International Journal of Development and Sustainability
ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 8 Number 3 (2019): Pages 211-228
ISDS Article ID: IJDS18051501

Evaluating the relative importance and uncertainty of climate risks in Sub-Saharan Africa: A framework for Prioritization

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Abstract

Effectively addressing the risks posed by climate variability and change in the context of a resource limited development portfolio means making difficult choices about how to prioritize and sequence investments. To effectively target limited climate change adaptation resources, donors need to weigh the relative importance of climate risk against other barriers to development. The premise of this work is three-fold: 1) countries where governance and institutional capacity are more advanced are better able to make use of resources to support climate resilience, 2) the relative importance of climate risk vis a vis non-climate barriers has implications for the sequencing of adaptation activities, 3) assessing uncertainty is important for deciding where to prioritize limited adaptation funds. To support adaptation planning, this paper develops a framework to facilitate evidence-based prioritization and sequencing of climate change adaptation investments. The framework proposed focuses on several priority sectors for development agencies in Sub-Saharan Africa: agriculture, water and disaster risk reduction, but could be expanded to incorporate other sectors as well as other regions of the world. Unlike previous frameworks and approaches, this framework seeks to inform investment discussions without providing prescriptive answers, and in doing so incorporates model-induced uncertainties associated with future climate risks.

Keywords: Prioritizing; Climate Change Adaptation; Climate Risks; Development Planning

Cite this article as: Zermoglio, M.F., Smith, B., Apostos, A. and Blaine, T. (2019), "Evaluating the relative importance and uncertainty of climate risks in Sub-Saharan Africa: A framework for Prioritization", *International Journal of Development and Sustainability*, Vol. 8 No. 3, pp. 211-228.

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1. Introduction

1.1. The Challenge

Development challenges across Sub-Saharan Africa (SSA) emanate from a complex set of inter-connected economic, social, political, and environmental factors (Conway and Schipper, 2011; Cooper et al., 2008; Downing, Ringius, Hulme, and Waughray, 1997; Heyer, 1996; SHAW, 2009; Smit and Pilifosova, 2003; Sullivan C.A., Meigh J.R., and Giacomello A.M., 2003). In striving to meet near and long-term development targets, countries in SSA are constrained by a variety of pressing development needs across a wide range of sectors. Many of these sectors (e.g., agriculture, water, sanitation) are extremely sensitive to climate variability and change and are also priorities for development agencies. Furthermore, given their high dependence on the natural resource base and a comparatively low capacity to adapt to changes in climate, countries in SSA are frequently invoked as being especially vulnerable to climate change(Boko et al., 2007; Niang et al., n.d.). Therefore, while development in many SSA countries is constrained by a range of factors, climate variability and change act as additional stressors that cannot be ignored.

The economic impacts from climate change in SSA countries are projected to be significant, with estimates ranging between USD 5-30 billion a year (Watkiss, Downing, and Dyszynksi, 2010)) at least partly owing to the high dependence on natural resources and low ability to adapt. As most SSA countries already suffer from significant development deficits, external financing to support climate adaptation will be critical. Without targeted external funding, many SSA countries will struggle to adapt, with the poorest and most vulnerable people, whose lives and livelihoods are almost completely dependent on the natural resource base, suffering the most (Adger et al., 2003; Ahmed et al., 2009; Douglas et al., 2008; O'Brien and Leichenko, 2000). Unfortunately, even considering the low-end of estimates for the climate change adaptation financing needed, only a fraction of the resources necessary has been allocated to date, clearly indicating that adaptation programming occurs in a resource constrained environment.

While climate change funding has been and is likely to continue to be limited relative to the needs across SSA, experiences to date are beginning to demonstrate the value of providing a targeted climate-lens to wider efforts associated with planning and operating under a development paradigm (Ayers and Huq, 2009; Fankhauser and Burton, 2011; Ziervogel and Taylor, 2008). However, the academic literature provides limited guidance on how to best prioritizes these limited funds to maximize their effectiveness (Barrett, 2014; Persson and Remling, 2014; Watkiss, Hunt, Blyth, and Dyszynski, 2015; Ziervogel and Taylor, 2008). While a logical argument can be made for using adaptation funds to work on general development challenges(Adenle et al., 2017; Ayers and Huq, 2009; Sherman et al., 2016; Thomas Tanner and Mitchell, 2008), the reality is that some grant funds from donor organizations, albeit limited funds, are mandated to specifically and directly target adaptation. Therefore, the effective targeting of adaptation funds requires the recognition that some prioritization is required and that this prioritization considers the existence of fundamental, non-climate development challenges (e.g., weak governance, corruption), which may complicate the task of achieving climate resiliency.

It is generally agreed that effective adaptation requires providing people the resources and agency necessary to take advantage of the opportunities their landscape and communities offer(Adger et al., 2003; Downing et al., 1997). In practice this means that governance structures, infrastructure and human capital are in place and are effective to facilitate action. Weak governance particularly has long been identified as a major barrier to development(Rogers and Hall, 2003; Unsworth, 2009), with key elements including the degree of political stability, level of corruption and rent-seeking behavior, predictability of the rule of law, and the degree to which government introduces price distortions, creating inefficient allocation of resources(Grindle, 2004; Handoyo, 2018; McMullen, Bagby, and Palich, 2008; Parker, 1995; Rutherford, Meagher, Lanyi, Kahkonen, and Azfar, 2018; Shubik, 2018). In the adaptation space these issues are often discussed in terms of sensitivity and adaptive capacity(McCarthy, Lipper, and Zilberman, 2018; Petersen, Aslan, Stuart, and Beier, 2018). Many of the factors that contribute to adaptive capacity and sensitivity (e.g., social capital, strong institutions), physical capital (e.g., infrastructure), human capital (e.g., knowledge, skills, health), financial capital (e.g., access to credit) and natural capital (e.g., soils, rainfall), are themselves closely aligned with robust economic development (Ficklin, Wood, Dougill, Sallu, and Stringer, 2017). Where adaptive capacity is low, there is likely to be an increased risk that adaptation investments will fail to meet their objectives (Adenle et al., 2017). For example, weak institutional contexts and political stability do not allow for sufficient continuity and predictability for multiple year investments, and gaps in basic infrastructure (e.g., roads) can cause investments (e.g., in agriculture productivity) to have limited impact (e.g., increased productivity is less impactful if crops cannot be taken to market).

Effective prioritization also needs to account for the reality that both climate risks and local conditions are dynamic, with priority needs changing over time. This implies that any prioritization framework needs to consider not just the investments that countries make, but also the appropriate sequencing of adaptation activities within a country's current development context.

This paper seeks to develop a framework to evaluate the relative importance of climate risk as compared to other barriers to development (e.g., weak governance, corruption). Such a framework would offer valuable insights on the different development and climate risks contexts that exist in different countries. This paper applies this framework to countries in SSA, focusing on agriculture, water and disaster risk reduction. However, the framework could be expanded to other sectors or regions of the world using the same methodology. This framework does not seek to provide prescriptive answers, but instead seeks to inform wider prioritization discussions. Therefore, it includes new visualization techniques that provide important insights, and seeks to better represent the uncertainties inherent in climate change projections.

1.2. Previous frameworks approaches and analyses

A growing number of tools are available to support prioritization of adaptation work, including tools focused on identifying adaptation options or screening projects for climate risks. While most of the examples published to date relate to the prioritization of specific activities (e.g., climate-smart agriculture practices), as opposed to informing strategic prioritization of countries for investment, they nevertheless embody useful principles to consider and are reviewed briefly here.

Assessment of adaptation options inVol.ves prioritization of strategies within a specific domain such as climate smart agriculture. The methods available apply classic economic appraisal tools such as cost-benefit analysis (CBA), multi-criteria analysis (MCA), and a range of tools borrowed and adapted from the financial sector, such as portfolio analysis (PA) and real options analysis (ROE) (Huang et al 2011; Linkov et al., 2006; Shardul and Samuel, 2008; Smit and Pilifosova, 2003; Watkiss et al., 2015) .The emphasis of these approaches is placed on sequencing of adaptation activities over time, while recognizing the need for flexibility in the structuring of a portfolio and for allowing users to define an acceptable level of risk based on local conditions rather than offering prescriptive answers. For example, the UK's Department for International Development (DFID) Value for Money (VfM) methodology was a cost benefit analysis designed to guarantee monetary returns from adaptation investments, prioritizing actions to address current adaptation deficits, while also investing in the enabling conditions to address longer-term risks. As noted above, while similar, these efforts focus on the prioritization of activities within a country or region as opposed to prioritizing countries or regions for investment.

Climate-risk screening tools, used by donors and multilateral development banks, range from automated data engines that generate risk reports for projects based on location (e.g., Asian Development Bank) to more qualitative processes that lead users through sets of structured questions and offer guidance on how to consider risks (e.g., World Bank, USAID) (Olhoff and Schaer, 2010; TM Tanner et al., 2007). These tools offer important insights on relevant climate risks to consider for specific sectors or country contexts. However, they do not speak to prioritization between countries or sectors, and tend to focus solely on climate risks as opposed to other barriers to development.

Vulnerability indices were developed to compare countries and regions when prioritizing activities and funding investments. ND-GAIN (University of Notre Dame Global Adaptation Initiative) Country Index is one of the better-known in this space and was, in fact, originally developed to offer a defensible prioritization framework for World Bank financing for climate change adaptation(Lo and Chow, 2015). ND-GAIN summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience and aims to help businesses and the public sector better prioritize investments for a more efficient response to global challenges(Van Leeuwen, et al. 2016). However, these indices tend to neglect uncertainty in future risks, and often provide static answers on which countries are most vulnerable.

2. Methods

The approach and aim of the framework developed here are similar to that of ND-Gain, with several notable differences: (1) visual outputs are used to encourage dialogue rather than offering a single prescriptive numerical quantification of risk, readiness and vulnerability, (2) current and future risk are presented in a way that points towards potential sequencing of investment strategies, and (3) the uncertainties inherent in future climate projections are incorporated into the framework. Acknowledging that the relative importance of climate risk will only be one component of a wider investment decision-making context, the framework does not offer prescriptive recommendations, but rather seeks to promote a dialogue among decision makers based on the available evidence and simplified visualizations on the evidence.

The starting point of this framework was a set of generic questions initially proposed by USAID in 2016 regarding the appropriate use of limited Climate Change Adaptation funds relative to their larger development portfolio: 1) Which countries/regions are better prepared to deal with climate risks than others and why? 2) In what countries/sectors will current climate risks be exacerbated under a changing climate? 3) How would the consideration of uncertainties alter the evaluation of relative risks?

To begin to answer these questions, a framework was developed that parses the available evidence into two categories: non-climate barriers to development and climate risks. As it is difficult to quantify generic climate risk across all sectors, the analysis was conducted at the sector level. This has a further advantage in that focusing on sector risks can provide evidence to inform the sequencing of potential activities. The rationale for these two categories is that both high-level aggregations (e.g., overall category of climate risk for a sector, general governance environment in a country) and individual scores on different sector components (water availability) can be accessed. Data availability and consistency were a considerable constraint to indicator choice and prevented analysis at a sub-national scale. Therefore, all indicators are compiled at the national scale. The selection of indicators for both categories was informed by the approaches and tools reviewed and summarized above.

In this paper, non-climate barriers to development are the institutional and governance structures and human capital that prevent the effective implementation of adaptation investments. Where these fundamental structures are weak, the barriers to development are significant and increase the risk that adaptation programming will fail to meet its objectives. For example, in a country like Chad, the underlying development deficient (e.g., a lack of capacity in the meteorological agency) might preclude effective delivery of climate and weather services. While selecting proxy indicators for non-climate barriers is challenging owing to the complex nature of general development barriers, the indicators selected here are intended to offer insights into whether a country currently provides the institutional and policy context to allow the effective delivery of development projects, including adaptation activities. The indicators selected are listed, along with an explanation for their selection, in Table 1.

Table 1. Indicators selected to represent the enabling conditions for development

Indicator	DESCRIPTION OR RATIONALE FOR INCLUDING IN ADAPTATION CONTEXT
WGI Political Stability	Measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. Critical in allowing the basic stability needed for development.
WGI Government Effectiveness	Captures perceptions of the quality of public services, civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation and the credibility of the government's commitment to such policies. This largely reflects the degree to which major development challenges are being addressed. A high score on this indicator means that the overall context for development is likely to be good.

Indicator	DESCRIPTION OR RATIONALE FOR INCLUDING IN ADAPTATION CONTEXT
	Includes data from three surveys of Health provision (Afrobarometer Health, Global Integrity Index Health, Institutional Profiles Database Basic Health Services), and four for Education (World Economic Forum Global Competitiveness Report: Quality of Primary Education; Afrobarometer Education, Global Integrity Index education, Institutional Profiles Database Public Schools).
WGI Voice and Accountability	Captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. This indicator is included because of its role in allowing public inVol..vement in the development sphere. In a repressive society there are likely to be major challenges to sustainable development.
WGI Control of Corruption	Captures the extent to which public power is exercised for private gain. Highly corrupt countries pose a challenge for development.
Human Development Index	The HDI uses high-level indicators of a country's development (life expectancy, GDP/capita, average years of schooling). Although it does not provide a full assessment, the aggregate nature of the indicators used means that a lot of development challenges are captured within the index.

Climate risks are assessed nationally at the sector scale for exposure to both current climate variability and potential future climate change. Similar to above, selecting proxy indicators for each sector is not straightforward and is subjective in nature. Table 2 lists the indicators used here, as well as the justification for their selection. One advantage of this framework is that other indicators or combination of indicators could be easily included.

Table 2. Indicators used to assess current and future climate risks to disaster risk reduction, water resources and agriculture sectors

DISASTER RISK REDUCTION		
Risk	**Indicator of current risks**	**Justification**
Current Risk	Annualized exposure to floods, droughts and tropical cyclones (% population	The combination of annualized exposure to different hazards, and the associated economic losses, provides a sound assessment of current disaster risk. Economic losses were normalized according to GDP, as otherwise they reflect economic development more than the magnitude of disasters. Annualized exposure is a probabilistic measure, combining observed disaster data with modelling of the likelihood of low-frequency, high-magnitude events, which may not be adequately represented in the historical record. As such it is a more robust indicator than records of population affected by past events.[1]
	Annualized economic losses from disasters as proportion of GDP	

[1] UNISDR (2015). Making Development Sustainable: The Future of Disaster Risk Management. Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction (UNISDR). Available at http://www.preventionweb.net/english/hyogo/gar/2015/en/gar-pdf/GAR2015_EN.pdf

Future Risk	Max 5-day rainfall	This is an area where it is difficult to fully capture the spectrum of disaster risk. A combination of Max 5-day rainfall and changes to rainfall intensity gives a good indication at the broad level of likely changes to flood risk. The science of changes to cyclone tracks, frequency and intensity is underdeveloped, and a lot of uncertainty exists in any assessment. This matters, as relatively small changes in both track and magnitude can have very large impacts. Drought risk is clearly a major concern. Proxies such as soil moisture content or water flux are available and might be acceptable, but do not provide insight on drought duration (multi-year, or decadal droughts, for example). Some of the difficulties with modelling drought risk are discussed above.

WATER RESOURCES		
Risk	**Indicator of current risks**	**Justification**
Current Risk	Falkenmark indicator of Water Scarcity (renewable water resources/capita)	The Falkenmark indicator is a widely used indicator of water stress first proposed by Falkenmark et al., in 1989[1]. It uses water availability per capita as a measure of the water available to the population of a country, and thus the overall availability of the resource. T By definition it does not capture differences in water availability within a country, however, at the national level it is a widely used indicator and an important measure of water stress.[2]
	Water Vulnerability Index (water use as % renewable resources)	The Water Vulnerability Index, or Water Use Ratio, measures the level of exploitation of the available water resources in a country; it is a measure of demand relative to supply. The Water Vulnerability Index is complementary to the Falkenmark indicator and accounts for the fact that different countries have varying levels of water use, both domestically and within critical sectors. The Falkenmark indicator can be thought of as showing biophysical sensitivity, while the Water Vulnerability Index represents socioeconomic exposure.[3]
Future Risk	WRI's Aqueduct Water Stress Projections Change in annual precipitation	WRI's projections of future water stress combine socioeconomic projections of changes in withdrawals with different scenarios of climate change that will affect water availability.[4] These indicators allow a robust assessment of changes in water availability and water stress. Change in annual precipitation is a clear indicator of how the overall availability of water at a national level will change. By itself, however, it does not capture the impact of factors such as population growth and changes in water use, which are also major contributors to water stress.

[1] Falkenmark, M., Lundquist, J. and Widstrand, C. (1989), "Macro-scale Water Scarcity Requires Micro-scale Approaches: Aspects of Vulnerability in Semi-arid Development", *Natural Resources Forum*, Vol. 13, No. 4, pp. 258–267.
[2] Brown, A., and Matlock, M.D., (2011), *A review of water scarcity indices and methodologies*, White paper,*106*: 19.
[3] Füssel, H. M., (2010), *Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts*, Background note to the 2010 World Development Report.
[4] Luo, T., Young, R. and Reig, P., (2015), *Aqueduct Projected Water Stress Country Rankings*, Technical Note, Washington, D.C., World Resources Institute.

AGRICULTURE[1]		
Risk	**Indicator of current risks**	**Justification**
Current Risk	Standardized Precipitation Evapotranspiration Index (SPEI)	SPEI is an extension of the Standardized Precipitation Index (SPI) to include the effect of potential evapotranspiration alongside precipitation. The SPI was adopted by the World Meteorological Agency (WMO) as a way to measure drought,[2] while the SPEI was designed to take into account the effect of higher temperatures on drought risk.[3] It is a measure of anomalies in precipitation and Potential Evapotranspiration (PET) – in essence it shows the number of standard deviations away from the long-term mean for a chosen time period. Data are derived based on the Climatic Research Unite (CRU) dataset, and the index is designed to allow comparisons between countries. The SPEI gives a very credible indicator of drought risk by country, a key component of the current climate risk to agriculture.
	IWMI Socio-Economic Drought Vulnerability Index	Can be used to show the relative exposure of different countries to drought. It is constructed using data on employment in the agriculture sector, the contribution of non-agricultural sectors to GDP, and the relative diversity of crops within a country[4]. This indicator shows the degree to which a country will be affected if suffering from drought conditions.
	Yield of Cereal Crops	Yield value acts as an integrating indicator, showing to some extent both climatic suitability, but also the degree to which the sector in a country has access to efficient technologies and inputs. Differences in yield are a good proxy for the sensitivity of the sector to climate-related risks, with those countries able to achieve higher yields likely to be better prepared to deal with the effects of different climate hazards.
Future Risk	Precipitation-Evapotranspiration Change in maximum temperatures	Changes to water flux, as measured by precipitation-evapotranspiration, are an important indicator of the combined effects of rainfall and temperature changes on the availability of water for agriculture.

[1] The approach taken with the agricultural indicators is that the major climate risk for the sector is drought, and therefore indicators of current climate risk should assess the vulnerability of the sector to drought, and indicators for future climate should broadly assess likely water availability. It is clear that warming will have different effects depending on the type of geographic area and cropping system. However, the combination of water availability and extreme temperatures is frequently identified as a major cause of potential yield decreases.[1] Indicators based on climatic variables were chosen to be generally applicable across a variety of crop types; strong increases in maximum temperatures and decreases in water availability can be assumed to have strong negative effects on the agriculture sector. While the response of specific crops is varied (i.e., beans and maize are highly vulnerable in Sub-Saharan Africa, whereas sorghum is much better adapted), the chosen indicators provide a simple comparison of likely impacts across countries. These indicators allow for a generalized assessment of risks, rather than assessments of the effect of climate change on specific crops, which are highly sensitive to model assumptions in the crop model used, and can vary significantly from study to study.

[2] Hayes, M., Svoboda, M., Wall, N. and Widhalm, M., (2011), "The Lincoln declaration on drought indices: universal meteorological drought index recommended", *Bull. Am. Meteorol. Soc.*, Vol. 92, pp. 485–488.

[3] Vicente-Serrano, Sergio M., and National Center for Atmospheric Research Staff, (2015), The Climate Data Guide: Standardized Precipitation Evapotranspiration Index (SPEI).

[4] Eriyagama, N., Smakhtin, V.Y. and Gamage, N., (2009), *Mapping drought patterns and impacts: a global perspective* (Vol. 133). International Water Management Institute.

For some visualizations, the raw values for the indicators could simply be plotted in a scatter plot. However, such visualizations can be complicated, and are not always conducive for communicating simple messages to decision-makers. Therefore, climate risks are also assessed and visualized based on the relative ranking of each parameter. While there are multiple methods for categorizing variables, an equal intervals approach was used here as a. natural breaks approach did not allow for sufficient differentiation between countries. The equal intervals approach places each country into one of five classes on a Likert-scale depending on their percentile rank among the other countries in the analysis., For future sector indicators, ranks are assigned based on the nature (e.g., increasing or decreasing rainfall) and degree of change (e.g., extent of difference based on the baseline). For example, the potential future risk in the water sector is approximated using the projected change in annual precipitation. A country in which the rainfall is projected to increase 5 percent would rank as at a lower risk than one with a projected decrease of 10 percent. However, the exact relative ranking would depend on the relative changes in all of the other countries included in the analysis.

Where possible, variables for future climate risk are derived from the Intergovernmental Panel on Climate Change's Fifth Assessment Report Archive (IPCC AR5). This allows a consistent approach in characterizing uncertainty in future changes and avoids the uncertainty associated with sector impact models. For each sector, two indicators are chosen and ranked as described above. The overall sector risk is the sum of the two component indicators, thus providing a score for each country examined on a 10-point scale.

2.1. Characterizing uncertainty in future climate risk

The science of climate change is complex and inexact, and therefore considerable uncertainty surrounds future climate change and its impact on development. These uncertainties include: the emission scenarios of future states of the world and the assumptions surrounding them; difficulties with modeling the complex climate system; lack of data; and significant knowledge gaps of how the climate system operates. These uncertainties tend to increase the longer the time horizon and the smaller the geographic scale.

While methods for simulating the climate system are improving, uncertainty is embedded in the output from any climate model. However, this uncertainty has not been adequately incorporated into most previous prioritization frameworks. As the framework developed here seeks to inform discussions, and not provide prescriptive answers, helping decision-makers understand how this uncertainty affects the relative climate risk is important. Therefore, this framework aims to capture and communicate the uncertainty derived from climate models – the only uncertainty that can be comparably quantified – in two ways:

Uncertainty rank: An uncertainty rank is calculated based on the standard deviation of the full suite of Global Circulation Model (GCM) projections available from the Coupled Model Intercomparison Project 5 (CMIP5). The larger the standard deviation, the larger the uncertainty in the projections and thus the higher the uncertainty ranking. Based on the interquartile range of the projections, the uncertainty rank, which spans values from 1 to 5, provides an estimate of the range in projections relative to that in other countries. For example, for the projected change in maximum precipitation over a five-day period, Zambia has a 10 percent difference between the 25^{th} percentile and the 75^{th} percentile in the range of model projections, while Malawi has a 20 percent difference. Therefore, Malawi has a higher uncertainty rank that Zambia with regards to maximum five-day precipitation.

Visualization of the envelope or range of projections: Most prioritizations methods use the model mean value (i.e., 50th percentile) in all their estimations of potential impact. However, it is important to understand how the relative importance of climate risk changes depending on whether the 25th, 50th or 75th percentile of the models projections are used. Table 4 shows that for Angola, a difference of two categories arises between its ranking on the 25th and 50th percentiles, whereas Botswana shows no difference. In this example, uncertainty is greater around Angola's ranking than Botswana's. This may be a function of the limited observational data available for Angola, as discussed above.

Table 4. Differences between model percentiles for Angola and Botswana

Country	Category (25th)	Category (50th)	Category (75th)
Angola	4	2	2

3. Results and discussion

While this framework could be used to examine a wide array of context specific questions, in this paper the outputs of the framework are illustrated through three conceptual case studies: 1) Which countries/regions in SSA are better prepared to deal with climate related water risks than others? 2) In what countries/sectors will current climate risks be exacerbated under a changing climate relative to other countries? and 3) How does the consideration of uncertainty alter the evaluation of relative risks?

3.1. Which countries/regions in SSA are better prepared to deal with climate related water risks than others?

Political stability measures perceptions of political instability and/or politically motivated violence, including terrorism. Combined, these indicators can offer a window into the degree to which major development challenges are being addressed, though certainly other variables could also be used. By plotting these measures of readiness against the climate indicators meant to approximate sectoral risk (e.g., Figure 1), one can begin to get a sense of in which countries the highest needs and ability to effectively engage exist. Here, the climate variable of importance is rainfall availability, which is tied to water availability. While these plots display climate variables on the 50th percentile, the 25th and 75th percentiles could also be plotted.

On both sub-plots, Botswana has a relatively high projected decrease in precipitation and appears to experience relatively "good" governance. Conversely, Guinea-Bissau is projected to experience an even larger decrease in precipitation but appears to experience a significantly "worse" governance environment. Based on this, there is a judgment to be made. The climate risks in Guinea-Bissau appear to be relatively higher but one might expect that investments in Botswana may have a greater chance of success due to a better enabling environment. Since all funding decisions will be made based on numerous factors, this approach provides insight to be incorporated, but not prescriptive answers in terms of where a donor should invest.

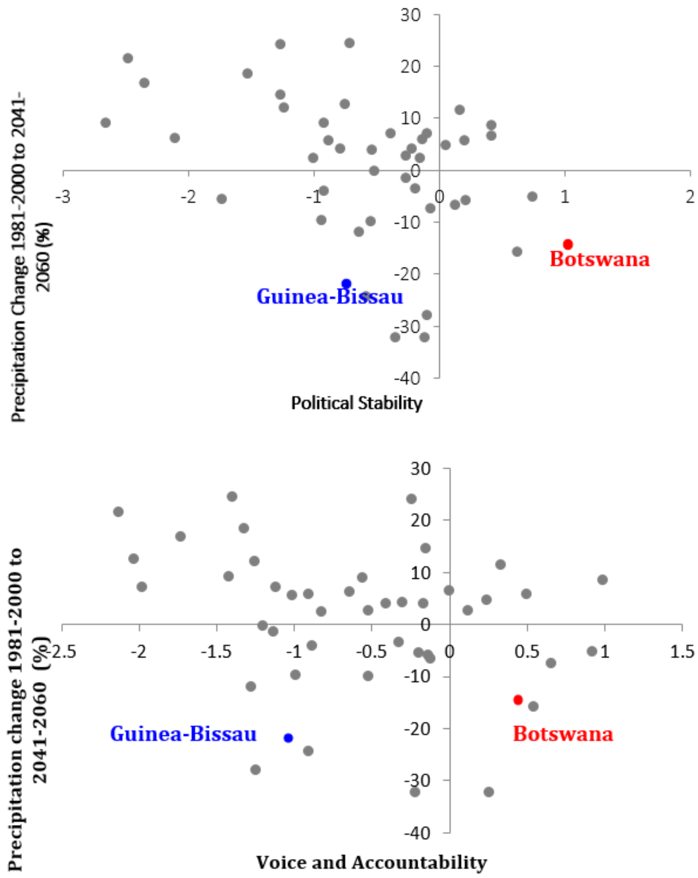


Figure 1. Plot of change in precipitation versus two indicators of the enabling environment for development, Botswana and Guinea-Bissau

3.2. In what countries/sectors will relative risk change under a changing climate?

This framework evaluates relative rather than absolute risk Using the water sector as an example, Table 3 evaluates current and future relative risks across countries in SSA. The matrix approach offers a simple way of visually evaluating how the relative risk from climate change is likely to change in SSA countries. Starting from current risk (left column) and then moving on to future risk (right column) as an indicator of which countries' water sectors are vulnerable now and which will be vulnerable in the future. This analysis suggests that the relative water sector risks for the Gambia and Madagascar will shift from "Moderate" to "Very High" under projected climate changes based on the indicators used. However, as this is a relative measure, it should not be misinterpreted as suggesting that climate change is increasing (or decreasing) the absolute stress on the sector. Instead, what this suggests is that in the future The Gambia and Madagascar are likely to be relatively more vulnerable to water risks that other SSA countries, which could have implications for prioritization of limited adaptation funding.

Table 3. Current and future risks to the water sector risk

Future / Current	Very Low	Low	Moderate	High	Very High
Very Low	Congo	Cameroon DRC CAR Equatorial Guinea Gabon	Guinea Liberia Sierra Leone		
Low	Sao Tomé and Principe		Guinea-Bissau	Mozambique Namibia	Angola
Moderate	South Sudan	Benin Rwanda Uganda	Ivory Coast Togo Zambia	Comoros Lesotho Mali	**Gambia** **Madagascar**
High		**Ethiopia** Niger	Burundi Chad Ghana Nigeria	Mauritius Swaziland Tanzania	Botswana Senegal
Very High		Djibouti Kenya	Eritrea Malawi Somalia Sudan	Cabo Verde	Mauritania South Africa Zimbabwe

Group A countries (in red): Medium-high water stress now, and changes in climate are likely to be high relative to other countries (e.g., Zimbabwe). Clear immediate needs, and strategies must be in place to manage the potential increasing stress from climate change.
Group B countries (in green): Medium-high water stress now; changes in climate are smaller than in Group A, but could still make the situation worse and are still relatively high compared to other countries (e.g., Ghana). Clear immediate needs, and strategies must be in place to manage the potential increasing stress from climate change.
Group C countries (in yellow): Low water stress at present, but the effect of climate change may be greater than in many other countries, so climate change could potentially make the situation worse (e.g., Sierra Leone). Need to have a plan to monitor effects of climate change and keep on top of any changes in water stress.
Group D countries (in blue): High current water stress, but the relative effect of climate change in increasing stress is low (e.g., Ethiopia). Relative to other countries, climate change itself might have a lower impact, but will take place in the context of an already fragile situation. Need to address major current needs while keeping an eye on how additional climate stress is progressing.
Group E countries (in green): Current water stress is low or moderate, and relative change in climate change parameters is also low (e.g., Gabon). Climate effects on water stress are likely to be relatively low.

Conversely, for countries such as Ethiopia, while the relative current risks are considered "High," the risks relative to other SSA countries in the future are lower. This is likely owing to the projected increases in precipitation in Ethiopia, which will make for more favourably growing conditions in many parts of the country. However, similar to the above, this should not be confused with the conclusion that Ethiopia will become less vulnerable in the future. Instead, Ethiopia could become more vulnerable owing to increased temperatures or frequency of drought but other SSA country's might simply become relatively more vulnerable owing to decreases in rainfall.

Understanding when these changes in relative climate risk will occur is also important. For example, current stresses are likely to continue, at least in the near term, and where problems presently exist, will need targeted interventions. Similarly, changes in climate (e.g., increased variability or extremes) that exacerbate current or create new risks may require a different set of interventions. The analysis above could suggest that in terms of sequencing and/or prioritizing funds, one should consider strengthening the water sector in Ethiopia to address current problems, while considering early investments in Madagascar that would build resilience to future challenges posed by a changing climate. In this way, the matrix may suggest different types of interventions that could be implemented to support adaptation.

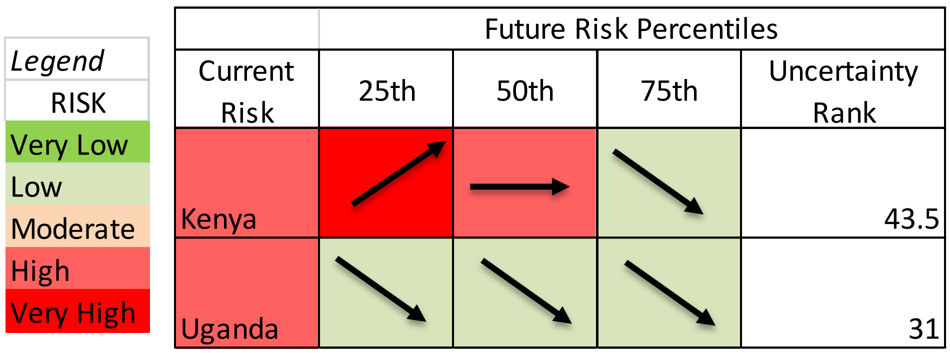
The table also indicates the importance of doing this analysis as the sectoral level, as individual country relative risk may change differently owing to the same climate signals. While this table currently does not include uncertainty, it could easily be modified to incorporate uncertainty in such a way as to provide a holistic overview of the current and potential relative risks across SSA for a given sector.

3.3. How would the consideration of climate model uncertainties alter the evaluation of relative risks between countries?

As noted throughout this paper, uncertainty poses a challenge to prioritizing climate adaptation investments, and therefore needs to be considered in prioritization discussions. It is often acknowledged that robust planning that includes all potential futures is critical but using only the model mean to rank the relative risk of climate change fails to provide the necessary information to evaluate potential, uncertain risks. Figure 2 offers a way to examine and visualize this how uncertainty might affect prioritization discussions using the agriculture sector for Kenya and Uganda as an example. Figure 2 includes not only the current risk to each country, but also the relative future risks using three different projected changes (e.g., the 25th, 50th and 75th percentiles of projections) as well as the uncertainty rank. In this case, both Kenya and Uganda are characterized as having high current risks. However, the two countries could have very different relative risks in the future depending on which future scenario is realized. First, even though Uganda has a relatively high risk currently, irrespective of the future scenario that materializes, the relative risk in Uganda (as compared to other SSA countries) appears to be low, likely owing to non-climate factors such as governance. In this case, it might not matter whether uncertainty is evaluated as the results are robust across the range of future projections. Conversely, in Kenya, the relative risk to agriculture appears to depend greatly on the future scenario that materializes, with the future risk in Kenya varying between very high if the 25th percentile future materializes and low if the 75th percentile future materializes. As the results are not robust across future scenarios, it is important for decision-makers to understand the wider variations in risk categories in Kenya relative to Uganda.

To support increased interpretation of the results, the arrows show the direction of change relative to current risk (arrows pointing upward suggest that projected risk will increase; horizontal arrows show no change in projections from current risks; arrows pointing downward suggest risk will decrease in the mid-21st century (2050)). The fact that future risks in Kenya are more uncertain than in Uganda are collaborated by the estimated uncertainty rank, which is higher for Kenya than Uganda.

Figure 2. Climate risks in agriculture for Kenya and Uganda



4. Assumptions and limitations

As in all types of similar analysis, there is a risk of oversimplification given the multi-faceted, complex, and uncertain nature of climate risk. However, the framework developed here seeks to, as much as possible, objectively evaluate the relative importance of climate risks to other non-climate barriers to development when prioritizing the use of limited climate funds. This is done by the crafting the framework to provoke discussion, and not a prescriptive tool, by including a measure of uncertainty, and by providing transparency around the indicators used.

Nevertheless, challenges and limitations remain. This is partly because climate risks and non-climate barriers to development are complex, inter-connected and difficult to capture using proxy indicators. It is also partly due to data availability and consistency, which significantly constrain the choice of indicators selected under this framework. For example, using a joint World Health Organization, World Bank and UNICEF dataset[1], it is possible to get data on the proportion of children under-5 stunted from malnutrition for every SSA country, but there is no consistency in the year of data collection. Given the varied years of data collection (2004 for Equatorial Guinea, 2012 for Uganda) fair comparisons are not possible, and so this indicator was not used.

The indicators proposed seek to capture the general climate risks for the sectors examined, as well as the general national barriers to development. Nevertheless, we recognize that those indicators do not capture all possible climate and non-climate risks, nor the spatial variations that exist at sub-national scales. For example, evaluating the climate risk to the water sector in Mali at the national level would gloss over significant differences that exist at the sub-national level owing to differences in annual rainfall and proximity to major rivers. Unfortunately exploring this subnational heterogeneity requires data at finer resolutions, which

[1] http://data.worldbank.org/indicator/SH.STA.STNT.ZS

currently are not available or robust enough for such analysis. Similarly, obtaining subnational indicators for non-climate barriers (e.g., voice and accountability, political corruption) is not possible for almost all SSA countries. Furthermore, it is possible that the same change in a climate variable might affect differently countries differently (e.g., a 20% reduction in rainfall may have very different implications for the water sector in Niger as compared to the Democratic Republic of Congo), which is currently not captured in this framework.

The framework is also constrained by the accuracy of climate modelling, particularly in regions where observational data are sparse and understanding of large-scale climate processes is imprecise. Displaying the uncertainty ranks, as described previously, is an attempt to acknowledge these limitations within the assessment. Regions such as West Africa, where lower certainty surrounds the dominant climatic processes, will tend to have greater disagreement among climate models and, as a result, a higher uncertainty rank. Similarly, as the framework currently does not include future projections beyond those for climate, it is unable to provide information on how the relative importance of climate risk as compared to non-climate barriers will change.

As the purpose of this research was to develop an initial method for provoking discussion related to investment prioritization, it examines relative as opposed to absolute risk. That is, countries are ranked based on comparison to other countries, rather than absolute thresholds of change (e.g., they are assigned the very high-risk category if their projected decrease in precipitation is within the top 20 percent of countries, rather than if their projected precipitation change is beyond a specific threshold, such as -20 percent,). Therefore, as noted above, the framework cannot be used to evaluate the absolute risk of any country, neither currently nor in the future. Quantification of absolute risk, while exceedingly important, is significantly more difficult than evaluating relative risk. Therefore, this framework cannot be used to indicate which countries will or will not require assistance based on an absolute risk threshold. However, within SSA this is not a significant issue as it is generally agreed that all countries will require some level of support.

Finally, the framework presented herein was restricted to sectors for which the links between climate and risk are relatively robust. While the opportunity to explore the utility of the framework in comparing risks across other sectors, such as health and biodiversity, remains, the framework may be difficult to generalize to other sectors, such as transportation, where the links between climate risk are less robust or are complex. In these sectors it would be even more difficult to capture potential climate impact with a few proxy indicators.

However, many of these limitations and challenges plague most other prioritizations efforts and will be difficult to resolve given the complex nature of climate risk and the dearth of data and proxy indicators. Therefore, we believe this, framework still serves its purpose of stimulating discussion associated with which countries may be most likely to benefit from adaptation funding, and what types of interventions might be most productive for a given country and sector.

5. Conclusions

In a resource constrained world and given the large (and growing) development deficits in many SSA countries, identifying where to prioritize limited climate change adaptation funds is a challenging, but necessary, task for development practitioners. This is complicated by the fact that dedicated climate change funds and activities are likely to be less successful in countries where large non-climate barriers (e.g., weak governance, corruption) to development exist, even as those countries may be highly vulnerable to climate change. This suggests that a framework based purely on climate adaptation needs would likely miss importance considerations. Here a structured, evidence-based framework was developed to support evaluation of the relative importance of climate risk as compared to other barriers to development. This framework incorporates some important aspects from similar previous efforts, but frames the output somewhat differently. Instead of offering a prescriptive number or qualification, the framework is designed to provide visualizations that stimulate discussions; discussions in which the relative importance of climate and non-climate risks is likely to be only one component. Furthermore, this framework expands beyond what previous frameworks have done by explicitly including uncertainty in the evaluation and visualization of climate risk. While currently limited to SSA and a few selected sectors, this new framework offers insights for using the available evidence base to prioritize allocation of limited funds dedicated to adaptation.

Acknowledgement

This analysis was conducted by the Adaptation, Thought Leadership and Assessments (ATLAS) Project, funded by the United States Agency for International Development (USAID). The contents of this report are the sole responsibility of the author or authors and do not necessarily reflect the views of USAID or the United States government

References

Adenle, A.A., Ford, J.D., Morton, J., Twomlow, S., Alverson, K., Cattaneo, A., … Ebinger, J.O. (2017), "Managing Climate Change Risks in Africa - A Global Perspective", *Ecological Economics*, Vol. 141, pp. 190–201.

Adger, W.N., Huq, S., Brown, K., Conway, D. and Hulme, M. (2003), "Adaptation to climate change in the developing world", *Progress in Development Studies*, Vol. 3 No. 3, pp. 179–195.

Ahmed, S.A., Diffenbaugh, N.S. and Hertel, T.W. (2009), "Climate Volatility deepens poverty vulnerability in developing countries", *Environmental Research Letters*, Vol. 4 No. 3, pp. 034004.

Ayers, J.M. and Huq, S. (2009), "Supporting Adaptation to Climate Change: What Role for Official Development Assistance?", *Development Policy Review*, Vol. 27 No. 6, pp. 675–692.

Barrett, S. (2014), "Subnational climate justice? Adaptation finance distribution and climate vulnerability", *World Development*, Vol. 58, pp. 130–142.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M. and Yanda, P.Z. (2007), *Africa*, Retrieved from https://cgspace.cgiar.org/handle/10568/17019

Conway, D. and Schipper, E.L.F. (2011), "Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia", *Global Environmental Change*, Vol. 21 No. 1, pp. 227–237.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B. and Twomlow, S. (2008), "Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change?", *International Agricultural Research and Climate Change: A Focus on Tropical Systems*, Vol. 126 No. 1, pp. 24–35.

Douglas, I., Alam, K., Maghenda, M., Mcdonnell, Y., McLean, L. and Campbell, J. (2008), "Unjust waters: climate change, flooding and the urban poor in Africa", *Environment and Urbanization*, Vol. 20 No.1, pp. 187–205.

Downing, T.E., Ringius, L., Hulme, M. and Waughray, D. (1997), "Adapting to climate change in Africa", *Mitigation and Adaptation Strategies for Global Change*, Vol. 2 No.1, pp. 19–44.

Fankhauser, S. and Burton, I. (2011), "Spending adaptation money wisely", *Climate Policy*, Vol. 11 No. 3, pp. 1037–1049.

Ficklin, L., Wood, B.T., Dougill, A.J., Sallu, S.M. and Stringer, L.C. (2017), Reconsidering climate compatible development as a new development landscape in Southern Africa. In, Nunan, F. (Ed.), *Making climate compatible development happen*, Routledge, London and New York, pp. 44–65.

Grindle, M.S. (2004), "Good enough governance: poverty reduction and reform in developing countries", *Governance*, Vol. 17 No. 4, pp. 525–548.

Handoyo, S. (2018), "The Relationship of Good Public Governance and Easy of Doing Business Performance: An Exploratory Study", *Sustainable Collaboration in Business, Technology, Information and Innovation (SCBTII)*, Vol. 1 No. 1.

Heyer, J. (1996), "The complexities of rural poverty in sub-Saharan Africa", *Oxford Development Studies*, Vol. 24 No. 3, pp. 281–297.

Huang, I.B., Keisler, J. and Linkov, I. (2011), "Multi-criteria decision analysis in environmental sciences: ten years of applications and trends", *Science of the Total Environment*, Vol. 409 No. 19, pp. 3578–3594.

Linkov, I., Satterstrom, F.K., Kiker, G., Batchelor, C., Bridges, T. and Ferguson, E. (2006), "From comparative risk assessment to multi-criteria decision analysis and adaptive management: Recent developments and applications", *Environment International*, Vol. 32 No. 8, pp. 1072–1093.

Lo, A.Y. and Chow, A.T. (2015), "The relationship between climate change concern and national wealth", *Climatic Change*, Vol. 131 No. 2, pp. 335–348.

McCarthy, N., Lipper, L. and Zilberman, D. (2018), Economics of Climate Smart Agriculture: An Overview, In Zilberman, D., Goetz, R. and Garrido, A. (Eds.), *Climate Smart Agriculture* Vol. 52, pp. 31–47). Springer, Rome, Italy.

McMullen, J.S., Bagby, D. and Palich, L.E. (2008), "Economic freedom and the motivation to engage in entrepreneurial action", *Entrepreneurship Theory and Practice*, Vol. 32 No. 5, pp. 875–895.

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel, A., Lennard, C., Padgham, J. and Urquhart, P. (2014), Africa. In, *IPCC Fifth Assessment Report*, Geneva, Switzerland, pp. 1199–1265.

O'Brien, K.L. and Leichenko, R.M. (2000), "Double exposure: assessing the impacts of climate change within the context of economic globalization", *Global Environmental Change*, Vol. 10 No. 3, pp. 221–232.

Olhoff, A. and Schaer, C. (2010), Screening tools and guidelines to support the mainstreaming of climate change adaptation into development assistance-a stocktaking report. *Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance-a Stocktaking Report,* United Nations Development Program, New York, NY., pp. 46.

Parker, A.N. (1995), *Decentralization: the way forward for rural development?* (Vol... 1475), World Bank Publications, Washington, D.C.

Persson, A. and Remling, E. (2014), "Equity and efficiency in adaptation finance: Initial experiences of the adaptation fund", *Climate Policy*, Vol 14 No. 4, pp. 488–506.

Petersen, B., Aslan, C., Stuart, D. and Beier, P. (2018), "Incorporating Social and Ecological Adaptive Capacity into Vulnerability Assessments and Management Decisions for Biodiversity Conservation", *BioScience,* Vol. 68 No. 5, pp. 371–380.

Rogers, P. and Hall, A.W. (2003), *Effective water governance*, TEC background papers, No. 7, Global water partnership, Stockholm, Sweden.

Rutherford, D., Meagher, P., Lanyi, A., Kahkonen, S. and Azfar, O. (2018), Decentralization, Governance and Public Services: The Impact of Institutional Arrangements. In *DeVolution and Development: Governance Prospects in Decentralizing States*, Routledge, New York, NY, pp. 45–88.

Shardul, A. and Samuel, F. (2008), *Economic aspects of adaptation to climate change costs, benefits and policy instruments: costs, benefits and policy instruments*. OECD Publishing, Paris, France.

Shaw, T.M. (2009), "African Development: making sense of the issues and actors", *The Journal of Modern African Studies*, Vol. 47 No. 3, pp. 480–481.

Sherman, M., Berrang-Ford, L., Lwasa, S., Ford, J., Namanya, D.B. and Llanos-Cuentas, A. (2016), "Drawing the line between adaptation and development: a systematic literature review of planned adaptation in developing countries", *Wiley Interdisciplinary Reviews: Climate Change*, Vol. 7 No. 5, pp. 707–726.

Shubik, M. (2018), *Who Gets What, When, How? Power, Organization, Markets, Money and the Allocation of Resources*. Cowles Foundation Discussion Paper No. 2118, January 16, 2018, Cowles Foundation for Research in Economics Yale University, New Haven, CT.