ANNEX 1

MINISTRY OF FOREIGN AFFAIRS
OF DENMARK
Danida

NURI
Danida

Climate Risks and Vulnerability in Northern Uganda

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A Rapid Desk Assessment

Consultancy report
(contract DC F2 2022-7576)
Reint J Bakema
March 2022

Table of Contents

* Front page photograph: A village savings and loans association in session in Northern Uganda in 2015

This document was prepared by Reint Bakema under a contract with the Embassy of Denmark in Uganda. The contents is the sole responsibility of the author and does not necessarily reflect the views of the Government of Denmark or Danida.

ABBREVIATIONS

AR	Assessment Report (of the IPCC)
CC	Climate Change
CE	Climate Envelope
CRVA	Climate Risk and Vulnerability Assessment
CF	Coordination Function (of NURI)
CSA	Climate Smart Agriculture
DKK	Danish Kroner
DRA	Disaster Risk Assessment
DRM	Disaster Risk Management
EoD	Embassy of Denmark
GHG	Greenhouse Gasses
HH	Household
IFAD	International Fund for Agriculture Development
IPCC	Intergovernmental Panel on Climate Change
IOD	Indian Ocean Dipole
MAM	March- April - May rainy season
NbS	Nature-based Solutions
NURI	Northern Uganda Resilience Initiative
OECD-DAC	Organisation for Economic Co-operation and Development- Development Assistance Committee
OND	October-November-December rainy season
RAU	Resilience Agriculture Units
RCP	Representative Concentration Pathway
RI	Rural Infrastructure
SSP	Shared Socioeconomic Pathway
UNCDF	United Nations Capital Development Fund
VSLA	Village Savings and Loans Association
WRM	Water Resources Management

INTRODUCTION

The assignment

The report is made under contract DC F2 2022-7576 with the Embassy of Denmark (EoD) in Uganda, running from 1 February to 31 December 2022. As per the Terms of Reference for this specific task, it contains a rapid desk assessment that sets out the context, climate risks, vulnerabilities and impacts related to climate variability and climate change in the operational area of the Northern Uganda Resilience Initiative (NURI). The broader objective of the contract is to incorporate climate adaption and sustainability interventions in the NURI results framework and interventions for the remaining implementation period, up to December 2023. The combined outcome of the contract would qualify NURI for a principal score under the OECD-DAC Rio climate change adaptation marker[1] scoring system.

The contract deliverables are: 1) facilitate a brainstorming workshop on the extension of NURI; 2) execute a rapid assessment of climate change risks in Northern Uganda; 3) incorporate corresponding adaptation strategies and actions in the NURI results framework; 4) support the drafting of the NURI extension note for the Ministry of Foreign Affairs of Denmark. Optionally, the consultant may be involved in further support to NURI in terms of the implementation of climate adaptation and sustainability interventions.

This report is the second deliverable under the contract. It was submitted to the Embassy of Denmark on 10 March 2022.

Background to NURI

NURI is a five-year (2018-22) rural development project funded by the Danish Government. Its current budget is DKK 325 million. It is part of the larger Danish Upside programme in Uganda, consuming 50.4% of its budget. NURI is managed by a Coordination Function (CF), headed by a Danida Programme Management Adviser and Financial Management Adviser, supported by local programme officers, mostly placed in the beneficiary areas. NURI's activities are partly funded from the Danish Climate Envelope (CE), which contributions are fully integrated into the NURI work plan.

The Strategic Objective of NURI is '*resilience and equitable economic development in supported areas of Northern Uganda, including for refugees and refugee-hosting communities, enhanced*'.

NURI intends to achieve this objective through three Outputs[2]:

1. Climate-smart Agriculture (CSA): Increased agricultural output of small-scale farmers;
2. Rural Infrastructure (RI): Agriculture related rural infrastructure renovated / constructed using a labour-intensive approach;
3. Water Resource Management (WRM): Climate change resilience improved through agriculture related physical & natural water infrastructure.

The beneficiary districts are: Arua, Koboko, Moyo/Obongi, Adjumani, Nebbi, Pakwach, Terego and Zombo in the West-Nile region, and Kitgum, Lamwo and Agago in the Acholi region (Annex 1). The aim of NURI is to reach 120,000 farming households under Output 1 through 4,388 farmer groups. About 75% of these households are also benefiting from VSLA support. 28% are expected to be from the refugee community. Under Output 2, 1,800 groups (54,000 HHs) are intended to be reached, of which about 30% are expected to be refugees. Eight communities at micro-catchment level will participate in the programme under Output 3. Some of these will be in refugee hosting areas.[3]

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[1] OECD DAC Markers for Climate Change: Handbook;

[2] There are some minor differences in the formulation of the Outputs between the Project Document and the latest NURI progress report. The formulation of the progress report is used

[3] NURI Project document, 2017. The exact targets were to be set during the base-line survey at the start of the programme.

NURI's Theory of Change (Annex 2) works as follows: Activities in support of agriculture focus on improving host and refugee farmers knowledge on climate-smart agriculture production methods, as well as their understanding of and ability to engage with markets and services. Support to rural infrastructure, in particular community access road and markets, leads to better market opportunities, linkages and access to services. NURI's support to water infrastructure and water resource management enhances the availability of water, and reduces the impact of extreme weather events and environmental degradation. Ultimately, the combined impact of the three components will increase HH income and food security for host and refugee farmers.

Adaptation to climate change (CC) and variability has been part of NURI from the outset, and was underpinned in the programme design, in particular by the focus on CSA, the establishment of Resilience Agriculture Units (RAU), and broadly in the inclusion of WRM in its own right as Output 3.

Under Output 1, CSA interventions include at crop level the promotion of intercropping, drought tolerant and early maturing crop varieties and exploring the viability of small-scale irrigation. At farm level, NURI promotes diversification of farm enterprises and off-farm income, and soil and water conservation measures. At institutional level, the programme focuses on further strengthening of CSA knowledge of extension staff, and active exposure to local and international research and new developments. In addition, NURI intends to forge strong links between the CSA and WRM interventions, for example by linking micro-catchment plans to agricultural production. While under Output 2, RI, climate considerations were not explicitly mentioned in the project document, a resilient design approach for RI was adopted in the course of 2020, to cater for, amongst others, persistence and heavy downpours as a result of climate change, and giving opportunities to make linkages with CSA.

Following the recommendations of the mid-term review of the Danish Country Programme in 2021, the EoD decided to extend the implementation period of NURI until December 2023, and add 26m DKK to its budget from the Danish CE. According to the rules of the CE as well as the Danish Ministry, climate focus should be in line with the OECD DAC Rio Marker Handbook. Moreover, the additional 26m DKK from the CE for NURI should be geared towards interventions that enhance adaptation to climate change and variability. This rapid desk assessment of climate change in Northern Uganda, is to inform the design of additional interventions and update the results framework of NURI.

Facts and Trends in Climate Change

Global facts and trends

The first statement (A1) in the 6th Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) is: 'It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred[4].' Since the assessment period for the previous IPCC report (2003-2012), global temperatures have increased by 0.19^{0}C, and since the period 1850-1900 by a best estimate of 1.07^{0}C. AR6 also mentions that the global average precipitation over land has *likely* increased since 1950, with a faster rate of increase since the 1980s. World-wide, CC has caused an increase in hot-extremes, heavy precipitation and agricultural and ecological droughts. The hot-extremes are well documented for East Africa, the changes in precipitation and agricultural droughts are as yet less clear for the region[5].

There is very broad scientific consensus that CC is primarily driven by human influence, and in particular by Greenhouse Gas (GHG) emissions. Since 2011, GHG concentrations in the atmosphere have continued to increase, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO_2) alone, a

[4] Masson-Delmotte et al., (eds.) (2021), Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis.
[5] Ibid; see for example page 10

concentration higher than at any time in at least the last 2 million years[6]. There is a near linear relationship between GHG emissions and global warming. Therefore, future changes in the global temperature and climate depend to a large extent on the level of future GHG emissions.

To describe the impact of future GHG emissions, climate scientists developed four Representative Concentration Pathways (RCPs) with numeric codes (2.6, 4.5, 6.0 and 8.5) representing from low to high increasing radiation energy per square meter. More recently, models have been developed that capture how socioeconomic factors, such as technological development, population, economic growth, education and urbanisation may influence CC over the current century. These "Shared Socioeconomic Pathways" (SSPs) look at five different ways in which the world might evolve in the absence of climate policy and how different levels of climate change mitigation could be achieved when the mitigation targets of RCPs are combined with the SSPs. While the AR6 uses SSPs to describe possible future climatic developments, the current literature for Uganda is using the RCPs in their modelling of impacts.

Table 1: The 5 SSP scenarios [7]

- SSP1-1.9: a world of sustainability-focused growth and equality;
- SSP2-2.6: a "middle of the road" world where trends broadly follow their historical patterns;
- SSP3-4.5: a fragmented world of "resurgent nationalism";
- SSP4-7.0: a world of ever-increasing inequality;
- SSP5-8.5: a world of rapid and unconstrained growth in economic output and energy use.

Under all scenarios, global surface temperature will continue to rise until at least mid-century. Up to 2040, the best estimate of a global temperature increase is 1.5-1.6^{0}C for all SSPs, whereas the estimated range runs from 1.2 to 1.7^{0}C for SSP1 and 1.3 to 1.9^{0}C for SSP5. In the period 2040-2100, the SSP temperature scenarios start to divert considerably, stabilising to slightly dropping off under SSP1, and doubling to tripling under SSP5. With every additional increment of global warming, changes in extremes - for example the frequency and intensity of heat waves, heavy precipitation and agricultural droughts - continue to become larger and more variable [9].

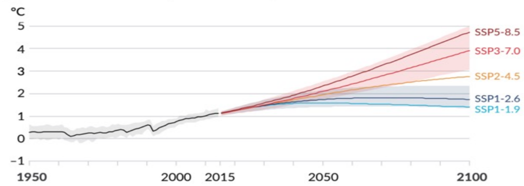

Figure 1: Global surface temperature change relative to 1850-1900[8]

Given the near certainty of the sustained global warming effect of historic GHG emissions for the next few decades, adaptation strategies, alongside GHG emission reduction and removal strategies, have become imperative to cater for its negative impacts.

Trends in Uganda

In Eastern Africa, CC is manifested so far primarily by the occurrence of higher temperatures and hot extremes, while there is limited data and agreement on changes in other CC phenomena, such as increased or more intense precipitation and agricultural and ecological drought.

Trends in temperature

The average temperature in Uganda has increased by 1.3^{0}C since the 1960s, or by 0.28^{0}C per decade. Notably, minimum temperatures have increased 0.5–1.2°C for this period, while maximum temperatures increased by 0.6–0.9^{0}C. Temperature observations since 1960 show significantly increasing trends in the frequency of the number of hot days, and much larger increased trends in the frequency of hot nights[10].

[6] Other important GHGs are CH_4 and N_2O, which atmospheric levels are higher than any time in the past 800,000 years
[7] https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change (5/03/2022)
[8] Ibid, 2; page 22
[9] Ibid, 2; B.2.2, B.3.1 and B.3.2
[10] The World Bank Group (2020); Climate Risk Profile: Uganda

In the medium future, the mean annual temperature is projected to increase by between 1.0 (RCP2.6) and 3.1°C (RCP8.5) by the 2060s, and between 1.4 (RCP2.6) and 4.9°C (RCP8.5) by the 2090s[11]. Warming is likely to be greatest during the period June to August[12][13]. The temperature projections follow the global trend and are labelled 'near-certainty' for the next 2 decades under all RCPs.

Alongside the general rise in temperature, the number of very hot days (T_{max}>35^{0}C) is likely to increase, and the number of hot nights (T_{max}>26^{0}C) even more quickly. Under the medium/high emissions scenario RCP6.0, 13 more very hot days are projected per year in 2030 than in 2000, 26 more in 2050 and 39 more in 2080. In Northern Uganda, this amounts to about 150 very hot days per year by 2080[14]. This will have significant implications for human and animal health, agriculture and ecosystems.

On average, around 10% of the Ugandan population is expected to experience water scarcity in any given year, and that number can be substantially higher in a dry year[15]. Drought conditions in 2010 and 2011 caused an estimated loss and damage value of $1.2 billion, equivalent to 7.5% of Uganda's 2010 gross domestic product. Projected changing rainfall patterns and quantities, compounded by increasing heat conditions, are likely to exacerbate water scarcity situations.

Trends in rainfall

Precipitation in eastern Africa shows a high degree of temporal and spatial variability, caused by a diverse topography and a variety of interrelated climatic processes. In addition, different studies show different outcomes with respect to historic rainfall trends, with some claiming no robust and significant change during the last 60 years[16], while others mention a statistically significant reduction in annual as well as seasonal rainfall over the last decades.

Nevertheless, there seems to be consensus about a reduction in rainfall during the long rainy season (March-April-May - MAM), with some authors reporting decreases of 6.0 mm per month, per decade[17]. Decline in rainfall has been observed in some Northern districts: Gulu, Kitgum, and Kotido. While trends in extreme rainfall conditions are more difficult to define due to the lack of data and seasonal variability, droughts have increased in Uganda over the past 60 years. Specifically, over the past 20 years, western, northern and north-eastern regions have experienced more frequent and longer-lasting drought conditions[18].

For the medium-term future, the overall trend in rainfall emerging from different CC assessment reports varies from an 6% reduction[19] to a small increase in rainfall across the East African region[20]. Also, a shift is predicted in the rainy seasons due to a warming of the Indian Ocean and more frequent positive Indian Ocean Dipoles (IOD). Generally, positive IODs cause a decrease in rainfall during the MAM season[21], and more intense rainfall and an increased risk of flooding over central Kenya and Uganda during the October-November-December (OND) rains. The OND rains may be extended into January and February and the onset of the MAM season may be delayed[22]. This seasonal shift could have strong impacts on

[11] ACCRA (?); Climate trends in Uganda, the National Picture
[12] https://www.adaptation-undp.org/explore/africa (accessed 8 March 2022)
[13] The World Bank Group (2020); Climate Risk Profile: Uganda
[14] Tomalka J. et al. (2021?) Climate Risk Profile: Uganda; GIZ GmbH
[15] The World Bank Group (2019); Disaster Risk Profile Uganda Africa Disaster Risk Financing Initiative
[16] Caffrey P. et al., 2013: Uganda Climate Vulnerability Assessment Report; USAID (ARCC)
[17] Hunter, R. et al., 2020. Research Highlights – Climate Change and Future Crop Suitability in Uganda. University of Cape Town
[18] Ibid, Climate Risk Profile Uganda (2020)
[19] Ibid, Hunter et al.
[20] Ibid, Caffrey et al.
[21] Niang, I et al., 2014: Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects.
[22] Ibid; Hunter et al.

agriculture, especially with respect to tree crops (e.g., coffee) and post-harvest activities such as drying and storage[23].

Some longer-term projections show that at the end of the 21st century there will be a wetter climate specifically along the northern coastline of Lake Victoria, with more intense wet seasons and less severe droughts during OND and MAM. This increase is likely to be accompanied by greater seasonal variation in rainfall patterns, a possible increase in the occurrence of intense precipitation events, and an increased frequency of drought. In addition, under a high-emission scenario (RCP8.5), annual precipitation is expected to decrease, notably in the northern and north-eastern areas[24].

The frequency of extreme events can increase as hydrological cycles intensify due to increased vapour holding capacity of a warmer atmosphere. Under RCP6.0, median climate model projections show an increase in the number of days with heavy precipitation from 8 in the year 2000 to 10 in the year 2080. Under RCP2.6, the number of days with heavy precipitation is projected not to change[25].

Climate Risks and Vulnerability in Uganda

Uganda has contributed minimally to the build up of human-derived GHG emissions, and yet out of 182 countries it ranks 10th in terms of vulnerability to CC.

In the past 4 decades, floods accounted for most natural disasters, with both flash floods and slow-onset floods very common in urban areas, low-lying areas and along riverbanks and swamplands (Figure 2).

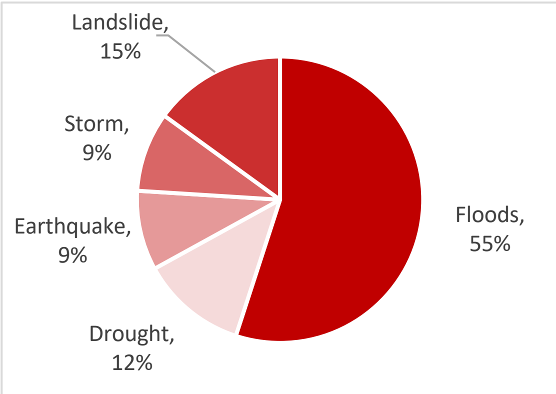

Figure 2: prevalence of disasters (1985-2021)[26]

According to the Ministry of Water and Environment, disasters such as floods and landslides are caused by more *intense* rainfall. Eight out of the 10 most severe floods and droughts in terms of numbers affected since 1900 have occurred during the last 20 years[27]. The impact of heavy rainfall has led to more deaths and damage due to expanded infrastructure, degradation of wetlands, and the gradual expansion of human settlements on steep slopes, especially in the Mount Elgon region. Each year, floods impact nearly 50,000 people and costs over $62 million. In urban areas flood damage buildings and cause loss of life because of rapid and unplanned developments and weak enforcement of zoning and building codes. Droughts, on the other hand have affected the largest number of people in the last few decades. The 2016/17 drought on its own impacted on more than 1 million persons, and caused a significant economic growth slowdown for several years.

Disaster risks, whether caused by CC or not, are estimated by the chance of a hazard occurring, the presence of people and assets that are potentially exposed to the hazard, and their vulnerability to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and the (lack of) capacity to cope and adapt[28].

In the context of CC, climate risks are primarily driven by change in temperatures (mean temperature and number of heat days), precipitation (amount and distribution) and extreme weather (heat waves, downpours and storms) events. The Climate Risk and Vulnerability Assessment of UNCDF[29], released in

[23] Ibid, Caffrey et al.
[24] Ibid, 4, Climate Risk Profile, Uganda (2020)
[25] Ibid, 4; Tomalka et al.
[26] International Monetary Fund (2022); Uganda: selected issues
[27] Ministry of Agriculture, Animal Industries and Fisheries (2018); Uganda National Adaptation Plan for the Agriculture Sector
[28] UNCDF (2021); Climate Risk and Vulnerability Assessment; Local Climate Adaptive Living Facility
[29] Ibid

November 2021, disaggregates drought and flood hazards to district level, and overlays it with a vulnerability assessment based on sensitivity and adaptation capacity.

The indicators used for determining adaption capacity are considered the same for droughts and floods, and include, for example, access to health infrastructure, and various poverty metrics. For many of these indicators Northern Uganda scores moderate to low as compared to most other regions, apart from Karamoja (Figure 3). IFAD[31] followed a slightly different definition of adaptive capacity for the four main regions in Uganda, based on education level, access to agricultural information and adoption of improved agricultural practices. Also in their analysis, Northern Uganda ranked by far the lowest of the four regions.

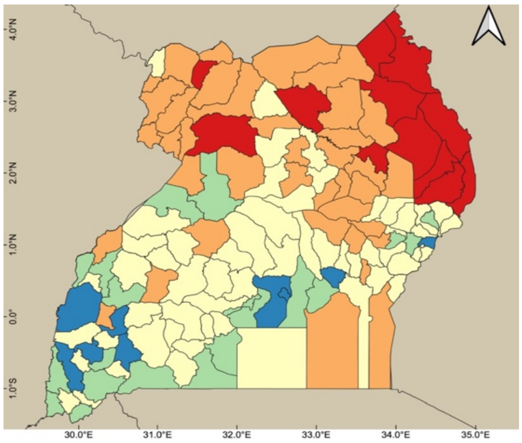

Figure 3: normalised adaptation capacity for drought and floods (very low (red) to very high (blue))[30]

Combining the analysis of hazards, sensitivity and adaptation capacity, IFAD produced a Risk Assessment for the medium (RCP4.5) and high (RCP8.5) CC scenarios. Medium-term projections of drought risks are shown in Figure 4. Under the RCP4.5 scenario, Uganda's entire northern half, but also parts of Central and South Uganda, face a significant drought risk in the future. For the longer term and more severe RCP scenarios (not shown), Northern Uganda's drought risk remains significant, apart from Zombo and Maracha districts, which remain classified as moderate. Climate change is also expected to increase the risk and intensity of flooding.

In the past four decades (1985-2021) floods accounted for most natural disasters, with both flash floods and slow-onset floods very common in urban areas. None of the district in Uganda falls in the severe flood risk category now and in the future (Figure 5), however, a number of districts increase their risk category to from moderate to significant by 2030. This is notably the case in some districts in West Nile, as well as in Central Uganda.

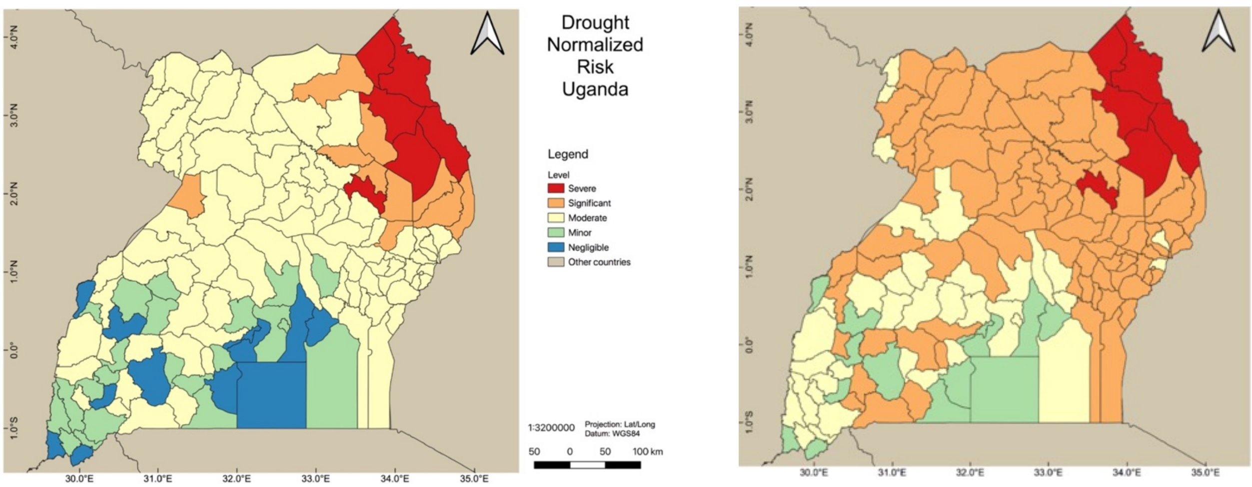

Figure 4: Current normalised drought risk (left) and the 2030-2039 drought risk under RCP4.5 (right)[32]

[30] Ibid

[31] Ibid, 4; Hunter et al.

[32] Ibid, 5; Climate Risk and Vulnerability Assessment (2021)

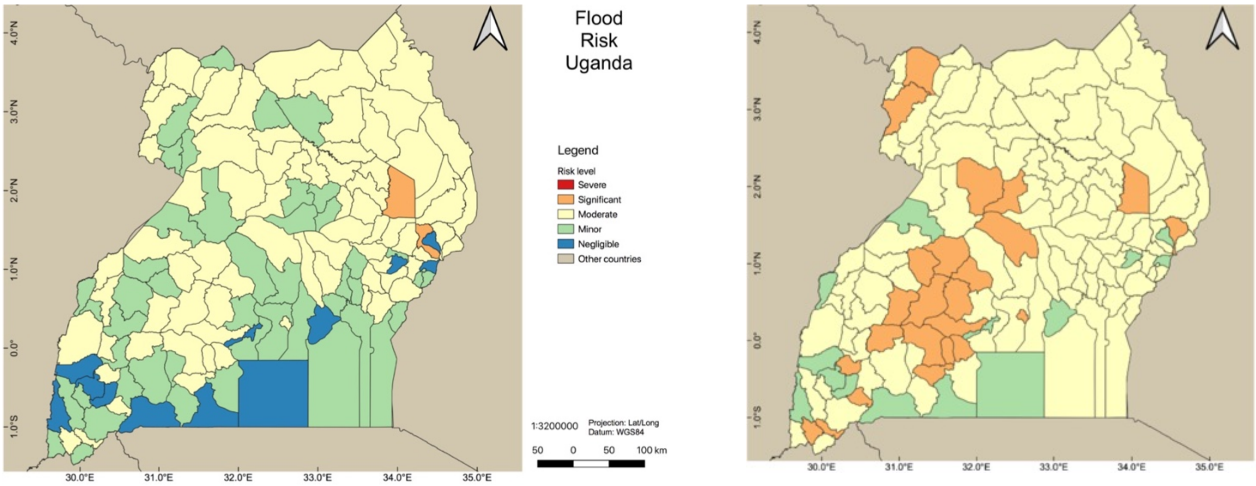

Figure 5: Current normalised flood risk (left) and 2030-2039 flood risk under RCP4.5 (right)[33]

Climate Change Impacts

Costs to the Economy

Droughts and floods often have persistent macroeconomic effects. The IMF estimates that across Africa droughts cause 0.3% GDP growth loss, and floods 0.4% in the year that they occur. But two years later, the impact is still seen, because of the wider economic and fiscal impacts the disaster has, such as lower tax revenue, disaster relief spending and rebuilding of damaged infrastructure[34].

Climate change is predicted to have a significant impact on Uganda. A study commissioned by the Climate and Development Knowledge Network (CDKN)[35] in 2015 shows that without any adaptive action, annual costs could be in the range of US$3.2 - 5.9 billion within a decade (that is by 2025), with the biggest impacts being on water, followed by energy, agriculture, and infrastructure. The economic impacts of climate change are closely interconnected with economic growth. Under a high-level growth path, the damages might reach 2-4% of GDP by 2050. Even if there were no further increases in climate impacts, the cost of inaction would rise over time because of an increase in population. Poor and vulnerable groups are mostly likely to be impacted through damages to their assets, livelihoods and their food security.

Table 2: The cost of inaction to CC to the agriculture and infrastructure sector 2010-2050 for two CC scenarios in million USD[36]

Year	2025		2050		Total	
Scenario	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
Agriculture						
Food Crops	157	313	750	1,500	12,000	23,000
Livestock	2	4	10	20	200	300
Export Crops	134	196	641	938	10,000	15,000
Total agriculture	293	513	1,401	2,458	22,200	38,300
Infrastructure						
Extreme event damage	34	429	234	3,236	3,610	48,369
Lost resilience	60	76	347	621	2,868	4,378
Total Infrastructure	94	505	581	3,857	6,478	52,747

Table 2 summarises the costs for agriculture and infrastructure in the face of inaction. For the agriculture sector, the largest impact is on food crops, which shows a wide range between the two CC scenarios, and

[33] Ibid, 5; Climate Risk and Vulnerability Assessment (2021)
[34] Ibid, 5; Uganda, selected issues.
[35] Ministry of Water and Environment (2015); Economic Assessment of the Impacts on Climate Change in Uganda
[36] Ibid, 6

a rapid increase after 2025. While losses as a percentage of GDP are not large, they are significant relative to the size of the sector. The impact on livestock is estimated to be rather small, but this may also reflect the lack of understanding on the response of livestock to CC. For the export crops, coffee, and in particular the arabica variety, will see the greatest losses. Given the vulnerability of the rural population, the implications of the losses for poverty and wellbeing are high[37]. For the infrastructure sector, the costs do not include the normal wear and tear on infrastructure because of CC, but only the cost of damage by extreme events and the costs of making infrastructure more resilient against climate impacts, and the additional maintenance costs to avoid future damage by the then prevailing climate.

Climate adaptation is not cheap. The CDKN report estimates the cost for Uganda over USD 100-150 million per year for the next 10 years, which is 3.2% of total government revenues. Of this, agriculture will consume around 12% and infrastructure 28%. While these are substantial amounts in relation to the Ugandan economy and revenues, the cost of inaction is estimated to be 26 to 46 times more[38]. Simulations show that investing in adaptation is cost-effective, if only because it reduces post-disaster relief and reconstruction funding. Financing in CC adaptation, also by the donor community, therefore makes perfect economic sense.

The remainder of this chapter focuses on the impact of climate change on NURI related interventions, i.e. agriculture and road and water infrastructure.

Agriculture

Risks

Africa's food production systems are among the world's most vulnerable because of extensive reliance on rainfed crop production, high intra- and inter-seasonal climate variability, recurrent droughts and floods that affect both crops and livestock, and persistent poverty that limits the capacity to adapt[39]. This general statement from the IPCC, applies directly to the operational area of NURI, and even more so than to most other areas in Uganda. It should, however, be realized that climate change in Africa will have an overall modest effect relative to other drivers of risks, such as population growth, urbanization, agricultural growth, and land use change[40]. For example, assuming a constant population, projections of future water availability show no change under RCP2.4 and an 18% reduction under RCP6.0. Yet, when accounting for Uganda's population growth, per capita water availability in Uganda will have reduced by 80% across all RCP scenarios by 2080[41]. CC adaptation measures need therefore be designed and executed together with measures to deal with non-climate related stressors.

Higher temperatures and droughts have multiple and compounding impacts on agricultural production systems. The manner in which a crop is affected by CC depends on its phenological characteristics. In rainfed smallholder agriculture, the optimal conditions for growth and production are rarely present throughout the crop's production cycle. Fortunately, most crops will still produce under suboptimal conditions. However, CC may aggravate these suboptimal conditions even further. Higher soil temperatures, for example, will cause higher soil moisture evaporation and aridity, and an accelerated breakdown of organic matter. This, in turn, will reduce the soil's water holding capacity, and make the topsoil vulnerable for erosion due to dust forming and water run-off during downpours. CC, therefore, potentially accelerates ongoing soil degradation, with a knock-on effect on crop yields.

Rising temperatures are also expected to increase suitable conditions for crop diseases and pest infestations such as blast and bacterial leaf blight in rice, aflatoxin in maize, fungal and viral diseases in

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[37] Ibid, 6
[38] Ibid, 6
[39] Ibid, 4; Niang et al.
[40] Ibid, 4; Niang et al.
[41] Ibid, 4; Tomalka et al.

banana and beans, and coffee rust in coffee trees, which may offset the increased production potential because of increased rainfall. Also, changing growing seasons, and in particular shorter grower seasons may alter the occurrence and distribution of pests and diseases[42].

Heavy downpours and flooding may damage property and infrastructure, and may result in water logging of crops, decreasing yields and increasing food insecurity. Furthermore, land degradation and soil erosion, exacerbated by recurrent floods and droughts, adversely impact agricultural production, further affecting the livelihoods of the smallholder farmers[43]. Various analyses show that the impact on agriculture because of extreme events, such as floods and droughts, is likely to be bigger than the general reduction in yields[44].

Caffrey (2013) analysed the vulnerability of eight important crops in Uganda to the impact of CC (Figure 6). Cassava and sweet potatoes showed the least vulnerability to higher temperatures and erratic rainfall patterns. However, while cassava and sweet potatoes tolerate CC relatively well, both crops are also highly vulnerable to pests and diseases. Little is known about the possible interaction between crop diseases and CC, but the increasing unpredictability of precipitation and extreme events could be a significant challenge to the production and preservation of planting materials during the dry season. Without access to clean planting material, these crops can become highly vulnerable[45].

Other important crops for Northern Uganda, such as sorghum and beans fall somewhere in the middle of the vulnerability scale, while arabica coffee, grown in Nebbi and Zombo, is most vulnerable. For coffee and other perennial / tree crops, an additional complication in adapting to CC is the long lead time and relatively high investments before they get into commercial production. For example, coffee takes 3-4 years to reach full production capacity, while commercial production forests take 15-20 years. Over such a period of time the climate may have changed, or better suited varieties may have become available, making the initial investment unviable.

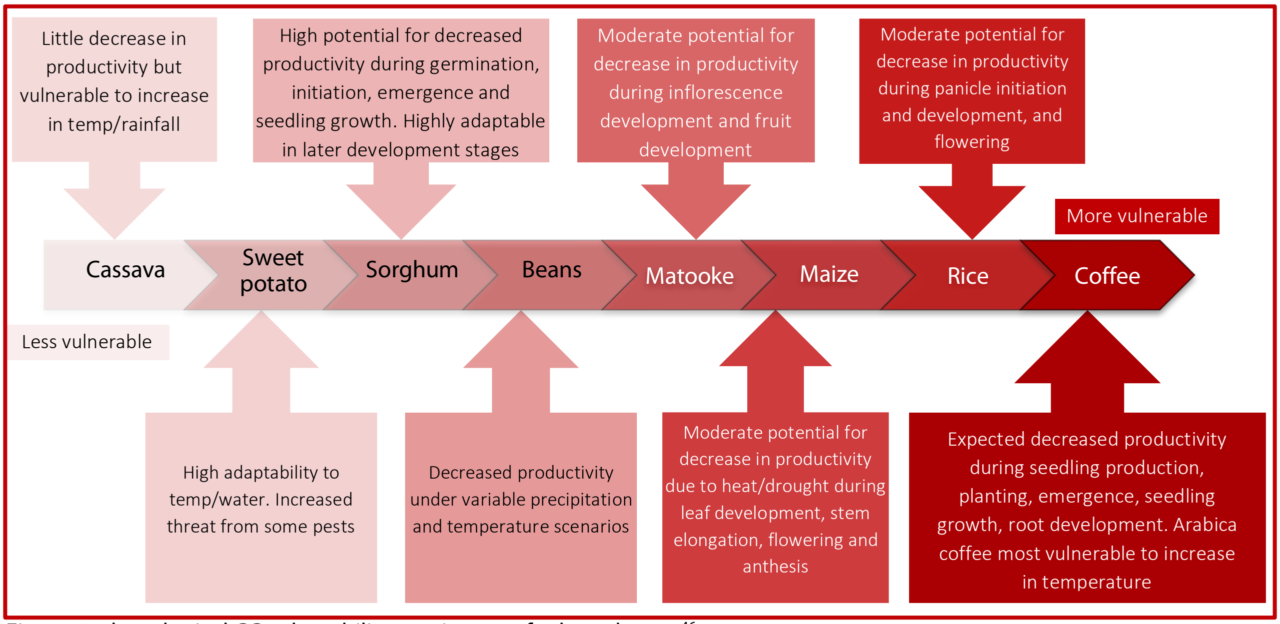

Figure 6: phenological CC vulnerability continuum of selected crops[46]

A quantitative approach in analysing the impact of CC on six selected crops was taken by IFAD (Table 3), using a crop suitability index generated by EcoCrop for the RCP8.5 scenario. The authors emphasized that

[42] Ibid, 4 Caffrey et al.
[43] Climate Risk Profile: Uganda (2020)
[44] Ibid, 6; Economic assessment of the impact of climate change in Uganda
[45] Ibid, 4; Caffrey et al.
[46] Ibid, 4; Caffrey et al.

the outcomes are indicative and are primarily meant to inform local decision making. Their findings show that beans, cassava and maize are predicted to experience moderate to severe decreases in production. For Northern Uganda, the predicted decrease in bean suitability is substantial and worrying, given the importance of beans in the local diet and its dietary value as a source of protein. The authors recommend to promote the adoption of a variety of bean cultivars and other legume species, such as cowpeas and groundnuts, which are expected to be relatively resilient to CC.

The reduced suitability of cassava in Northern Uganda, albeit small, is also worth noting. The estimated drop in production in Northern Uganda is being offset by increased suitability in other regions, resulting in a net positive production potential. Being an important food security crop, efforts should be geared towards providing better disease resistant varieties, and farmer training.

Table 3: changes in agricultural production (% and kg) and value (USD) of 6 crops due to CC in Northern Uganda and nationally (MT and USD)

Change	Northern Uganda				National	
	% / person	Kg / HH	USD / person	USD / HH	MT	USD
Beans	-23	-112	12.9	67	116,400	69.8
Cassava	-5%	-86	4	19	44,200	9.5m
Groundnuts		0% or minor +			-3,611	3.5m
Maize					-89,000	31m
Sesame		0% or minor +			3	?
Soybean		0% or minor +				

The various crop-level analyses seem to suggest that in the short to medium term CC will not have a major impact on Uganda's national food-security. However, at HH level smallholder farmers will be increasingly exposed to shifting seasons and less predictable weather, which is likely to increase the frequency of low yields or failing crops, and low crop production quality. Extreme events, such as heat waves, may particularly affect the livestock sector, and in particular beef and dairy cattle.

Adaptation strategies

During the last decade there has been a shift away from promoting technological solutions towards building resilience by offering a diverse range of adaptation options to the multiple livelihood-vulnerability risks[47]. For example, while irrigation is often mentioned as an option for smallholder farmers to deal with CC, for many in Northern Uganda this is probably not an immediate or viable solution to deal with multiple CC stressors. Access to sufficient quantities of water is limited and the cost of installing and managing even a small-scale irrigation system is for the, mostly, semi-subsistence farmers in Northern Uganda prohibitive. In some cases, the construction of small reservoirs, for example in combination with road drainage works, can help to foster diversification towards irrigated high-value horticultural crops, or to provide for drinking troughs for cattle. Such investments are more beneficial if they go hand in hand with improved access to inputs and markets.

Both Caffrey (2013)[48] and Niang (2014)[49] found that in the absence of affordable technological solutions, farmers are already designing their own coping strategies: by shifting planting dates, changing their crop varieties and crop mix, planting additional crops, and investing in livestock and fruit trees. HHs also look for short-term other sources of income outside agriculture, and for the longer term invest in the education of their children, or migrate off the farm. The greater the income diversity of a HH, the higher the ability to adapt to CC by managing a more diverse agricultural portfolio, planting more crops and investing more in livestock.

The lesson is that the most feasible short to medium-term coping strategy for smallholder farmers is to diversify the farming system and cropping pattern, and to take basic agronomic actions to cater for rising

[47] Ibid, 4: Niang et al.
[48] Ibid, 4; Caffrey et al.
[49] Ibid, 4: Niang et al.

temperatures and agricultural droughts. Intercropping, agroforestry, measures to capture (ridging, micro-catchments, run-off harvesting) and retain (mulching, minimum tillage, cover crops) moisture, improve soil fertility and reduce water run-off, the inclusion of shade trees (in coffee) and woodlots on the farm, should become an integral part of farmer training. In addition, proper post-harvest handling techniques and improved local storage systems, such as plastic or metal silos and triple-sealed plastic bags, are instrumental in supporting families during the lean period, to prevent the sale of assets to buy food when market prices are higher. Many of these are low-cost and simple low-regrets adaptation measures that reduce people's vulnerability to current climate variability, have multiple developmental benefits, and are well-positioned to reduce vulnerability to longer-term climate change as well[50].

Many of the above far-based practices have been increasingly promoted in various forms and various terminologies during the last decades: conservation agriculture, sustainable agriculture and, more recently, regenerative agriculture are all agricultural production approaches that intend and claim to deal with the negative effects of 'modern' industrial agriculture on soils, ecosystems, biodiversity, climate, dietary diversity, food security and farm income. More recently, the term Nature-based Solutions (NbS) is used as an umbrella concept to cover a range of ecosystem related approaches to protect, sustainably manage, and restore natural or modified ecosystems, such as agriculture production systems. In the context of NURI interventions NbS across the three NURI Outputs would possibly fall primarily in the managed production systems and artificial landscapes.

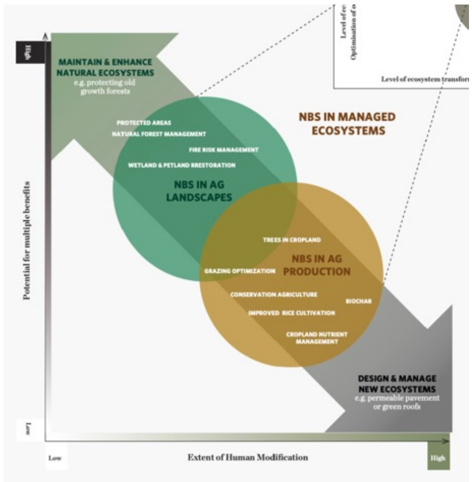

Figure 7: the spectrum of ecosystem conditions in which NbS can apply[51]

The NbS concept also shows that, in addition to farm-based solutions, climate actions often require a more holistic landscape approach, whereby communities are mobilised and trained to protect, restore and manage the commons, such as wetlands, forests and grazing lands for the benefit of all. In this wider context, NbS may provide a framework for action, in conjunction with other types of strategies, for example regional or watershed planning, policy making, or economic development, to achieve societal purposes[52]. Often this also requires stricter enforcement of environmental laws, especially for wetlands and water bodies, soil and water conservation measures, and investments in reforestation. Together, they will increase drought and floods resilience, enhance soil water holding properties, and contribute to emission reduction through carbon sequestering[53].

These measures require a reorientation of the extension service and farmers alike, with a greater emphasis on a farming systems and landscape approach rather than on individual crop production maximalisation. While such adaption strategies are location specific and implemented at farm or local level, the identification and dissemination of adaptation options, and promoting and enabling their adoption, requires a strong national effort[54]. In turn, this creates opportunities to enhance awareness amongst policy- and decision makers that maintaining ecosystem functions underpins human survival and development in a most fundamental way, and to motivate to think about new development paradigms and trajectories.

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[50] Ibid. 4: Niang et al.
[51] Iseman, T. and Miralles-Wilhelm, F. (2021). Nature-based solution in agriculture – The case and pathways for adoption
[52] Ibid
[53] Ibid, 6; Uganda, selected issues
[54] Ibid, 4; Caffrey et al.

Rural Infrastructure

CC induced flooding and droughts may have a significant impact on Uganda's infrastructure. Transport infrastructure is essential for social and economic development. Roads serve communities to access health, education and financial services and household goods, and to trade their agricultural produce. At the same time, roads and bridges are vulnerable to flooding and deteriorate quicker under high and fluctuating temperatures. Road design, including the design of community access roads, will need to take these potential stressors into consideration. This may lead initially to more expensive designs, but when assessing the costs over the entire life cycle of the road, the higher upfront costs may be offset by the lower annual costs of maintenance and repairs. Also, the economic costs of a road shut down as a result of a weather /climate hazard, in terms of disrupted supply chains and access to services, must be taken into consideration when evaluating road design options[55].

Table 4: impacts of CC on roads and possible adaptation measures[56]

Impacts of CC on roads	Possible adaptation measures
• Higher intensity heat waves make pavement soften and expand. • Heavy storms and flooding increase erosion, make the road impassable, increase maintenance costs, and reduce the life expectancy of the road	• Choose sites for new roads that are at lower risk of flooding • Design roads with increased drainage capacity; or, leave more room on the shoulder to increase drainage capacity later as needed • Choose materials that are less likely to be damaged by heat, or permeable pavement to reduce water pooling and flooding

Specifically, the road materials selected, and aspects of road design and improvement, will affect the sensitivity of the road and its users to climate variability and change. A thorough CC risk analysis helps to ensure the long-term viability of the road and its ability to provide services even during extreme weather events. Here, choices need to be made between 'soft path' and 'hard path' approaches, whereby softer, low-regret approaches, such as using wetlands for flood risk management vs dams and embankments, are often cheaper, easier to maintain with locally available resources, and more pro-poor[57].

At the same time, road construction should be done in such a way to minimize greenhouse gas emissions, for example by the efficient operations of equipment, and minimizing the removal of trees and bushes by climate-smart road routing. Limiting road access to undisturbed forest land and protected areas also helps maintain the benefits of natural ecosystems, including atmospheric carbon sequestration by trees and other natural cover[58]. Rural road construction could also contribute to carbon sequestering directly through incorporating grasses, trees and woodlots in embankments and road reserves.

Markets, HHs and farm infrastructures are also exposed to CC hazards. They may become vulnerable to storm damage, uncomfortable, or even dangerously hot during heat waves and very hot days. Improved designs would include optimal ventilation, adequate stormwater drainage and storage facilities, and climate-smart compound design to maximise shade, natural ground cover and windbreaks. Also, the location of the infrastructure in relation to potential future flood hazards must be carefully evaluated. Climate resilient designs need not only be incorporated in specifications and bill of quantities for contractors, but should also be incorporated in agriculture and health training programmes offered to rural households, extension staff, village health teams and local leaders and politicians.

[55] Cervingni, R. et al., (2017); Enhancing the Climate Resilience of Africa's Infrastructure: The Roads and Bridges Sector
[56] Rural Roads (2003 -partial update 2018); Sector Environmental Guidelines; USAID
[57] Ibid, 4: Niang et al.
[58] Ibid, 9; Rural Roads (2003 -partial update 2018)

Equity and Gender

Not all smallholder farming HHs are equally well positioned to deal with CC and adaptation. More vulnerable HHs are those with many of the following characteristics[59]:

- More likely to be headed by females;
- Lower proportion of able-bodied (working) members;
- Less well educated;
- Less likely to sell a portion of their crops or livestock;
- Less access to loans;
- Participate less frequently in community groups such as producer associations, cultural or labour savings groups, and religious organizations; and
- Earn income less frequently from off-farm sources (and when they do, that income is less than the amount that more secure households earn).

These characteristics are directly related to economic and social poverty, and such HHs will, naturally, be more risk adverse, have a smaller social network to fall back on when things get difficult, and have less money to invest in adaptation. They may also be the last to be informed about upcoming hazards, and the least informed about adaptation options. In Northern Uganda, this group may be particularly prevalent amongst refugees. The consequence is that special efforts are needed to include such HHs in the design and decision-making around CC adaptation, and that adaptation options must be sufficient diverse and flexible to cater for the variety of HHs and their capabilities to implement them.

The above list also shows that, although CC affects all smallholder farmers, it is not gender neutral. Apart from the first bullet, which is 100% gender related, most of the other characteristics also apply disproportionally to women. In addition, research has shown that women have different priorities and use different methods and strategies to adapt to climate change[60]. Moreover, there is increasing evidence that because rural women are more reliant on natural resources, they have both the knowledge and the desire to act as stewards of them and the environment[61]. Therefore, their inclusion in decision making processes at all levels is critical for effective climate action, and adaptation.

Special attention needs to be given to vulnerable HHs, be it refugees, female headed HHs, or poverty-stricken families. Their priorities are different and their options to adapt to CC are limited. This is not to say that they should just get a special status or treatment, but more importantly that they should be encouraged to actively participate in policy development and decision making. A diverse mix of different interest groups, women and men, old and young, rich and poor, under appropriate leadership is likely to come up with the best mix of adaptive innovations[62] for a specific location.

Lastly, smallholder farmers are not just victims of CC. They have longstanding traditional mechanisms of managing variability through, for example, crop and livelihood diversification, migration, and small-scale enterprises, all of which are underpinned by well-developed social networks, and indigenous knowledge systems[63]. These mechanisms should be recognised for what they are, and effectively used and enhanced as a first line of defence against the CC challenge.

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[59] Ibid, 4; Caffrey et al.
[60] https://gsdrc.org/topic-guides/gender/gender-and-climate-change/ (accessed on 9 March 2022)
[61] Bahous, S. S., and Adekemi Ndieli (2022); New Vision, 8 March 2022
[62] Ibid, 4; Caffrey et al.
[63] Ibid, 4: Niang et al.

Conclusions

Disaster Risks Assessments (DRA) and Climate Risk and Vulnerability Assessments (CRVA) are not in short supply for Uganda. Since the beginning of the previous decade, a wide range of ever more sophisticated assessments have been made, fed by ever more sophisticated climate models and comprehensive analyses. As a result, the level of certainty about the impact of CC on global and local temperatures, and to a lesser extent rainfall amounts and patters has increased substantially.

The Government of Uganda has been highly involved in and responsive to CC action as well. Uganda signed and ratified both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP) and signed and ratified the Paris Agreement thus committing itself to the adoption and implementation of policies and measures designed to mitigate climate change and adapt to its impacts.

A National Climate Change Policy was prepared in 2018 by the Climate Change Department of the Ministry of Water and Environment, and a comprehensive Risk and Vulnerability Atlas was produced under the responsibility of the Office of the Prime Minister. The Ministry of Agriculture, Animal Industries and Fisheries produced a National Adaptation Plan for the Agricultural Sector. This desk study intends to bring all these efforts these together, overlay them with global insights and lessons, and give them a Northern Uganda focus.

Not all CRVAs arrive at the same conclusions. There is a broad consensus about rising temperatures, up to or slightly over 1.5^{0}C in around 20 years from now, and up to 5^{0}C by the end of the century in the worst-case scenario. Also, the expected increase in hot and very hot days, and nights is very likely to happen. The trend in rainfall is less clear, with some documents reporting a drop of 6% and others a small increase in the next 3 decades. Two things, however, seems to be rather likely: a shift in seasons, with more and longer rains in the OND season stretching to December and January, and a shorter MAM season; and secondly more extreme rainfall events. In all the scenarios, Northern Uganda will become hotter, and less wet than the south of the country.

The impact of CC on smallholder agriculture in Northern Uganda is also not entirely clear. For some crops, such as coffee, beans and maize, the growing conditions will become less suitable, but the impact on the local oil crops, sorghum, millet and cassava is, according to most of the models, manageable. However, the uncertainty around some of these projections require that smallholder farmers are taking actions now to make their farms climate smart. Many of them are already doing so, but they need broad support in terms of information and advice to diversify their enterprises, and build more resilient farming and cropping systems. They also need access to climate proof varieties, suitable agroforestry and tree species, farm inputs, and finance.

To improve their adaptive capacity and resilience, smallholder farmers need to be encouraged to strengthen their asset base. Financial assets can be improved by encouraging saving and loans schemes, crop insurance and asset purchase programmes, for example for cattle or oxen. Their human capital is built through training programmes and access to information and knowledge. With modern ICT technology, this can be done more efficiently and permanently than ever before. This is in particular relevant for privatised agricultural advisory service provision, input supply and marketing. Social assets consist of social and business networks, such as family and community ties, market linkages and linkages with local and national policy makers and researchers, and through farmer groups, or local cooperatives. Such linkages are crucial to spread risks, move information up and down the decision-making chains, and to build resilience beyond the HH and farm.

Ecosystem and landscape-based approaches, as promoted by the Nature-based Solutions standard, and pro-poor integrated adaptation-mitigation initiatives hold promise for a more sustainable and systemoriented approach to adaptation, as does promoting equity goals, key for future resilience, through emphasizing gender aspects and highly vulnerable groups.

Implementing adaptation as a participatory learning process enables people to adopt a proactive or anticipatory stance to avoid "learning by shock". This is a time-consuming and costly process for development managers, and has its own challenges and set-backs. Information and communication technologies, including mobile phones, radio, and the internet, can play a role in facilitating participatory learning processes and helping to overcome some of these challenges.

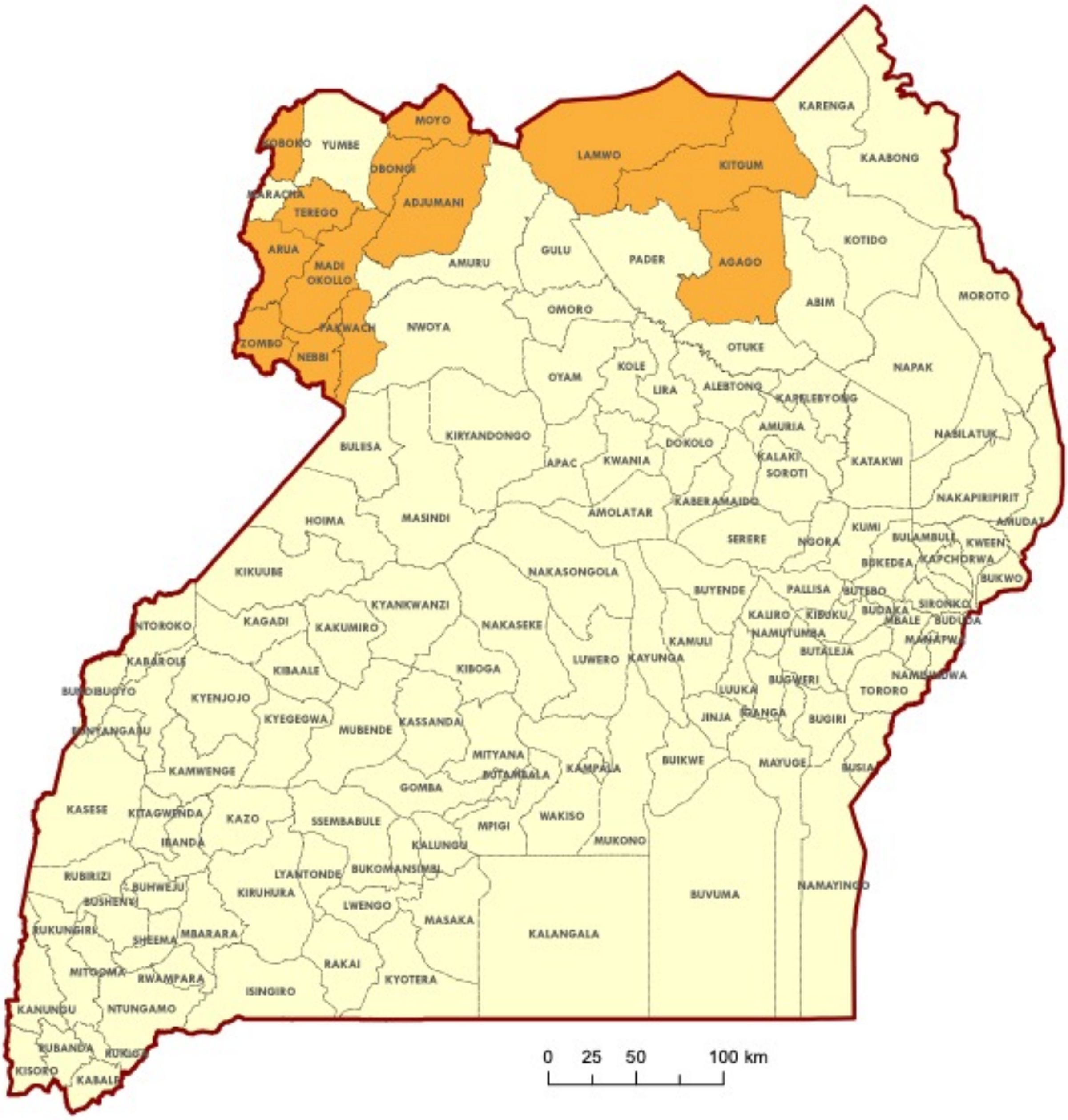
Niang et al. (2014) [64] identifies five common principles for adaptation and building adaptive capacity:

1. supporting autonomous adaptation through a policy that recognizes the multiple-stressor nature of vulnerable livelihoods;
2. increasing attention to the cultural, ethical, and rights considerations of adaptation by increasing the participation of women, youth, and poor and vulnerable people in adaptation policy and implementation;
3. combining "soft path" options and flexible and iterative learning approaches with technological and infrastructural approaches and blending scientific, local, and indigenous knowledge when developing adaptation strategies;
4. focusing on building resilience and implementing low-regrets adaptation with development synergies, in the face of future climate and socioeconomic uncertainties; and
5. building adaptive management and social and institutional learning into adaptation processes at all levels.

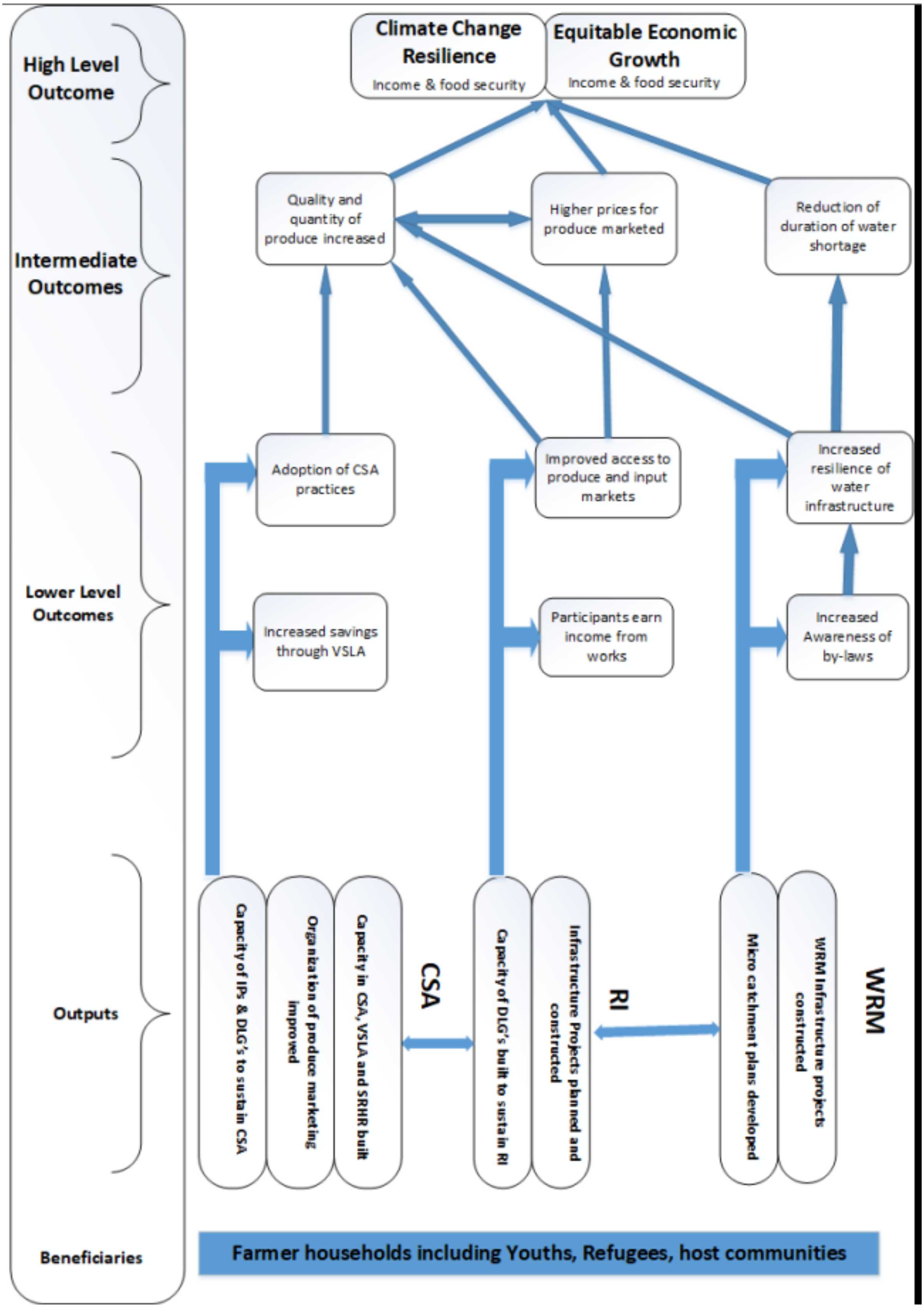
NURI is largely operating according to the principles and practices outlined above. For the remaining implementation period, mainstreaming these into the local policy- and decision-making organs, and within the beneficiary communities is critical to ensure that current benefit streams derived from the programme continue to flow beyond 2023.

[64] Ibid, 4; Niang et al.

Annex 1: Operational area of NURI



Annex 2: Theory of Change of NURI



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