



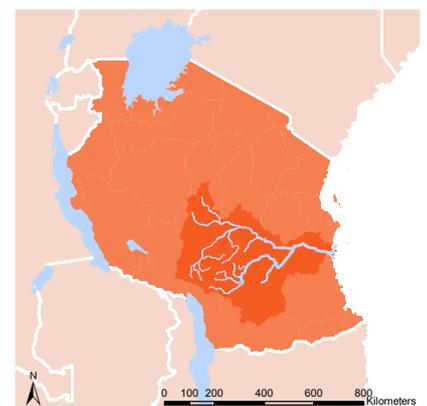
## Designing a process for assessing climate resilience in Tanzania's Rufiji river basin

### Overview

This brief introduces the concept of climate information and reasons for its use in major decisions about water, energy and agriculture, including new infrastructure investments. It outlines the innovative approach taken in the Rufiji River basin in Tanzania by the UMFULA research team of the Future Climate for Africa (FCFA) programme to assess trade-offs between plans for water use in the energy, agriculture and environment sectors in order to identify adaptation options that are robust and resilient in the face of climate change. A second brief will show the results of the analysis. The brief is designed to inform programmes, donors, and government decision-makers who need to make similar assessments.

### Key messages

- Major policy and sectoral decisions require careful planning; in cases involving large investments, long life-times and irreversibility, there is a strong argument for assessing resilience to future climate change and river basin infrastructure exemplifies this.
- Assessing climate resilience is challenging because future climate projections and impacts are highly uncertain particularly for rainfall conditions.
- Because of the uncertainties, a family of approaches (Robust Decision Making and Decision Making Under Uncertainty) has emerged that help identify decisions and adaptation options that work reasonably well across large ranges of uncertain future conditions.
- The UMFULA research team has applied a novel approach combining a regionalised Global Hydrological Model and Robust Decision Making approach in Tanzania's Rufiji River basin to identify river basin interventions (infrastructure and management changes) which could work well under different climates, and present trade-offs between different performance metrics that represent stakeholders involved in the country's water, energy and food sectors.
- The process of assessing climate resilience involves: developing an understanding of the basin and the key decisions being made; identifying what is important for stakeholders and how they assess benefits; identifying options that achieve greater aggregate, and more sustainable development benefit despite climate risks, and deliberating their merits with stakeholders.



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## Factoring climate change into decision-making processes

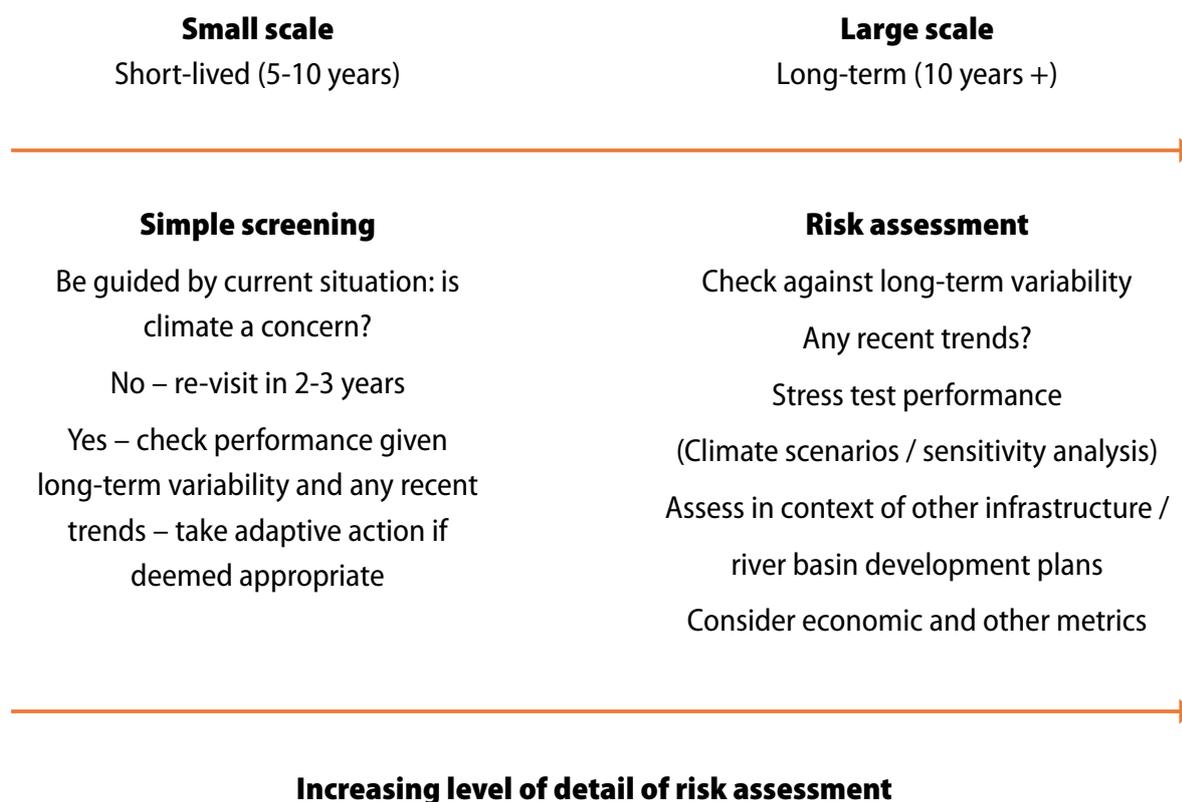
Big decisions require careful planning. Where large investments are involved and their planned lifespan is long, decisions are irreversible. It is therefore essential to consider future climate risks. This is necessary to reduce damage and losses – and capitalise on opportunities – from new combinations of extreme weather. Indeed, funders and investors are increasingly likely to require that

infrastructure decisions are screened for climate risk. Major development plans in the Rufiji river basin that rely on future water availability are a good example; changes in the future behaviour of rainfall could compromise the performance of infrastructure essential for energy and food production.

Many approaches are available to suit the scale of the decision situation, however, it remains the case that operationally there are very few instances where assessments have formed part of formal

decision processes. Figure 1 shows there is a continuum moving from a light touch approach suitable for many small and short-lived decisions (for example small-scale water and sanitation technologies) through to an increasingly detailed approach for major long-lived decisions such as irrigation projects and dams. Deciding which approach is most suitable is important (and may require guidance) – detailed assessments can be technically demanding, time consuming and costly and should not be undertaken lightly.

**Figure 1: The type of climate risk assessment needs to suit the decision situation – illustrative examples**





## The stages in a climate risk assessment

Many frameworks have been proposed for adaptation or climate risk assessment (Willows *et al.*, 2003). Most approaches involve a sequence of actions that include: consulting about the problem and agreeing the aims of the exercise; developing an understanding of the system of interest; identifying what is important for stakeholders, assessing the significance of future climate risks to development plans and identifying options. Further stages can include implementing decisions, followed by monitoring, evaluating and adjusting.

Figure 2 shows the process followed by UMFULA since 2015, and what each stage involves for the case of the Rufiji, described below.

## Dealing with uncertainty: Robust Decision Making and Decision Making Under Uncertainty

The assessment of risks is challenging because future climate conditions and impacts are highly uncertain, even in the near term, and particularly for future rainfall conditions. UMFULA has reviewed the range of climate projections available from the leading source of global climate model results. These show that continued warming is highly likely (roughly 0.8 C to 1.8 C by the 2040s) but that projections of future rainfall averaged across Tanzania are mixed. Out of 34 models roughly one third project lower rainfall and two thirds higher rainfall (Conway *et al.*, 2017). The range of rainfall change across the 34 models is fairly modest, with 20 models projecting changes of less than +/-5% by the 2040s. Changes in daily rainfall suggest more variable conditions, with both higher likelihood of dry spells and a higher likelihood of intense rainfall events (often associated with flooding). The changes in precipitation generate substantial changes in river flows.

Because of the uncertainties that exist in knowing what the future will look like (due to changes in climate and many other socio-economic factors), a family of approaches has emerged around the ideas of Robust Decision Making (RDM) or Decision Making Under Uncertainty (DMUU). These approaches help identify decisions and adaptation options that work reasonably well across large ranges of uncertain future climatic conditions (introductions to the range of approaches are found in Lempert *et al.* (2003), Walker *et al.* (2013) and Hamarat *et al.* (2014)).

Decision-makers face important long-term planning issues with deep uncertainties which cannot be reduced by gathering more information. However, using RDM or DMUU the decisions can be addressed by considering the performance of different options under varying future conditions. Examples of their application in developing countries are still rare – but through FCFA and UMFULA several cases are underway, including in the Rufiji River basin (Bhave *et al.*, 2019).

**Figure 2: Overview of the UMFULA approach to assessing climate resilience in the Rufiji**



## Development options in Tanzania's Rufiji river basin

The Rufiji produces half of Tanzania's river flow, supplying water for a variety of uses. This includes providing water for domestic use for 4.5 million people, water for irrigation and livestock and using water to generate roughly 80% of the country's hydropower (approximately 47% of the country's total installed electricity generating capacity). As a result, many stakeholders across multiple sectors are affected by planning and decisions about the industrial and agricultural investment are required to meet development aims.

Explicitly considering trade-offs between many objectives can be helpful in defining acceptable

compromise plans in water systems planning problems (Geressu and Harou, 2015), and help achieve greater aggregate, and more sustainable, development benefit, especially important in a context of typically limited available investment resources.

The basin includes several major wetland systems, formal and informal irrigation schemes, several hydropower reservoirs and areas of high conservation value, including National Parks. Large areas of the basin are targeted by the Government of Tanzania for major socio-economic development over the next two decades as part of the Southern Agricultural Growth Corridor of Tanzania (SAGCOT).

The aim of SAGCOT is to increase agricultural productivity to meet national demand but also for export

and to shift the trade balance. The corridor supports the development of value chains to link small-holder producers to markets. The success of the initiative relies on water availability for agricultural production.

But a major factor has recently re-entered this mix with the decision in 2017 by the government of Tanzania to build the Rufiji Hydropower Project at Stiegler's gorge on the Rufiji main river. The high development potential and present political momentum throws into sharp relief the need to characterise, explore and deliberate the critical trade-offs between the water, energy, agriculture and conservation sectors both now and as they evolve under future climate conditions.

## Step 1: Consult and agree on decision problem

The overarching aim was to examine the climate change risks to sustainable achievement of the key components of the basin development plan, that would challenge the perception of the Rufiji basin as being a "Basin of Great Potential and Promise" (WREM, 2015). Key development targets in the Rufiji basin plan, are: the expansion of hydropower, with a potential additional energy supply in excess of 8,000 GWh/year added to the national grid eliminating present electricity shortages, and; increase in agricultural area under irrigation, to almost quadruple by 2035 (to 319 thousand hectares), with expansion concentrated in the Kilombero district and downstream areas (Figure 3).

Trade-offs in these aims comprise the extent of irrigated agriculture expansion versus the potential of hydropower

dams downstream, and the impact of both these new irrigation systems and dams on environmental flows at locations of high environmental and economic (tourism, fisheries) importance. Possible synergies are improved water supply to agriculture if various small and medium sized hydropower dams are developed upstream. On a more detailed level, trade-offs between small holder expansion and planned irrigation sites are expected. Already, evaluating the sustainability of increased demand for water abstraction is one of the challenges for the Rufiji Basin Water Board (RBWB) who issues permits for water use.

## Step 2: Develop an understanding of the river basin system

A recent basin scale study was conducted to support the Rufiji Basin Water Board in their planning of estimated water demands for hydropower production and

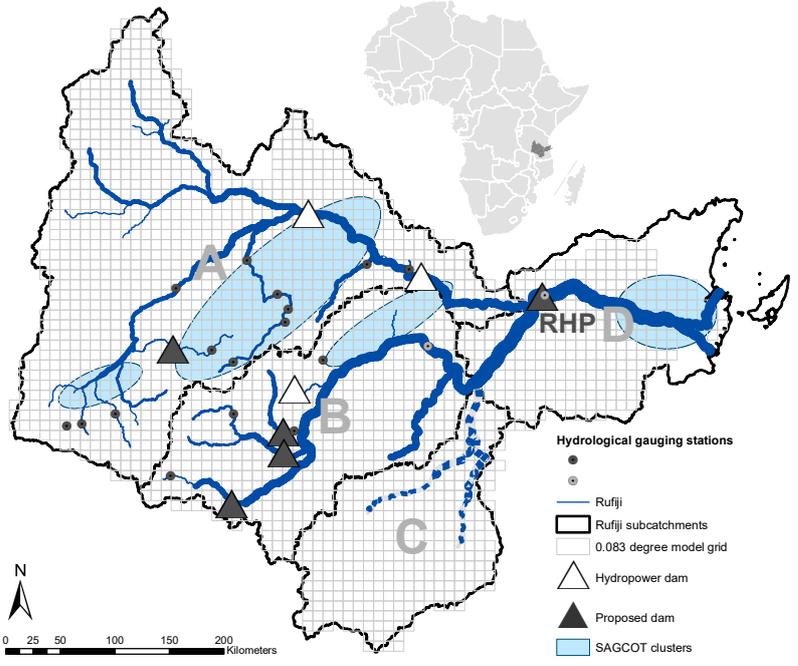
agriculture (WREM, 2015). Building on the findings, and to support our detailed climate risk analysis, the UMFULA team further developed a detailed hydrological model for the Rufiji using the underlying structure of a global hydrological model (Figure 3).

Many river basin models are developed using proprietorial software that require licences to run. However, novel application of a regionalised global hydrological model has potential to allow consistent modelling of multiple basins, and opportunities for local researchers to link with global research networks using open access source models, thereby improving utility in a developing country context. With limited and fairly simple modification, the model produced a reasonable simulation of river flows in most parts of the basin – with a performance good enough to support use for scenario exploration given the very limited observational data (Siderius *et al.*, 2018).

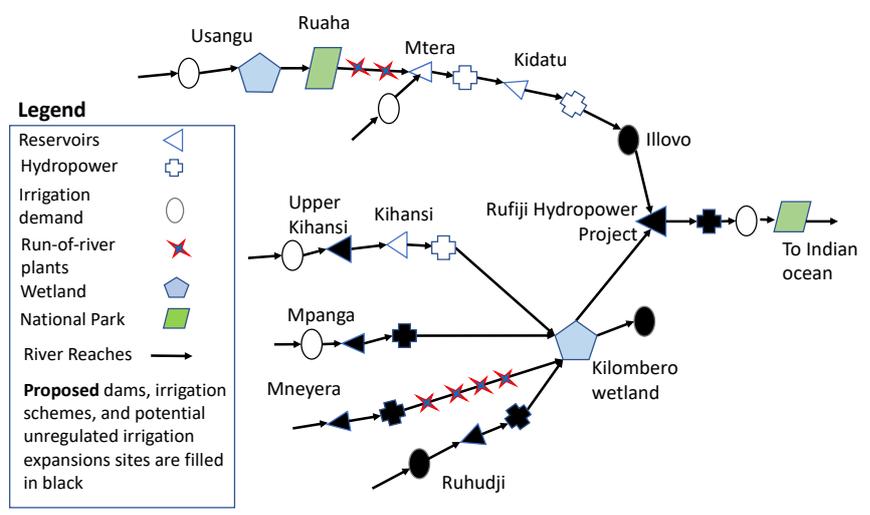
The hydrological system then needs to be coupled with a water resource system model that simulates the operation and effects of dams and irrigation in the basin. Figure 4 shows a simplified version that includes present and planned infrastructure and new irrigation in the basin. The simulator is set up to calculate the water flows and use for irrigation at key points, together with the energy that can be generated from hydropower sites. Many thousands of simulations can be used to test different combinations of options (e.g. new dams and irrigation developments) and their management (e.g. by varying reservoir release policy) and identify options that perform well across the multiple performance indicators.

In both models we have had to make a number of assumptions due to the complexity of the basin and data sparsity – a key priority for future management is to establish and maintain gauging sites at critical points in the basin, particularly on the Rufiji main channel and Kilombero and Luwegu tributaries.

**Figure 3: Hydrological model of the Rufiji system overlaid with 0.083 ° (~9 by 9 km) grid and areas identified for irrigation expansion (SAGCOT clusters) (Siderius *et al.*, 2018). RHP is Rufiji Hydropower Project. Letters refer to main tributaries: A is Great Ruaha, B is Kilombero, C is Luwegu and D is the Main Rufiji channel.**



**Figure 4: Major existing and planned dams and main areas of irrigation simulated in the water resources systems model developed by UMFULA (currently 11 irrigation demand nodes, four existing reservoirs, five new reservoirs and six run of the river hydropower dams).**



### Step 3: Identify what is important for stakeholders

There are assumptions and values incorporated within any analysis of performance metrics and such exercises sit within a much wider political process involving (to varying degrees) many actors, alternative perceptions and social preferences. Therefore, it is important that different formulations of decision problems should be considered to better understand the implications of particular decisions, including how vulnerable they may be to climate change.

A suite of performance objectives (key objectives for sustainable basin development) were identified through a detailed process of literature review and consultation and taking into account whether data availability was sufficient to support a metric. Consultation with government, research institutions and NGOs took the form of small workshops held in March 2017, March 2018, November 2018 and July 2019. This produced a long list of indicators that was narrowed down to a short

list due to limited data availability and the computational limits to the optimisation process. The final objectives included maximizing annual total and firm monthly energy from all existing and new dams; maximizing irrigation water supply reliability; and minimising impacts on river flows downstream of the Rufiji Hydropower Project, in order to maintain as far as possible the environmental benefits to wildlife, tourism and livelihoods.

### Step 4: Next step – assess options and stress-test under climate change

Since the decision to build the Rufiji Hydropower Project has been made, our analysis will therefore consider its performance as affected by upstream development comprising irrigation expansion (increased consumptive water use) and the presence and operation of other proposed dams by 2030. In this final step, over the next few months the optimisation will investigate different combinations of proposed and existing

assets (i.e. dams and irrigation schemes) and how the dams could be operated to achieve the best possible performance across multiple benefits (energy, irrigation and environmental services) throughout the basin, now and under climate change.

### Final considerations

Through this work we aim to demonstrate the value of performing a multi-objective optimisation to explore where multiple water resource system components can work in coordination (have synergy) or where different development projects impact each other's performance (involve trade-offs) – under future climate change conditions, Geressu and Harou, 2015. In addition to generating useful information to inform planning and management decisions in the Rufiji River basin, UMFULA is testing a new approach based on a regionalised global hydrological model and robust decision making that has potential to be applied in other data-constrained contexts in the developing world.



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## About Future Climate for Africa

Future Climate for Africa (FCFA) aims to generate fundamentally new climate science focused on Africa, and to ensure that this science has an impact on human development across the continent. This brief is based on ongoing work by the authors; Declan Conway and Christian Siderius (Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science-UK), Robel Geressu and Julien Harou (University of Manchester-UK), and Japhet Kashaigili (Sokoine University of Agriculture-Tanzania). The authors are immensely grateful to the stakeholders who took out time from their busy schedule to attend meetings to engage in discussions, advise on the model, and provide valuable feedback. This includes representatives of the Rufiji Basin Water Board (Mr Idris Msuya and Mr David Munkyalala) and the Ministry of Water. We also acknowledge funding from the UK Research and Innovation's Global Challenges Research Fund (UKRI GCRF Development Corridors Partnership).

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