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How to spend 5 billion dollars? Prioritising climate change adaptation measures in Rwanda

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- Rwanda has an ambitious updated Nationally Determined Contribution (NDC) that identifies USD 5.4 billion of adaptation priorities by 2030, of which 40% are unconditional. i.e., to be funded domestically.
- Current analysis indicates a large financing gap (domestic and international) for these NDC actions. This leads to a question of which adaptation measures to prioritise.
- This study has reviewed the benefit to cost ratios for the 24 adaptation interventions in the NDC and finds that nearly all of them have positive ratios, though some offer better value for money than others.
- The study has also reviewed the NDC adaptation options for their green recovery potential, in terms of stimulating the economy and providing jobs.
- A number of adaptation options score positively against both these criteria. Such information may be useful in helping to prioritise and sequence adaptation resources for Rwanda in the near-term.

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This policy brief focusses on the economics of climate change adaptation in Rwanda. It undertakes a literature review of the potential costs and benefits of the adaptation interventions in Rwanda's updated Nationally Determined Contribution (NDC). It also assesses the alignment of these adaptation NDC measures to the key criteria for a green recovery. Based on this analysis, the paper provides some key messages and policy recommendations on adaptation prioritisation. The project was funded by the International Growth Centre (IGC) and was undertaken by Paul Watkiss Associates.

Rwanda's updated Nationally Determined Contribution (NDC)

The updated Rwanda Nationally Determined Contribution (NDC) (RoR, 2020[i]) builds on the Green Growth and Climate Resilience Strategy (GGCRS) (2011) and the first Rwandan NDC (2016). It has undertaken a detailed assessment of mitigation and adaptation and provides a priority list of actions.

> **Rwanda has published an ambitious updated Nationally Determined Contribution, which sets out the need for investment in adaptation.**

The NDC identifies a **total investment need of USD 11 billion by 2030** to deliver these actions, with broadly equal resources allocated to mitigation (USD 5.7 billion) and adaptation (USD 5.4 billion). This is a very large investment, and while it is over a decade, it is nearly equal to the country's annual GDP (of USD 10.33 billion/year, 2020)[ii]. This is shown below.

The NDC also splits these costs into **unconditional** measures, which are based on domestically supported (financed) and implemented measures and policies, and **conditional** measures, which represents an additional targeted contribution, based on the provision of international support and funding.

TABLE 1. Estimated mitigation and adaptation funding needs. Source updated NDC.

USD million	Unconditional	Conditional	Grand Total
Mitigation measures			
2020-2025	1,057	1,754	2,811
2025-2030	953	1,912	2,866
Mitigation Total	2,010	3,667	5,677
Adaptation measures			
2020-2025	916	1,374	2,290
2025-2030	1,229	1,844	3,073
Adaptation Total	2,145	3,218	5,364
Combined Total	4,155	6,885	11,041

These costs are based on a more detailed analysis of mitigation and adaptation options, summed to give the totals above. There are 30 mitigation options and 24 adaptation options prioritised in the NDC.

For mitigation, these options were chosen from a long list using a cost-effectiveness analysis, to prioritize those mitigation measures that would deliver the greatest reduction in GHG emissions for least cost (in USDtCO_2e abated). This was presented in the NDC technical report (RoR, 2020[iii]). The analysis identified many mitigation measures that lead to positive financial benefits [cost savings], such as energy efficiency measures.

For adaptation, the NDC Technical Report undertook a multi-criteria analysis to select a short-list of priority options, but it did not undertake a more detailed economic analysis of options. The adaptation priority options selected in the NDC are presented in Appendix 1. The costs are dominated by irrigation, followed by improved transport infrastructure, storm water management, high density building, disaster risk management, sustainable land management and water catchment management. The split of these adaptation priorities between unconditional and conditional contributions is also shown in Appendix 1 (with the total values for adaptation presented in Table 1).

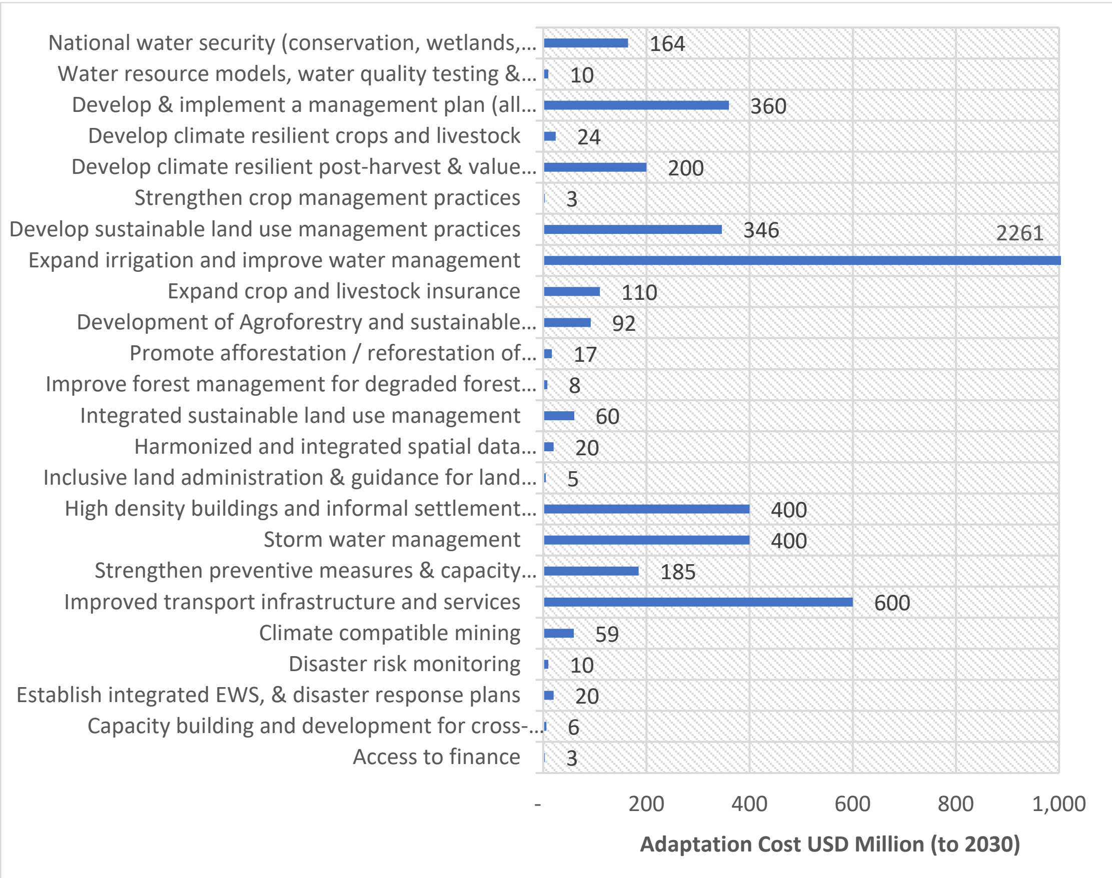


FIGURE 1. Costs of Adaptation Priorities (2020 – 2030) in Updated NDC[1].

[1] The costs are based on the reported estimates in the updated NDC, which are reported as the costs in the period 2020-2030 (note that the price year is not specified).

There is likely to be a major financing gap for the Rwanda NDC.

The total adaptation financing needs for NDC priorities of USD 5.364 billion are allocated at 40% from unconditional (domestic) sources (USD 2.1 billion) and 60% from conditional (international) sources (USD 3.3 billion). The adaptation costs are dominated by the agriculture sector priorities (USD 3.0 billion, which is 55% of total NDC adaptation costs).

However, a review here identifies there is likely to be a major financing gap for adaptation, for both conditional and unconditional sources.

For domestic (unconditional) sources, the NDC was costed based on the proposed budgets in the sector development plans. However, these costs were based on planned budgets, and actual out-turns are much lower, not least due to the COVID-19 pandemic and the impact on the public finances, and more recently, increasing inflation due to supply chain disruptions and the effects of the Ukraine conflict.

To illustrate, the agriculture sector development plan, PSTA 4 (2018 – 2024) was budgeting at 2.7 trillion RWF (approximately USD2.7 billion). However, the PSTA4 mid-term review indicates the likely budget will only be around 40% of planned. This pattern is repeated for other sector budgets. There will therefore be a large financing gap in the delivery of the PSTA4, and in turn, a large financing gap for the NDC.

For international (conditional) sources, while Rwanda has been extremely successful in attracting international climate finance, the available finance flows are not high enough to deliver the anticipated conditional targets in the NDC. The latest global figures (CPI, 2021[iv]) report the annual global flow of adaptation finance (for the most recent years) to all developing countries was USD 44 billion. A review of the potential for climate finance for Rwanda, based on an analysis of international multi-lateral climate finance (notably from Green Climate Fund), and bi-lateral development partners and international finance, has identified a current potential pipeline of USD 500 million of climate finance up to 2030. This is a large amount, but it is still small compared to the estimated unconditional financing needs for adaptation in the NDC of USD 3.2 billion.

A key conclusion, therefore, is that **there will be a very large financing gap for adaptation in Rwanda.**

It is possible this gap could be filled by additional domestic funding, but that would have very significant implications for other development priorities, and for the public finances, given it would likely require additional borrowing. It is perhaps more likely that a shortfall for adaptation financing will exist.

Against this background, a key question is which adaptation measures to prioritize.

The mitigation analysis in the NDC already has undertaken an economic analysis, identifying the cost-effectiveness of different options, as well as their net present value. The information on which mitigation options to prioritize is already available.

The same is not true of adaptation. It is therefore useful to explore the economic case for the different adaptation interventions in the NDC, to see how these vary, and identify potential priorities. At the same time, the Rwandan economy is emerging from the COVID-19 pandemic and there is a need for a post COVID recovery plan. The short-term priority for the public finances is likely to be toward stimulating the domestic economy and increasing jobs. The adaptation options in the NDC have therefore also been considered against the potential criteria for a good, green recovery.

Evidence on the benefit-to-cost ratios of adaptation options in Rwanda's NDC

While adaptation is context- and site-specific, there is a growing body of project studies that show early adaptation delivers high benefit-to-cost ratios (Shreve and Kelman, 2014[v]; Mechler, 2016[vi]; ECONADAPT, 2017[vii]; GCA, 2019[viii]). This study has reviewed the evidence on adaptation economic studies in the academic and grey literature, focusing on information for Rwanda (where available) and in Africa, to identify the potential benefit-to-cost ratios (BCRs) for each of the Rwanda NDC adaptation options. The review has focused on economic cost-benefit analysis studies, which adopt a societal perspective, and include the valuation of non-market effects, such as environmental, social and health benefits[2]. The results are expressed as the Net Present Value (NPV) or the benefit-to-cost ratio (BCR). An option that generates a BCR>1 has a net positive economic effect. The analysis has identified 80 studies of relevance (for the 24 adaptation priorities in the NDC), of which around half include Rwanda specific studies. This literature is summarised in Appendix 2.

In general, the review of evidence finds positive economic benefits for the options in the NDC, or to put another way, **investing in the NDC adaptation priorities should lead to positive overall economic benefits**. The results are summarised by intervention in Figure 2. As shown in the figure, BCRs are mostly above 2:1 (i.e., a dollar invested generates double this in terms of economic benefits), and often above 5:1, which is high.

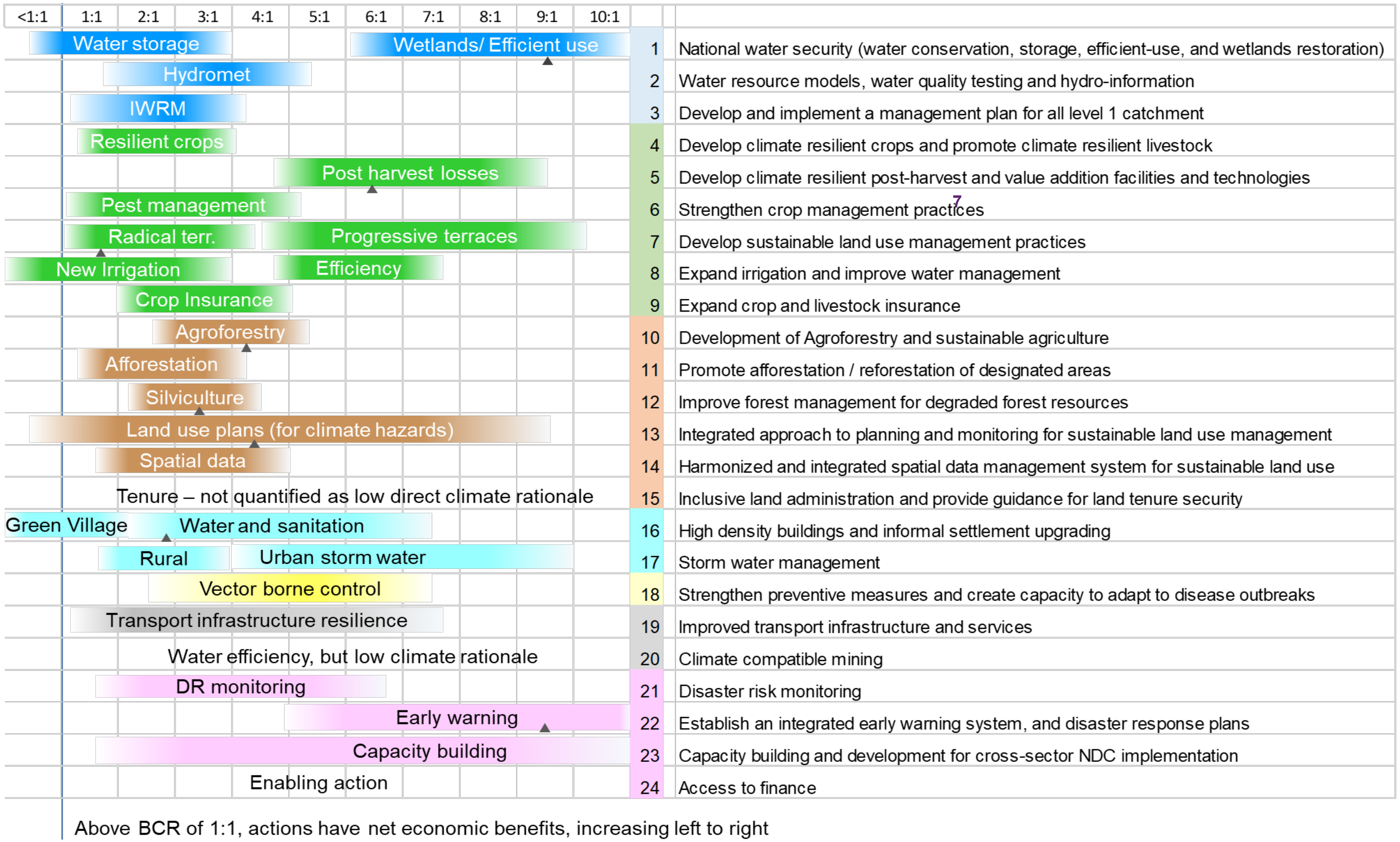
The highest returns are generally found for measures that are low or no-regret in nature, i.e., that address the existing adaptation deficit in Rwanda. Adaptation can deliver high economic benefits immediately by reducing current

[2] Note that this is different to a financial appraisal, which looks at a project from the perspective of a private investor, and excludes non-market benefits.

weather and climate-related losses, and these options also (generally) enhance resilience to future climate change. The highest BCRs are associated with actions that are likely to address the deficit quickly, such as reducing post-harvest losses and early warning systems. Adaptation can also deliver high benefits when it delivers efficiency savings, such as from water efficiency measures (improved efficiency or reduced losses). While climate smart agriculture (including soil and water conservation) do have positive benefit to cost ratios, the ratios are often modest due to the time taken to deliver benefits (and thus discounting of benefits as compared to up-front costs).

However, as well as options that deliver adaptation, there is a need for capacity building. Capacity building has positive BCRs, as it improves the efficiency and effectiveness of adaptation delivery (Watkiss and Cimato, 2016[ix]). It is noted that the NDC has a lot of actions centred on plans (e.g., integrated water resource management, land use planning). These align to sector development plans. These can generate positive BCRs, but this is dependent on the subsequent use of this information in better decisions. The benefits of these actions are therefore much less certain, and arise through more indirect pathways, than more direct actions. One action there merits some discussion is irrigation, because it is such a large part of the NDC adaptation budget. There are high benefit to cost ratios from improving existing irrigation, e.g., reducing losses and rehabilitation. However, the results for new irrigation are more mixed. The BCRs are often negative, because of the high capital costs. Further, there can be issues with new building large amounts of new irrigation under a changing climate, because of the risk of changes in water supply or demand (thus there is a risk of maladaptation). This is an area that warrants further consideration.

Figure 2. Adaptation Benefit-to-Cost Ratios (from the literature) for Rwanda NDC adaptation options



See appendix 1 for intervention descriptions. The figure shows indicative benefit-to-cost ratios and ranges, and where available (triangle) average values. It is based on the evidence review. It is stressed that BCRs of adaptation measures are highly site- and context-specific and there is uncertainty over climate change. Actual BCRs will depend on these factors.

Assessing how the options in Rwanda's NDC align to a green recovery

Following the COVID-19 pandemic, the public finances of many countries have been badly affected. As governments aim to recover post-COVID, many will be looking for measures to reduce debt and raise revenues. To help this, many countries are now moving to a recovery phase. This recovery phase can include stimulus packages to address the economic and financial impact of the crisis, either from domestic budgets or from external finance.

Governments are thinking carefully about how to provide such support to ensure that recovery packages are as effective as possible. This includes consideration of different options that governments can introduce. As an example, the Rwandan government is keen to boost local firms and employment to increase money flowing in the economy.

There have been a number of papers and commentaries that have called for these recovery packages to be built around a green recovery (e.g., Bhattacharya and Rydge, 2020[x]: Hammer and. Hallegatte, 2020;[xi] Hepburn et al, 2020[xii]; IMF, 2020[xiii]). These argue that is should be possible to introduce low carbon and climate resilience measures and reforms as part of planned stimulus or recovery packages, to create jobs and economic growth. The incentives for doing so are now much stronger due to the lower costs of renewable and higher fossil fuel prices, and a greater focus on the perception of risks and the need for improved resilience, including for climate change.

These studies also identify characteristics that define a 'good' recovery, which include:

- Measures can be introduced quickly;
- They are labour-intensive in the short-run;
- They have high economic multipliers in the short-term that extend in the long-run.

Some studies also highlight measures might be more positive if they focus on domestic production or limiting imports, and the opportunity for positive gender or distributional benefits to be included in the choice.

The same papers highlight that many low carbon and climate adaptation measures perform well against these various criteria. There is evidence that backs-up these findings, from the recovery packages introduced after the 2008-09 global financial crisis (Levy et al., 2020[xiv]). Well-targeted stimulus measures in low carbon and green infrastructure generated more jobs than traditional alternatives and delivered high fiscal multipliers. Hepburn et al. (2020) identified promising interventions for adaptation and resilience that included:

- Disaster preparedness,

- Natural capital investment (nature-based solutions for ecosystem resilience and regeneration including restoration of carbon-rich habitats and climate-friendly agriculture).
- For low-income countries, rural support scheme spending, particularly associated with sustainable agriculture, ecosystem regeneration, or accelerating clean energy installations.

For example, disaster preparedness has high real-world impact and the short- and long-run economic multiplier, while nature-based solutions have high potential for jobs. This study has reviewed the adaptation options in Rwanda's NDC to assess their alignment with these good recovery characteristics. This is shown in the Figure 3 below.

The analysis finds that some, but not all, of the NDC adaptation options align to a good green recovery, and can result in jobs creation, income growth, economic development and have co-benefits. These include projects that are more direct interventions (project based), rather than projects.

The impact on the public finances/debt will very much depend on the financing approach, whether this is met through domestic contribution or from external finance (e.g., from international finance institutions, development partners), and for the latter, whether this is in the form of grants or loans. Some measures are likely to be more suitable for private sector financing or blended finance (where public finance is used to de-risk private finance), such as insurance.

NDC Adaptation Measures	Speed of project implement-ation	Are benefits generated quickly?	Quality job creation / high employment intensity	Economic mutliplier	Long-term growth potential	Skills develop-ment	Benefits domestic production	Positive environmental impacts	Ability to attract Int. climate finance
Water									
National water security, water conservation, storage, efficient use & wetlands restoration	Medium	Fast	High	High	High	Medium	Medium	High	High
Water resource models, water quality testing and hydro-related information	Fast	Slow	Low	Medium	Medium	High	Neutral	High	High
Develop and implement a management plan for all level 1 catchment	Medium	Slow	Medium	Medium	High	High	Neutral	High	Medium
Agriculture									
Develop climate resilient crops and promote climate resilient livestock	Medium	Medium	Medium	Medium	High	High	High	Medium	Medium
Develop climate resilient post-harvest and value addition facilities and technologies	Fast	Medium	High	High	High	High	High	High	Medium
Strengthen crop management practices	Fast	Medium	Low	Medium	Medium	High	Medium	High	Medium
Develop sustainable land use management practices (soil erosion control)	Fast	Medium	High	Medium	Medium	Low	High	High	High
Expand irrigation and improve water management	Medium	Medium	High	High	High	Medium	High	Low	Low - Med
Expand crop and livestock insurance	Fast	Fast	Low	High	Medium	Medium	High	Medium	Medium
Land and Forestry									
Development of Agroforestry and sustainable agriculture	Fast	Medium	High	Medium	High	Medium	High	High	High
Promote afforestation / reforestation of designated areas	Fast	Slow	High	Low	Medium	Medium	Medium	High	High
Improve forest management for degraded forest resources	Fast	Medium	High	Medium	Medium	Medium	Medium	High	High
Integrated approach to planning and monitoring for sustainable land use management	Fast	Slow	Low	Medium	Medium	High	Neutral	High	Medium
Harmonized and integrated spatial data management system for sustainable land use	Medium	Slow	Low	Medium	Medium	High	Neutral	High	Medium
Inclusive land administration that regulate and provide guidance for land tenure security	Medium	Slow	Low	Medium	Medium	Medium	Medium	High	Low - Med
Human Settlements									
High density buildings and informal settlement upgrading	Medium	Medium	High	High	High	Medium	Medium	High	Medium
Storm water management	Medium	Fast	High	High	High	Medium	High	High	High
Health									
Strengthen preventive measures and create capacity to adapt to disease outbreaks	Fast	Fast	Medium	High	High	High	High	High	High
Transport									
Improved transport infrastructure and services	Medium	Medium	High	High	High	Medium	High	Medium	Medium
Mining									
Climate compatible mining	Medium	Medium	High	Medium	Medium	High	High	Medium	Low - Med
Cross sectional									
Disaster risk monitoring	Fast	Medium	Low	High	High	High	High	High	High
Establish an integrated early warning system, and disaster response plans	Fast	Fast	Low	High	High	High	High	High	High
Capacity building and development for cross-sector NDC implementation	Medium	Medium	Low	High	High	High	Neutral	High	High
Access to finance (Resource Mobilisation)	Medium	Medium	Medium	High	High	High	Neutral	High	High

Figure 3. Analysis of the Rwanda NDC adaptation options for green recovery potential.

Discussion and recommendations

Rwanda has an ambitious updated Nationally Determined Contribution which sets out a major planned investment in adaptation of USD 5.4 billion by 2030. This includes 24 priority interventions, which span a range of climate sensitive sectors.

However, a problem is that the COVID-19 pandemic has affected the public finances, and domestic budget out-turns are lower than the sector plans anticipated. This in turn, affects the planned unconditional finance set out in the NDC. At the same time, the level of international adaptation finance proposed in the NDC is unlikely to be realisable. This study estimates that there will therefore be a large financing gap for NDC adaptation measures for Rwanda.

Against this background, there is a question of which adaptation measures in the NDC to prioritise. This study has considered two key factors that could help such an analysis. These factors could be used to help prioritise adaptation, or at least to provide a rationale for the sequencing of which options could be implemented first.

First, the study has reviewed the literature on the indicative benefit to cost ratios for the 24 adaptation interventions in the NDC. The analysis finds that nearly all the NDC adaptation options have positive benefit to cost ratios, although there are some interventions which have higher and more robust BCRs and that might offer greatest value for money.

Second, the study has reviewed the literature on which adaptation investments may have green recovery benefits, in terms of stimulating the domestic economy, jobs, etc. and could provide benefits as part of a post COVID recovery plan. Again, many (but not all) of the options in the NDC have potential positive benefits for the public finances as green recovery measures, though there are some measures that will generate higher numbers of jobs and economic multipliers.

There are some options that score positively against both of these criteria (economic benefits and green recovery benefits). These include options which address current climate impacts, so called low- and no-regret measures, as these provide immediate economic benefits, especially when this involves more direct investment (action on the ground) as this creates jobs and local multipliers. Such actions include climate smart agriculture (soil and water conservation, livestock resilience) or addressing post-harvest losses and value chains. However, in some cases there are trade-offs. For example, if Government priorities are towards jobs creation, then planning actions do not score so highly, even though these latter measures could lead to high economic costs if not taken forward (and thus have positive BCRs).

For this reason, we do not list priority options here, but highlight that the information above can be used to consider the attractiveness of options based on Government priorities.

Appendix 1: Adaptation measures, costs and conditional/unconditional status in Rwanda updated NDC

Source NDC (RoR, 2020). Note discussion with the NDC team has identified that all 'conditional' adaptation actions in the NDC are actually co-financed, with the allocated splits for all such actions being 40% domestic funding (unconditional) and 60% international (conditional).

			COST USD	Uncond.	Cond.
Water	1	A national water security through water conservation practices, wetlands restoration, water storage and efficient water use	164,308,682		X
	2	Water resource models, water quality testing and hydro-related information	10,000,000	X	
	3	Develop and implement a management plan for all level 1 catchment	360,000,000		X
Agriculture	4	Develop climate resilient crops and promote climate resilient livestock	24,058,040		X
	5	Develop climate resilient post-harvest and value addition facilities and technologies	200,000,000		X
	6	Strengthen crop management practices	3,000,000	X	
	7	Develop sustainable land use management practices	346,173,836		X
	8	Expand irrigation and improve water management	2,261,484,491		X
	9	Expand crop and livestock insurance	109,678,958		X
Land and Forestry	10	Development of Agroforestry and sustainable agriculture	92,066,812		X
	11	Promote afforestation / reforestation of designated areas	16,835,134	X	
	12	Improve forest management for degraded forest resources	8,134,490		X
	13	Integrated planning & monitoring for sustainable land use management	60,000,000		X
	14	Harmonized & integrated spatial data management system for sustainable land use	20,000,000		X
	15	Inclusive land administration - regulate & provide guidance for land tenure security	5,000,000	X	
Human Settlement	16	High density buildings and informal settlement upgrading	400,000,000		X
	17	Storm water management	400,000,000		X
Health	18	Strengthen preventive measures and create capacity to adapt to disease outbreaks	185,000,000		X
Transport	19	Improved transport infrastructure and services	600,000,000	X	X
Mining	20	Climate compatible mining	59,290,672	X	
Cross Sectional	21	Disaster risk monitoring	10,000,000		X
	22	Establish an integrated early warning system, and disaster response plans	20,000,000		X
	23	Capacity building and development for cross-sector NDC implementation	6,000,000		X
	24	Access to finance	3,000,000	X	
TOTAL			5,364,031,115		

Appendix 2: Benefit-to-cost studies

This table summarises the literature review findings for each of the 24 adaptation priorities in the NDC. Where possible, Rwandan specific studies are reported.

NDC Adaptation Option	Economic evidence
A national water security through water conservation practices, wetlands restoration, water storage and efficient water use	Efficient water use. International, very high positive economic BCR, often above 10[xv],[xvi],
	Water storage. Some international studies report water storage option BCRs are below 1 as an adaptation option[xvii], [xviii]Internationally, there are some studies showing good BCRs for farm storage[xix]
	Wetland restoration positive economic BCR in International literature[xx]. Some Rwandan specific analysis, CBA for Kigali wetland found net positive present values[xxi] with BCRs of 2:1, 6:1 and 19:1 for different options, and overall 10:1.
Water resource models, water quality testing and hydro-related information	Positive benefit from value of information (downstream improved decisions) International evidence estimated the BCR for improving meteorological and hydrological services at 4:1 to 36:1, largely driven by EWS benefits[xxii]. Upstream and foundational focus of this option likely to be lower BCR but still positive.
Develop and implement a management plan for all level 1 catchment	Integrated water resources management positive BCR internationally in high capacity countries. However, requires high levels of institutional strengthening and capacity building, which challenging, thus very difficult in practice. Institutional strengthening, capacity building including technical assistance to support implementation of climate adaptation options and investments in climate sensitive sector e.g., water (increases efficiency of implementation)[xxiii]. Some regional studies estimate IWRM could have benefits, with BCR of 2:1, based on a 1% improvement in efficiency[xxiv]. But often long results chains between upstream work and the downstream benefits. Furthermore, needs to include future climate change projections in IWRM plans important, but adds to complexity. Some information from Rwanda Water for Growth programme, but no economic analysois..
Develop climate resilient crops and promote climate resilient livestock	General international literature with positive BCR, but sometimes trade-off involved (resilience vs. productivity). International studies report reasonable BCRs, especially for general R&D and development[xxv]. Shongwe et al. (2014[xxvi]) in Swaziland found switching to drought resistant crops had a high NPV. Wamatsembe et al. (2017[xxvii]) in Uganda found drought tolerant hybrid maize had lower returns and a value/cost ratio of 1.5. Studies in South Africa also found BCRs of 1.9:1 for drought resilient varieties[xxviii]. The performance of new varieties is also highly site, location and context specific. There is some evidence on high BCRs in SSAfrica from drought resilience measures for livestock[xxix] and likely high BCRs for climate resilient grass for feed from a Rwanda NAMA application and analysis. The NDC option is focused on crossbreeds,
Develop climate resilient post-harvest and value addition facilities and technologies	Good literature on positive BCR. International studies report high BCRs, e.g., 6:1[xxx]. In Rwanda, previous projects generated high return. IFAD Climate-Resilient Post-harvest and Agribusiness Support Project led to a 20% reduction in the level of post-harvest losses over the baseline[xxxi] and USAID-funded Post-Harvest Handling and Storage (PHHS) Project reports cooperatives supported with the training and grants for appropriate post-harvest technology were able to reduce losses from an estimated 35-40% to less than 5%[xxxii].But note value addition is not really adaptation.
Strengthen crop management practices	International evidence on good economic benefits of integrated pest management (IPM), e.g. 15-40%, rate of return[xxxiii],, though modest BCR for push–pull technology (PPT) with BCR 1.5[xxxiv]. One Acre Fund (2019) conducted field trials (2019) and recorded relatively low incidences in fall in armyworm.
Develop sustainable land use management practices	General international literature with positive BCR for sustainable soil management with a median BCR of approximately 2:1, but range from 1:1 to 6:1 [xxxv] from IFAD's Adaptation for Smallholder Agriculture Programme estimated average BCR of 1.8:1 (median) – though this study reports a value of 1.01:1 for Rwanda programme. However, often include important opportunity, transaction and implementation costs[xxxvi], e.g. labour costs. Radical terraces. Rwanda specific radical terraces[xxxvii] reports IRRs range from 11% to 22% depending on location, though 1st year only. Rwanda's Land Husbandry, Water Harvesting, and Hillside Irrigation project assumed 30% greater productivity in traditional annual crops and 50% greater productivity in perennial crops[xxxviii]. Progressive terraces. An economic cost-benefit analysis was undertaken (ex ante) for the GCF Gicumbi project (FONERWA, 2017) and estimated grass strips had a BCR of 13:1 at a 10% discount rate, though tree belts a BCR of 2:1 due to establishment time. Rutekuba et al. (2021[xxxix]), looked at the relative performance of traditional slope farming, bench terraces and progressive terraces in terms of runoff, soil losses, and topsoil fertility in two contrasting agro-ecological zones, the Eastern Plateau (Murehe) and Buberuka Highlands (Tangata). They found that both terracing techniques effectively reduced runoff and soil loss. Bench terrace proved to be the most effective (especially at Tangata). However, while bench terraces more effective at soil erosion but much higher cost than progressive.

	Ujeneza (2018[xl]) looked at the status and benefits of constructing (rehabilitating) bench terraces for Hinga Weze project which conducted the study to acquire relevant information to support the construction of 4,000 hectares in 6 districts of Rwanda. It was found that constructing a new terrace would cost $2,277 per hectare against $1,776 per hectare for the terrace rehabilitation. Over a 10-year evaluation, newer terraces would generate an additional benefit estimated at $140 per farmer or $738 per hectare. A CBA of the suggested strategy indicated that the activity was worth the investment. When the technical support and a grant to increase the assets were combined ($528,719 for the 1,300 hectares), the farmers registered net benefits of $1,575,918 for the 1,300 hectares of rehabilitated terraces. The BCR yielded is positive at 3:1 with a 23% IRR. However, the construction of new terraces was projected to cost $528,719 while registering net benefits of $839,091 on the 1,300 hectares of new terraces. This means $1.59 is returned in benefits for each $1 invested on new terraces, at IRR of 16%. Guthiga (2020)[xli] study for FAO and UNDP assessed CBA for agroforestry practices and soil and water conservation for climate change adaptation in Kenya. EIRR (32%) found were greater than FIRR (30%) for terracing.
Expand irrigation and improve water management	General international literature with positive BCR but sometimes environmental trade-off and competition issues (water). Water for Growth. Modelling studies indicate high benefit to cost ratios for irrigation as an adaptation option, with academic literature projecting wide uptake (globally) under future climate change[xlii]. However, some literature is not as positive, e.g. finding[xliii] the BCR of groundwater irrigation was low (1.6:1) although found this rose to 2:1 under climate change. Studies also find impacts on irrigation performance/return from future climate change[xliv], hence need to ensure design is climate smart. BCRs depend on the type of irrigation (gravity, surface, drip, etc). Some climate studies report higher BCRs for drip over sprinkler[xlv], though in these cases, alternative climate smart agriculture options have even higher BCRs. Further, some studies highlight the risks of irrigation lock-in and mal-adaptation under a changing climate, especially in drought prone areas where there is likely to be multi-sectoral competition for water. There are also potential trade-off with mitigation objectives if the source of energy for pumped irrigation is diesel, due to GHG emission dis-benefits. The ECA study [xlvi] looked at irrigation and reports drip and sprinkle irrigation had positive BCRs (in Asia and Asia), highly dependent on baseline assumptions and risks, but 2:1 to more than 5:1. The risk to resilience study (2009[xlvii]) estimated the BCRs for irrigation at approximately 2:1 (groundwater) at a 10% discount rate. Mohamed (2013)[xlviii] found for example that conversion from flood to drip irrigation (Tadla region in Morocco) could improve farm-level net returns and public net benefits. In addition, NPV of drip irrigation for small-scale farmers could be improved if the technology was extended to include food crops rather than limiting it to cash crops. Lunduka (2013[xlix]) (Lake Chilwa catchment in Malawi) found win-win for the local farming and fishing community if soil and water conservation techniques complemented irrigation and rain-fed agriculture. Analysis of solar irrigation for tea for the Gicumbi project did not find positive BCRs. This was because tea is produced all year round, and thus the improved productivity from irrigation is largely constrained to the dry season spell. It was difficult to justify the large investment in irrigation for this period alone. Cost-Benefit Analysis of USAID Rwanda's Hinga Weze Activities[l] that is looking at terracing, small scale irrigation and good agricultural practice Byiringo et al. (2020[li]) report on how operation & maintenance costs is paramount to ensuring the sustainability of irrigation investments. They indicate that large scale irrigation canals involve a high economic cost that can be recovered in 25 years or more. With the data on constructed irrigation canals, the authors estimate the approximate cost per irrigated hectare to be $9,250. An economic evaluation of the O&M intervention conducted found a net benefit of $125 per farmer per hectare. The net benefits appear to be nine times more than the total costs of the O&M intervention per farmer. Cost-benefit analysis of JLIFAD on Kayonza Irrigation and Integrated Watershed Management project[lii] found negative net present value and a financial internal rate of return of 9.2% when 17% discount rate (same as lending rates of commercial rates) was used. These results were for a hillside farm. Economic cost and benefit results found a EIRR of 15.06% when using a 12% discount rate. i.e EIRR>FIRR. Thus, the project was deemed profitable from an economic standpoint. The case study on impact of participatory irrigation management (2014)[liii] assessed all aspects of irrigation management at all levels for Rwamagana rice project for three cooperatives. The BCR calculated were 1.48, 1.33 and 1.38. It was found that the BCR is positive and over one. Mangisoni et al. (2021)[liv] underook a cost benefit analysis of stimulating farmer uptake of irrigation in Malawi. BCRs results were 0.6 being the lowest for maize irrigated land and 6.2 being the highest for Tomato. Most commodities resulted in a BCR value between 1 and 2.
Expand crop and livestock insurance	Insurance is often reported as a low regret option[lv], but the evidence varies. International studies[lvi] report high BCRs (10:1) in Malaysia for flood insurance but

	modest BCRs for insurance in India (2:1) and noted there is often a need for subsidies to make insurance affordable. Insurance often performs modestly when compared to other options, for example in India, insurance had one of the lowest BCRs[lvii]. BCR strongly influenced by the frequency of events and premiums. However, it is a complementary tool to adaptation as it spreads the financial risks of probabilistic extreme events. It should not be seen as an answer to address slow onset change (trends) - or frequent events - because premiums become unaffordable. As climate change increases extremes, increasing risks will be factored into premiums, which will lead to differential pricing and make it harder to obtain insurance (at low cost) for more vulnerable individuals and places. While many proponents of micro-insurance, notably index based schemes, there is varying evidence on the actual BCRs. There are some moderately positive BCRs for index-based insurance (e.g. drought in India, BCR2:1[lviii]) though interestingly this found the BCR dropped under climate change (to 1.2:1) because of changing risk patterns. Micro-insurance products are quite high cost (as require higher product design and marketing costs) and there are issues of affordability, which means take up is too low at market prices and subsidies are required. Some also argue it can create perverse incentives, i.e. reducing risk diversification. This is leading to more interest in index based insurance for meso- and macro-level insurance. The empirical evidence shows low uptake by farmers due to a range of barriers mainly financial (high cost), behavioural (personal perceived risk; low trust in providers), and technical (basis risk).
Development of Agroforestry and sustainable agriculture	International literature with positive BCR plus Rwanda case studies for agroforestry., though the EIRR>FIRR An economic cost-benefit analysis was undertaken (ex ante) for agroforestry as part of the GCF Gicumbi project preparation (FONERWA, 2017[lix]). This quantified the stream of benefits both on-farm and off-farm including increased agricultural yields due to reductions in soil erosion, reduced sediment loading in waterways, and carbon sequestration for the additional above and below ground biomass. Agricultural yield was estimated to increase 20% by the fifth year of implementing agroforestry practices. Initially, disruptions to the soils and crops were assumed to cause a loss in yield by an estimated 30%, but then beginning with the harvest the following year, yield was assumed to increase as soils are stabilized. In addition, it was estimated that sediment loading in the waterways will be reduced by 1.13 tons of soil per hectare per year, avoiding damage costs of $14 per ton of soil. Increasing the above and below ground biomass in agroforestry systems was estimated to sequester 0.5 tC/ha/year. This was valued using a social cost of carbon. The benefit to cost ratios depends on the discount rate and also the SCC value. At a 10% discount rate, the BCR was 4.2. At a 5% DR, it was 6.3 and at 13% (official GoR rate) it was 3.4. The financial rate of return was lower, because of the non-market and downstream benefits, although a 17% Internal Rate of Return was calculated.
Promote afforestation / reforestation of designated areas	International literature with positive BCR plus Rwanda case studies from Gicumbi. An economic cost-benefit analysis was undertaken (ex ante) for forestry as part of the GCF Gicumbi project preparation (FONERWA, 2017). This looked at a number of different interventions. For improved farmer woodlots, a stream of benefits, including revenue from fodder, timber and poles as well as stabilized slopes and increased carbon sequestration was quantified. The benefit to cost ratios depend on the discount rate and also the SCC value. At a 10% discount rate, the BCR was 3.2. At a 5% DR, it was 4.6 and at 13% (official GoR rate) it was 2.6. For protective forests, the same benefit streams were considered. At a 10% discount rate, the BCR was 3.0. At a 5% DR, it was 4.3 and at 13% (official GoR rate) it was 2.5. The benefit to cost ratios depend on the discount rate and also the SCC value. These options has quite low financial rates of return, because of establishment times. The FIRR was estimated at 7 to 8%. However, analysis of fast growing species grown more commercially with improved varieties and silviculture found higher IRR, with 16% for Eucalyptus, and 12% for Pine.
Improve forest management for degraded forest resources	Silviculture. International literature with positive BCR plus Rwanda case studies from Gicumbi. For improved farmer woodlots, a stream of benefits, including revenue from fodder, timber and poles as well as stabilized slopes and increased carbon sequestration was quantified. The benefit to cost ratios depend on the discount rate and also the SCC value. At a 10% discount rate, the BCR was 3.2. At a 5% DR, it was 4.6 and at 13% (official GoR rate) it was 2.6.
Integrated approach to planning and monitoring for sustainable land use management	A national land use development master plan (NLUDMP) is currently being developed. This adaptation intervention aims to introduce a number of additional measures to support climate-sensitive integrated land use and spatial planning. International study of nine project that undertook CBA for flood zoning policies found BCRs from 0.6 to 20:1, with an average of 4:1[lx].
Harmonized and integrated spatial data management	This intervention is therefore to strengthen the quality and coverage of data on exposure to climate vulnerability of households and infrastructure in high-risk areas, and to develop a geospatial information framework integrated with environmental and socio-economic statistics.

system for sustainable land use	
Inclusive land administration that regulate and provide guidance for land tenure security	Land tenure is important in incentivising sustainable land management, this intervention aims to update the land register and make land administration more effective. However, there is a question mark over whether this is really adaptation, given the lack of a direct climate rationale.
High density buildings and informal settlement upgrading	This intervention is to reduce the percentage of urban population living in informal settlements; to increase the percentage of rural population living integrated green settlements; to increase open and green space for public use; and to increase access to water and sanitation services. There is some information on the economic benefits of moving people out of informal settlements, because of the lower climate risks they face (informal building are much more at risk). High density building can be detrimental for heat, as they increase the urban heat island effect
	There is a larger literature on Water, sanitation and hygiene (WASH). A review of 7 CBA studies (Hunt, 2011)[lxi] reports a wide range depending on option and context (OECD vs LDC). BC ratios were positive, with values of 2-3:1 in most studies, but with one study (Hutton et al., 2007[lxii]) reporting BCRs of 5 – 46:1 in developing regions and 5 to 12:1 for the LDC context. A review of the economics of adaptation for WASH and WRM (water resource management) summarises studies but does no report BCRs (ODI, 2014[lxiii]).
	In terms of new clustered settlements, an economic cost-benefit analysis was undertaken (ex ante) for the green village concept as part of the GCF Gicumbi project preparation (FONERWA, 2017). This included the avoided damage and loss from new locations, the benefits of water supply and reduced indoor air pollution (health, productivity), reduced carbon emissions (embodied energy in building and cooking) and livelihood benefits. However, these settlements are quite capital intensive, and the benefit to cost ratio was estimated to be less than 1 (0.65 at a 10% DR).
	There is also recent economic analysis of the benefits of green space in Kigali. This was found to have high economic benefits, though the adaptation benefits are a small proportion (most benefits come from the recreational and well-being value)[lxiv]. However, can have large opportunity costs associated with land. If these are minimised (e.g. wetland areas), then benefits are very high. If in more built up areas, then the economic case is not as strong, thus location and siting is important.
Storm water management	Flood protection. There is also a large international literature on the BCRs of investments for flood protection, including to climate change. As well as the studies above (Shreve and Kelman, 2014; Mechler, 2016) the ECONADAPT study (2015)[lxv] compiled a database of DRM investments for floods in Europe containing 110 observations on investments/projects from 32 studies and databases, covering 16 European countries, and including ex ante and ex post studies. This found that investments in flood risk protection in Europe had, on average, a Benefit-to-Cost Ratio (BCR) of 6:1, whilst the median BCR was 3:1. DRM investments that enhanced preparedness to disasters had the highest economic returns, while investment that mitigate the damage of floods following the event also show high BCRs. Preparedness had the highest mean BCR (11:1), followed by ex post flood damage mitigation (BCR = 8.5:1), "hard" flood control such as dikes (4.1). In all cases, BCR results are very- site- and context specific and vary further, depending on whether intangible as well as tangible benefits are included, and whether indirect effects are included. They also depend on the objectives used for setting flood protection levels, i.e. whether based on the economic optimal level or to meet acceptable risk levels (i.e. defined return levels for standards of protection). When considering future climate change, a number of studies show that BCRs are similar or larger than those for the present day for coastal and river flooding. There are sectoral models that find high BCRs for Africa for coastal and river flood protection. The World Bank Urban Development Project for the six secondary cities in Rwanda. This includes investments in urban infrastructure, which covers a number of types of infrastructure, but include roads, drainage, solid waste management, and sanitation. The BCRs in appraisal range 2:1 up to 10:1 overall (different BCRs for different cities)[lxvi]These included consideration of better drainage and reduced flooding, however, flood related benefits are low – and do not drive the positive BCRs – these are generated by increased property prices and travel time savings. An economic cost-benefit analysis was undertaken (ex ante) for stormwater management as part of the GCF Gicumbi project preparation (FONERWA, 2017[lxvii]). The benefit to cost ratios depend on the discount rate. At a 10% discount rate, the BCR was 1.2. At a 5% DR, it was 1.75 and at 13% (official GoR rate) it was 1.0.
Strengthen preventive measures and create capacity to adapt to disease outbreaks	Evidence that existing health protection measures are extremely effective in dealing with anticipated increases under climate change [lxviii] for food borne (including diarrheal illness), water borne and vector borne (malarial) disease. Studies also highlight low regret option of increases in monitoring and surveillance, which especially important for climate change (and changes in prevalence and incidence of disease). High distributional benefits (pro-poor).

	In 2011, a cost–benefit analysis was conducted (CHAI, 2011[lxix]) that demonstrated that a sustained control programme in Rwanda (2011-2015) would avert an estimated 38 million cases, saving $267 million for the country's health system (compared to an estimated cost of the control program of $265 million); while households could avert about $547 million in direct and indirect costs—equivalent to about 7% of household income. USAID (2015[lxx]) report that the dramatic decline in child mortality that occurred in Rwanda from 1996–2000 to 2006–2010 coincided with a period of a rapid increase in malaria control interventions. Child mortality fell 61% during the evaluation period, and the prevalence of severe anaemia in children aged 6 to 23 months declined by 71%. These reductions in childhood morbidity and mortality were seen concurrently SEI (2009) found that health intervention (tackling malaria under climate change) will have high economic costs through increased health care and lost productivity, estimated at close to USD 100 million/year[lxxi].
Improved transport infrastructure and services	This intervention is to develop environmental and engineering guidelines for climate resilient road infrastructure and reduce the length of roads vulnerable to flood and landslides. It also intends to increase the length of paved national roads, rehabilitate feeder roads, and incentivise the use of public transport. Making new infrastructure climate resilient**.** Infrastructure often has a long life-time, and new infrastructure built over the next few years may operate under a very different climate to today. If these future risks are not considered, climate change will cause asset damage or failure, and affect operating costs and/or revenues. There is an opportunity to design infrastructure to be climate resilient when it is built. Recent analysis by the World Bank has identified that on average, building climate resilience into new infrastructure involves low marginal cost, and has a benefit to cost ratio of 4:1 (Hallegette et al., 2019[lxxii]). This analysis was further refined in the Global Commission on Adaptation (2019[lxxiii]) report, which also reports BCRs of 4:1 (with a range of 2:1 to 10:1). However, both these studies are highly aggregated and stylised, and they are not based on specific ex ante or ex post review of projects. Actual analysis of the costs and benefits of making specific infrastructure climate-resilient shows these are extremely site- and context-specific (e.g. ADB, 2014[lxxiv]; ADB, 2021[lxxv]), and BCRs vary with the objectives set for adaptation as well as the adaptation options considered. They also vary with climate change and scenario projections, how uncertainty is included (with decision making under uncertainty), as well as discount rates. There is therefore a very large range of potential BCRs, including the potential for economic maladaptation (BCRs <1). Including resilience is particularly important for new critical infrastructure[lxxvi], because of the risks of cascading risks (or to put another way, the benefit to cost ratios of critical infrastructure resilience are much higher, because of the additional benefit of reducing cascading impacts). However, in practice climate proofing infrastructure is complicated because of uncertainty.
Climate compatible mining	Underlying mining including artisanal mining has high environmental impact, and so economically, low BCRs[lxxvii]. While measures to improve environmental benefits are positive, these do not have a strong climate rationale. Check FCDO business case
Disaster risk monitoring	Disaster risk reduction and management. There is a robust international literature on the economic benefits of disaster risk reduction and management. General reviews find high BCRs, e.g. such as studies by World Bank (2012)[lxxviii,]and in systematic review by Mechler (2016[lxxix]): the latter (based ex ante and ex post) found average BCRs of 5:1 for flood related risks, and 4:1 for windstorms, but none of these were for Africa. Shreve and Kelman (2014[lxxx])undertook a review of the cost-benefit ratios for disaster risk reduction, which highlighted the potentially high benefits, but also the challenges and limitations of such analysis. It found an extremely wide range of BCRs for DRR, with maximum values from 3: 1 to 60:1 (with one outlier above this). However, this only include one study in Africa, with the study of Venton et al. (2010) for drought in Malawi (maximum BCR 24:1) and one outlier with a very high BCR in Sudan. Cabot Venton et al. (2013) [lxxxi] reviewed benefit cost ratios for 23 field tested community-based adaptation DRR pilots in terms of humanitarian aid avoided from social protection and early intervention, worldwide, finding BCRs of 1.8-2.7:1. Incorporating the value of avoided losses increases these BCR estimates to 2.3-3.3:1. This includes interventions in Africa for Kenya and Sudan (not quantified), for Malawi for drought with crop diversification, soil and water conservation, and drought-resilient livestock (BCRs of 24:1) and Gambia for drought ex post finding BCRs of seeds and fertilizer (3.3); fire belts (38.7); and tree-planting (2.6), and Kenya for drought of 1.5 – 3:1.
Establish an integrated early warning system, and disaster response plans	Weather and climate information services, including early warning systems. This includes a range of services including hourly, daily and short-term weather forecasts (e.g. up to 10 days) through to climate services (e.g. seasonal forecasts). There are a number of international reviews of the benefit to cost ratios of these services that show high BCRs (Clements et al. (2013)[lxxxii], WMO (2015[lxxxiii]), ECONADAPT (2017[lxxxiv]) which generally report average values around 10:1 and a range from 2:1 up to 36:1. Economic benefits arise from the use of services to improve decisions (the value of information). These provide immediate benefits, and these usually increase with climate change, though there is an increasing focus on extending W&CIS to adaptation services. Values

	vary with site and location, and benefits depend critically on the delivery of climate information along the value chain (forecast accuracy, communication and reach, uptake an use, effectiveness). While historically the focus has been on agriculture, W&CIS can provide important benefits for multiple sectors, e.g. energy, water, tourism, health and others. Early warning systems can include short-term (hourly to weekly) forecasts of major extreme events, such as floods, as well as longer term seasonal early warning, e.g. for droughts. These are generally reported as having high BCRs, e.g. with the GCA (2019) reporting a value of 9:1. Law (2012[lxxxv]), cited in WMO (2015) estimated BCRs of 3:1 to 6:1 for the Benefits of Ethiopia's Livelihoods, Early Assessment and Protection (LEAP) drought early warning and response system. Watkiss et al., (2021) undertook a CBA for marine early warning information on Lake Victoria, and found a BCR of 16:1, driven by the combination of avoided deaths and fuel savings. Benefits of EWS are projected to increase under future climate change, because of increasing events, although costs and residual damage will increase as well. These EWS have focused on flood and windstorm related hazards. In the OECD, there is a greater focus on heat alert warnings, which have been found to have high BCRs (greater than 10:1) (Ebi et al., 2004[lxxxvi]: Hunt et al., 2016[lxxxvii]: Chiabai et al., 2018 [lxxxviii]) and there may be some potential for similar system in major African cities. Assessment of food security early warning systems for East and Southern Africa[lxxxix] indicated that strong evidence has emerged on the benefits of investing in Early Warning Systems (EWS). In Ethiopia, investing in a drought EWS, which would reduce livelihood losses and dependence on assistance, has a BCR of between 3:1 and 6:1. The study found that the BCR of improving national hydrometeorological services in developing countries range from 4:1 to 36:1. In terms of cost-benefit analysis, disaster risk reduction has been estimated to amount in savings of $7 (sometimes $4-7) for every $1 invested.[xc] A study by NEF Consulting (NEF, 2016[xci]) for Meteo Rwanda estimated a benefit to cost ratio of 4:1, though this was dominated by EWS and reduced fatalities. There has also been a major USAID-funded project – Rwanda Climate Services for Agriculture (RCSA) - that has improved weather forecasts for farmers. This four-year project ran from 2016 to 2019. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) funded an evaluation of RCSA project, published in 2020 (Birachi et al., 2020[xcii]). A socio-economic benefit assessment of the WISER Enhancing Climate information Services for Agriculture and Disaster Risk Reduction in Rwanda (Iteganyagihe Ryacu) project was undertaken (WISER, 2021). The total estimated benefits (undiscounted) of the Rwanda national project were estimated at £19.2 million, with annualised benefits of £3.4 million/year. The cost- benefit analysis estimated a benefit to cost ratio of 23:1, although did not include farmer action.
Capacity building and development for cross-sector NDC implementation	Capacity building and institutional strengthening is generally reported as being extremely effective, but is very challenging for valuation. There have been some international reviews that identify high economic benefits (LSE, 2016)[xciii] as well as a number of context-specific studies that have estimated BCRs, reporting results of >10:1 though these are are not specific to the African context[xciv]. There is one study from South Africa, where Cartwright et al. (2013[xcv]) compared institutional options against hard options in Durban in the context of adaptation[xcvi] and found these had among the highest BCRs. Information, dissemination and capacity building have high economic benefits[xcvii] and these 'soft' options increase significantly under higher climate change. Furthermore, a number of studies report that capacity building and institutional strengthening options lead to higher benefits for outcome-based options (e.g. farm-level interventions) as they enhance the effectiveness and efficiency of these options. A number of studies report higher benefit cost ratios when capacity building/institutional strengthening are combined with outcome orientated adaptation options. a portfolio of improved seeds, soil and water conservation, better extension services and improved climate information, was most effective in enhancing agricultural production in climate vulnerable areas [xcviii]
Access to finance	Not an intervention.

References

[i] Republic of Rwanda (2020). Updated Nationally Determined Contribution. May 2020. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Rwanda%20First/Rwanda_Updated_NDC_May_2020.pdf
[ii] https://data.worldbank.org
[iii] RoR (2020). Revising Nationally Determined Contribution (NDC) mitigation and adaptation priorities for Rwanda. Final Report. 24 March 2020. Prepared by: Gregory Cook (Mitigation lead), Alex Mulisa (Adaptation lead), Innocent Nkurikiyimfura (Energy), Elisée Gashugi (Waste and IPPU), and Svetlana Gaidashova (Agriculture and Forestry).
[iv] CPI (2022). Climate Finance Landscape. https://www.climatepolicyinitiative.org/the-topics/climate-finance-landscape/
[v] Shreve, C.M., & Kelman, I. (2014) 'Does mitigation save? Reviewing cost-benefit analyses of disaster risk reduction', International Journal of Disaster Risk Reduction, 10(A), 213–235. https://doi.org/10.1016/j.ijdrr.2014.08.004
[vi] Mechler, R. Nat Hazards (2016) 81: 2121. https://doi.org/10.1007/s11069-016-2170-y
[vii] ECONADAPT (2017). "The Costs and Benefits of Adaptation", results from the ECONADAPT Project, ECONADAPT consortium, http://econadapt.eu/.
[viii] Global Commission on Adaptation (GCA). 2019. Adapt Now. www.gca.org.
[ix] LSE (2016). Economics of Adaptation and Climate-Resilient Development: Lessons from Projects for Key Adaptation Challenges. London School of Economics/ Grantham Research Institute. Watkiss and Cimato http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2016/05/Working-Paper-235-Watkiss-and-Cimato.pdf
[x] Bhattacharya A. and J. Rydge (2020). Better Recovery, Better World: Resetting climate action in the aftermath of the COVID-19 pandemic Prepared for the Coalition of Finance Ministers for Climate Action. May 2020
[xi] Hammer S. and S. Hallegatte (2020). Planning for the economic recovery from COVID-19: A sustainability checklist for policymakers. The World Bank. April 2020.
[xii] Hepburn, C., O'Callaghan, B., Stern, N., Stiglitz, J., and Zenghelis, D. (2020), 'Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change?', Smith School Working Paper 20-02.
[xiii] IMF (2020). Greening the Recovery. Special Series on Fiscal Policies to Respond to COVID-19, Fiscal Affairs Department.
[xiv] Levy J., Carter B., Studart R. (2020). The global economy will not be the same after the shock of the COVID-19 pandemic. WRI Commentary.
[xv] ARUP (2008). Your home in a changing climate. Retrofitting existing homes for climate change impacts. Report for policy makers.
[xvi] Wood Plc (2019). Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector - Final Report. Prepared for the Committee on Climate Change.
[xvii] Climate Works Foundation (CWF) 2009: Economics of Climate Adaptation: Shaping climate resilient development: a framework for decision-making. A report of the economics of climate change adaptation working group. http://www.swissre.com/resources/387fd3804f928069929e92b3151d9332-
[xviii] Yoder, Jonathan, Adam, Jennifer, Brady, Michael, Cook, Joseph, Katz, Stephen, Johnston, Shane, Malek, Keyvan, McMillan, John, and Yang, Qingqing, 2017. Benefit-Cost Analysis of Integrated Water Resource Management: Accounting for Interdependence in the Yakima Basin Integrated Plan. Journal of the American Water Resources Association (JAWRA) 53(2): 456– 477, DOI: 10.1111/1752-1688.12507
[xix] IISD (2014). https://www.iisd.org/system/files/publications/mb_water_storage_options.pdf
[xx] Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R. and Davidson N. (2013) The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP: London and Brussels; Ramsar Secretariat: Gland.
[xxi] ARCOS(2021): Economic Valuation of Ecosystem Services of Kigali City Wetlands. Complex in Rwanda. Technical Report
[xxii] Hallegatte S. (2012). A cost-effective solution to reduce disaster losses in developing countries. hydro-meteorological services, early warning, and evacuation. Policy Research Working Paper 6058. The World Bank.
[xxiii] Economics of Adaptation and Climate-Resilient Development: Lessons from Projects for Key Adaptation Challenges. London School of Economics/ Grantham Research Institute. Watkiss and Cimato http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2016/05/Working-Paper-235-Watkiss-and-Cimato.pdf
[xxiv] FCDO. Business case for Tanzania IWRM programme.
[xxv] Terrance M. Hurley, Philip G. Pardey, Xudong Rao and Robert S. Andrade (2016). Returns to Food and Agricultural R&D Investments Worldwide, 1958-2015. https://ageconsearch.umn.edu/record/249356/files/InSTePPBriefAug2016.pdf
[xxvi] Shongwe P., Micah B. Masuku2 & Absalom M. Manyatsi (2014), "Cost Benefit Analysis of Climate Change Adaptation Strategies on Crop Production Systems: A Case of Mpolonjeni

Area Development Programme (ADP) in Swaziland". Sustainable Agriculture Research; Vol. 3, No. 1.
[xxvii] Wamatsembe I.M., G. Asea and S.M. Haefele (2017),"A Survey: Potential Impact of Genetically Modified Maize Tolerant to Drought or Resistant to Stem Borers in Uganda". Agronomy 2017, 7, 24.
[xxviii] Ncube M., et al. (2016), "Climate change, household vulnerability and smart agriculture: The case of two South African provinces". Journal of Disaster Risk Studies, Vol 8, No 2. https://jamba.org.za/index.php/jamba/article/viewFile/182/382
[xxix] Venton C et al (2010). . Cost-benefit analysis for community-based-climate and disaster risk management: synthesis report. London, U.K.:Tearfund;
2010.
[xxx] FANRPAN (2017). *Cost Benefit Analysis of Post-Harvest Management Innovations in Mozambique.* Pretoria. Available at
https://media.africaportal.org/documents/PHLM_CBA_Mozambique_Report_-_Mar_2017.pdf.
[xxxi] IFAD (2019). The Food Loss Reduction Advantage. Building Sustainable Food Systems. Available at
https://www.ifad.org/documents/38714170/41335091/food_loss_advantage.pdf/373e787f-fc6f-0426-eea0-d730f79d38c3.
[xxxii] USAID (2013). Post-Harvest Handling and Storage (PHHS) Project. Final Report. Available at https://www.usaid.gov/sites/default/files/documents/1860/Post-Harvest%20Handling%20and%20Storage,%20Final%20Report.pdf
[xxxiii] Consultative Group on International Agricultural Research, Technical Advisory Committee (CGIAR) (2000). An Evaluation of the Impact of Integrated Pest Management Research at International Agricultural Research Centres. Available at
https://www.ipcinfo.org/fileadmin/user_upload/sciencecouncil/Impact_Assessment/ipm.pdf
[xxxiv] Chepchirchir Ruth T., Ibrahim Macharia, Alice W. Murage, Charles A.O. Midega, Zeyaur R. Khan (2018). Ex-post economic analysis of push-pull technology in Eastern Uganda, in *Crop Protection*, Volume 112, 2018, Pages 356-362. Available at
https://www.sciencedirect.com/science/article/abs/pii/S0261219418301777.
[xxxv] Ferrarese C., Mazzoli E., Rinaldi R. 2017. Review of economic and livelihood benefits for ASAP-supported investments. IFAD Publications, Rome, Italy.
[xxxvi] Nancy McCarthy, Leslie Lipper and Giacomo Branca (2011) Climate-Smart Agriculture: Smallholder Adoption and Implications for Climate Change Adaptation and Mitigation. Mitigation Of Climate Change In Agriculture Series 4. Food and Agriculture Organization of the United Nations (FAO).
[xxxvii] Bizoza, A.R. and de Graaff, J. (2012), Financial cost–benefit analysis of bench terraces in Rwanda. Land Degrad. Dev., 23: 103-115. https://doi.org/10.1002/ldr.1051
[xxxviii] The World Bank. Project Appraisal Document. Land Husbandry, Water Harvesting and Hillside Irrigation Project. November 2009. Report No: 50901-R-W
[xxxix] Rutebuka, Jules et al. "Effectiveness of Terracing Techniques for Controlling Soil Erosion by Water in Rwanda." *Journal of environmental management* 277 (2021): 111369–111369.
[xl] Ujeneza, Noel. (2018). Hinga Weze Activity on Bench Terraces. Feed The Future. Pre-Final Report.
[xli] Guthiga, M. Paul (2020). Assessing Agroforestry practices and soil and water conservation for climate change adaptation in Kenya. https://www.adaptation-undp.org/sites/default/files/resources/cba_kenya_120721.pdf
[xlii] As examples:
World Bank (2010). Economics of adaptation to climate change. Washington, DC: World Bank.
Ignaciuk, A. and D. Mason-D'Croz (2014), "Modelling Adaptation to Climate Change in Agriculture", OECD Food, Agriculture and Fisheries Papers, No. 70, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/5jxrclljnbxq-en
Parrado, R, Bosello. F., and Dellarole, A. (2016). Deliverable 8.2.2: "The implications of irrigation as a planned adaptation measure on an economy wide context". Deliverable of the Econadapt Project. Available at
https://econadapt.eu/sites/default/files/docs/Deliverable%208_2%20approved%20for%20publishing.pdf. Accessed October 2018.
[xliii] The Risk to Resilience Study Team (2009): Catalyzing Climate and Disaster Resilience: Processes for Identifying Tangible and Economically Robust Strategies: Final Report of the Risk to Resilience Study, eds. Moench, M., Fajber, E., Dixit, A., Caspari, E., & Anil Pokhrel, ISET, ISET-Nepal, Kathmandu, Nepal, 328 pp.
[xliv] Cervigni, Raffaello; Liden, Rikard; Neumann, James E.; Strzepek, Kenneth M.. 2015. Enhancing the Climate Resilience of Africa's Infrastructure : The Power and Water Sectors. Africa Development Forum;. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/21875 License: CC BY 3.0 IGO. Available https://openknowledge.worldbank.org/handle/10986/21875
[xlv] Climate Works Foundation (CWF) 2009: Economics of Climate Adaptation: Shaping climate resilient development: a framework for decision-making. A report of the economics

of climate change adaptation working group.
http://www.swissre.com/resources/387fd3804f928069929e92b3151d9332-

[xlvi] ECA (2009). Shaping Climate-resilient Development a framework for decision-making. A report of the economics of climate Adaptation working group. Economics of Climate Adaptation.

[xlvii] The Risk to Resilience Study Team (2009): Catalyzing Climate and Disaster Resilience: Processes for Identifying Tangible and Economically Robust Strategies: Final Report of the Risk to Resilience Study, eds. Moench, M., Fajber, E., Dixit, A., Caspari, E., & Anil Pokhrel, ISET, ISET-Nepal, Kathmandu, Nepal, 328 pp.

[xlviii] Mohamed, B. (2013). Better economics: supporting climate change adaptation with stakeholder analysis: a case study of Morocco. International Institute for Environment and Development (IIED), London, UK.

[xlix] Lunduka, R.W. (2013). Multiple stakeholders' economic analysis of climate change adaptation. A case study of Lake Chilwa Catchment, Malawi. International Institute for Environment and Development (IIED), London, UK.

[l] https://limestone-analytics.com/project/cost-benefit-analysis-of-usaid-rwandas-hinga-weze-activities/

[li] Byiringo et al. (2020). Impacts, maintenance, and sustainability of irrigation in Rwanda. https://www.3ieimpact.org/sites/default/files/2020-03/IE112-DPW1.1085-Rwanda-Irrigation.pdf

[lii] JLIAFD. (2019). https://webapps.ifad.org/members/eb/126/docs/EB-2019-126-R-22-Project-design-report.pdf

[liii] https://medcraveonline.com/APAR/impact-of-participatory-irrigation-management--case-study-cocurirwa-cooperative-rwamagana-rice-project-rwanda.html

[liv] Mangisoni et al. (2021). The Malawi Priorities Project.
https://www.copenhagenconsensus.com/sites/default/files/mp_irrigation_report.pdf

[lv] Mechler, R. Nat Hazards (2016) 81: 2121. https://doi.org/10.1007/s11069-016-2170-y

[lvi] Prabhakar, S.V.R.K., Solomon, S., Abu-Bakar, A., Cummins, J., Pereira, J.J. & Pulhin, J.M. (2017) Case studies in insurance effectiveness: Some insights into costs and benefitsI, Southeast Asia Disaster Prevention Research Initiative. https://pub.iges.or.jp/pub/case-studies-insurance-effectiveness-some

[lvii] Climate Works Foundation (CWF) 2009: Economics of Climate Adaptation: Shaping climate resilient development: a framework for decision-making. A report of the economics of climate change adaptation working group.
http://www.swissre.com/resources/387fd3804f928069929e92b3151d9332-

[lviii] The Risk to Resilience Study Team (2009): Catalyzing Climate and Disaster Resilience: Processes for Identifying Tangible and Economically Robust Strategies: Final Report of the Risk to Resilience Study, eds. Moench, M., Fajber, E., Dixit, A., Caspari, E., & Anil Pokhrel, ISET, ISET-Nepal, Kathmandu, Nepal, 328 pp.

[lix] FONERWA (2017). Rural Green Economy and Climate Resilient Development Project. Preparatory studies completed on behalf of the Ministry of Natural Resources Rwanda and funded through the Project Preparation Facility of the Green Climate Fund. Report 4a-Technical-PPF-MINIRENA-Mar-2017: Supplementary technical report: Ecosystems. March 2017

[lx]

[lxi] Hunt (2011) Policy Interventions to Address Health Impacts Associated with Air Pollution, Unsafe Water Supply and Sanitation and Hazardous Chemicals. Environment Working Paper No. 35. OECD.

[lxii] Hutton, G., L. Haller and J. Bartram (2007), Economic and health effects of increasing coverage of low cost household drinking-water supply and sanitation interventions to countries off-track to meet MDG target 10, World Health Organization, Geneva.

[lxiii] ODI (2014). The economics of climate change adaptation in Africa's water sector. A review and way forward. Julian Doczi and Ian Ross. March 2014.
https://odi.org/en/publications/the-economics-of-climate-change-adaptation-in-africas-water-sector-a-review-and-a-way-forward/

[lxiv] Jonathan Bower, Remy Ruberambuga, and Patrick McSharry (2021). Transforming the vision of Kigali. The economic case for investing in public parks. Policy brief. RWA-21021 | March 2021

[lxv] ECONADAPT (2015). Assessing the economic case for adaptation to extreme events at different scales. Kuik, O. et al. Deliverable 5.1
https://econadapt.eu/sites/default/files/docs/Deliverable%205-1%20approved%20for%20publishing_1.pdf

[lxvi] World Bank (2016). PROJECT APPRAISAL DOCUMENT to the REPUBLIC OF RWANDA FOR AN URBAN DEVELOPMENT PROJECT MARCH 8, 2016

[lxvii] FONERWA (2017). Rural Green Economy and Climate Resilient Development Project. Preparatory studies completed on behalf of the Ministry of Natural Resources Rwanda and funded through the Project Preparation Facility of the Green Climate Fund. Report 4a-Technical-PPF-MINIRENA-Mar-2017: Supplementary technical report: Ecosystems. March 2017

[lxviii] Ebi, K.L. (2008) 'Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030', Globalization and Health, vol. 4, no. 9.
[lxix] Clinton Health Access Initiative (2021). Maintaining the Gains in Global Malarian Control. October 2011.
[lxx] USAID (2015). Evaluation of the Impact of Malaria Control Interventions on All-Cause Mortality in Children under Five Years of Agein Rwanda, 2000–2010. President's Malaria Initiative.
[lxxi] SEI (2009), Economics of Climate Change in Rwanda. Stockholm Environment Institute.
[lxxii] Hallegatte, S., J. Rentschler, and J. Rozenberg. 2019. Lifelines: The Resilient Infrastructure Opportunity. Sustainable Infrastructure Series. Washington, DC: World Bank.
[lxxiii] Global Commission on Adaptation (GCA). 2019. Adapt Now. www.gca.org.
[lxxiv] ADB (2014). Climate proofing ADB investment in the transport sector: initial experience. Published by the ADB, the Philippines.
[lxxv] ADB (2021). System-wide Approach for Infrastructure Resilience. Technical Note. January 2021. Asian Development Bank, Manila, https://www.adb.org/sites/default/files/publication/672501/system-wide-approach-infrastructure-resilience.pdf
[lxxvi] Thacker S, Kelly S, Pant R, Hall JW. Evaluating the Benefits of Adaptation of Critical Infrastructures to Hydrometeorological Risks. Risk Anal. 2018 Jan;38(1):134-150. doi: 10.1111/risa.12839. Epub 2017 Jun 30. PMID: 28666064.
[lxxvii] IUCN (2014). Cost Benefit Analysis of the Mining Sector in Karamoja, Uganda. https://www.iucn.org/sites/dev/files/import/downloads/karamoja_mining_webversion1.pdf
[lxxviii] World Bank (2012). A Cost Effective Solution to Reduce Disaster Losses in Developing Countries: Hydro-Meteorological Services, Early Warning, and Evacuation. Stéphane Hallegatte. Policy Research Working Paper 6058.
[lxxix] Mechler, R. Nat Hazards (2016) 81: 2121. https://doi.org/10.1007/s11069-016-2170-y
[lxxx] Shreve, C.M., & Kelman, I. (2014) 'Does mitigation save? Reviewing cost-benefit analyses of disaster risk reduction', International Journal of Disaster Risk Reduction, 10(A), 213–235. https://doi.org/10.1016/j.ijdrr.2014.08.004
[lxxxi] Courtenay Cabot Venton, Lorraine Coulter, Hanna Schmuck (2013). The Economics of Early Response and Resilience: Lessons from Mozambique Report to DFID.
Courtenay Cabot Venton, Shuman Majumder (2013). The Economics of Early Response and Resilience: Lessons from Bangladesh. Report to DFID.
Courtenay Cabot Venton, Lorraine Coulter (2013). The Economics of Early Response and Resilience: Lessons from Niger. Report to DFID.
[lxxxii] Clements, J et al (2013). The Value of Climate Services Across Economic and Public Sectors. Report to the United States Agency for International Development (USAID). Available at http://www.climate-services.org/sites/default/files/CCRD-Climate-Services-Value-Report_FINAL.pdf
[lxxxiii] WMO (2015). Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. World Meteorological Organization, Geneva.
[lxxxiv] ECONADAPT (2017). "The Costs and Benefits of Adaptation", results from the ECONADAPT Project, ECONADAPT consortium, http://econadapt.eu/.
[lxxxv] Law, A., 2012: Evaluating the cost-effectiveness of drought early warning early response systems for food security: A cost-benefit analysis of Ethiopia's Livelihoods, Early Assessment, and Protection (LEAP) system. Submitted in partial fulfilment of the requirements for the degree of Master of Science in Environmental Change and Management. Environmental Change Institute, University of Oxford
[lxxxvi] Ebi, K.L., Teisberg, T.J., Kalkstein, L.S., Robinson, L., and R.F. Weiher (2004), "Heat Watch/Warning Systems Save Lives: Estimated Cost and Benefits for Philadelphia 1995-98", Bulletin of the American Meteorological Society, August, 1-7.
[lxxxvii] Hunt, A., Ferguson, J., Baccini, M., Watkiss, P., Kendrovski, V. (2016). Climate and Weather Service Provision: Economic Appraisal of Adaptation to Health Impacts. Climate Services. DOI: 10.1016/j.cliser.2016.10.004
[lxxxviii] Chiabai, A., Spadaro, J.V., Neumann, M.B., 2018. Valuing deaths or years of life lost? Economic benefits of avoided mortality from early heat warning systems. Mitigation and Adaptation Strategies for Global Change. https://doi.org/10.1007/s11027-017-9778-4
[lxxxix] World Bank (2017). Assessment of Food Security Early Warning Systems for East and Southern Africa. https://documents1.worldbank.org/curated/en/195261520889090479/pdf/Assessment-of-food-security-early-warning-systems-for-East-and-Southern-Africa-final-report.pdf
[xc] Building Flood Resilience Capacities in Rwanda. GGI & GCF Report. (2020). https://www.greenclimate.fund/sites/default/files/document/rwanda-nap-gggi.pdf
[xci] NEF (2016). Forecastive Cost Benefit Analysis of the 'Strengthening Meteo Rwanda's Weather and Climate Services to Support Development' Project. Report by New Economics Foundation (NEF) Consulting for Meteo Rwanda.
[xcii] Birachi E, Hansen J, Radeny M, Mutua M, Mbugua MW, Munyangeri Y, Rose A, Chiputwa B, Solomon D, Zebiak SE, Kagabo DM, Nsengiyumva G. 2020. Rwanda Climate Services for Agriculture: Evaluation of farmers' awareness, use and impacts. CCAFS Working Paper no.

304. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

[xciii] Economics of Adaptation and Climate-Resilient Development: Lessons from Projects for Key Adaptation Challenges. London School of Economics/ Grantham Research Institute. Watkiss and Cimato http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2016/05/Working-Paper-235-Watkiss-and-Cimato.pdf

[xciv] Mullen, J., Gray D., de Meyer, J (2015), Evaluating the impact of capacity building by AICAR. Contributed paper prepared for presentation at the 59th AARES Annual Conference, Rotorua, New Zealand, February 10-13, 2015

[xcv] Cartwright, A., Blignaut,J., De Wit, M.,, Goldberg, K., Mander, M., O'Donoghue, S., and Debra Roberts, D (2013). Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment and Urbanization 2013 25: 139. DOI: 10.1177/0956247813477814

[xcvi] Anton Cartwright, James Blignaut, Martin De Wit, Karen Goldberg, Myles Mander, Sean O'Donoghue and Debra Roberts (2013). Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment and Urbanization 2013 25: 139. DOI: 10.1177/0956247813477814

[xcvii] The Risk to Resilience Study Team (2009): Catalyzing Climate and Disaster Resilience: Processes for Identifying Tangible and Economically Robust Strategies: Final Report of the Risk to Resilience Study, eds. Moench, M., Fajber, E., Dixit, A., Caspari, E., & Anil Pokhrel, ISET, ISET-Nepal, Kathmandu, Nepal, 328 pp.

Anton Cartwright, James Blignaut, Martin De Wit, Karen Goldberg, Myles Mander, Sean O'Donoghue and Debra Roberts (2013). Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment and Urbanization 2013 25: 139. DOI: 10.1177/0956247813477814

[xcviii] Di Falco S. and M. Veronesi (2012) How African Agriculture Can Adapt to Climate Change? A Counterfactual Analysis from Ethiopia. University of Geneva, Mimeo