases: malaria, Rift Valley fever and schistosomiasis. Z_GIS, the Centre for Geoinformatics at the University of Salzburg, is working alongside the Centre for Geographic Information Systems and Remote Sensing at the National University of Rwanda (CGIS-NUR) on the project. Rwanda also has a designated malaria unit within the Ministry for Health (MOH) for eradicating malaria in the country, called TRAC Plus. Both these programmes would benefit from robust data on the impact of future climate on a range of time scales to aid in developing a greater capability to forecast epidemics and understand potential future spread of diseases. Such knowledge might be expected to provide important inputs into government policies on improving and maintaining the health of the population.

Water

The water sector in Rwanda is required to meet competing demands for future use, including ambitious targets for expansion of irrigation and hydropower. While Rwanda has substantial water resources, they are not evenly distributed across the country and rainfall is notably variable from one year to the next (see Figure 4).

Similar to meteorological data, recording of hydrological data has suffered during the genocide. Hydrometric data was collected in the second half of the 20th century from 35 gauging stations; however, today only four stations are operational and are not reliable[2]. A thorough understanding of Rwanda's hydrology is necessary, particularly for an early-warning system, but also to understand how it may change with a changing climate and to facilitate the implementation and delivery of policies regarding national water security.

Informed hydrological resource management is required for long-term planning nationally, as well as regionally, with regard to trans-boundary resources. Rwanda is one of the Nile Basin countries with 85% of the waters from the 19 rivers of Rwanda flowing into the Nile (ibid). Rwanda is therefore party to the treaties on use of the Nile waters, and in May 2010 Rwanda – along with Ethiopia, Tanzania and Uganda – signed a new agreement on the Nile River Basin Cooperative Framework. Trans-boundary agreements are also in place for the Kagera and Ruzizi Rivers.

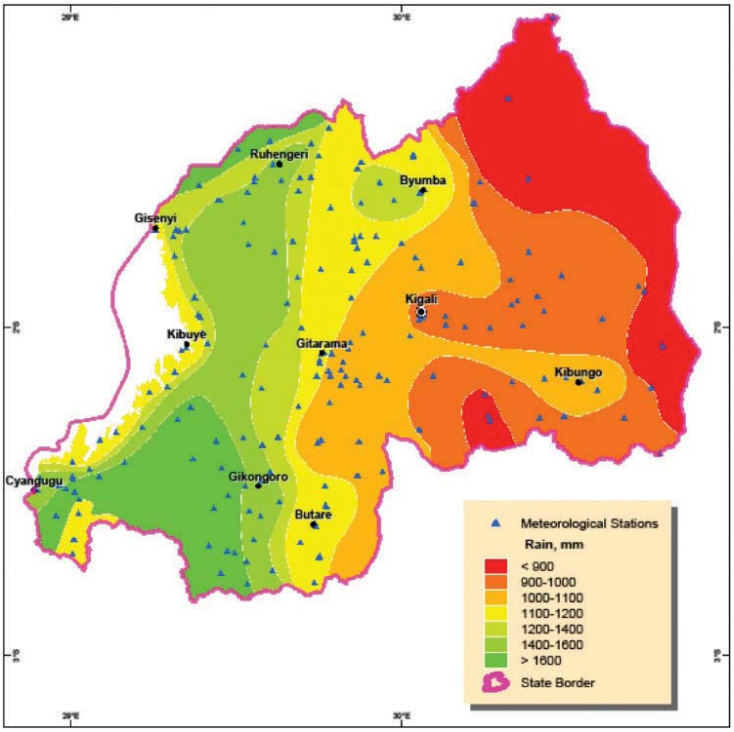

Figure 4: Distribution of rainfall across Rwanda, with annual average total figure[2]

Rwanda's National Policy for Water Resources Management highlights the uncertainties in the future climate as one of the key challenges in the sector and identifies policy objectives regarding water-related disasters and stresses. It also identifies the need for capacity building for research in the impact of climate change and potential adaptation measures. Such research would require data and information on climate change to assess future scenarios of water availability, and to formulate appropriate management responses.

Natural Resources

In many instances, the primary threat to Rwanda's biodiversity is socio-economic (e.g. deforestation for charcoal) rather than natural; however, the impact of the climate needs be taken into consideration in the management of Rwanda's habitats. The relative threat to natural resources from human activities should be considered alongside the impacts of a variable climate and of climate change.

Maintaining the habitats of native species also requires being able to identify how they may change. In these instances, projections for future climate change specific to areas of Rwanda are required together with their interpretation in conjunction alongside data on the habitat in question.

In July 2010, the Rwanda Environment Management Authority (REMA) held a launch of new climate change programmes. Initially, two projects have been launched with funding from the Government of Japan and from the Global Environment Facility (GEF) through the UNDP. These are AAP (Supporting Integrated and comprehensive Approaches to Climate Change Adaptation in Africa) and LCDF (Reducing Vulnerability to Climate Change by Establishing Early Warning and Disaster Preparedness System and Support for Integrated Watershed Management in Flood Prone Areas)[3]. LCDF, for example, includes components to establish a functional early-warning system, enhance data collection, incorporate climate risks in planning, and provide guidance on land use

practices to reduce flood risk (for further details see [4]).

Transport and the Built Environment

Heavy rainfall events pose a considerable problem for road transport as the majority of roads in Rwanda are not surfaced and suffer heavily from erosion. Where road building is proposed, guidance on heavy rainfall events could be provided, thus allowing engineers to factor in sufficient drainage in design. Climate and climate change are also relevant for choice of location of roads, with the cheaper option of roads at the base of a valley being less viable than the more expensive option of roads at higher elevations because of the increased flood risk.

For the built environment, climate change may have an impact on the design of buildings; particularly those, for example, that use passive warming and cooling systems and therefore require information on temperature, humidity and sunshine hours in their design. Cooling is a particular issue as rising temperatures may result in retrofitting of air conditioning in existing buildings, which has associated impacts for energy demand. Implementation may take place through the creation of climate-informed building codes.

Mining and Industry

For mining and industry, sunk costs are high as considerable investment in infrastructure is required. With long intended lifetimes, the sector ideally should consider the impacts of climate and climate change in design and planning. Licenses for mining in Rwanda include concessions that last 30 years, and the lifetime of mines can be substantially longer; therefore, the medium-to-long term impacts of climate variability and climate change are a factor in mining policy at both company and government levels. The industry uses large quantities of water and mines are also potentially at risk from inundation in heavy rainfall events, and so there is a requirement for information on current rainfall events and variability and on future rainfall changes that can be linked with mine operational procedures and with national water security policies.

Energy

With hydropower currently the main source of electricity and with considerable future expansion planned, it is necessary to have the capacity to assess current and future rainfall and runoff when identifying new projects. Hydropower generation is susceptible to droughts; for example, oil-fuelled power plants were brought in during the drought in 2004 and have now become a fixture as part of Rwanda's energy mix.

The Ministry of Infrastructure (MININFRA) has developed a Hydropower Atlas, which contains a database of 293 sites that have been identified as having potential for hydropower. The details for each site includes data on head and flow; however these data are not widely available for rivers across Rwanda, and hence not for all 293 sites. There is no meteorological information included, nor any information in respect of future climatic changes.

Data on climate change are required for appropriate design and siting of new hydropower plants. Use of water for energy generation must be managed with consideration of other users, and with a long plant lifetime, future water availability should also be assessed. There are, for example, large hydropower plants situated on the Ruzizi River on the outlet of Lake Kivu, which affect the outflow and level of the lake (as mentioned earlier there is a trans-boundary agreement in place for use of water from the Ruzizi River).

With plans to increase electricity supply and expand the grid, there is also a risk to energy infrastructure from damage from heavy rainfall events, high winds, flooding and landslides. It is therefore necessary to identify how climate variability and climate change will affect the frequency and strength of such events to ensure that new plants, sub-stations and power cables are correctly sited and sufficiently protected from damage. In all cases there are direct links with development policies, not least including those related to water security, and social, environmental and economic development.

Context

3.1 Infrastructure and Resources

Various examples of the need for enhanced climate services and of the translation of climate information into decision making capabilities in Rwanda, including the provision of information on current climate and its variability, as well as on expected climate change, have been provided in the previous section. In this section the issues surrounding the provision of these services and uses in decision making are considered. Within that regard, Figure 5 provides a clear illustration of one critical aspect of the resource issue over Africa, namely the observational data that fundamentally underpins all climate knowledge:

The European Centre for Medium-Range Weather Forecasts (ECMWF) acts as a global monitoring facility of all meteorological data observed and received at the Centre on a daily basis as part of standard WMO international protocols, and the geographical distribution of received surface data on a representative day in 2010 is shown in Figure 4. Several data voids may be recognised immediately in the map shown, perhaps the most prominent being that over Africa.

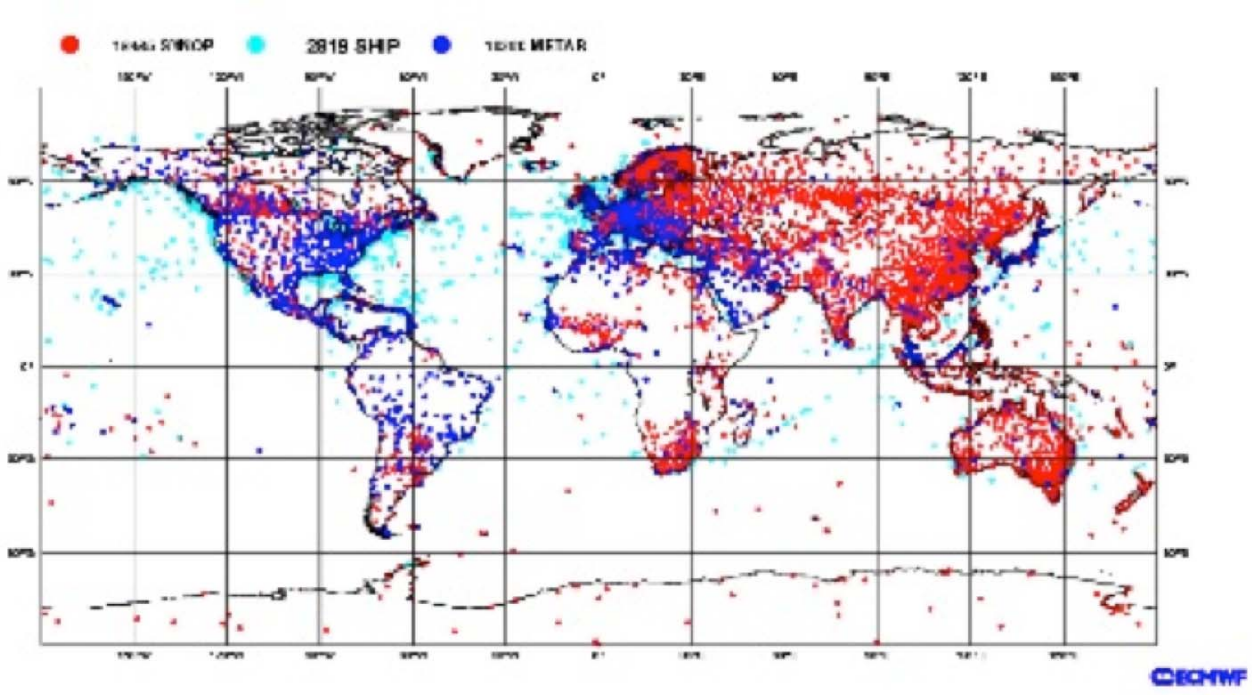

Figure 5: Synoptic information received on one day in 2010 at ECMWF

A similar picture emerges in the geographical distribution of upper-air meteorological data obtained from ground-based sources. Were the diagram above to represent, say, 1960 instead of 2010 then a lesser void would be apparent over Africa, the two diagrams together indicating the steady reduction in the numbers of observing platforms in most countries (not limited to just Africa) in the intervening decades. It is argued on occasion that remote sensing such as from satellites, together with model approaches such as re-analyses, can fill in data voids, and it is correct that information can be produced through these approaches but in situ surface observations are nevertheless required for the calibration of remote measurements.

Satellite infrared imagery and passive microwave data is used to estimate rainfall by application of an appropriate algorithm, which can be calibrated for individual countries using in situ rain gauge data. Reanalysis data are generated using a fixed numerical prediction model and data-assimilation of quality-controlled observational data to extend climate records over a historical period[5]. There are number of satellite-derived and reanalysis products available for African countries, including:

Satellite-derived:

- National Oceanic and Atmospheric Administration Rainfall Africa Rainfall Estimates 2.0 (NOAA RFE 2.0) at NOAA in the USA.
- Tropical Applications of Meteorology using SATellite data and ground-based observations (TAMSAT) at the University of Reading in the UK.
- Global Precipitation Climatology Centre One Degree Daily (GPCP-1DD), part of the World Climate Research Programme (WCRP).
- European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) multi-satellite data archive.
- African Monitoring of the Environment for Sustainable Development (AMESD).

Reanalysis:

- European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-40 and ERA-Interim products.
- National Centres for Environmental Prediction/National Centre for Atmospheric Research (NCEP/NCAR) DSI-6160 through to DSI-6165.
- Japan Meteorological Agency (JMA) and Central Research Institute of Electric Power Industry (CRIEPI) Japanese Reanalysis Project (JRA-25).

Figure 6 shows an example of decadal (10-day) rainfall estimates from TAMSAT, which uses thermal infrared imagery from the Meteosat satellite. In the example of TAMSAT, training is provided to national meteorology services on the methodology behind the algorithm and how to use the software, a quality control check of the national rain gauge data used to calibrate the algorithm, and techniques for analysing the data for trends. In a recent training session in Uganda, a representative from RMS was invited but unfortunately was unable to attend.

Both reanalysis and satellite-derived data use observational data for calibration, and so do not solve the lack of data entirely. The reliability (or availability, in the case of satellite-derived data, for which capable satellites were not operational before the 1980s) of data is limited before 1980. However, rainfall data from the recent past are of particular interest for Rwanda, which lost the majority of its rainfall stations in the genocide and therefore lacks a full record of rainfall since the mid-1990s.

For some satellite data, meteorological services in many African countries have the capability to download data themselves. For example, through a previous EU-funded programme, all African national meteorological services were supplied with the hardware and software necessary for downloading Meteosat data, giving them the information in real-time. A satellite-derived or reanalysis record could

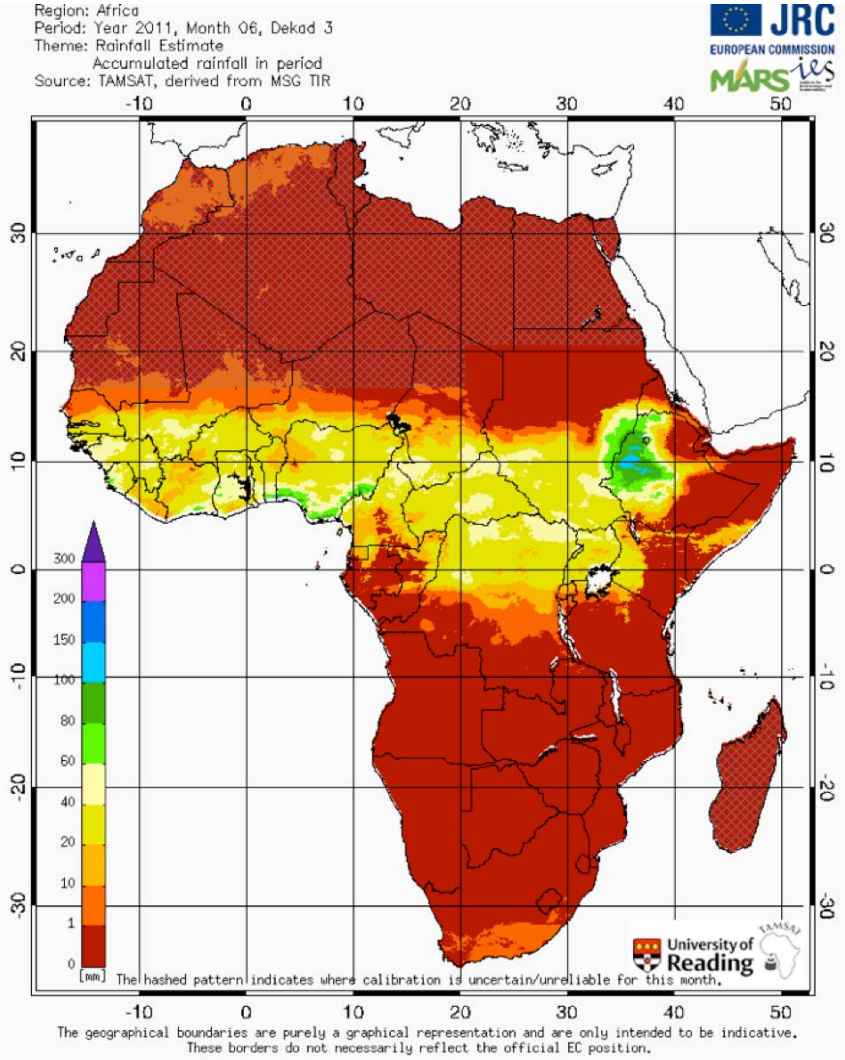

Figure 6: Image of TAMSAT rainfall estimates for 3rd dekad (i.e. 3rd 10-day period) of June 2011[6]

therefore be used to create a complementary, and on-going, record for Rwanda, which could subsequently be used for assessments of climate changes. However all such approaches require in situ measurements for calibration, and in data-void areas, such as over much of Africa, these modern techniques typically produce information with substantial errors. No substitute exists to replace an in situ climate observing system.

Much of Africa is now adequately linked to the internet and computing resources are no longer the scarce resource of recent years. The capability to transfer and produce information should be therefore, in principle, no longer an issue. Even in regard to observations all essential observation platforms can be automated with built-in remote transmission of information to data collection servers, with projects such as AMESD and the related EUMETCast (EUMET is a contraction of EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites) and RANET (RAdio and InterNET for the communication of hydro-meteorological information for rural development) providing ready facilities for the distribution of data and information. The limited number of observations therefore represents the main technological impediment in terms of collating the base information required to guide development

in climate sensitive areas. However, it should be noted that this summary also covers the need for data from all sectors (i.e. not limited to just climate data) that are required to determine the climate sensitivity of each sector and to translate predictions and projections into management decisions; data flows are required also from agriculture, from water resources, from health, and so on. Weather and climate data have long been managed and archived to internationally agreed standards, but in general data policies in other sectors are less formalised than for meteorology and it is not uncommon for the required sectorial data to be unavailable or inaccessible. A survey of pertinent sectorial data availability within Rwanda is recommended.

3.2 Capacity

The human resource to translate data into information, information into knowledge, and knowledge into advice and decisions is the other critical resource lacking in Africa, one that may well take rather longer to resolve than the technology issues. Given the focus on the provision within meteorological institutes of weather services, as discussed in the earlier section Regional Role, the human resource available within climate is critically restricted in all African countries without exception. Numerous initiatives have been run to address aspects of this resource limitation, but these have tended to be piecemeal and, while successes undoubtedly have been achieved, the overarching lack remains serious. As one example, the SADC-CSC has been run for years with a permanent staff of just one, although the position within the ICPAC is rather better.

The complexity of modern climatology in itself produces barriers difficult to overcome; for example, to understand the need for, to explain the reasons for, and to interpret and to use a large range of climate models to produce predictions and projections, are skills still restricted globally to a relatively small number of centres and experts. One consequence is the taking of economic and political positions regarding, say climate change, not adequately informed by all the available information. In Africa this situation is exacerbated through a basic lack of research focussed on climate change over the continent, with the result that generic statements are made frequently regarding the consequences of climate change for Africa but with limited substantive background evidence. It is unlikely that issues of this type will be resolved unless institutes focused specifically on African climate issues are either created independently or are attached to existing institutes. It is fully recognised in the planning for ClimDev-Africa that the resolution of all resource and information delivery issues for Africa should come from within Africa itself.

The reason frequently offered for the technological and human resource gaps identified above is a lack of finance for investment into an issue not always recognised in the past as enjoying high priority within the political debate. The balance may be changing, however, given recent estimates of the costs of climate change to, and of the investment needed for adaptation in, Africa, while substantial new funding appears to be about to become available through the Copenhagen/Cancun process. This change in balance towards full recognition of the criticality of climate in African development was expressed strongly by delegates to the October 2010 African Development Forum VII at UNECA in Addis Ababa.

In the case of Rwanda the loss of physical and human climate infrastructure in recent years has been accelerated as a consequence of conflict in combination with a long-standing deficiency of capacity building. Rwanda does not stand alone with these issues, but is equally as vulnerable to climate change as other countries on the continent. Two options exist for addressing the issue. The first is the passive option to rely on external support for some, or all, information on and management of climate-sensitive activities in the country. This option might be taken, and it has been the default option of recent years, but as argued above it is unlikely to provide the country-specific information needed on reasonable time scales. The alternative is the proactive option, which forms the basis of the

recommendations herein and is consistent with Vision 2020.

As mentioned previously, while rebuilding the technological infrastructure is a matter mainly of investment, it will take years to rebuild the human resource required, with Rwanda's tertiary education institutes necessarily taking a lead role. Neither of Rwanda's two main tertiary institutions – the National University of Rwanda (NUR) in Butare and the Kigali Institute of Science and Technology (KIST) – currently offers degrees in climate or environmental science. However, NUR does offer training in climate change as part of a Masters course in Biodiversity Conservation, and it will also be included as part of a new Masters programme in Geo-Information and Environment Sustainability in the Department of Geography from next academic year.

In terms of future plans, NUR intends to launch a Masters degree course in Geo-sciences – focusing on environmental modelling, meteorology and climatology – in collaboration with MIT as part of the proposed Observatory (see following section Climate Observatory). KIST currently has a proposal in place to develop a Faculty of Geosciences, which would have departments in Environmental Science, Geology and Mineralogy and offer four-year undergraduate BSc degree courses in those subjects, with a view to adding equivalent Masters courses in the future. Climate science will be included as one of the modules offered.

Links to industry are also important in developing applied science skills in addition to academic knowledge. KIST undergraduate courses, for example, require students to undertake a 10-week industrial placement as part of their degree; placements include government ministries, agencies such as REMA or RMS, and private companies.

At the important school-level, REMA is engaging schools on weather issues by trialling the installation of simple weather stations in schools, with the schoolchildren then learning about the weather and understanding the data. In addition, a trial of Geographical Information Systems (GIS) software is being carried out in conjunction with ESRI, introducing secondary school children to environmental data and how to process and present it.

Thus a foundation for building the required climate human resource is being created, but more needs to be done, perhaps with both more direct climate focus and focus on the impacts of climate variability and change, if Rwanda is to build its own capacity for incorporating climate issues into development.

3.3 Climate Observatory

The concept of a Climate Observatory was developed following a visit from President Kagame to MIT (Massachusetts Institute of Technology) in 2008 and further meetings between MIT and senior representatives of the Rwandan government in 2009. The objectives of the Observatory are to "collect atmospheric observations to contribute to meteorological forecasting and monitor climatic conditions, and to build scientific and engineering capacity within the Republic of Rwanda"[7]. Following the meetings, MIT undertook a scoping exercise to identify suitable instrumentation and potential sites for the observatory, and to develop a plan for installation, maintenance and capacity building for Rwandan scientists to run the Observatory[7]. Six sites were assessed for suitability, which was subsequently refined to two options, and then a final recommendation made of Mount Karisimbi. The Observatory has a Rwandan technical team of stakeholders, which includes RMS, REMA, KIST, NUR, RDB, MINIRENA, MINEDUC and the Rwandan Air Force.

At present, three high-frequency Greenhouse Gas (GHG) stations exist in Africa as part of the WMOs GAW (Global Atmosphere Watch) network (Tamanrasset, Mount Kenya and Cape Point); however, there is currently no African station within the AGAGE network, which would be the focal network of the Mount Karisimbi observatory. The nearest GAW station, that on Mount Kenya, is currently in operation taking measurements equivalent to those proposed for Mount Karisimbi,

although there would be benefits, including cross-comparison of measurements and sensing of different area flows, by having a second station. The Observatory would also complement the development of other infrastructure on Mt. Karisimbi by COMESA (Common Market of Eastern and Southern Africa) and the RDB (Rwandan Development Board) with regard to improving broadcasting coverage, the digital switchover, and air-traffic management[7]. The Government of Rwanda has signed a Memorandum of Understanding with COMESA for collaboration on activities on Mt. Karisimbi, including the Observatory. The Observatory would also require a cable car to be constructed from the base camp to the summit to permit simpler access to the station and other infrastructure.

Part of the Observatory proposal is the building of local expertise in climate science, including the support of the establishment of climate science programmes at NUR and KIST, and the recruitment of the on-site technicians locally. Indeed, a Physics graduate from the National University of Rwanda has already been admitted on to the doctoral programme at MIT with a view to becoming involved in the operation of the Observatory and engaging with the AGAGE community[7].

Further to the proposed Observatory, Professor Panday at the University of Virginia was asked to make recommendations on the wider needs for climate research in Rwanda. In a brief working paper, he identified the following six objectives:

i. To begin monitoring the changes taking place.
ii. To build up understanding about the processes driving the changes.
iii. To acquire the tools that will allow attributing responsibility for drivers of change.
iv. To acquire the tools needed to forecast future changes.
v. To assess vulnerability to future changes.
vi. To gather the knowledge needed to design mitigation and adaptation strategies.

These objectives are to be achieved through the following research activities:

- AGAGE GHG measurements on Mt Karisimbi.
- Meteorology measurements at multiple locations.
- Aerosol optical property and vertical distribution measurements from lower elevations.
- Aerosol composition measurements.
- Aerosol, gas, and meteorology measurements from the cable car.
- AGAGE GHG back-trajectories using global models.
- High resolution regional modelling of meteorology and climate.
- High resolution regional modelling of aerosols and atmospheric chemistry.
- Hydrological modelling.
- Ecological studies.
- Multidisciplinary studies of settlements, agriculture, flood/landslide hazards.

Professor Panday's recommendations have now been expanded in a wider proposal; a summary of these expanded proposals, in particular where there are overlaps, is given in the Section on Further Implementation Issues. The proposed implementation timetable for the Observatory runs from mid-2011 to the Observatory becoming operational in early 2013.

3.4 Rwanda Meteorological Service

Established in 1963, the Rwandan Meteorological Service (RMS) is Rwanda's designated National Meteorological Authority, providing short-term weather predictions (up to 10-days) and managing a network of meteorological stations for data collection. Based in Kigali, RMS is

currently part of the Ministry for Infrastructure (MININFRA), but will shortly be granted autonomy as an agency.

RMS has five business units: Weather Forecast, Databank, Climatology, Meteorological Instruments, and Maintenance and Procurement; however, as a result of shortage of staff, the five units are not fully operational[8]. Current staff numbers are as follows:

- Meteorologists (Class I): 3
- Meteorological officers (Class II): 16
- Meteorological assistants (Classes III and IV): 28
- Support staff: 0

Recently RMS has recruited a further 20 staff to be trained as forecasters. They are to be trained over two years, including a year studying for a postgraduate Diploma in Meteorology at Arba Minch University in Ethiopia and a year training on-the-job at RMS (including further training from the UK Met Office). RMS has also recruited a number of other staff, including two electrical engineers for network and instrumentation maintenance, and several support staff in administration. There are still several positions that RMS has not yet been able to fill, including one Director. A new organisational structure is proposed, with the following four Directorates:

- Directorate of Forecasting
- Directorate of Data Management, Research and Applications
- Directorate of Meteorological Observations and Maintenance
- Directorate of General (Corporate) Services

Meteorological stations in Rwanda were established throughout the 20th century, but during the genocide the majority of the stations were lost and many RMS personnel were displaced. Since the genocide, some stations have been restored; the current number of stations is listed in Table 1, along with the planned additions (ibid). Further to these stations, it has been proposed that RMS take over responsibility for the stations currently held by MINAGRI and MOH. Records from the majority of stations are taken manually; however, there are plans to install an Automatic Weather Station (AWS) at each synoptic and agro-synoptic station, which will transmit data to RMS directly (ibid). This improvement and expansion of Rwanda's station network is fundamental to building understanding of how climate variability affects Rwanda.

In June 2010 the Rwandan Meteorological Services (RMS) published its five-year Strategic Plan. The plan was developed with reference to a range of Rwanda's development strategies, including Vision 2020 and the Economic Development and Poverty Reduction Strategy (EDPRS). The development process involved a number of stakeholders, including government ministries, at a two-day workshop in Kigali in April 2010. The aim of the workshop was to devise an updated vision, mission and values for RMS, identify

Table 1: Numbers of existing and planned meteorological stations[7]

Station type	Current	Operational	Planned
Synoptic	8	8	11
Agro-synoptic	5	5	12
Climatological	8	5	40
Rainfall	60	41	200
Weather radar	0	0	1
Upper air station	0	0	1

client needs, and formulate objectives, targets and performance indicators for the Strategic Plan.

The UK Met Office was contracted to assist with implementation of the Plan over the period January to December 2011, and produced an Implementation Plan to this effect[9]. This plan does not overlap with suggestions below for a Centre for Climate Knowledge for Development but is supportive of them, and in certain areas, such as observations, would provide important underpinning for a Centre. The Strategic Plan identified the following ten objectives for the next five years[8]:

i. Improved operating environment with efficient and effective Human Resources, administrative and support services (by 2013)
ii. Users, customers and stakeholders fully sensitized on weather and climate issues (by 2013)
iii. Decentralised financial and procurement management systems compliant with relevant legislations installed (by 2012)
iv. Information and Technology Systems attained optimal utilization (by 2013)
v. Meteorological operations modernized in line with emerging technologies (by 2013).
vi. Ninety per cent (90%) station network requirement (by 2015)
vii. Regulatory Manuals, Quality Management Systems and Standards, Practices and Procedures improved, customized and disseminated (by June 2012)
viii. Meteorological Research improved and Application Services enhanced and disseminated (by June 2015)
ix. National, Regional and International cooperation, collaboration and networks established and enhanced (by June 2015)
x. User tailored and general meteorological services improved (by June 2012)

Of these, Objectives ii, and iv to ix, are particularly relevant to the possible aims as discussed later of a new Centre. The importance of the quantity and the quality of observed data – highlighted in Objectives v, vi, vii and viii – has been discussed above. One of the services already offered by RMS is a databank service for providing historical data to organisations (some of these data are analysed in the report, Rwanda Climate: Observations and Projections). The Implementation Plan highlights issues such as the actual extent of data that are held on the database, and how additional real-time observational data are dealt with. Objective ix covers how RMS will collaborate with organisations and networks on a regional, national and international scale. This will also be anecessary feature of a new Centre, which will be discussed further in the following.

In developing the Strategic Plan, RMS completed a SWOC (Strengths-Weaknesses-Opportunities-Challenges) assessment and from this identified fourteen critical issues. These included a low effective contribution to disaster preparedness and that climate change issues and its impacts through effective monitoring and assessment are not adequately addressed. The establishment of a Centre for Climate Knowledge for Development could therefore address some of the responsibilities for the critical issues identified and allow RMS to concentrate on the core elements and responsibilities of a meteorological authority.

3.5 The Inter-Governmental Perspective, including the Regional Economic Communities (RECs)

The Inter-Governmental perspective offers a regularly changing background to Vision 2020 and to the possible establishment of a new Centre in Rwanda. Hence only brief notes will be offered in the following regarding selected aspects pertinent to any future Centre for Climate Knowledge for Development in Rwanda with a remit to assisting and informing sustainable development in the country and to supporting the transfer to a knowledge-based economy. At the full international level:

- Technology transfer, trade-related aspects of intellectual property rights and

provisions on environmental goods and services are agreed through WTO (the World Trade Organisation), although the current position remains in flux given limited progress on the Doha Round of negotiations. Property rights regarding meteorological and climatological information are covered in WMO Resolutions 40 and 25 (the latter for hydrological information).

- The three Rio Conventions are all of immediate concern regarding sustainable development within Africa, although less so for Rwanda in the case of the UNCCD (the UN Convention to Combat Desertification); any Centre for Climate Knowledge for Development might reasonably be expected to advise regarding the UNCBD (the United Nations Convention on Biological Diversity) and would certainly be required in regard to the UNFCCC (the United Nations Convention on Climate Change) and its related Kyoto Protocol (and any successors) and other linked international agreements (such as UN-REDD, the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries). Within the context of the latter Convention, any new Centre might be required to submit towards knowledge of the overall consequences of climate change in Africa and appropriate responses thereto, in which a contribution towards future amendments to the African Common Position on Climate Change might be anticipated. It might be appropriate for a Climate Centre to cooperate with the newly-formed units at UNECA and the AUC, the ACPC (African Climate Policy Centre) and CCDCU (Climate Change and Desertification Control Unit) respectively.
- In the field of Disaster Risk Reduction (DRR) any Climate Centre could be requested to assist with regards to the Hyogo Declaration and future Rwandan responses under the Hyogo Framework for Action.
- Numerous aspects of the Millennium Development Goals (MDGs) incorporate climate sensitivities in terms of which a Climate Centre should offer support, presumably continuing beyond the completion date of the Goals in 2015.
- International reporting under various conventions could be supported through a Climate Centre, including the NAPAs (National Adaptation Programmes of Action), the National Communications to the UNFCCC and the PRSPs (Poverty Reduction Strategy Papers).

At the African level, recognition of the vital role played by climate, climate variability and climate change has grown considerably in recent years, not least as represented in the various AU-NEPAD (New Partnership for Africa's Development) plans such as EAP (Environmental Action Plan), DRR (Regional Strategy for Disaster Risk Reduction) and in its Programme Area 5, Combating Climate Change in Africa. Climate Change has been discussed at high level by ACMEN (African Ministerial Conference on the Environment) and AMCOW (African Ministers' Council on Water). The latest African Development Forum (ADF) – the seventh – held in Addis Ababa in October 2010 was devoted to climate change with delegates expressing clearly the need and the urgency to address the issues within Africa. ClimDev-Africa is a major pan-African implementation response, to which ACPC and CCDCU are related.

At the regional level within Africa, Rwanda is a member of the Common Market for Eastern and Southern Africa (COMESA) and of the East African Community (EAC), two of the eight RECs recognised by the African Union; it may be noted that Rwanda is not a member of IGAD under which ICPAC is established. Activities are presently under way to enhance the roles of the RECs in the development of Africa, including within the African

Union Commission Minimum Integration Programme in which the environment and climate change are seen as priority areas, as are many climate-sensitive areas of development and also science and technology for socio-economic development.

In summary, there are numerous activities at international levels to which a Centre for Climate Knowledge for Development might contribute. If reference is made to the section on "Lack of Resources / Infrastructure Building / Education" then it may be seen that the current level of resource within Africa to respond to these activities is somewhat limited, and in the view of the authors the scope for any new Centre to contribute at international and regional, as well as at national, levels is substantial.

3.6 Other Regional and International Programmes

The list of regional and international programmes pertinent to a new Centre is too long to be given in full, and thus the list following is rather selective. Thus, in no particular order, and in general omitting initiatives already mentioned above or to be mentioned following:

- WMO has numerous programmes relating to climate; some, such as WCRP, are research based (but includes AMMA), but amongst those relating to implementation are:
  - CLIPS, with capacity building, the RCOFs, etc., with a focus on seasonal time scales
  - GCOS, the Global Climate Observing System, which has produced programmes for improving climate observations as required to monitor climate change in many parts of the world, including Africa
  - WCDMP, the World Climate Data and Monitoring Programme, that works particularly to assist in data collection, quality control and archiving in the developing world
  - GFCS, the Global Framework for Climate Services, has emerged from the World Climate Conference No. 3 but currently has not been formulated in full
  - In addition there are pertinent weather- and climate-related programmes in hydrology, agriculture, applications, DRR and training.
- UNEP, the United Nations Environment Programme, has various climate change initiatives, including the Global Climate Change Adaptation Network (GCCAN) and the Adaptation Learning Mechanism (ALM).
- FAO, the Food and Agriculture Organisation, runs activities such as FAO-Adapt, the Framework Programme on Climate Change Adaptation, and a new programme for Capacity Development for Climate Change.
- ACCCA, Advancing Capacity to support Climate Change Adaptation, is a collaborative programme of several organisation lead by UNITAR (the United Nations Institute for Training and Research) and including START, the Global Change System for Analysis, Research and Training, which itself runs several pertinent programmes which include projects in Africa
- The UN Millennium Villages Programme, which includes CRM (Climate Risk Management) and already is working in Rwanda
- CCAA, due to terminate in 2011, Climate Change Adaptation in Africa, is a joint project of the IDRC, the International Development Research Centre, and DFID, the UK Government Department for International Development

- The Centre for Environmental Economics and Policy in Africa (CEEPA) is based at the University in Pretoria but aims to assist researchers throughout the continent
- FARA, the Forum for Agricultural Research in Africa, provides an umbrella for agricultural research and development.

Almost certainly the main international programme directly pertinent to a possible Centre for Climate Knowledge for Development is ClimDev-Africa, jointly managed by the African Union Commission (AUC), the United Nations Economic Commission for Africa (UNECA) and the African Development Bank (AfDB). ClimDev-Africa, expected to be implemented during 2011, has been under development since 2005 in recognition of the vital roles climate plays in Africa in terms of development in all contexts, and of the limited, and in general declining, African resource in this regard. All related issues, and the Programme itself, were reiterated and endorsed at the October 2010 African Development Forum VII held at UNECA. The design of ClimDev-Africa is generic for any country on the continent in which the need is recognised to rebuild climate resources, from the creation and handling of information, through the interpretation of that information and its translation into knowledge, to all pertinent decision making based on that information. ClimDev-Africa's design allows the Programme itself to be linked to activities in those climate-sensitive sectors whose scopes are not covered directly by the Programme. The recommendations made later in this document do not mimic the design of ClimDev-Africa as they incorporate the Rwandan situation but otherwise are substantially parallel in scope and direction.

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Recommendations

The Recommendations section is split into several parts. In the first section, General Recommendations, the top-level recommendations are provided. These top-level recommendations are based in part on the needs identified in earlier sections of this report but also on the suggested fundamental structure of a Centre for Climate Knowledge for Development (see Outcomes in Figure 6). In this section, possible outcomes of initiating a new Centre within the concepts of Vision 2020 are identified and based on those the basic building blocks required to achieve the outcomes listed. In subsequent sections more specific details of recommendations within the scope of each building block are offered.

Each of the sections following has been written from the assumption of developing from a non-existent resource base. This approach has been adopted intentionally in order to provide in each case a vision of the activities that might be undertaken and of their role within the broader perspective. Nevertheless this is not to disregard the work already completed or currently under way within Rwanda. References to existing work are included insofar as we have become aware of the details; it is possible some work may be omitted, but that is not done with intent, and by taking the approach assuming a non-existent base will permit all current work within Rwanda to be placed into context. A summary of identified existing work in Rwanda is listed against each of the building blocks in Table 2, which follows the introduction to the Outcomes and building blocks.

4.1 General Recommendations

It is the opinion of the authors that, on the basis of the issues covered above and in the main strategy document, the requirement for information on climate, past, current and future, to inform national development has been firmly established. In the previous sections the existing facilities both within Rwanda and within the surrounding region have also been outlined; while there exists regional resources on which to build knowledge and capability in climate matters within Rwanda, they fall short of the requirements as judged beneficial within Rwanda. Nor are regional developments foreseen that would bridge the gap from the Rwandan perspective, notwithstanding the expectation that the resources of ACMAD and ICPAC (plus the other regional centres) will be strengthened in as yet unspecified manners through ClimDev-Africa.

Therefore the major recommendation is that a centre of excellence be created within Rwanda, based in Kigali in order to foster links with the government, to cover all aspects of climate, including the science, the impacts, the management options and practices, and the policy. Had the same analysis been undertaken in other countries within the region then it is likely that in many, if not all, a similar recommendation could have been made (notwithstanding the existence of ICPAC in Nairobi and the pan-African ACMAD in Niamey, wherein the scopes are significantly narrower than for the suggested centre of excellence as outlined in the following). Hence a centre of excellence in Rwanda might act as a seed

for further development of climate resource in nearby countries.

Formally it is suggested that the centre of excellence be called the Centre for Climate Knowledge for Development, CCKD, which would reflect the broad interdisciplinary scope of work that might be covered. The choice of a name similar to that of ClimDev-Africa, Climate for Development in Africa, is fully intentional, as both reflect that the purpose of the Centre in one case and the programme in the other is not to improve and provide climate services as such but to contribute directly to development in all of its forms, and as such the scopes of both the suggested Centre and the programme both extend well beyond (but include) support for climate services. Further within that context the suggested scope of the CCKD overlaps to an extent with that of RMS in certain regards but that the CCKD's proposed scope, as outlined in following sections, is far wider than the current and planned scope of RMS, and thus it is suggested that a CCKD be established independently of RMS but that RMS provide climate services within a CCKD. Options for a possible infrastructural implementation of a CCKD are covered in the next section.

A suggested Vision Statement for a CCKD might be derived in association with Vision 2020, as a CCKD as suggested in principle shares the same vision as that in the overall government programme. Given that, a possible Mission Statement for a CCKD might be:

"To provide the knowledge of climate, of climate variability, of climate change, and of their relationships with all components of the development of Rwanda required in the delivery of Vision 2020"

The scope of the independently proposed Climate Observatory on Mount Karisimbi is interrelated to, but only marginally overlapping, that of the suggested CCKD. It is therefore recommended, should both facilities be established, that consideration is given to co-management of the Observatory alongside the CCKD. In the recommendations that follow it should be noted that as the Observatory Proposal comprehensively covers the needs and objectives for data collection for atmospheric chemistry, these aspects have therefore not been included here, where the focus is towards climate, climate variability, climate change, impacts and vulnerability.

4.2 Institutional Implementation Options

The foundation work of the suggested CCKD is to ingest information streams from a number of sources, to interpret those streams into pertinent collated information, and to translate that information into the knowledge base required for decision making and policy generation in regards of the social, environmental and economic development of Rwanda at all levels. Thus the inputs of a CCKD are information streams covering climate, agriculture, health, water, energy, infrastructure, and so on, whereas the outputs of a CCKD are pertinent to the knowledge requirements of development in all climate-related contexts. This would include informing not only activities at National, District and through to local levels but also international activities such as responsibilities related to the three Rio Conventions, to the MDGs, to the Hyogo Framework for Action, and to other responsibilities some of which were listed in an earlier section. This list might include contributions to the African Common Position on climate change.

It is recognised that climate is not the only driver requiring consideration in regards to development, and that these additional drivers in themselves may have interrelationships with climate. One aspect of the work of a CCKD might therefore be to incorporate information on these additional drivers and their impacts, at least insofar as they interrelate with climate.

Institutional involvement in a CCKD at the national level might include the RMS, several Government of Rwanda ministries, centres of tertiary education and sectorial research organisations. The scope of potential institutional involvement extends when the international

perspective is considered, an important consideration as, at least in the early stages, it appears unlikely that Rwanda has sufficient national resources to support a CCKD independently.

No single institute has the capacity to manage and interpret all the information input streams required by a CCKD, nor does any single institution normally have the management capacity to lead such a multi-disciplinary CCKD. In any management structure of a CCKD it may be difficult, then, to draw dividing lines between the interests and responsibilities of individual existing institutes, and to introduce new resources to cover gaps, without disturbing existing activities within the country. The suggested structure outlined in the following is one option for addressing this issue, but other options undoubtedly exist.

Any proposals for institutional structures must take into consideration the current situation within Rwanda and thus the necessity to avoid duplication of resources, whether in terms of need or of use. At one end of the list of options are a full new institute covering all aspects of a CCKD and at the other a completely virtual organisation, coordinated by a dedicated management team but formed from a collaboration of existing institutes within Rwanda. In our assessment, however, a fully virtual institute cannot be formed as in a number of areas the resource does not exist at present.

A key question that arises is the placement of management of a CCKD. It may be argued that no government organisation is in a position to provide adequate management across a broad multi-disciplinary organisation, nor are most non-governmental institutes. A tertiary education institute, or a collaboration thereof, might be considered provided the necessary expertise in all disciplines was covered, but at present this structure cannot be constructed within Rwanda.

Therefore the principle proposal offered is that a partially virtual organisation be established linking all climate-related work at RMS, REMA, ministries, universities, etc., with appropriate strengthening within these institutes where necessary. Areas not currently covered might be developed within existing institutes, but we suggest better is to establish a new "core facility" to cover these areas and to include a management team with appropriate cross-disciplinary, climate and development, expertise. A basic management structure of a partially virtual CCKD within the Strategy for Climate Change and Low Carbon Development is illustrated in Figure 7.

Various adjustments to this design are possible. For example the CCKD could be fully virtual, with

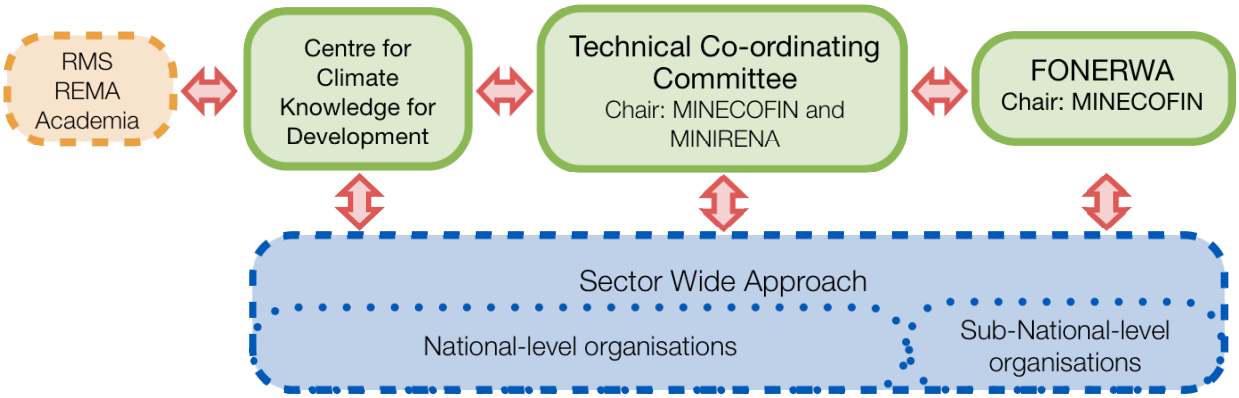

Figure 7: Possible implementation of a partially virtual CCKD within the National Strategy on Climate Change and Low Carbon Development for Rwanda. The diagram focuses on the three core institutions that will drive the implementation of the Strategy. It does not include all institutes that might be part of a CCKD

appropriate institutes all extended in scope and with an independent management team. Alternatively an entirely new CCKD might be created as a real institute taking services as needed from existing institutes, these continuing to undertake no more than their current programmes of work.

It is proposed that partially virtual institute be established, the CCKD, with the core facility independent of existing institutes. Under that proposal:

- The CCKD will have its own management independent of any ministry or existing institute, with expertise in areas appropriate to the mission of the Centre
- CCKD management will report to the Technical Coordinating Committee, the body formed from representation of government, institutes, private sector, civil society and academia, as the central coordinating body of the strategy; the Technical Coordinating Committee will have responsibilities that include:
  - Determining funding of the CCKD
  - Determining the policies and work programme of the CCKD
  - Examining the needs, gaps, priorities, etc., in all respects as determined by members of the Committee and incorporating those into the work programme of the CCKD
  - Ensuring that information and knowledge produced by the CCKD is channelled appropriately and is used as intended
  - Assessing the overall performance of the CCKD and of the application of information and knowledge produced
- The core facility of the CCKD will be newly created to address gaps in resource such that the CCKD is able to fulfil its complete programme of work
- Existing facilities, such as in RMS, REMA, pertinent areas of ministries and other institutes, will address all disciplinary areas not covered by the core facility and will act virtually within the CCKD work programme, the virtual facilities together with the core facility comprising the entire CCKD and synergistically delivering its programme of work.

4.3 Additional High-Level Recommendations

Additional recommendations covering the work of the CCKD in more detail are provided in the following sections; additional specific high-level recommendations are:

i. That all meteorological and observational climate data are collected, managed and distributed by RMS, including any data from the proposed Observatory on Mount Karisimbi (with chemistry data collected according to AGAGE and GAW protocols); the CCKD should not be responsible for any continual data collection.

ii. That all other required data, for water, health, agriculture, etc., are managed by appropriate ministries and institutes, with CCKD management reporting to the Technical Coordinating Committee on any data gaps to be filled in order for the programme of work to be completed

iii. That RMS holds all responsibility for research and operations related to the delivery of climate services (defined in more detail in the following section), and that all ministries and other responsible institutes similarly hold responsibility for research and operations within their current areas of responsibility, while the core facility holds responsibility for all other areas of the work programme except as agreed otherwise

iv. That the CCKD be multi-disciplinary, including expertise in climate, in all pertinent sectors, and in policy, to the extent required to complete the programme of work while further disciplines may be included as deemed appropriate by the Technical Coordinating Committee, perhaps such as those related to atmospheric chemistry, to adaptation and to mitigation

v. That the CCKD develop links with extant pertinent national, regional and international climate, sectorial, social and policy research programmes and, where appropriate, implementation programmes, not necessarily limited to those listed in previous sections, both to kick-start activities and to assist in capacity and resource building

vi. That capacity building be given highest immediate priority alongside rebuilding of the observations network and that the CCKD establish training programmes and links with pertinent national tertiary education departments, including but not necessarily limited to those in KIST and NUR, and at institutes external to Rwanda

vii. That within the context of the CCKD, options are explored for becoming linked officially under either or both of COMESA and EAC.

A systematic programme of work, incorporating a realistic timeline, will be required if the recommendations above are to be adopted in full; a preliminary timeline is provided in a later section. Through that programme the CCKD would be developed in stages. Technical aspects may be addressed in principle without difficulty other than funding, but the key impediment is likely to be the one of human resource, and that resource cannot be created over the short term. In all probability the human resource development required, building on international assistance, will only be realised over a decade or more, and it is recommended that the programme of work itself be built around the development of human resource in order to balance work projects appropriately with that resource.

Further details regarding these and additional recommendations are given in the sections following.

4.4 Specific Recommendations: Introduction to Outcomes

The recommendations in the following sections and those above have been developed on the basis of ten *outcomes* envisaged for a Centre for Climate Knowledge for Development, CCKD, in Rwanda. These ten *outcomes* have been proposed in consideration of the needs expressed within Rwanda, including within Vision 2020, for the development of climate-related information and knowledge nationally, and perhaps regionally, and of the roles that Rwanda might take in the future within the contexts of international climate negotiations.

Each *outcome*, as illustrated in the right-hand column of Figure 8, is consistent with the vision expressed by the Rwandan people within Vision 2020. In combination all *outcomes* build towards the establishment of the CCKD as a centre of excellence with a prominent role locally, regionally and internationally, that supports the development of the country economically, environmentally and socially, while at the same time establishing new capacity in the drive towards a knowledge-based economy.

In order to clarify any possible misunderstanding between an *outcome* and an *output*, an *outcome* is a statement of a new facility or capability that results from the work of a project, programme or institute, in this case the CCKD. Thus *outcomes* define the benefits derived through undertaking an activity, but do not describe any work specific to that activity. In general *outcomes* result from *outputs*, which are the specific products of a project, programme or institute required so that each *outcome* may be obtained. *Outputs* are tangible products, such as a service, a report, or a technology; in this case they

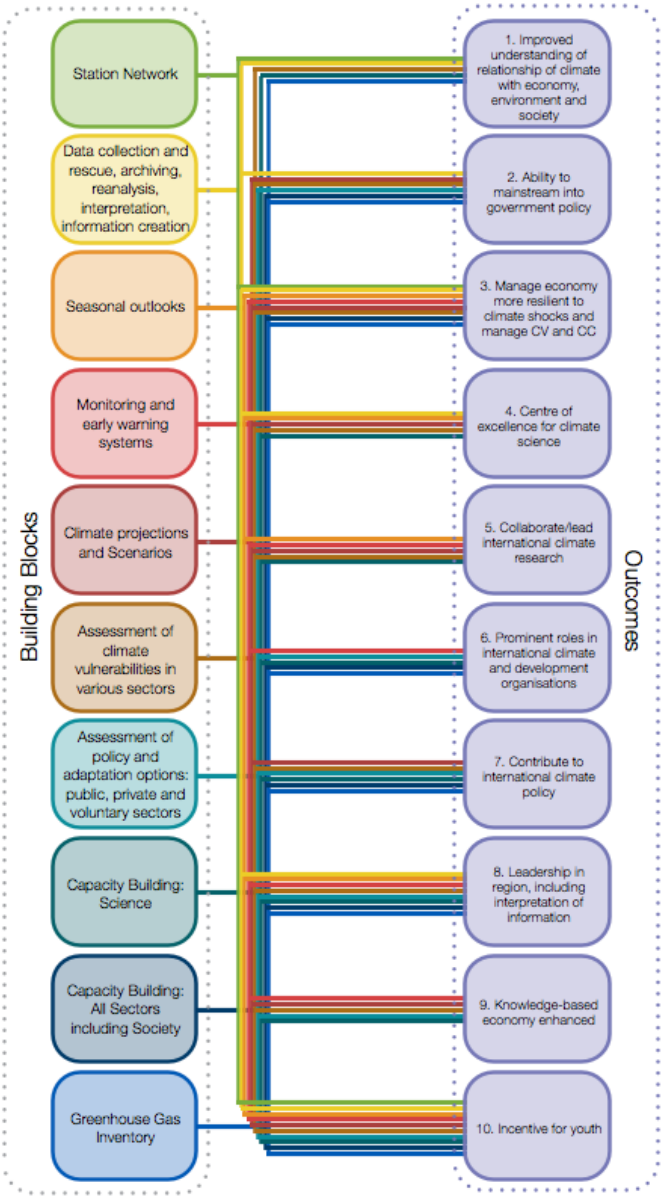

Figure 8: Schematic representation of the interrelationships between the envisaged Outcomes for a CCKD and the Building Blocks

would be the products of the CCKD. The next stage of implementation planning of a CCKD would be to define the *outputs* required to support in full the outcomes as shown in Figure 8 (followed by further steps detailing how these *outputs* would be created). These steps in planning implementation have not been considered in this strategy report, other than mention in the detailed listed of *outcomes* following of candidate outputs against each *outcome* and within the context of identifying the building blocks illustrated in Figure 8. Note that it is normal for individual outputs to support more than a single outcome.

Thus the possible functions, building blocks, of a CCKD as illustrated in the left-hand column of Figure 8 are the recommended minimum activities required to be undertaken within a CCKD if all *outcomes* are to be achieved, and may need to be revised once a full implementation plan has been produced. Against each building block are arrows identifying supported *outcomes*; in all cases each building block supports a number of *outcomes* while, conversely, each *outcome* requires support from a number of building blocks. Were fewer building blocks incorporated into a CCKD then an indication may be gained from Figure 8 of the consequent impacts on the achievement of the *outcomes*. It should be noted, however, that the *outcomes* will not be achieved through the work of a CCKD alone in that a CCKD will provide the

climate knowledge support but other areas of government, society and the private sector may have various responsibilities regarding implementation, and perhaps research, towards each *outcome*.

Note that all building blocks support *Outcome 10*, Incentive for Involvement of Youth, and consequently that only an indicative arrow points to *Outcome 10* in the diagram. Recommendations for each building block individually are provided later.

Individually the *outcomes*, using the same abbreviated titles as in Figure 8 are (it is assumed throughout the list that advantage will be taken of international experience and of external collaborative opportunities in delivering the outcomes):

1. Improved understanding of the relationship of climate with economy, environment and society

A basic stage in developing the ability to manage societal, environmental and economic development is to define the sensitivities and vulnerabilities of each development activity to climate, including to climate variability and to climate change. This is a multidisciplinary pursuit requiring the inter-comparison and interpretation in terms of sensitivities and vulnerabilities of information on climate and on pertinent aspects of each development activity. It requires long-term data sets as well as the climate and sectorial insight necessary to undertake the work. Supporting outputs might include reports of studies, perhaps including modelling activities, and information campaigns to government and to society.

2. Ability to mainstream into government policy

Given knowledge of the sensitivities and vulnerabilities from Outcome 1, options for their management may be derived. Options may then be reviewed and translated into government policy. Supporting outputs might include lists of policy options to specific needs, together with quantified advantages and disadvantages of each.

3. Manage economy more resilient to climate shocks, and manage climate variability (CV) and climate change (CC)

Government policy from Outcome 2 ideally should work in conjunction with practices and policies in all relevant areas of society and of environmental and economic management to deliver an economy with overall increased resilience to climate variability and climate change. Prediction on various time scales will make an important contribution towards improving resilience to climate variability, while projections and scenarios will be invaluable in planning for climate change. Supporting outputs might include predictions and projections on various time scales and lists of options for response actions quantified in terms of advantages and disadvantages.

4. Centre of excellence for climate science

Through building the science base for Outcomes 1, 2 and 3 the CCKD will become a centre of excellence, with no other known comparable institute covering the same range of science within the region. Note that the science base referred to covers not only climate sciences per se but also all science related to societal, environmental and economic development. Supporting outputs might include research documentation, and also guidance to governments and institutes in other countries.

5. Collaborate/lead international climate research

More often than not climate-related research in all pertinent disciplines in Africa is undertaken from a capacity building perspective in which the work carried out is often at least as within the interests of the overseas institute leading the work as it is within that of the African institute. This approach does not always deliver outputs fully tuned to African requirements. Through Outcome 4 the CCKD ultimately will be in the position to collaborate and then lead research on a national, regional and international basis. Supporting outputs might include high quality research products and research project management.

6. Prominent roles in international climate and development organisations

Africans already take prominent roles in international climate and development organisations, but the potential for Rwandans to assume these roles, and for their work to result in improved benefits for the country, will be enhanced through Outcomes 5 and 6. Supporting outputs might include position documents related to international policies and staff capable of performing within the international arena.

7. Contribute to international climate policy

International climate policy, including that under all Rio Conventions, tends to reflect developed world perspectives modified to incorporate developing world concerns; without doubt the vast majority of the climate change research work (such as from the IPCC) originates in the developed world, as do many relevant policies. The influence of developing world countries on international policy will be strengthened once these countries are capable of providing independent, authoritative information. Through the various Outcomes the CCKD would place Rwanda in a strengthened position in this regard. Supporting outputs might include detailed examinations of options available in international policy.

8. Leadership in Region, including interpretation of information

Given that the are no comparable institutes within East Africa to a CCKD as suggested, unless ICPAC is extended under ClimDev-Africa to provide a similar scope of activities (which is not proposed to the authors' knowledge at present), then the net sum will be regional leadership. All of the tasks of the CCKD as suggested could be extended readily into regional contexts. Supporting outputs might include various forecasts, response options, and policy options.

9. Knowledge-based economy enhanced

Strong science bases have been used in many countries as nuclei around which to build knowledge-based economies. No single science base can provide a full nucleus, the ultimate objective being achieved through an array of nuclei with differing sciences. The CCKD may not therefore produce results in this outcome if alone but would be a key component alongside others. Supporting outputs may include quality staff and technologies.

10. Incentives for Involvement of Youth

Capacity building alone is insufficient if the incentive for individuals to take up careers in climate and in development is missing, but through the structured development, and broadcasting of the outputs, of a CCKD an incentive for engagement should be created for all Rwandans. Supporting outputs may include education programmes across the country.

4.5 Specific Recommendations: Building Blocks

In the following sections each of the building blocks suggested for incorporation into a CCKD, as in Figure 8, is described individually. Some preliminary details are provided of how each building block might be established or developed, and of current facilities within Rwanda. It is not intended that the following be comprehensive but that they are introductions to the resources and activities appropriate under each building block. Known existing activities mentioned in the following, together with some gaps identified, are summarised in Table 2.

Station Network

The weather and climate observing network provides information fundamental to all understanding and monitoring of climate and climate impacts; it links directly with *Outcomes 1 and 3* but underpins all other Outcomes. In this section only climate information is discussed, but it is essential to collect all other pertinent information related to climate-sensitive sectors required for their management, such as agricultural data, health data, and so on; as noted earlier it is assumed these extra data sets will not be the responsibility of the

Table 2: Summary of the current activities in Rwanda against each building block and the gaps identified

Building Blocks	Key Stakeholders	Current Actions	Gaps
Station Network	RMS	Responsible for national weather and climate observations; extension planned to station network.	Designed on a synoptic-scale, may need further development for adaptation needs.
	MINAGRI	Holds 100 rain gauges through FAO programme; to be transferred to RMS.	
	MOH	Malaria Unit holds 9 stations with a further 10 planned.	
	Climate Observatory	Observatory will collect data on atmospheric concentrations of GHGs, and additional station(s) for meteorological variables.	
	NGOs	Various NGOs, such as the Wildlife Conservation Society (WCS), collect climate data on very limited scales.	
Data collection, Rescue, Archiving, Reanalyses, Interpretation and Information Creation	RMS	Responsible for majority of stations and archiving data. Holds Databank of meteorological data; currently improving techniques of data collection and verification. Data freely available. Data access into GTS being improved with UK Met Office	Needs coordination with regard to responsibility of stations, data collection and management, quality assurance, and accessibility of data. RMS should be the focal point for holding all climate data collected in Rwanda. Increase capacity – RMS do hot have capacity at present to take on the 100 MINAGRI rain gauges.
	MINAGRI, MOH and NGOs	Have been responsible for own climate data collection and handling	
	Ministries and other organisations	Responsible for collection and handling of all sectorial data required for climate-related work – situations unknown and should be assessed	
Seasonal Outlooks	RMS/ MINAGRI	Both organisations collect regional seasonal forecast data from ICPAC twice a year; MINAGRI provides a seasonal outlook via district agronomist. RMS considering use of RCM	Interpreting the outlooks for sectorial decision-making.
Monitoring and Early Warning Systems	Regional institutions	Various regional early-warning systems exist that cover Rwanda: e.g. for famine, malaria, humanitarian issues.	Coordination needed. Rebuild Rwanda's monitoring and assessment systems in order that the maximum possible lead times are obtained. RMS Strategic Plan identifies need for better contribution to disaster preparedness.
	REMA	Recently launched project for an early-warning system and disaster preparedness for flood-prone areas – pilot project at Gishwati.	
	RMS/ MIDIMAR/ Others	Initial proposal for establishing a Rwanda-specific early warning system for climate-related disasters.	
Climate Projections and Scenarios	RMS	No projection/scenario work currently undertaken.	Needs to be addressed on national level with one institute responsible. RMS Strategic Plan identifies need for effective monitoring and assessment of climate change impacts. Potential to use output from existing climate modelling centres, with a longer-term view to build capacity in running regional models.
	REMA	Climate projections used in National Communications and NAPAs produced by external consultant.	
	International Institutions	Regional and national projections produced by various institutions, such as CSAG (e.g. CORDEX).	

Table 2 cont.

Building Blocks	Key Stakeholders	Current Actions	Gaps
Assessment of Climate Sensitivities	REMA	Some assessment undertaken as part of National Communications, NAPA and CCLCD Strategy.	Coordination needed. Needs regular review based on new climate data and projections.
	Relevant Ministries	Limited assessment undertaken.	Vulnerability mapping.
Assessment of Adaptation and Mitigation Policy Options: Public, Private and Voluntary Sectors	REMA	Climate Change Unit with some climate change expertise. Second National Communication covers Mitigation Options and the NAPA covers adaptation options. Both need to be updated with the Strategy recommendations.	Coordination needed. Needs broader approach across all sectors – Strategy used to develop Sector policies, which are reviewed annually.
	RDB	UNFCCC representative for Rwanda that attends climate negotiations.	
	MINIRENA	Limited assessment undertaken.	
	Relevant Ministries	Limited assessment undertaken.	
Capacity Building: Science	MINEDUC/MIT	Working with KIST and NUR to support planned development of climate science courses (see below). NUR graduate currently on PhD course with MIT with a view to working at Observatory.	Coordination needed for climate in education, from school through to university. Complementary skills should not be overlooked – hydrology, agrometeorology, etc.
	KIST	Proposed establishment of Faculty of Geosciences; will offer environmental courses and include module(s) in climate science.	Needs expansion of relevant work experience and placement options; potential for greater links between academia and RMS/REMA/etc for research projects.
	NUR	NUR intends to launch a Masters degree course in Geo-sciences – focusing on environmental modelling, meteorology and climatology – in collaboration with MIT as part of the proposed Observatory.	
	REMA	Pilot of collecting climate data at schools to engage schoolchildren in the issues. Programme of developing GIS skills in schools with ESRI.	
Capacity Building: Government, Commerce and Society	REMA/ Relevant Ministries	Some awareness raising for public as part of climate change programmes.	Needs to be addressed at national and sub-national levels. Potential for training sessions for government, and dissemination of non-technical summaries of climate change issues. Needs investigation of methods of communication: internet portal, radio, newspapers, RANET, etc

Key:		In progress		Limited Progress		Needs Attention

CCKD to collect and manage, but that they will be available through a ministry or institute.

There are several international standards that cover hydro-meteorological and climate observations networks, data collection and archiving. The relevant ones for climate data are those under WMO; data in other sectors may, or may not, be covered by standards set by other organisations:

1. The World Weather Watch (WWW) synoptic standards. These cover the numbers of stations per unit area, instrument standards, observation standards, recording and disseminating standards and, finally, quality control and archiving standards. Numerous sources of surface and upper air data are included. The prime objective under WWW is to create a network of sufficient density and quality, with data disseminated timeously to major centres, to support weather forecasting, in particular using numerical models.
2. The Global Climate Observing System (GCOS) network is a subset of the WWW network aimed primarily at establishing the current climate baseline and at measuring climate change. Many of the standards used are taken from WWW but, because the identification of trends normally requires more precise measurements than synoptic work, instrumental standards are adjusted accordingly.
3. The World Hydrological Cycle Observing System (WHYCOS) standards are equivalent to those of WWW but refer to hydrological measurements.
4. Finally, the Global Atmosphere Watch (GAW) standards relate to measurements of atmospheric chemistry within the GAW network.

It will be noted that no standards are listed above, nor yet exist, for climate observations as required for managing any aspects of national development. The WWW standards are however adequate in most regards for development, with the critical exception that a higher density of stations is required, particularly in regard to critical parameters such as rainfall. The synoptic network is being rebuilt under RMS in a project with the UK Met Office; it is not stated within the documentation which standard the new network is being built to meet, but it is most likely to be WWW, and thus this network may not on its own provide the spatial density of information required for climate studies and for development and adaptation.

In addition to the RMS/Met Office programme on rebuilding the observing network, it is known that MINAGRI owns about 100 currently non-functioning rain gauges, the management of which is to be transferred to RMS; the density implied by this number of gauges is closer to that required for development and adaptation work. A small number of stations, with more planned, are operated by the Malaria Unit of MOH, while it has been proposed under the Observatory plan that new stations be established on Mount Karisimbi and positioned along the gondola pylons up to its summit. At least one NGO, the Wildlife Conservation Society (WCS), operates one or more stations. Thus, while a number of networks have been or are being established, it appears that coordination between these has been limited although the synergistic benefits available from a coordinated network are unambiguous.

Hence it is recommended that:

1. A study be concluded of all existing and planned weather and climate data sources in context of the requirements both for all climate work and for Early Warning Systems; this will reveal whether or not the station list above is sufficiently comprehensive.
2. Additional observations as needed be arranged in collaboration with RMS.

In many countries it has become a challenge to obtain accurate and reliable readings from a network of stations where volunteers take many of the observations. Economical automated equipment is available with the capability to make recordings at any required frequency and to transmit data via landline or microwave to a base station with only a maintenance requirement for RMS staff; these stations are fully adequate to meet the requirements of development.

Given sufficient funding and maintenance resource, a network covering the entire country might be established within a relatively short period, probably less than two years. This network will provide all climate information necessary for future monitoring, climate trend detection, management of climate variability, early warning and disaster management, etc., but what it will not be capable of doing is providing any historical data, without which it will be several decades before sufficient data will be available from which to calculate stable statistics. Options to produce historical climate data are covered under the next building block.

Data Management and Collection

Data management and collection is directly critical to *Outcomes 1, 2, 3, 4 and 8*, and some of the activities suggested in the following will extend the data records to be collected from the reconstructed weather and climate station network. Note, as per the previous building block, only weather and climate data will be covered here but the need exists to manage all other data streams, such as from agriculture, health, and so on, in equivalent manner to that discussed in the following.

Data collection and archiving standards have been defined under WWW (and GCOS and WHYCOS) and are the ones generally in use for climate observations. It is recommended than any observations and archiving be taken to these standards, including observations under any networks not run by the RMS. Assistance in archiving, if needed, can be obtained from the WCDMP. Further, all observations should be shared according to international, i.e. WMO, protocols. Given these principles it is not clear whether or not all observational data collected by organisations other than RMS have been collected and archived according to these standards. It is also known that not all observational data have been made available between organisations. Problems of data access are widespread throughout the meteorological community, but it would be advisable to minimise these by agreeing protocols at the earliest date possible.

Data transmission into the WMO system known as the GTS (Global Telecommunication System) is the responsibility of RMS. This aspect is being improved in collaboration with the UK Met Office.

In order to provide as extended a climate record as possible it is, it goes without saying, necessary to include all available historical data within the archive. Should any records be on paper or microfilm or similar then these will require digitisation. The objective is to create as long a quality controlled and consistent climate record across the country as is achievable. There are other sources of historical records for data rescue, including those held by institutes other than the RMS and those in documents such as agricultural records, historical diaries, etc.; WCDMP is able to advise on DARE (Data Rescue). As far as the authors can determine none of these have been addressed.

One additional aid to extending climate records backgrounds through recent decades is to use reanalyses; several centres including ECMWF, NCEP, and a few others, have produced, and continue to produce improved, reanalyses. Reanalyses are produced in hindsight using modern numerical weather forecasting techniques to generate consistent fields of weather variables at the surface (and at a number of levels in the upper atmosphere) at a scale of a few tens of kilometres. One reanalysis extends back to 1948, but data quality is reduced at earlier periods and as a rule of thumb reanalyses might not be used prior to 1979 (other projects are under way to take the

observation record back even into the 19th Century, but this work is unlikely to provide benefit for Rwanda). While the spacing of information is a little coarse for use in climate work reanalyses still provide invaluable information for extending the observational record back through the recent few decades. There is, however, one major issue with reanalyses – the quality of these, not least for parameters such as rainfall, declines in areas with few or no ground stations; it is expected that this factor would affect Rwanda. Reanalyses can, however, be corrected statistically to an extent provided sufficient in situ observations are available. There appears to have been no use of reanalyses within or for Rwanda.

Remotely-sensed observations from satellites may also be examined to improve historical records for Rwanda. However, as with reanalyses, satellite data tend to be of reduced quality in areas lacking in situ observations.

It is recommended that all climate data work be handled by RMS in an activity that would include rescue and digitisation of all historical records as well as archiving of future data and extension of time series through reanalyses. It is recommended that data from all networks, not limited to those directly under RMS, should be included in the RMS database and should be available freely to CCKD. Analysis and interpretation of historical and future data, including use of reanalyses, within the climate context would also be the responsibility of the CCKD.

Once archives have been created the next stage would be to analyse and interpret the climate information in terms related to national social, environmental and economic development, and in the process (as detailed further in the appropriate section following) identifying sensitivities and vulnerabilities; in this stage additional data will be required from climate-sensitive sectors (such as agriculture, water and hydrology, health, etc.) and will involve sectorial expertise. The objective would be to provide the essential information required to manage climate sensitivities in all sectors and to provide the basis for developing policy. In this context it would be helpful to develop a review of all analyses of weather and climate data undertaken for Rwanda, whether at RMS, at NUR, or KIST, in MINAGRI or elsewhere. As a preliminary estimate, this area of work might include RMS, Ministries, other linked research institutes and the core facility of the CCKD.

The time scale for the work identified above is open ended, most certainly for the interpretation and information creation stages. The basic work on creating the digitised historical record, from existing records, DARE and reanalyses as appropriate, might be achieved over a relatively short time scale, perhaps no more than two years.

Greenhouse Gas Inventory

A greenhouse gas emissions inventory is a required for UNFCCC communications and the development of Nationally Appropriate Mitigation Actions (NAMAs), to access certain international climate funds and to identify the largest sources of GHG emissions, and therefore target areas for mitigation. As an insignificant emitter of GHG emissions and a LDC, the focus of mitigation in Rwanda is on reducing dependency on oil. Oil and diesel used for all transport and 39% of power generation are imported at high cost which has a large impact on the economy. Oil imports use limited financial resources that could be better spent on domestic energy production, which would create jobs and support the local economy. For example, by moving to clean renewable power generation (geothermal, hydro and solar) and replacing chemical fertiliser with organic fertiliser, Rwanda will reduce its GHG emissions whilst boosting its economy and promoting sustainable development. This is explained further in the Energy and Agriculture Sector Working Papers and the Strategy.

REMA is responsible for compiling the GHG inventories for UNFCCC communications and could be supported by CCKD in this task. By collecting the data on a regular basis in a formalised manner, Rwanda can monitor its progress from the 2005

baseline year in the draft Second National Communication, respond to changes in renewable energy supply and demand, and apply for climate finance for low carbon development.

Seasonal Outlooks

Seasonal outlooks is a title that covers all time scales from 10 days through until interannual, i.e. it extends onwards from the shorter-range forecasts provided by RMS but does not cover time scales much beyond a year, including climate change. Practical work in this field has been in progress for over a decade through the operational activities of ACMAD and of ICPAC, not least with the regular Regional Climate Outlook Forums, in all of which Rwandan scientists from RMS and MINAGRI have been involved. Activities under this building block would build on this past work and would contribute directly towards *Outcomes 3, 4, 5 and 8*.

Work in this building block might be divided into two main areas, that related to the production and improvement of the outlooks themselves and that related to the use of the outlooks in decision making in various sectors; in the past more attention has been given to the former than to the latter.

Production of numerical seasonal outlooks requires the resources of a major centre, of which only a limited number exist, and there is no justifiable reason why Rwanda should do other than use the products of these centres. Downscaling of numerical outlooks using numerical models (RCMs) and statistical approaches are readily accessible to countries such as Rwanda, and the RCM approach is being explored by RMS with the UK Met Office; the issue with either the numerical or statistical downscaling approach is a possible focus on single predictions rather than on the broad ensemble of predictions from all sources necessary to provide full guidance to future climate.

Numerous countries in Africa, but not yet including Rwanda, have created empirical models to produce the outlooks. At RCOFs outlooks from all sources have been combined to produce the final consensus outlook. Numerous opportunities exist to improve this entire process and to assess and improve the quality of the outlooks for Rwanda, perhaps including the uses of empirical and/or numerical downscaling. It is proposed that all modelling work and outlook production be undertaken by RMS.

More critical for Rwanda is the interpretation of the outlooks in terms of decision making in the various sectors, a multidisciplinary area in which comparatively limited research has been undertaken. One common issue is in terms of the probabilistic nature of the outlooks (i.e. a range of projections are often, and should be, given, with probabilities attached to each), an inevitable aspect from the scientific perspective but one that often creates impediments for users. Nevertheless, the use of these outlooks provides an invaluable training ground for scientists, for government workers, and for society in general, in working with the equivalent uncertainties involved with climate change projections. The objective would be to gain the maximum possible value from the outlooks, and thus to increase the resilience of current and future development activities. Work on interpreting the outlooks for sectorial decision-making, which would be a collaborative effort across the CCKD including the core facility, would be supported by the interpretation and information creation activities under the previous building block. Only one regular interpretation of RCOF outlooks is known to be carried out at present, for Rwandan agriculture by a MINAGRI argometeorologist.

Other issues that might be addressed include the training of users, the implementation of existing and/or development of new decision making tools in all sectors, the distribution of information to users, and the incorporation of outlooks into Early Warning Systems (see next section).

Given the existing RCOF activity in the region the scientific side of this building block might be established within a relatively short time scale, although the research work involved is an open-ended agenda. Capacity building is likely to be required. Also open-ended is the multidisciplinary interpretation work, and it is likely that this will

require development of the necessary human resource base.

Monitoring and Early Warning Systems

Monitoring and Early Warning Systems are closely linked with observations and seasonal outlooks, although it is only recently that outlooks have become used regularly in some systems; Early Warning Systems contribute in particular to *Outcomes 3, 5, 6, 8 and 9*.

Early Warning Systems (EWSs) are typically focussed on specific issues, often food and health related, and in general monitor appropriate parameters (which might include climate, food stocks, reservoir levels, disease incidence, etc.) watching for certain predetermined levels to be exceeded to trigger action. In this form EWSs are entirely reactive, but have other roles in terms of policy advice, to provide early advice on possible threats and to catalyse international cooperation based on best-available scientific and technical capabilities. Often tied in with EWSs are Early Detection Systems (EDSs), which monitor for impacts but do not, on their own, provide warnings. A generic example of trigger levels within an environmental change example is given in Figure 10.

Existing EWSs that cover Rwanda already include FAO's Global Information and Early Warning System on food and agriculture (GIEWS), the United States Agency for International Development's (USAID) Famine Early Warning System (FEWS) and the UN's Inter-Agency Standing Committee's (IASC) Humanitarian Early Warning System (HEWS). It is quite possible that other smaller systems remain from the time when EWSs proliferated under various NGOs across developing countries.

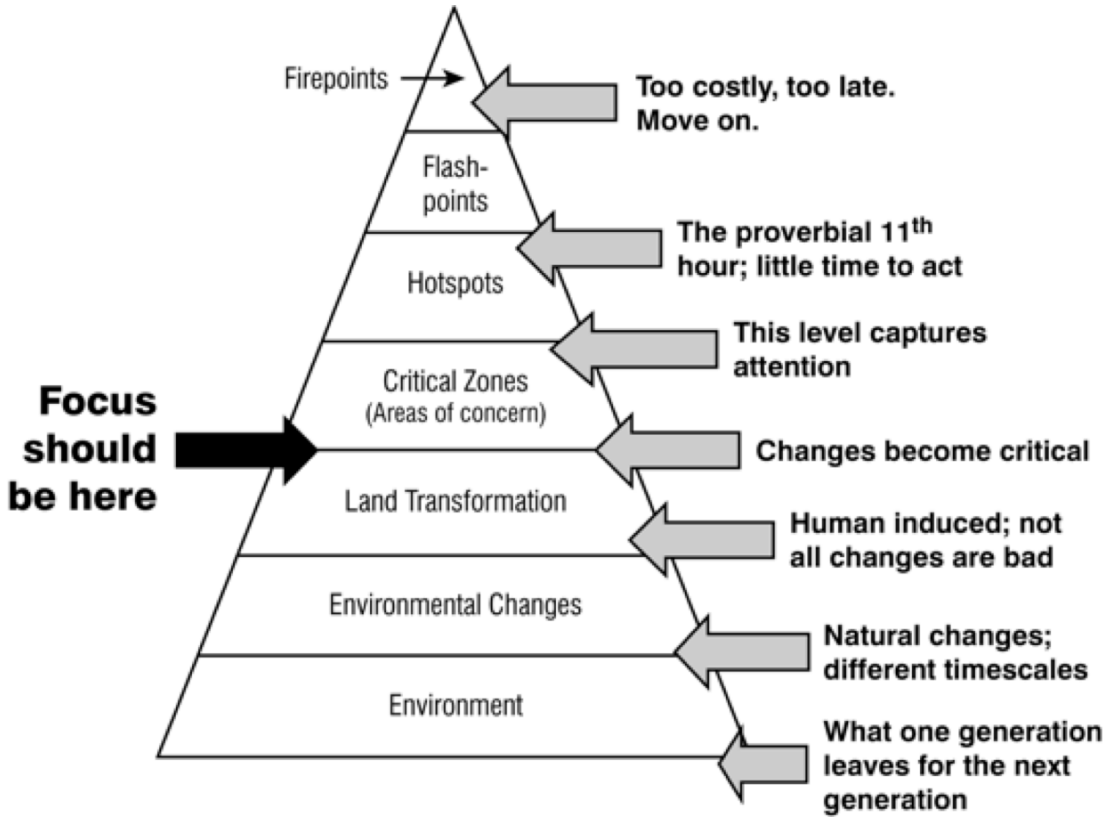

Figure 10: Stages through which environmental changes might translate to become firepoints, by which stage it is too late to address an issue which should have been handled at the 'critical zones' level; based on an analogy with chemistry.

Proactivity versions of EWSs have been slow in coming, partly because of the difficulties of translating probabilistic seasonal predictions into the existing structures of EWSs, but examples do exist; in that context research has provided a basis for integrating forecasts in the World Health Organisation's (WHO) Malaria Early Warning System (MEWS) (see Figure 11), while forecasts have been incorporated within FEWS, plus the developing African Early Warning and Climate Advisory Services (AEWACS) organised by ACMAD is designed to incorporate predictions.

REMA has recently launched an EWS and disaster preparedness system for flood-prone areas, with a pilot study at Gishwati, while there is a proposal for an EWS for climate-related disasters from a consortium including RMS, MIDIMAR and MINALOC. There is no current use known to the authors of any of the existing EWS systems mentioned above.

It is recommended that the suggested CCKD work collaboratively to the extent possible with initiatives within Rwanda and with existing international EWSs but that alongside these it rebuilds Rwanda's monitoring and assessment systems in order that the maximum possible lead times are obtained. The rebuilding of the climate observing system by RMS, as covered in the section "Station Network", would provide only part of the required EDS, other monitoring aspects being required dependent upon the specific objective(s) of any EWS and thus would be the responsibility of a Ministry or institute. Introducing monitoring of the other climate-sensitive areas pertinent to an EWS not only will work towards an EDS but also will help build the data sets required for the overall assessments and management of the role of climate within development. Provided that the Seasonal Outlooks building block is put into place, as defined in the previous section, then it is

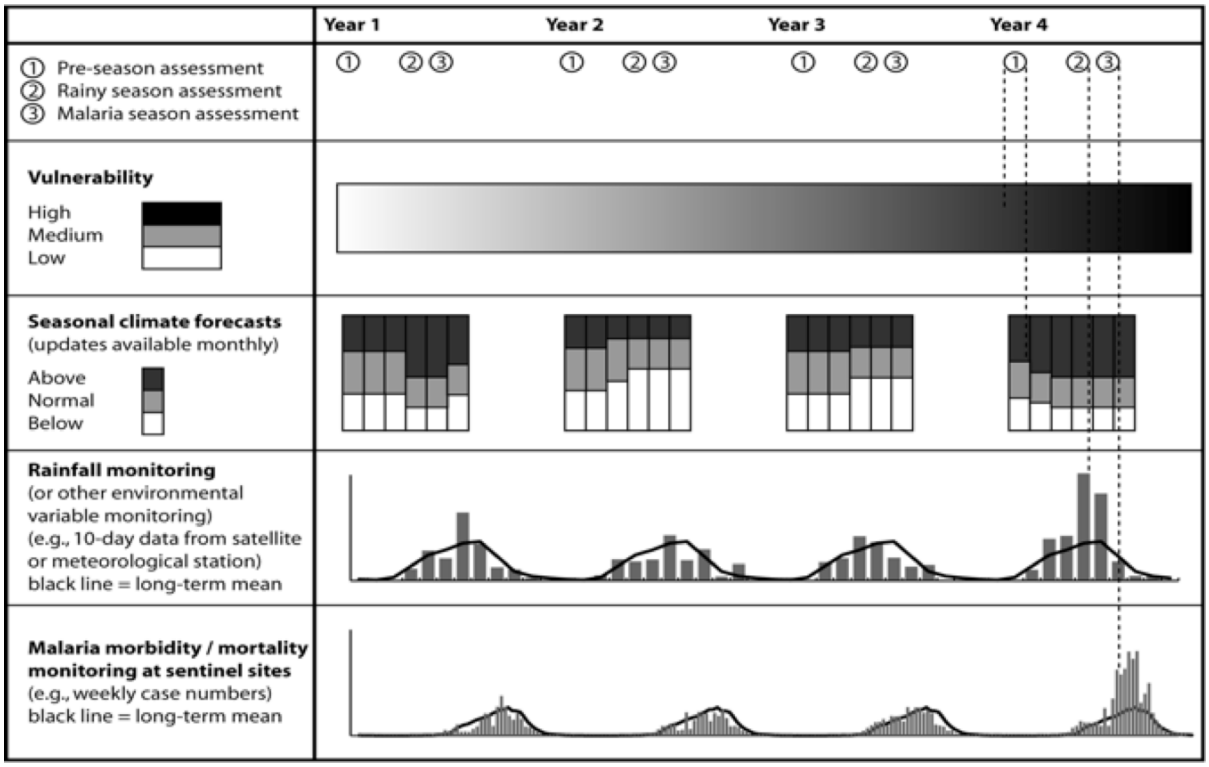

Figure 11: Feasibility diagram illustrating the possible incorporation of seasonal forecasts (middle row) within a malaria early warning system (research from the International Research Institute for Climate and Society).

recommended that any EWS be made proactive through the incorporation of the outlooks as well as of weather forecasts.

In principle this building block might be put into place in a reactive sense reasonably quickly once the necessary observations streams are in place and in a proactive sense once approaches to incorporation of predictions into the information have been determined.

Climate Projections and Scenarios

The development of expertise in climate projections is central to *Outcomes 2, 3 and 4* and directly supports *5 and 7*. Climate projections give an insight into the potential future climate and can be developed from global climate models with or without downscaling using Regional Climate Models. Such is the level of expertise and computer power needed that development of General Circulation Models (GCMs) is limited to around 20 institutions across the world. Regional Climate Models (RCMs) are of similar complexity to GCMs; they use output from a GCM and produce climate information at a higher resolution. However there are now several RCMs that can run on standard desktop computers, and hence can be run by developing world organisations in collaboration with institutes that run GCMs. The issue here is similar to that mentioned in the section on Seasonal Outlooks, that use of an RCM tends to focus attention on single projections rather than on the ensemble that is required.

Climate projections for Rwanda are crucial to understanding the future impacts of climate change and developing scenarios to assess the potential futures of Rwanda. However, developing capacity in climate modelling from scratch is not an easily or quickly achieved objective, even given the relative straightforwardness of projects such as running of an RCM. Currently, Rwanda does not carry out any climate modelling itself but did undertake work to interpret climate model output for the production of the draft Second National Communication on Climate Change for the UNFCCC and for the NAPA, which was completed by an external consultant on behalf of REMA, using MAGICC (Model for the Assessment of Greenhouse gas Induced Climate Change). Some preliminary climate projections undertaken by the authors, as well as the ensemble of projections built by CSAG in Cape Town, in both cases for Rwanda, are presented in the report Rwanda Climate: Observations and Projections, another appendix to the Strategy.

Developing capacity in Rwanda in climate modelling would need to be a gradual process, under the responsibility of RMS, and initially it is recommended that the focus for the CCKD would be the processing and interpretation of model outputs that have been produced by existing institutions. For example, CORDEX (COordinated Regional climate Downscaling Experiment) is an international collaboration to produce downscaled climate model (RCM) information on a regional basis across all continental areas of the world, and data from this project will be released shortly. Such data would be appropriate and available for use in Rwanda.

Scenarios take the examination of projections to the next level through the creation of plausible storylines covering the interrelated impacts of climate change on society, on the environment, on the economy and on all aspects of development themselves. These scenarios, intended to guide the creation of policy, of NAPAs, and so on, would take into full consideration the full range of projections from all models and would thus cover all future climates as simulated by these models. Creation of scenarios is a complex multi-disciplinary task that would use resources across the CCKD. As with the production of the projections themselves, creation of scenarios would likely be a gradual process in which the first stage is the development of the human capacity.

Assessment of Climate Sensitivities

As described in the report 'Rwanda Climate: Observations and Projections', Rwanda has a complicated climatology with a series of microclimates; given Rwanda's vulnerability to climate-related disasters, identifying how climate

change will affect the country is pivotal but may not be straightforward. An important stage in this process is undertaken in this building block, which individually supports more Outcomes than any other (see Figure 8).

Some investigations have been completed to identify the interaction between climate and activities within a particular sector, with the Irrigation Master Plan a good example of using climate information to support plans and policies for Rwanda's development. Some assessments were made by various Ministries while developing the National Communication and the NAPA, and further work has been done in the current project which is outlined in the National Strategy on Climate Change and Low Carbon Development. While assessment of current climate sensitivities is necessary, ensuring Rwanda's development planning is resilient to climate change requires similar analysis but with a focus on future climate. The CCKD should therefore take responsibility for analyses of both observed meteorological data and of climate change projections to assess current and future projected trends, to identify and map microclimates, and to develop a series of vulnerability maps for different sectors.

Such an assessment of climate sensitivities requires expertise across the different sectors of the economy, environment and society. The advantages of increasing the availability of climate information would be lost without proper interpretation with regard to vulnerability across those sectors. It is therefore necessary that the CKCD hold knowledge of – and expertise in – all pertinent sectors. The CCKD should establish a team to assess the vulnerabilities of sectors to current and future climate; the skills and background experience of the team would have to cover a range of sectors. In addition, the CCKD should develop links to collaborate with specific Ministries and organisations to draw on their specific sectorial knowledge. The information developed by the CCKD can be used to produce guidance for government Ministries on how climate change will affect their Ministry's objectives. Information might be provided in two forms: non-technical summaries for policymakers and detailed documents for technical staff. Such information should subsequently be developed for all other aspects the economy and society.

This building block links closely with those relevant to data collection and development of projections. Accurate interpretation of climate vulnerabilities will depend heavily on reliable sets of observed data and indications of future climate. This is not limited to climate information and data sets, and an element of the collaboration referred to above will also be with reference to data needs for impacted sectors. Hydrological data, for example, is essential for identifying the influence of climate on water availability for domestic, industrial and agricultural use, while also being necessary for development of an early-warning system.

Work in this building block might be established relatively quickly, with necessary expertise probably already available within Rwanda, provided the necessary data sets are available.

Assessment of and Adaptation and Mitigation Policy Options: Public, Private and Voluntary Sectors

The sum total of the outcomes from the suggested CCKD is that policies will become identifiable that will facilitate development within Rwanda in all public, private and voluntary sectors that exhibit sensitivity to climate variability and to climate change, and in all that emit greenhouse gases, and thus this building block contributes to *Outcomes 2, 3, 6, 7, 8 and 9*. Identification of policy options is a multidisciplinary task involving collation of the underlying sensitivities, through the building blocks on "Station Network", "Data Collection and Information Creation", Greenhouse Gas Inventory" and "Assessment of Climate Sensitivities", with capabilities for foreseeing the future, through "Seasonal Outlooks", "Monitoring and EWS" and "Climate Projections and Scenarios", and merged within objective analyses of policy options.

On the public side work in this building block would contribute towards many areas, perhaps including:

- Future versions of Rwanda's NAPA, EDPRS and National Communications to the UNFCCC
- National development policies in terms of health, food, water and energy security, infrastructure, social services, education, etc.
- International policy, not least as this affects Rwanda, and through this work the CCKD might contribute with increased authority towards international environmental negotiations and the Common African Positions, including that under the UNFCCC.

On the private sector side policies might be considered that address climate-sensitivity issues in areas such as:

- Agriculture
- Transportation
- Mining
- Energy production.

Finally in the voluntary sectors improved climate-resilient policies may be developed in areas such as:

- Famine relief
- Flood relief
- Health management
- Social development.

In general the activities mentioned in this section are referred to either as adaptation or as mitigation when cited in connection with climate change, and in this regard the CCKD could work closely with other organisations both within Rwanda and internationally in respect of adaptation/mitigation research and implementation per se. However, note that adaptation and mitigation activities per se have not been included within those suggested for the CCKD; rather the design has been one of providing the background information base for adaptation and mitigation through which to advise the actions of other organisations more immediately involved in pertinent sectors. A more proactive role of the CCKD within adaptation and mitigation could be devised readily if required.

The work of a CCKD within the policy arena should be collaborative with existing activities within Rwanda, including the work of the Climate Change Unit, with the RDB-based UNFCCC focal point, and with assessments such as those undertaken by MINIRENA (and in regards to the previously-mentioned Second National Communication and NAPA). A straightforward initial work programme if needed in this area might be to assess policy options used elsewhere and to examine current policies within Rwanda to check the extents to which they accommodate climate issues.

Capacity Building: Science

Building capacity in science is essential in developing the knowledge and skills required in the suggested CCKD. It directly underpins *Outcomes 1, 2, 4, 5 and 9* and forms the basis of developing Rwanda's role on a wider basis, as in *Outcomes 6, 7 and 8*. In addition to climate science, it is necessary to develop expertise in mechanisms by which the climate will impact various sectors, such as agriculture and health. The building of capacity in climate science also has wider benefits of supporting the vision for a knowledge-based economy.

Capacity building of staff is, of course, a normal activity of any organisation, and a CCKD might address this through all opportunities available within collaborative projects, courses such as those run by WMO, attendance of staff at workshops and conferences, running of meetings within Rwanda, and so on. National tertiary education institutes naturally will play a key role, and in that regard it is noted that KIST has a proposal for a Faculty of Geosciences while NUR plans a Masters degree course in environmental modelling. It is noted, however, that the applied sciences, such as agriculture and health, etc., and their links with

climate from adaptation and mitigation perspectives, may require further attention.

Capacity building through international links is a key approach to accelerating capacity building, and in this regard links have already been made with MIT with regards to training in atmospheric chemistry. Further similar links could be made regarding climate science, modelling, and sectorial aspects in regards to adaptation and mitigation with many international organisations. Rwandan participation in internationally coordinated research programmes, such as those under the ESSP (Earth System Science Partnership), will lead most likely to high-level capacity building.

At the school level (and in regards to capacity building in government, commerce and society as discussed in the next section), the CCKD could have a role in both raising awareness of climate change and supporting climate science in the curriculum. The CCKD could advise on the content of the national curriculum and be consulted on materials and suitable resources for teachers. The CCKD could also conduct presentations in schools (and elsewhere).

For both secondary school children and university students, the CCKD should provide opportunities for placements for work experience. For schoolchildren, these would be short-term placements in keeping with any designated requirement for work experience in the national curriculum. For university students, there should be the opportunity for longer placements (such as the 10-weeks of work experience expected of undergraduate students at KIST) and collaboration and support on their research projects. Placements can engage and incentivise students for future careers in climate science and encourage university students to undertake relevant research as part of their studies.

Capacity building in science is one of the most fundamental aspects of the strategy outlined here and it underpins all other aspects of the scientific work. It is not possible to achieve this overnight, but it does represent one of the highest priorities for attention, and it could be implemented with minimal delays.

Capacity Building: Government, Commerce and Society

While it is vital that capacity building in the education system gives Rwanda's schoolchildren and students the opportunity to study climate, it is also necessary to build capacity and awareness in climate change in the current workforce and society as a whole. This will maximise the opportunities to use climate information appropriately and contribute to achieving *Outcomes 2, 3, 6, 7 and 8*.

The government will be responsible for putting in place many of the actions forwarded in this Strategy and in developing climate change policy in the years ahead; therefore, it is necessary that staff have a thorough understanding of the causes of climate change, its impact and responses to it. As such, it is recommended that the CCKD create training sessions for government staff on the basic issues of climate change and develop a programme of delivery for the different government ministries. Further to the training sessions, the CCKD might produce simple, non-technical summary documents on the issues of climate change and how they relate to each Ministry. Outputs of wider initiatives, such as those listed in these recommendations should of course be shared with relevant Ministries.

A similar approach to that for government could be adopted regarding capacity building in commerce, in many areas such agriculture, construction, health, water management, and so on. Policy options for addressing capacity building in the critical area of commerce will have been covered in the appropriate building block as discussed above.

In wider Rwandan society, raising awareness of climate change will help the public to understand the issues and engage with the responses being taken by government. The CCKD should therefore investigate the potential for raising awareness of climate change to reach the wider public. This could use traditional media, such as radio and newspapers, but should also investigate the

possibility of other channels of communications, such as RANET (RAdio and interNET communication system).

The internet is also an increasingly useful tool for communication and dissemination of information. Therefore, as with the planned development and expansion of the RMS website, the CCKD should look towards the internet as a key method of communication with the public. It is recommended that the CCKD create a straightforward portal for climate change information, which should be part of a more comprehensive website for the CCKD. The website would summarise the climate change issues for Rwanda and provide suggestions for further information/resources. Publications by the CCKD should be freely available for download from the portal. This could build on the Climate Finance Toolkit already developed as part of the Strategy.

Most, if not all, of these capacity building activities could be initiated without delay.

Further Implementation Issues

5.1 Intercomparison with the MIT Climate Observatory proposal

A Task Force under MINEDUC is in the process of considering implementation of the plan forwarded by MIT for a Climate Observatory on Mount Karisimbi, a plan that incorporates certain aspects of a CCKD. It is reasonable to suggest that a single Task Force cover both the MIT proposal and the strategy outlined within this document, not least to eliminate possible duplication; this may lead to co-management of a CCKD and the Climate Observatory should both be created.

By-and-large the scopes of the present proposal and that forwarded by MIT differ, the main focus of the MIT proposal being the measurement of trace gases and the interpretation of that information in terms of climate change in Rwanda and globally while in the current study the focus is on the creation of climate knowledge in support of social, environmental and economic development in Rwanda. Areas of similarity, based on the items presented, including in Tables 1 and 2, in the MIT proposal, "Proposal for the Development of Rwanda as the Center for COMESA Climate Research" prepared by Arnico Panday in late June 2011, include:

1. **Meteorology measurements at multiple locations.** The MIT proposal mentions supplementing a network of observing platforms across Rwanda and surrounding countries, plus platforms at the summit and cable car base station on Mount Karisimbi. Supplementation of the observing network is central to the present study also and thus the two proposals are similar.
2. **Analysis of satellite measurements.** There is no equivalent in the present document to the atmospheric chemistry aspects suggested by MIT as they are not related to development. The use of remote sensing for weather and climate measurements, for EWS, for land, agricultural and hydrological monitoring, etc., is implicit within the building blocks.
3. **High resolution regional modelling of meteorology and climate.** Use of all modelling approaches, not just high resolution and not limited to meteorology and climate, is fully incorporated into the building blocks.
4. **Hydrological modelling.** Fully incorporated within the building blocks.
5. **Ecological studies.** In all fairness the intent of the MIT proposal is not clear in this area, but all areas of environmental studies pertinent to development are covered in the building blocks.
6. **Multidisciplinary studies of settlements, agriculture, flood/landslide hazards.** Covered in full within the context of development through the building blocks.
7. **To monitor the changes taking place.** Covered in its entirety in the building blocks other than in regard to gases, which is unique to the MIT proposal. In the current document monitoring

additionally covers all aspects related to development, including agriculture, health, etc., as well as suggested approaches to enhancing historical records.

8. **To acquire the tools needed to forecast future changes.** Covered in full through the building blocks.
9. **To assess vulnerabilities to future changes.** Covered in full through the building blocks.
10. **To gather the knowledge needed to design mitigation and adaptation strategies.** One of the underlying principles in the present document is to develop the knowledge across all sectors required to advise adaptation and mitigation activities and decisions.

5.2 Priorities and Timeline for a CCKD

A full timeline can be developed only within an implementation plan, but immediate priorities are the establishment of the observations and data handling aspects of a CCKD and addressing capacity and resource issues. An alternative view of the building blocks is provided in Figure 12, in which the structure is illustrated in approximate terms of the flow of data and information through a CCKD. This alternative structure also suggests areas of priority in setting up a CCKD.

Observations not taken cannot be recovered, although approaches such as use of reanalyses may assist but will remain uncalibrated without observations. Development of a fully-automated weather network should be considered in order to reduce issues regarding dependence on observers. The position regarding data collection, management and recovery in all other climate-related sectors (agriculture, health, etc.) should be examined and plans put in place to address any gaps.

The human resource aspect cannot be addressed in the short term and requires a coordinated approach through all educational levels and into training under employment. Climate and related disciplines tend to be scientifically complex, and individuals require numerous years of experience to work at the highest levels. There appears to be no alternative therefore to undertaking work with institutes external to Rwanda, both from the perspective of extending the education of Rwandans within the disciplines involved and from that of expeditious

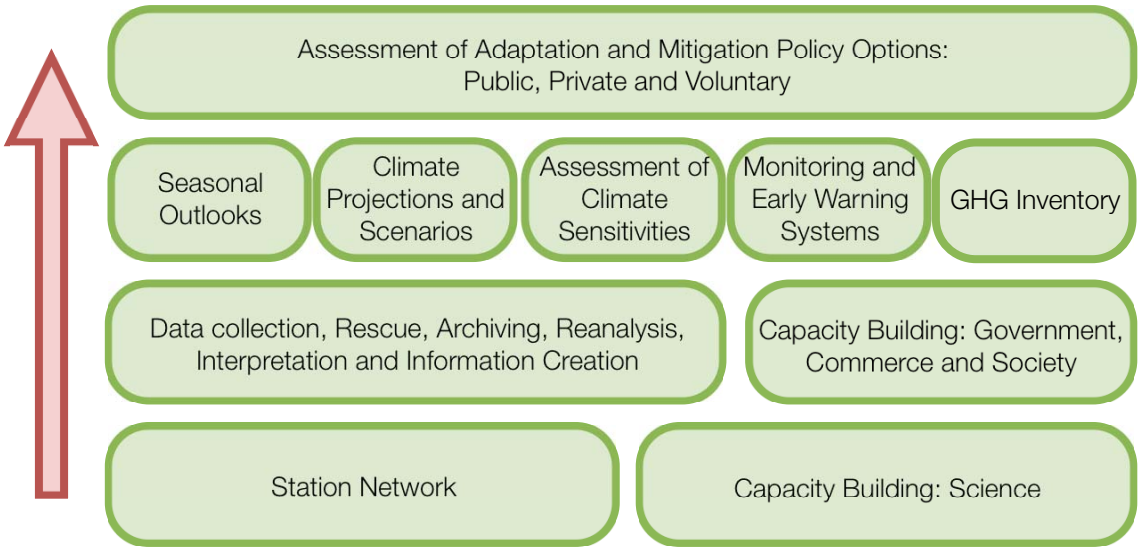

Figure 12: Alternative view of the structure of the building blocks in terms of the through-flow of information

implementation of parts of the various building blocks. In the first case approaches might be made to international universities and institutes to assist the education and training of suitably-qualified Rwandans, and a human capacity building programme designed. In the second case Rwanda can take advantage of the numerous activities already under way in Africa and elsewhere, many mentioned in this document, to assist in implementing building blocks while looking for opportunities to collaborate in the implementation of activities within Rwanda itself.

With top priority given to the building blocks 'Station Network' and 'Capacity Building: Science', attention can turn to the other building blocks. That on 'Data collection, Rescue, Archiving, Reanalyses, Interpretation and Information Creation' might be initiated, at least as far as the information handling aspects are concerned, together with 'Station Network' (recognising that under RMS these are included within the Met Office-assisted project). Use of reanalyses and data interpretation could well form valuable capacity building exercises.

The 'Seasonal Outlooks' building block includes several useful capacity building aspects, from the improvement and generation of the outlooks, through the understanding and interpretation of the outlooks, to decision making in all sectors. As such, capacity built under this building block will prepare the ground for building blocks related to climate change, and would be advantageous in developing the EWS building block.

It might be argued that the remaining building blocks are of lower immediate priority: that on climate projections and scenarios will benefit from that on seasonal forecasts and from preparing ahead of new projections due to be released; that on climate sensitivities might be preceded by literature work to identify current knowledge relevant to Rwanda; that on policy matters might be addressed similarly initially by examination of work elsewhere. Finally the plans for the broader capacity building block can be developed alongside the other activities.

Possible Sources of Funding

There are numerous sources of funds that might be utilised to assist start-up of the suggested CCKD, but all of these are short-term only and planning should be in place for transferring ultimately most, perhaps all, funding to national and, if implemented under a REC, Regional sources, at that stage using external funding sources primarily for further start-up and project activities rather than for foundation institutional spending.

In all probability the major source of funding will be from the ClimDev-Africa Special Fund (CDSF) once this has been implemented, which is expected during 2011 with funding opportunities beginning in 2012. The building blocks outlined on the left-hand side of Figure 6 all map directly onto CDSF funding areas and the suggested work of a CCKD is fully aligned with the objectives of ClimDev-Africa. CDSF is likely to be a competitive demand fund, meaning that calls will be made in those areas for which there are the greatest demands. Thus it is unlikely that funding across all the building blocks will be obtained from the CDSF and alternate sources need to be sought. The precise size of the CDSF remains to be determined, and in current planning the Fund will terminate by about 2022.

A further fund expected to be set up under the AfDB is the African Green Fund (AGF), which will act largely as a mechanism for channelling funds from the Copenhagen/Cancun commitments; the total amounts discussed for the full have been substantial, although Africa's share remains to be determined and negotiations continue under the UNFCCC to identify the precise sources of the funding. The AGF is not likely to be available in time for initial implementation of a CCKD, but might fund useful resources at a later stage.

One final AfDB fund worth mentioning is the African Water Facility (AWF) that, although not precisely aligned with the suggested objectives of a CCKD, might provide funding for some of the hydrological aspects.

Most of the funds for climate change activities, related to the UNFCCC and/or the Global Environment Facility (GEF), have been designed with specific foci in mind, which will restrict their use in establishing a CCKD. Nevertheless funding opportunities include the Pilot Programme for Climate Resilience (PPCR) of the Strategic Climate Fund (SCF), and UNFCCC's Special Climate Change Fund (SCCF) and new Adaptation Fund. The Least Developed Countries Fund (LDCF) may assist with those aspects identified in Rwanda's NAPA, specifically EWS for agricultural and water systems. The EU's GCCA provides relevant regional funds. Additional funding is available on a project basis is available from the development banks, the World Bank and the AfDB.

Numerous other funds might be tapped in order to fund or part-fund specific research or implementation activities of a CCKD. The full list is too long to publish here, but includes: bilateral funding from many countries, including the UK, USA, Canada, France, Italy, Sweden, Japan; several opportunities under START; the European Capacity Building Initiative; the CGIAR CCAFS; modelling activities under the Global Facility for Disaster Reduction and Recovery.

Conclusions

Within this document has been highlighted the availability of climate and climate-related information in the region and the various needs required from the climate perspective to support the achievement of Rwanda's development objectives. The current shortfall in infrastructure and resources has also been discussed, as have the complementary activities of strengthening RMS and establishing a Climate Observatory. There has also been discussion of potential interactions with inter-governmental organisations and Regional Economic Communities and other relevant international programmes.

On the basis of the information presented above, it is recommended that these needs are met through the establishment of a Centre for Climate Knowledge for Development, which would serve to provide the necessary climate information in support of government, commerce and the wider society of Rwanda. Further to this, a series of specific recommendations have been outlined on how this could be achieved, focussing on key areas such as the need for robust data, assessments of climate sensitivities, and capacity building.

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