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Socio-Economic Assessment of Value for Climate Services Case Study, Uganda and Kenya

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Abstract

The study re-affirmed that the economy of IGAD region as very vulnerable to climate change. The vulnerability of population to climate change is exacerbated by the structural issues that reinforces poverty, inequality and deprivation in the society, making the poor most impacted. Climate variability, ranging from unpredictable, intense and at times extreme weather events such as droughts, floods and landslides, are on the rise, and a likely trend for years ahead, threatening ecosystems and livelihoods at alarming rates. The region is experiencing increasing frequency and intensity of droughts and floods, putting the livelihoods of many at risks and also testing the legitimacy of national governments as custodian of social services for their citizens. Repeated failed weather inform of prolonged droughts are becoming a regional new normal, a trend that is worrying for poverty alleviation efforts of achieving the national social economic transformation such as ongoing 2030 Sustainable Development Agenda, working towards African Union (AU) agenda 2063, and could reverse the past gains across member states in elimination of hunger and poverty.

Kenya and Uganda targeted in this assessment, lose annually on average of US$56.96 million and US$ 113.86 million respectively to natural disasters related damages resulting from droughts, mudslides, and floods among others. In the coming century (2100), Kenya is projected to lose about 7.2% of its GDP (US$ 18.8 billion), while Uganda 6.3% of GDP (US$ 9.5 billions) annually to climate disasters. However, the provision of climate services inform of early warning and decision advisory in production system would significantly reduce the levels of these losses across all sectors. For examples:

<u>Economically</u>, improvements of climate services has been linked to: 1) Agricultural sector (avoidance of crop losses from unsuitable weather; timing of crop protection, planning and harvesting; increased farm production and scales; more efficient scheduling of the use of agricultural machinery, minimization of drought relief costs. In air transport (aviation), reduced fuel consumption through route planning, improved scheduling of flight arrival and departures; minimization of airline costs from aircraft diversions; minimization of search and rescue costs; reduction of accidents and emission; saving in passenger times, materials and working times (airport maintenance).

In marine transport (reduction of accidents and environmental damages, fuel savings, more efficient rescue operations). In oil prospecting (avoidance of unnecessary shutdown of offshore oil and gas operations; more efficient planning of energy production and diversity). In energy sector (Prediction of power demands, power failure reduction, savings in material and working times (maintenance), energy savings). In construction sector (potential to eliminate serious construction problems a priori (risk control system). In flood/humanitarian protection (savings in human lives and property, more efficient rescue operations.

<u>Socially</u>: protection of life and property through avoidance of loss of life and property from natural disasters. In research, improved information and data to the scientific community. Leisure: Contribution to the day-to-day safety, comfort, enjoyment and general convenience of citizens, including recreation, travel/ commuting and other direct and indirect forms of societal benefits.

<u>Environmentally</u>: In terms of air quality monitoring and warnings; Reducing adverse health impacts; saving human lives in possible environmental accidents (evacuations); minimization of release of toxic substances and other pollutants; management of local environmental quality.

The World Bank estimates that upgrading climate services e.g. hydromet development could reduce the levels of disaster losses by about 10% for low-income countries, such as Uganda; a 20% reduction in lower middle income (e.g. Kenya), 50% in upper middle income, and 100% in high income (OECD) countries.

Across all the models applied in these estimations i.e. the 'Benefit Transfers' and 'Avoided loss' methods, the provision of climate services have all yielded positive results in both short and long term in climate change adaptation and mitigation efforts across these economies.

In a short and medium run, Uganda is capable of avoiding an estimated US$11.39 million per year to economic losses from natural disasters by strengthening early warning systems through climate services. This is about 0.028% of its GDP losses avoided per year to climate disasters. These gains are even higher, where the systems are upgraded to European standards (100%), saving the country almost US$113.86 million per year to avoid economic loss.

Kenya, a lower middle income country is able to avoid losses equally estimated at US$ 11.392 million per year from the provision of climate services. This is about 0.01% of the GDP saved per year. In the same way, the gains are higher if the systems are developed to European Standards, saving the country almost US$ 56.96 million per year in avoiding disaster losses.

Results of Benefit Transfer showed that smallholder farmers alone in Uganda, the provision of climate services could generate approximately US$ 143.92 million per year in revenue gains through their payments to climate services in form of 'willingness to pay'. This approximates to about 0.35% of GDP in revenue gains at current GDP of (US$ 40.53 billion) for Uganda. The amount is just enough to service almost 0.6% (US$ 143.7 million) of the country's current, public debts burden estimated at US$ 23.95 billion (2022 est.).

Kenya, investment in climate services is estimated to generate about US$ 281.6 million annually in revenue gains from smallholder farmers alone; when other sectors are not included. This approximates to about 0.26% of the country's GDP at current prices (US$ 110.35 billion) in revenue gains per year from smallholder farmers. The revenue is equally good enough to service almost 0.36% (US$ 279.5 million) of the country's public debts burden, currently standing at US$ 77.65 billion (2022 est.).

These results are remarkable, especially at a time where greater efforts are needed from developing countries to mobilize domestic revenue, particularly to finance their development, to rebuild better and stronger economies while recovering from the socio-economic impacts of the COVID-19 pandemic, and global crises like Russia-Ukraine war, couple with already rising macroeconomic fiscal imbalances, declining fiscal space to access international finance and donor fatigue in supporting development finance.

We are confident that for every (1) unit of US$ invested at IGAD level, yields in returns approximately US$ 5.0 in Uganda and US$ 9.0 in Kenya, annually The return is about X5 in Uganda and X9 times in Kenya compared to the costs of investments i.e. making the Benefit Cost Ratio (BCR) of 1:5 and 1:9 respectively. These benefits would be higher where more people and sectors are served due to non-rivalry and non-exclusivity nature of the services, and climate services are improved to effective and efficient levels. In a long run (2100), the benefits of climate services are even greater where the Paris Accord targets are achieved, i.e. the global temperature rise are restrained to a 2^0C (RCP4.5) scenario, saving Uganda almost US$ 4.82 billion per year and Kenya an estimated US$ 23.9 billion per year of GDP losses avoided to climate change impacts in the next Century ahead, i.e. year 2100.

From available data, for now, both countries are losing in terms and within US$ millions annually to climate related disasters but at increasing rates. However, by 2040, Kenya is predicted to reach beyond US$ billion mark; while Uganda by 2050, where more than a US$ billion will be lost to climate related natural disasters yearly. Therefore, the year 2040 for Kenya; and 2050 for Uganda will mark the thresholds where losses will jump from US$ millions to US$ billions to disaster damages, unless other actions such as climate services are strengthened and Paris Accord target are attained.

In light of this context and above findings, the consultant recommends that investing and ensuring access climate services to all citizens be a human right issue, and shouldn't be treated as an expense but rather an investment capable of life safety and unlocking the well-being of millions of vulnerable people out of poverty towards 2030 Sustainable Development Agenda; and African Union Agenda 2063. Climate services should be rated a high priority in the countries' budgeting processes at both local, sub-regional and national level; now that climate change has turned to be a global new normal, challenging nearly all adaptation measures. There is a need for stakeholders to upscale their resource mobilization efforts while exploring other climate finance avenues with both public and private sources at play to improve the generation, dissemination and support policy / decision making environment for accurate and real time access to climate information to the end-users.

Finally but most importantly, Climate Services just like any other transformative actions in climate adaptation programmes are more effective and welfare enhancing where member countries scale up efforts to address structural issues that reinforce poverty, inequalities and vulnerability of the smallholders and urban poor population by ensuring strong governance and functional pro-poor institutions.

Keywords: Climate Services, Willingness to Pay, Benefit Transfer, Avoided Losses, Climate Change
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1. Introduction

Globally, rural livelihoods are increasingly being threatened by climate change. The change is expected to exacerbate sudden-and slow disasters and gradual environmental degradation destabilizing the livelihoods of many people both in rural and urban poor alike. Smallholder farmers in many low-and middle-income countries, in particular are those whose livelihoods largely depend on rain-fed agriculture, are the most faced with the combined pressures of environmental degradation and climate change. These issues are of particular concern in sub- Saharan Africa, where livelihoods are highly linked to nature and land degradation is believed to be severe and where climate change will bring higher temperatures and shifts in rainfall. The fact that the consequences of climate change will particularly affect the poorer regions of the world has been widely accepted (Yamin et al., 2005). High temperatures and shifts in rainfall regimes, in turn, also increase the probability of agricultural failure (Fischer et al., 2005).

The IGAD region is not exceptional, climate variability, including unpredictable, intense and at times extreme weather events such as droughts, floods and landslides, is already threatening ecosystems and livelihoods. The region has experienced an increase in the frequency and intensity of droughts and floods in recent years. In response to the growing concerns to these sub-optimal environmental conditions that affect its member states, Intergovernmental Authority on Development (IGAD) under the IGAD Climate Prediction and Applications Centre (ICPAC); an entity accredited by the World Meteorological Organization (WMO) has intensified efforts to tackle the effects of climate change through providing a number of climate services (CS)/ instruments to users ranging from climate forecasting, dissemination of climate information dissemination, technical assistance to disaster risk reduction management, environmental monitoring, agriculture and food security monitoring, water resources monitoring, and capacity building in the 11 East African countries under its mandate, aimed at creating resilience in a region deeply affected by climate change and weather extreme events.

Climate services can be referred as the value-chain of the production, translation, transfer, and use of climate knowledge and information for climate-informed decision making”[1]. The practicality of these services depend on a range of factors: the availability of, and access to, timely, understandable, and useful climate information (Hansen et al., 2013; and Coulier et al., 2018). Limited actionability may be ascribed as gaps and inefficiencies between the steps in this value-chain. The provision of climate services have historically been linked to increased safety and efficiency in land use, sea, aviation and transport sector, helped communities prepare for and respond to extreme weather events, and facilitated improved decision making in production and weather-sensitive economic sectors. Increasingly, it has become easier for users (people and businesses) to access climate information and products due to breakthrough in the Internet and telecommunications systems.

Unfortunately, the provision of climate services has to ensure quality consistently, innovate, diversify and ensure adequate services to the end users in order to generate value for money investment; and all these come at a costs, grossly competing with other priorities in public budget. The National Meteorology and Hydrological Services (NMHS) also faces another dilemma in the media backlash where its often criticized for providing misleading weather and climate related information to intended users. This is common in developing countries where NMHS are inadequately equipped due to limited human resources capacity and lack modern technologies to help generate and distribute accurate and reliable real time information to guide their intended recipients. The National government and their donors faced with an increasing competitive budget priorities, there is a growing concern for NMHS mandated as the CIS custodians to demonstrate that the value / benefits of their services are sufficiently larger enough than the costs and thus worth to continue investing in such services in order to sustain the use of scarce public resources towards the sector.

The National Meteorology and Hydrological Services are continuously working to improve their services but challenged to provide, economic evidences and justification as worth investing tax payers’ money, with a 1) a clearer demonstration of the importance of observational and data processing infrastructure; 2) a more rigorous and widely understood demonstration of the socio-economic benefits, both public and private; 3) more systematic basis for prioritizing the use of available funding for infrastructure and service development and improvement; and 4) a stronger economic evidence for additional investment in climate services infrastructure necessary to support national commitments (World Bank, 2014, in COP20).[2] Surprisingly, studies of this nature have not been done in IGAD region, despites repeated calls and its unrelenting contributions to guiding planning and policy decisions among climate adaptation scholars.

Until, now a few CIS providers have attempted to conduct such studies outside IGAD region and where they are done no uniform approaches have been or not consistently applied for cross comparisons but rather on an ad-hoc bases; with each agency adopting different methodologies to suit data availability and costs feasible within their context. Each measure has both advantages and disadvantages, and there is a no ‘fit all’ method for this valuation. On a case-by-case basis, the analyst should adapt a particular method appropriate to the availability of data and the local context, or use a combination of methods to strengthen the estimations (Tesfaye et. al., 2018). However, what is clear generally is that findings from such economic studies have consistently yielded benefit–cost ratios (BCRs) of greater than one (1) (Andersen et al., 2015). Therefore, studies that made efforts to value climate services have helped benchmarked a need for more resource mobilization in the sector; while also strengthening the utilization of the results to improve service delivery through business optimization and communication with decision makers/ policy actors, users and the public. The underlying assumption here is that CIS is a public good item and none-rivalry by nature i.e. the use of the good/services by one agent does not deprive the others from the use of the same. Therefore, greater benefits from CIS provisions will accrued when many / all

[1] Climate Services Partnership http://www.climate-services.org/
[2] hrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cooperacionsuiza.pe/wp-content/uploads/2014/12/6_worldbankgroup_servicios_climaticos.pdf

end-users can access, understand and utilize this information in their production/ livelihoods decisions. In addition, improved hydro-met information can improve productivity, protect human lives, and build resilience, helping to stabilize the volatile markets and socio-political conditions (UNDP, 2016). It would also empowering developing countries more especially Sub-Saharan African towards poverty reduction, food security and socio-economic transformation, a region most vulnerable to climate change extreme events.

1.1 Project overview and the Horn of Africa (HoA) context

The Horn of Africa (HoA) region have a long-standing history of being prone to climate extremes events such as droughts and floods that exacerbate food, water insecurity and in some cases leading to cross-border conflicts. The economies and livelihoods of the HoA countries (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda) are dependent on rain-fed agriculture that is highly sensitive to weather as well as the climate variability and change. Rainfall has strong bearing on agricultural production and also linked to economic and social well-being of the rural communities in the region. Evidently, climate change in the region could result in an increase in the frequency and intensity of extreme weather /climate events, leading to more intensive flash floods and more recurrent drought and water scarcity. Climate risks impacting the livelihoods and food security situation of pastoralists and agro-pastoralists are also increasingly associated with resource-based conflicts in countries such as Kenya, Somalia, Ethiopia, Uganda, Sudan, and South Sudan that could lead to a further deterioration in vulnerability of the affected populations in the region.

It was in this context that the Intra-ACP Climate Services and Related Applications (ClimSA) project was initiated under the 11th European Development Fund (EDF) multi-year funding to support IGAD/ICPAC towards strengthening climate information services. Part of the initiative includes supporting IGAD with technical and financial assistance and infrastructure and capacity building to improve wide access and use of climate information, and to enable and encourage the generation and use of climate services and applications for decision-making processes at all levels. ClimSA provides tools to bridge climate services stakeholders and users in climate sensitive sectors to resource and implement GFCIS at all levels.

In this portfolio, ClimSA actions are envisioned to contribute to six (6)-Sustainable Development Goals i.e. SDGs 1, 2, 5, 7, 13 and 15 in the following ways: 1) building the resilience of the poor and vulnerable people and minimizing the risks to climate related extreme events and early warning; 2) enhancing food security tailored climate services through engagements of the regional multi-stakeholder Food Security and Nutrition Working Group (FSNWG), by closely working with IGAD Secretariat and its other implementing regional bodies especially the IGAD Drought Disaster Resilience and Sustainability Initiative (IDDRSI) and Cross-Border Cooperation Working Group) and international organizations; and 3) enhancing cooperation between institutions to tackle a major issue of common concern i.e. supporting improvements and capacity building on the use of climate services for improved adaptation planning from regional down to national and local levels.

Ultimately, the Action complements ICPAC's Strategic Plan 2016-2020 of enhancing the livelihoods of the people of the region so as to mitigate climate-related risks and disasters. ClimSA portfolio target five results chains: (1) ensure improved interaction between the users, researchers and climate service providers in the IGAD region through structured and strengthened User Interface Platforms (UIPs), (2) guarantee the provision of climate services at regional and national levels, (3) expand access to climate information; (4) enhance the capacity to generate and apply climate information and products; and (5) mainstream climate services into policy processes at regional and national levels.

1.2. Objectives of the study

The main objective of the study is to provide technical support on social economic impact assessment of the climate services in the IGAD region targeting Kenya and Uganda; where possible to apply the results broadly across the region.

1.2.1. Specific objectives

More specifically, the consultancy will address two objectives: (1) to estimate the economic value of climate services supported by ICPAC through Intra ACP ClimSA project; and (2) to estimate the social benefits and impacts of climate services implemented by ICPAC through Intra ClimSA project.

1.3. The Organization of the Report

The report is organized as follows. Section I, is the introduction and literature review chapter that gives an overview of climate change and associated impacts to the global economy and the Horn of Africa region; how the trend is evolving, and extent to which has shape rural livelihoods. Here objectives, and the description of the project (ClimSA) are also discussed. This section also discusses the benefits of the climate information services, case studies on benefits of climate services, indicators for measuring and valuations and the methodological issues in valuing the climate services. Section 2, presents the study area, data and the methodology. Research results are presented in section 3, while section 4, with conclusions, discussion and recommendations. References cited and author's bibliography are presented at the end of the research work.

1.4. Literature Review

1.4.1. The Public Good Nature of Climate Services

Climate information services (CIS) encompasses transforming climate and weather related data, tailoring such information and knowledge into format that can help decision makers, planners, and users, to make informed decisions in different production activities and sectors. In addition, its creates an enabling environment for decision makers at both local, national and regional level in position to better manage risks related to climate variability (Vogel et al., 2019). Climate services also forms a crucial steps towards successful climate change adaptation (Hansen et. al., 2019). In Sub-Saharan Africa, there is now evidence that smallholder farmers are already receiving and using climate services to guide their farming systems, and livelihood decisions that enhance their resilience to climate shocks (Gbetibouo et al., 2017, Tiitmamer and Mayai, 2018, McKune et al., 2018, Hansen et al., 2018, Nkiaka et al., 2019, Muasa and Matsuda, 2019, and Vaughan et al., 2019).

The information disseminated varies in scales ranging from short term weather forecasting, seasonal climate forecasts with information ranging couple of few months ahead to a long term projects which may reach an end of century (Bruno Soares et al., 2018; Vaughan and Dessai, 2014). The climate services information are diverse in nature, and may include provision of "….early warning systems for flood-prone communities, agro-met advisories to support farmers or sea level rise projections to inform coastal planning" (Suckall & Soares, 2022:103). In African countries, the dissemination of climate services are majorly a free offer, normally through radio broadcasting (Hampson et al., 2014, World Bank, 2016, Muema et al., 2018. Tesfaye et al., 2019), mobile phone and extension agents (Churi et al., 2012, Etwire et al., 2017, and Tesfaye et al., 2019). Therefore, the dissemination of climate services free of charge, is an indication of being public good resources (Tesfaye et al., 2020; see also Freebairn and Zillman, 2002).

The public good is defined by the two criteria i.e. non-excludability and non-rivalrous (Rollins and Shaykewich, 2003, and Gunasekera, 2010). The non-excludability refers to a situation where there is no easy way of preventing someone from having access to and benefiting from a good or service; while Non-rivalrous refers to a condition in which consumption by one agent does not diminish the availability of the good's benefit for others (Tesfaye et al., 2020: p3). Therefore, the provision of services of public good nature does not limit its supply only to people willing to contribute towards the generation of the services (Gunasekera, 2002, Freebairn and Zillman, 2002). However, the production of climate services is an expensive process, but the costs of reproducing is relatively cheaper (Tesfaye et al., 2020). The public good nature makes excluding other users very difficult and potentially expensive to implement. This argument justifies economic efficiency is attainable only by making the access to climate services a free good define by its public good nature (Freebairn and Zillman, 2002).

While the actual benefits to a country is huge, being provided freely tends to shadow the recognition of its benefits and also underutilized by the wider public (Gunasekera, 2004). The hydro-met services can be provided at the same cost of production to a thousand or a million users. Unlike most goods and services, one person's consumption/use of the met/hydro services does not reduce the availability of the services to others. Once a basic met/hydro service is provided for one person, it is available for all to use. This is important from the perspective of justifying met/hydro services provision because benefits increase with the number of users, whereas costs of production remain constant.

1.4.2. The rewards from investments in Climate Services

Meteorological, hydrological and future climate change affect everyone alike, and in particular, extremes in temperature, precipitation, wind and other natural hazards impact every country and every sector of economy. The provision of such services have been associated with reduced weather and climate related losses, saving lives, and reducing damages to livelihoods and properties (Vaughan and Dessai, 2014). Overall, CIS benefits are enormous. Take for instance, WMO estimates that CIS in agricultural sector solely through improved forecasting in all developing countries could generate about US$ 300 million annual increases in global productivity; and US$ 2 billion yearly in form of reduced asset losses and property damages (WMO, and Dobardzic et al., 2019).

In addition, improved early warnings in developing countries, could save averagely 23,000 lives annually, which approximates to about US$ 700 million - US$ 3.5 billion yearly (Copenhagen Consensus Center, 2014); besides adding in the range of US$ 3 billion and US$ 30 billion per year in the form of additional economic benefits, globally (WMO and Anderson et al., 2015). In total, these CIS benefits could reach yearly between USD 4 to 36 billion (Hallegatte and World Bank, 2012). In terms of Benefits costs ration (BCR), globally improvements of NMHS towards disaster losses reduction , produced a BCR of 4 to 1 or 36-1; while improving weather forecasting recently in USA resulted to a 4 to 1 BCR; similarly in Ethiopia, drought early warning programmes reduced livelihoods losses and over dependence on humanitarian assistance with a BCR in the range of 4 to 1; and in Mexico, where El Nino early warning was adopted in 5 regions of the country was associated with improved decision making in agricultural sector, reporting a BCRs ranging from 2 to 1 and 9 to 1(WMO and Anderson et al., 2015). A number of case studies filed by the World Meteorological Organization also re-affirms the substantial benefits related to climate services (Table 1, below).

Table 1: Samples of selected case studies demonstrating benefits of climate services

	Country/ Region	Consequential impacts
1.	India	Operational Agro-met Advisory Services in in the country have decreased cultivation costs overall by up to 25% and, increased net returns to farmers up to 83%.
2.	Bangladesh	Adopting Forecast-based financing (FbF) approach, implemented by World Food Programme (WFP) and the Bangladesh Red Crescent Society (BRCS), has created many benefits for flood-affected households. The average asset loss for Bangladeshis affected by floods has dropped from US$ 78 to US$ 57 – a 21% decrease.
3.	East Africa	The use of early warnings are protecting those living and working in the Lake Victoria Basin, East Africa. 46% of the beneficiaries – estimated at around 400 000 people – saved more than US$ 1,000, and 2.56% saved more than US$10,000 from loss of property.
4.	China	In China, Climate Services served as a starting point for shaping a climate change adaptation strategy. Average per capita income among farmers rose by USD 326 per year, and high-value crop production rose from 3.2 million tons to 4.2 million tons per year.
5.	West Africa	Roving Seminars on climate information increased crop production by building rural farmers' knowledge and access to information during the growing seasons. 35% increase in crops yields were reported in project evaluations for four countries and US$ 45/ha savings achieved by not weeding guided by climate information.

Source: Adopted from WMO, the state of Climate Services Report 2019, 2020[1]

Historically, countries and donors have invested heavily on the provision of weather and climate related services, with few evidence linking the socio-economic benefits of such investments, yet such analyses would ensure continuity, cooperation between actors, and adaptive capacity of the society in the wave of climate change. Where studies, have been done, a triple bottom line approach that takes into consideration economic, social and environmental benefits, have been the recommended in CIS socio-economic estimations, for details of sample benefits indicators (table, 2 & 3 below).

Table 2: Selected indicators for defining CIS benefits, a triple bottom line Approach

	Dimension	Indicators
	Social	• Avoidance of loss of life and/or injuries/illnesses from natural disasters • Safety and security of the traveling public • Improved information and data to the scientific community • Contribution to the day-to-day safety, comfort, enjoyment and general convenience of citizens, including avoided climate-related illnesses
	Environmental	• Long-term monitoring of basic indicators of the state of the environment • Minimization of release of toxic substances and other pollutants • Management of local environmental quality • Water savings • Reduced runoff from fertilizer application, resulting in improved water quality

[1] doc_num.php (wmo.int) ; 2019 State of Climate Services (wmo.int)

	Dimension	Indicators
	Economic	• Avoidance of crop losses from frost, hail or drought • Increased farm production and sales • Reduced transportation fuel consumption through route planning • Improved scheduling of flight arrivals and departures • Minimization of airline costs from aircraft diversions • Minimization of search and rescue costs • Efficient scheduling of ship loading facilities • Avoidance of unnecessary shutdown of offshore oil and gas operations • Avoidance of weather damage to personal property • More efficient planning of energy production and delivery

Source: World Bank, 2014 during COP20

Table 3: Quantitative returns on investment on climate services by key sector (Uganda)

	Dimension	Benefits
	Economic	**Agriculture:** Avoidance of crop losses from frost, hail, drought, flood or extreme temperature; timing of crop protection, planning and harvesting; increased farm production and scales; more efficient scheduling of the use of agricultural machinery, minimization of drought relief costs. **Air transport**: Reduced fuel consumption through route planning, improved scheduling of flight arrival and departures; minimization of airline costs from aircraft diversions; minimization of search and rescue costs; reduction of accidents and emission; saving in passenger times, materials and working times (airport maintenance). **Maritime transport**: Reduction of accidents and environmental damages, fuel savings, more efficient rescue operations. **Oil prospecting**: Avoidance of unnecessary shutdown of offshore oil and gas operations; more efficient planning of energy production and diversity. **Energy:** Prediction of power demands, power failure reduction, savings in material and working times (maintenance), energy savings. **Construction:** Potential to eliminate serious construction problems a priori (risk control system). **Flood protection**: Savings in human lives and property, more efficient rescue operations.

	Dimension	Benefits
	Social	**Protection of life and property:** Avoidance of loss of life and property from natural disasters **Research**: Improved information and data to the scientific community **Leisure**: Contribution to the day-to-day safety, comfort, enjoyment and general convenience of citizens, including recreation, travel/ commuting and other direct and indirect forms of societal benefits.
	Environment	**Air quality monitoring and warnings:** Reducing adverse health impacts; saving human lives in possible environmental accidents (evacuations); minimization of release of toxic substances and other pollutants; management of local environmental quality.

Source: UNDP, 2016; earlier retrieved from MDA Information Systems. A Modernization Plan for Uganda's Meteorological Services

Most studies have concluded the provision of weather and climate services as linked to beneficial impacts on the social, economic and environmental dimensions of the economy in general (World Meteorological Organisation, 2015; see also Zillman, 1999; Freebairn and Zillman, 2002; Gunasekera, 2004). It's envisioned that weather and climate information has a huge potential for a country in climate adaptation (Suckall and Soares, 2022), including supporting national NDC obligations towards the Paris agreement through better risks management against climate shocks and stresses (Williams et al., 2015). Where complex weather and climate information are generated, packaged, and future trends are predicted, end users are better placed to guide their production and commercial activities at both local, regional, and household levels in almost every section of the economy. Table 4, below gives examples of impact areas by sector, where climate information and related services are provided.

Table 4: Examples of quantitative indicators of returns on investment on Climate Services by sector

	Sector	Indicators for valuing benefits
1.	Agriculture	• USD per hectare or acre (e.g., increased revenues per hectare) • Total welfare gains (producer and consumer surplus) • Avoided revenue losses • Increase in total farm revenue • Change in crop prices • Growth in GDP • Producer surplus • Reduction in insurance prices • Willingness to pay for forecasts
2.	Energy	• Increase in electricity prices (benefit for electric industry) • Cost savings due to more efficient energy purchasing • Increased sales/revenue from hydro-power dams • Increased mean weekly income in wind energy sector • Cost savings from more efficient building operations • Consumer gains from reduced energy costs
3.	Water Resource Management	• Water savings • Total welfare gains • Avoided agricultural production losses • Savings to the state from reduced compensation to irrigators
4.	Transportation	• Avoided costs • National economic benefits

	Sector	Indicators for valuing benefits
5.	Disaster Management	• Avoided evacuation costs • Reduced asset losses • Reduced foregone drilling time (oil and gas industry)
6.	Tourism/recreation	• Consumer welfare • Increased recreational fishing days • Value of recreational fishing day (contingent valuation)
7.	Other sectors	• Household willingness to pay for weather services • Impact of weather variability as a percent of GDP • Avoided costs • Increased revenues

Source: Adopted from Clements, Anderson and USAID, 2013:p15-16

1.4.3. The costs of not using / upgrading climate services

Countries with well-developed and modern climate services happened to be those with high level of resilience[1] against climate extremes, typical of industrialized countries. Interestingly, a life without hydro-met services is even more disastrous as losses to weather variability is on increases and impacting global economies significantly. Take for instance, in USA, a country already industrialized, the effects of weather volatility /variations have been linked to unstable GDP performance in the range of +/- 1.7%; impacting the country to a tune of US$ 485 billion of the US$ 14.4 trillion GDP in 2008 alone, even when the impacts of natural disasters were not factored in such estimations (Lazo, 2011). Consider a period 1970 to 2012, the world recorded 8,835 disasters, 1.94 million deaths and US$ 2.4 trillion of economic losses associated weather-, climate- and water-related disasters, a term scholar referred to as hydro meteorological disasters. In the last four decades, the number of reported hydro meteorological disasters has increased almost five-fold, from about 750 in the period 1971–1980 to about 3,500 during 2001–2010 period (WMO, 2014). With this same period, cumulative economic losses have increased more than fivefold from US$ 156 billion to US$ 864 billion per decade (Andersen et al., 2015), which is particularly alarming.

Therefore, the provision of a reliable weather, climate and water information, mandated to NMHS and sister agencies should be a key budget priority as it translates to all the sectors of the economy. This will enables individuals, households, organizations, businesses and governments to take decisions which reduce the impacts of natural hazards, enhance the safety and convenience of daily life, increase business profitability, address the challenges of public health and poverty alleviation, improve productivity, strengthen national economies, protect the environment and provide a more secure basis for future planning on hourly to century timescales (WMO and Anderson et al., 2015).

The World Bank concurred that a clear understanding the value of climate services could make key sectors of the economy with informed decisions in their production activities, and reduce risks associated with climate change; also guides actions that could improve decision making processes (World Bank, 2008). In the same way, mapping out the values to climate services is important to motivate users of such information to attach their willingness to pay for the services or ensure improvement and upgrades for sustainability. It can also justify the continued budget support in the sector and priority setting in managing climate related shocks/ stresses affecting the economy (Zillman, 2007). Improvement in productivity associate with improved forecasting could lift millions of people in developing countries out of poverty, improved food security and social-economic transformation in a region which happens to be more at risks to climate related extremes.

This calls for efforts from development to modernize hydro-met services further to make service providers well connected to end-users towards the realization of sustainable development goals (SDGs) (Rogers, and Tsirkunov, 2013). It's imperative that given the increasing incidences and magnitudes of climate extremes and disasters worldwide (Newth et al., 2021; see also Coronese et al., 2019); accurate and real time provision of CIS to the end users would avoid them from making losses or reduce the levels of losses associated with these events. Therefore, analysis of CIS benefits will solve the public outcry to help decision makers, donor, governments, users, funding agencies and local communities at large improve their decision making, given the competing priorities.

1.4.4. Common approaches for valuing climate services

According to Hilton (1981), the value of information can be defined as the: i) maximum price that a user would pay for it, ii) minimum price under market equilibrium that a provider would accept for the information, and iii) expected improvement in economic benefit of management that incorporates the new information (Tesfaye et al., 2018: p12). In this work, the climate services takes consideration of the first or third of these definitions, to overcome the public good nature which limits the usefulness of assessing its value based on market equilibrium process going by Hilton's second definition (Tesfaye et al., 2018: p12). According to Tesfaye and group (2018),

[1] Resilience measures the capacity of a household to bounce back to a previous level of well-being (for instance food security) after a shock.

the public good nature of climate information generally prevent markets from revealing its value, except in the case where highly specialized information products and services (e.g. aviation forecasts) might be sold.

While the analysis of the benefits primarily focuses on gains inform of economic returns from using the information, others come in form of environmental and social benefits which the decision maker should take in consideration as well. In agriculture, the economic gains comes in when farmers make adjustments in their farming decisions leading to increased production, or reduced production costs resulting to increased income (Tall et al., 2014, LO and Dieng 2015). Social benefits may be seen in altered agricultural practices e.g. farming calendar knowledge management), coordinated planning in executing farm operations in terms of financial literacy and labour management (Tall et al., 2014, LO and Dieng, 2015), better food security and nutritional related outcome. The environmental returns from the use of such services may expressed in form of proper timing of application of nitrogen fertilizer to reduce nitrous oxide (N_2O)—a greenhouse gas with the highest global warming potential emissions from crop fields (Signor et al., 2013), and balanced application of fertilizer and other agro-chemicals reduces environmental pollution (Tesfaye et al., 2018: p12; see also Hautala et al., 2008, Lazo et al., 2009, Selvaraju et al., 2011), leading to efficiency in agronomic management.

In conducting such evaluations, the methods commonly available for the quantitative estimations of the value of climate services broadly has been the use of economic modelling, stated preference, avoided loss and benefit transfer (Freebairn and Zillman, 2002, World Bank, 2008, Clements *et. al*., 2013, and WMO, 2015). Each method is associated with strengths and limitations (see table 5, below), and a combination would help overcome these shortfalls.

Table 5. Methods for valuing Climate information services in Africa

Approach	Basis[1]	Methods	Strength	Limitations
Economic modelling	Improved economic benefit	Bio-economic modelling	Can sample many years of climate information and weather observations. Flexible model specification.	Realism limited by model ability to capture decisions and economic impacts. Ignores market impacts of adoption at scale.
		Economic equilibrium modelling	Captures market impacts of adoption of climate services at scale.	Realism limited by model ability to capture decisions and economic impacts.
		Game theory	Captures competition or coordination among decision-makers.	Significant data, time and expertise requirement.
Stated preference	Maximum price a user would pay	Contingent valuation	Seeks the value of goods and services from a hypothetically constructed market. Survey that presents scenario and elicits WTP for specified service	Bias from limited experience and understanding of planned information products.
		Choice experiments	Elicit individuals' preference for potential good or service by describing the good or service in terms of its attributes.	Sensitivity of results to survey design.
Avoided loss	Improved economic benefit		Straightforward when action thresholds, frequencies and losses are known.	Only considers downside risk, not opportunity under favorable climatic conditions.

[1] Based on the three definitions of value of information in Hilton (1981).

Approach	Basis[1]	Methods	Strength	Limitations
Benefit transfer	Extrapolation of estimates based on other approaches Use results obtained in one context in a different context	Any for which suitable comparison studies are available	Minimal data, cost and time requirements. Valuation exercises at another, similar site	Low and uncertain realism, especially when transferring results from a very different environment.

Adopted from Tesfaye et al., 2018, p13, with modifications from author

1.5. Assumptions

(1) All countries are assumed to be facing the same level of risk due to transboundary nature of climate and extreme weather events, and thus early warning can provide the same but relative benefits in terms of avoided disaster losses depending on the level of development in a country.

(2) Climate services is a public good item i.e. associated with non-exclusiveness and non-rivalry. Therefore, the costs remain the same for generation and distribution irrespective of the number of users of the services. When users receive but cannot make changes in their production decisions, the information has no direct value. Therefore, more benefits are accrued where many people can access and use this information in their livelihoods activities.

(3) The share of losses avoided by upgrading hydro-met services vary by country, where the World Bank estimates at 10% of these benefits in low-income countries; 20% in lower middle income, 50% in upper middle income, and 100% in high income countries. Therefore upgrading hydro-met to European standards would increase loss avoidance from disasters significantly (World Bank, 2012, see also Hallegatte, 2012).

(4) More values/benefits from CIS increases with economic growth of the country. There is evidence that losses to climate related disasters slows down with the level of wealth and economic growth (Hallegatte and World Bank, 2012; see also Toya and Skidmore, 2007; Mendelsohn et al., 2012). Economic growth is also linked to increase capacity to migrate, and increased investment in technology to de-risk disasters, further amplifying the risks reduction (Hallegatte, 2011, 2012a).

(5) Climate change and related disasters affects food security and nutritional outcome significantly which may have lasting effects on child development (Santos 2007, Alderman et al., 2006), in a long run affecting labour productivity, economic growth and wellbeing of a country forever. Improved CIS would reduce this long lasting benefits not captured in this valuations. Furthermore, migration is seen to be accelerated with disasters (Landry et al., 2007 on hurricanes Katrina, New Orleans). Migration has development consequences to national growth negatively especially where skills are lost due to brain drain, lowering productivity and growth as well (Zissimopoulos and Karoly, 2007). For example in USA, Strobl (2011) found that hurricanes reduced economic growth by 0.79% point in areas affected that year and only increased by 0.22% point the year that follows. Therefore, we can conclude that disasters not only increases the losses at one point, but will have a long lasting consequences to a nation, which the current analysis could not capture to add in the value of the climate services.

(6) Climate disasters are also link to poverty traps, where assets are destroyed and savings eroded. The affected households lack ability to invest leading to reduced productivity and resilience to climate shocks and stresses. Trapped in cyclical poverty, households are unable to rebuild their livelihoods (savings, assets back to pre-disaster income levels (Carter et al., 2007, Dercon 2004, 2005, Lopez and Servén 2009). These micro poverty traps also have consequences on macro-levels, where a country capacity to invest cannot keep pace with re-construction need of the country (Hallegatte et al., 2007, Hallegatte and Dumas, 2008).

1.6. Methodological challenges in valuing Climate Information Services

(1) Many scholar that have attempted to value the benefits to CIS have faced a number of challenges ranging from the followings. Firstly, CIS generation and distribution to end-users are taken as a public good concern and therefore no commercial profits are attached to the community (Newth et al., 2021). Therefore, the supply chain are normally funded by governments, donors for the case of developing countries and distributed free of charge. In cases where private firms take interest to invest and provide similar services, it's always difficult to introduce user fees to access them due to none- exclusive and non-rivalry nature of CIS as public good. In addition, as discussed above, CIS are characterized as both non-excludable and non-rivalrous, making their use by an individual not to exclude others from the use of the same resources; as

well as reducing the value and availability for others.

(2) Also, the optimal value/ benefits of CIS is obtained where there is sufficient skills, resolution and capacity to generate accurate information, interpreted and tailor them to the needs of users; and these costs are met by the government and donors. Its promising that ICPAC had worked on this to support the member countries with project supports from donor. In addition, more benefits from CIS are realized when the users attached generating profits from this information in their production decisions beyond the public goods perspectives. The CIS must be treated as an intermediate good expressing inform of technology and only creates enabling conditions to add value to other goods and service sectors in order to realize benefits. Therefore, monetarizing CIS gains directly, presents a big challenge to Socio-economic benefits (SEB) analysts, in which case approaches used are made hypothetical in designs to try to estimate such benefits, under many assumptions, which sometimes are ambiguous. For example, attempts have been to make indirect estimations such as Willingness to Pay (WTP), Benefit Transfers, and costs avoided measures from the utilization of CIS among others to support value estimations. The Willingness to pay approach measures the consumer surplus which gives the price difference a consumer is prepared to pay for a good or service and the price that the consumer has to pay; and proven successful in valuing CIS estimations (see Ouédraogo et al., 2018; Tesfaye et al., 2020).

(3) Another approach has been to explore, CIS as a technology which could improve productivity among users. Therefore, having knowledge of CIS alone will not automatically lead to a desired positive outcome unless, the users adopt this in their production decisions and actions. In this case, application of CIS and related technology is hypothesized to improved productivity among its users compared to non-users in the downstream sectors of the economy (Newth et al., 2017; Naab et al., 2019). Bearing this in mind, a household study of CIS benefits can be organized to see incremental changes in household productivity, incomes among those who accessing and using these information in their production systems against those who are not users (counterfactuals/ control groups) to attributes the differentials impacts, which can be interpreted as increases in value added in the sector (Newth et al., 2021). Furthermore, other scholars, have applied beneficial potentials using avoided costs estimates with proxy indicators measures such accidents/live losses, damage claims among others; related to weather and climate disasters, in which case improvement in CIS is hypothesized to reduce such their levels. This takes a form of cost-loss study, a common tool use in CIS benefit feasibility studies (Katz and Murphy, 1997).

(4) Another noticeable challenge relates to estimating costs in accessing CIS information adjustments needed at the end-user, media level are notoriously difficult to put together, and most often excluded by the analysts. Therefore, we risks underestimation of costs at this level, when most of costs are focus at the information providers i.e. the National Meteorological and Hydrological Services.

2.0 Study Areas and Methodology

2.1 Overview of study areas (pilot countries)

2.1.1 Kenya (geography, economy and state vulnerability) to climate change

Kenya, a member of IGAD is found in East Africa was selected besides Uganda as pilot countries in this assessment. Geographically, Kenya covers 582,646 square kilometers (KM^2) by total land size, comprising of land plains, escarpments, hills together with low and mountainous zones. Towards the Eastern side, there is Indian Ocean, the Western, comprises of low plateaus inland with elevated plateau and mountain ranges; to the South there is Kenya highlands. The country is bordered by Ethiopia in the North, South Sudan in the North West, Uganda to the West, with Tanzania in the Southern end. About 85% of the country is characterized a fragile arid and semi-arid, dominated by pastoral farming system (NEMA, 2015).

Considered as a lower middle income country and the largest East African economy, Kenya is a host to both economic, financial and transport hub for East Africa. The country has a population of 52.6 million (2019 estimation), with average population growth rate of 2.3% (World Bank, 2020); and 27% of population urbanized. Economically, the country is highly linked to agriculture especially in the highland areas, generating one-third of its GDP. Almost 75% of the population in some way derive their livelihoods from agricultural sectors, including livestock and pastoral activities.

Therefore, the roles of climate services especially in agricultural development and country's growth trajectory cannot be ignored given the strong linkage between weather and agriculture in developing countries. The GDP is estimated at $110.347 billion (2021 est.)[1], recording average annual growth in the range of 5-6% for more than a decade[2]. While the country has committed to economic and social transformation, it continues to grabble with major structural challenges ranging from corruption, widening inequality and poverty, living it exposed, vulnerable and less resilient to major climate related shocks/stresses such as droughts and floods (World Bank, 2019). Table

[1] https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KE
[2] https://www.cia.gov/the-world-factbook/countries/kenya/#economy

6, below shows samples of performance indicators selected and their implications to poverty and vulnerability to climate change.

Table 6: Selected development indicators to the country vulnerability, Kenya

	Indicators	Scores
1.	Corruption Perceptions Index (CPI) (scale 0-100); 100, very clean- 0, very corrupt	32 (2022 est.)[1] World Rank (123/ 180 countries)
2.	Population	55,864,655 (2022 est.)
3.	Population growth rate	2.12% (2022 est.)
4.	Life expectancy at birth	69.69 years
5.	Median age	20 years
6.	Dependency ratio	70.2
7.	Urbanization	29.5% of total population (2023 est.)
8.	Literacy (i.e. age 15 and over can read and write)	81.5% (male: 85% versus female: 78.2% (2018 est.)
9.	Real GDP (Current US$)	$110.347 billion (2021 est.)
10.	GDP growth rate (%)	5.39% (2019 est.)
11.	GDP per capita (US$)	$4,200 (2020 est.)
12.	Credit rating	Fitch rating: B+ (2007); Moody's rating: B2 (2018); Standard & Poors rating: B+ (2010)
13.	Unemployment rate	40% (2013 est.)
14.	Youth unemployment rate (age 15- 24 years)	12.9%; with male: 12%; female: 13.8% (2019 est.)
15.	Population in poverty line	36.1% (2015 est.)
16.	Gender Gap Index (GGI) (Scale 0 – 1) 0, very unequal - 1, very equal	0.729 (2022 est.)[2]
17.	Gini Coefficient Index (Distribution of family income) 0, very unequal – 100, very equal	40.8 (2015 est.)
18.	ND-GAIN Index rating[3] 100-Very resilient; 0 –very poor	149 / out of 182 countries (2020 est.) (i.e. highly vulnerable to climate change impacts. Scores 38.7%; vulnerability-0.525; and Adaptation readiness-0.299
19.	Human Capital Index (HCI) (Scale 0 – 1), 0, very poor - 1, very good	0.5 (2020 est.)

Source: World Bank, 2021; and CIA World Factbook, Kenya

The country is committed to international climate obligations in the UNFCCC processes such as the Kyoto protocol and the recent Paris Agreement. For example in 2005, it produced its 2nd National Communication; and also submitted an updated National Determined Contributions (NDC) to UNFCCC in 2020, highlighting areas of adaptation and mitigation efforts, to improve the country's ability to prepare for and respond to natural disasters and increase its resilience to climate change (World Bank 2021). By 2030, the country is expecting to be industrialized, thus making a renewed call for ensuring climate resilience across all sectors including weather and information services alike. Significant investments is needed in agriculture, energy and efficient drought management programmes such as strengthening climate information services[4].

2.1.2. The state of climate, natural hazards and impacts in Kenya

Available data shows that Kenya has continued to experience rising temperatures by average since 1960s, particularly the inland zones registering the highest increases in both minimum and maximum temperatures compared to the rest of the country. The country has recorded a 1.0^{O}C rise since then, with every 10 years averaging to a 0.21^{0}C temperature rises (NEMA, 2015). According to IPCC data, future trends is inclined to a further rise of about 1.7^{O}C by 2050s reaching to approximately 3.5^{0}C by end of Century (World Bank 2021, and MoENR, 2016). The number of hot days and nights are also expected to increase, with hot days averaging to 19%-45% by mid-century, while the hot nights estimated to increase rapidly tuning 45%- 75% of nights in similar period, and 64% - 95% by end of century. The days and nights of coldness are expected to be very rare and forgotten

[1] https://www.transparency.org/en/cpi/2022/index/ken
[2] https://www.weforum.org/reports/global-gender-gap-report-2022/in-full/1-benchmarking-gender-gaps-2022/?DAG=3&gclid=Cj0KCQiAj4ecBhD3ARIsAM4Q_jGNyuFRIDXhLxuf_4QVB328HZ0uWwhx8xer_ljri8S6pdYT2j7XuV0aAitaEALw_wcB
[3] https://gain.nd.edu/our-work/country-index/rankings/
[4] Ministry of Environment and Natural Resources (2016). Kenya's Nationally Determined Contribution. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Kenya%20First/Kenya_NDC_20150723.pdf

(NEMA, 2015), while the population struggles with a more sweaty hot conditions affecting labour productivity substantially.

The precipitation and rainfall patterns have also become unreliable and varying regions significantly. The trends have also brought in many surprises. For example, the Northern parts which used to be drier historically have now become wetter, while the converse is true for Southern areas becoming drier initially wetter since 1960s (World Bank, 2021). Weather extremes events have increased rapidly in both frequencies and intensities. The resurge of droughts has increased, "….with moderate drought events recorded on average every three to four years and major droughts every ten years" (World Bank, 2021: p7).

On record, prolonged droughts are becoming a national new normal (NEMA, 2015), a trend that is worrying for poverty alleviation efforts and achieving national social economic transformation such as ongoing Sustainable Development Goals (SDGs), working towards African Union (AU) agenda 2063, and reversing past gains in the country. The future precipitation is expected to be more unreliable, however predicted to increase by mid-century generally for period of short rains i.e. October – December. The extremes of rainfall will dominate the future in both frequency, duration, and intensity, with heavy rainfalls which used to occur in heavy rainy seasons (March-June) predicted to reduce. According to World Bank, the length heavy rainfall periods will increase but with less volumes received; and the arid areas likely to experience the rapid decreases.[1]

2.1.3. Natural hazards, projected trends and impacts to Kenya's economy

The country is ranked high in terms of exposures to natural hazards and extreme weather events such as floods and droughts. About 70% of natural disasters in the country are associated with extreme weather conditions (World Bank, 2021). Serious drought periods keep re-occurring every ten years, and moderate ones every 3-4 year cycles. Recurrent droughts and floods has huge impacts and economic losses in the country. For instance, between 1998 – 2000 alone, droughts have costed the country approximately US$2.8 billion in economic damages associated with agricultural failures in crops and livestock, bush fires, reduced productivity in fisheries, low hydropower generation capacity, lowered industrial activities as well as water supply[2]. Its estimate that almost 8% of GDP is lost every five years due to impacts of droughts (World Bank, 2021). For the last 100 years, the country has registered 28 droughts, and increasing in frequency recently, with greatest exposure in arid areas.[3]

Agricultural sector is experiencing the most impacts[4]. About 18-20 counties in the country are either arid or semi-arid (ASAL) in zoning, and happen to be the poorest and most vulnerable to drought extremes (World Bank, 2018). Droughts is common and affecting people most, but floods in the country have been linked to greatest losses of human lives. Baringo, West Pokot, Kisumu and Laikipia are some of the disaster hotspots for droughts, calling for more humanitarian and disaster investment portfolios[5]. Table 7 below, shows the disaster trends in the country in terms of floods, landslides, wildfires and storms.

[1] WBG Climate Change Knowledge Portal (CCKP, 2020). Kenya Water Dashboard. Data Description.
URL: https://climateknowledgeportal.worldbank.org/country/kenya/climate-sector-water

[2] WBG Climate Change Knowledge Portal (CCKP, 2020). Climate Data-Projections. Kenya. URL: https://climateknowledgeportal.worldbank.org/country/kenya/climate-sector-water

[3] Republic of Kenya (2013). Sector plan for drought risk management and ending drought emergencies, Second medium-term plan: 2013–2017. URL: https://www.ndma.go.ke/index.php/resource-center/send/43-ending-drought-emergencies/4271-ede-mediumterm-plan-2013-2017

[4] Republic of Kenya (2013). National Climate Change Action Plan, 2013–2017: Vision 2030. URL: https://cdkn.org/wp-content/uploads/2013/03/Kenya-National-Climate-Change-Action-Plan.pdf

[5] Development Initiatives Kenya (2019). Tracking subnational government investments in disaster risk reduction in Kenya. URL: https://reliefweb.int/sites/reliefweb.int/files/resources/Tracking-subnational-government-investments-in-disaster-risk-reductionin-Kenya.pdf

Table 7: Trends of natural disasters and associated impacts, Kenya (1900–2020)[1]

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Drought	Drought	16	196	52,911,500	1,500
Earthquake	Ground Movement	1	0	0	0
	Tsunami	1	1	0	100,000
Epidemic	Bacterial Disease	20	1,576	59,801	0
	Parasitic Disease	5	1,595	6,807,533	0
	Viral Disease	7	514	3,850	0
Flood	Flash Flood	8	245	193,500	500
	Riverine Flood	37	1,150	2,232,222	136,038
Landslide	Landslide	4	133	140	0
	Mudslide	1	20	6	0
Storm	Convective Storm	1	50	0	0

Adopted: World Bank, 2021, p14

Recurrent droughts and floods is affecting livelihoods, worsened food security situation as well as national development efforts in the country. For example, the droughts of 2008-2011 impacted almost 3.7 million population, leading to US$ 12.1 billion in economic losses, with over US$ 1.7 billion expenditure in recovery and reconstruction phases[2]. Land degradation in form of deforestation, loss of wetland and watersheds, unsustainable land use, coupled with weak natural resource governance and urbanization is also amplifying floods and droughts. The resultant effects are water scarcity and pollution. Heavy rainfall is causing water borne diseases (malaria and cholera), coastal and flash flooding.

2.2. Uganda, the geography, state of economy and environment

A second country piloted in this study, is a landlocked country in East African region. The country covers approximately 241,500 Km^2 by land size, and bordered by Kenya to the Eastern part, South Sudan in the North, Rwanda and Tanzania in Southern; with Democratic Republic of Congo (DRC) bordering the West. About 17% of the country is covered by water bodies and swamps. The topography in the central areas is a plateau, by mountainous ranges (Rwenzori, Elgon, Mufumbira and Moroto). The Rwenzori peak is considered the tallest reaching about 5,110m (MoWE, 2014). The country is a host to a number of natural resources such fertile soil in almost all parts, rich biodiversity, vegetation, water sources, mineral deposits (copper and gold), with oil recently discovered in Albertine Graben region of mid-Western Uganda.

Despite the opportunities the country has to spur development, it continues to face many challenges ranging from un-tamed corruption, post conflict situation in the Northern region which remains the poorest compared to other parts of the country; land degradation, malaria and HIV/AIDS; a high population growth rate among others. In 2022, the population is estimated at 46,205,893 with annual growth rate of 3.27%, considered one of the highest in the world according to USAID data[3]. The population is expected to reach 63.8 million by 2030 and 105.7 million by 2050[4], a trend that is worrying for attaining national development unless the quality of this population is guaranteed.

In addition, the government has failed to invest adequately in health education, burgeoning employment especially among the youth. The state of infrastructure is also weak, and electrification rate remains one of the lowest in Africa, with a stark 1 in 4 Ugandans (26%) only, living in households connected to electric grid (67% in urban versus 13% in rural areas) (Kakumba, 2021). Climate change has emerged also a serious threat and likely to amplify these development challenges, state of poverty and vulnerability especially the poorest section of the population (smallholder farmers and people in informal sector). Uganda rated a low income country, has a Gross Domestic Product (GDP) of $34.683 billion (2019 est.), growing at a rate of 4.8% over the years.[5] The economy is dominantly services sector (50.7%) by GDP contribution; followed by agriculture (28.2%); industry (21.1%)[6]. Whereas, services sector takes the greatest pie of the GDP, agriculture still remains the highest source of employment, where 72% of the population are either directly or indirectly deriving their livelihoods (FAO, 2015).

[1] EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir, Brussels, Belgium. URL: http://emdat.be/emdat_db/
[2] GFDRR (2020). Kenya Overview. URL: https://www.gfdrr.org/en/kenya
[3] World Factbook, Uganda. URL: https://www.cia.gov/the-world-factbook/countries/uganda/#people-and-society
[4] World Bank Data Bank (2020). Health Nutrition and Population Statistics: Population estimates and projections – Uganda. URL: https://databank.worldbank.org/data/reports.aspx?source=health-nutrition-and-population-statistics:-population-estimates-and-projections
[5] https://www.cia.gov/the-world-factbook/countries/uganda/#economy
[6] https://www.cia.gov/the-world-factbook/countries/uganda/#economy

For details of the country's performance, refer to table 8, below.

Table 8: Samples of key development indicators to the country vulnerability, Uganda[1]

	Indicator	Scores
1.	Corruption Perceptions Index (CPI) (scale 0-100) 100, very clean- 0, very corrupt	26 (2022 est.)[2] World Rank (142 / 180 countries)
2.	Total population	46,205,893 (2022 est.)
3.	Life expectancy at birth, total (years)	64 years (2020 est.)
4.	Population growth rate (Annual)	3.0 % (2021 est.)
5.	Dependency ratio (%)	92.3%
6.	Median age	15.7 years
7.	Unemployment among youth (14-24 years)	15.6%
8.	Net migration	843, 469 (2017 est.)
9.	Urban population	26.2% (2022 est.)
10.	Poverty head count ratio at $2.15 a day (2017 PPP) (% of population)	42.2% (2019 est.)
11.	GDP (Current US$)	40.43 (2021 US$ billion)
12.	GDP per capita (current US$)	858.1 (2021 est.)
13.	GDP growth (Annual %)	3.4% (2021 est.)
14.	Credit Rating	B2, Moody's rating**:** B2 (2016)
15.	Human Capital Index (HCI) (Scale 0 – 1), 0, very poor - 1, very good	0.4 (2020 est.)
16.	Gender Gap Index (GGI) (Scale 0 – 1)) 0, very unequal - 1, very equal	0.724 (2022 est.)[3]
17.	Gini Coefficient Index (Distribution of family income) 0, very unequal – 100, very equal	42.8 (2016 est.)
18.	ND-GAIN Index rating[4] 100-Very resilient; 0 –very poor	166 / out of 182 countries (2020 est.) (i.e. highly vulnerable to climate change impacts. Scores 35.4%; vulnerability-0.58; and Adaptation readiness-0.288

Source: World Bank[5] and World Factbook, Uganda.

2.2.1. Climate change and impacts to the national economy

Agriculture here is rain-fed and dominated with smallholder farmers' engaging in subsistence farming for food security and livelihoods. The smallholders are the poorest, and most vulnerable to climate change, yet forming the bulk of the population. Only 0.5% i.e. about 3.03 hectares of farmland are irrigated (MAAIF, 2017), leaving a greatest proportion land and people exposed to the impacts of climate change and related extreme weather events. The smallholders are most vulnerable, lack adaptive capacity to climate change, and likely to undermine the country's efforts towards the National Development and Vision Plan, as well as effective responses in many international obligations such as the SDGs and AU agenda 2063. There is urgent need to strengthen climate information services, such as early warning systems to guide and inform farmers in their production decisions in climate adaption to reduce the losses associated with changing weather, a country where temperatures are already on the rise, water scarcity emerging; floods and droughts now the norm.

Overall, the temperature in the country is on the rise. For example since 1960s. The country has recorded an increase of 1.3^{O}C, with the minimum in the range of 0.5–1.2°C and the maximum ranging from by 0.6–0.9°C increases (USAID, 2012). Every decade the country experiences an average of 0.28°C temperature rise since 1960. Hot days and hot nights are also on the rise. For example, during 1960-2003, the country has registered about 74 hot days' and at total of 136 hot nights increases (World Bank, 2020). This has implications on labour productivity. Therefore the role of climate services is paramount in such situation to guide major production decisions.

Drought condition have also increased over the years. For instance within the last 20 years, "….. Western, Northern and North-eastern regions have experienced more frequent and longer-lasting drought conditions. In the highly arid, north-eastern district of Karamoja, seven droughts occurred between 1991–2000, with additional droughts occurring in 2001, 2002, 2005, 2008 and 2011" (World Bank, 2020: 6; see also Future Climate for Africa,

[1] Retrieved from CIA World fact book; and World Bank data; at (https://data.worldbank.org/country/uganda?view=chart) & https://www.cia.gov/the-world-factbook/countries/uganda/
[2] https://www.transparency.org/en/cpi/2022/index/uga
[3] https://www.weforum.org/reports/global-gender-gap-report-2022/in-full/1-benchmarking-gender-gaps-2022/?DAG=3&gclid=Cj0KCQiAj4ecBhD3ARIsAM4Q_jGNyuFRIDXhLxuf_4QVB328HZ0uWwhx8xer_ljri8S6pdYT2j7XuV0aAitaEALw_wcB
[4] https://gain.nd.edu/our-work/country-index/rankings/
[5] https://data.worldbank.org/country/uganda?view=chart)

2016)). The heavy rainy seasons are expected to receiver above average of the normal rainfall, risking the country to more incidences natural disaster (floods and landslides), and water borne diseases such as malaria and cholera (USAID, 2012).

2.2.2. Climate related disasters and economic damages/losses to economy

The country is rated natural disaster risks prone. The extreme weather events have risen in the recent years leading to mud/land- slides and floods in the mountainous regions like Bugishu (MT Elgon) areas and Kasese (Mt. Rwenzori) surrounding areas (MAAIF, 2018). Flooding has become more frequent, largely due to more intense rainfall (MoWE, 2014). In the last two decades, about 200,000 people are affected annually due to natural disasters linked to intense heavy rainfall resulting to floods damaging infrastructures and human settlement, sabotaging development in the country at large.[1]. The high rate of poverty and overreliance on rain fed agriculture and climate sensitive sectors such as agriculture, water, fisheries, tourism, and forestry is exacerbating the vulnerability of population to climate extremes (World Bank, 2020). Natural disasters (flooding, drought, and landslides) have become rampant and complicated by the state of marginalized population. "…..Poverty, land degradation, rapid and unplanned urbanization since the 1960s, and weak enforcement of building codes and zoning regulations, and a lack of coordinated disaster response strategies present additional challenges to the country's adaption and resilience efforts. Environmental degradation, underdeveloped irrigation systems, and near-absence of disaster preparedness at the community level are contributing factors to increasing drought risk in Uganda" (World Bank, 2020: 10; see also OPM, 2016). For details for losses to natural disasters, please refer to table 9, below.

Table 9: Losses due to natural disasters, Uganda 1900–2020[2]

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Drought	Drought	9	194	4,975,000	1,800
Earthquake	Ground Movement	5	115	58,100	71,500
Epidemic	Bacterial Disease	28	3,204	237,665	0
	Viral Disease	10	466	108,036	0
Flood	Flash Flood	4	76	8,614	0
	Riverine Flood	15	267	1,051,945	6,871
Storm	Convective Storm	1	23	47	0
Landslide	Landslide	8	540	151,546	0
	Mudslide	1	51	0	0

Adopted: World Bank, 2020:p10

Flooding risks is highest in lowland areas. Annually 50,000 people are affected by floods costing over US$62 million in economic losses[3], more especially in Kampala, Northern and Eastern districts of Uganda[4]. Semi-arid and savannah areas experiences infrastructure damages, with some places like Gulu almost becoming impassible during rainy periods, affecting movement of food supplies, access to medical facilities (MoWE, 2014). The period 2004-2013 alone, droughts affected almost 2.4 million people. The droughts of 2010 and 2011 costed the country an estimated losses of almost US$1.2 billion in damages, which approximates to 7.5% of the country's 2010 GDP.[5] Droughts causing human and livestock deaths and reducing water tables and resulting into crop failures. Areas of 'Cattle Corridor' especially Karamoja sub-region are most prone to droughts, resulting in food security and agricultural failures.[6]

2.3. Data and Methodology

The study used a mixed of the approaches from commonly acceptable cost benefit analyses methods used for estimating the value of 'non-marketed' environmental goods, in this case climate services. Reflecting on the earlier discussions in the Literature Review section, practically each measure offers advantages and disadvantages, and

[1] Department of Disaster Preparedness and Management (2011). The National Policy for Disaster Preparedness and Management. URL: https://reliefweb.int/sites/reliefweb.int/files/resources/1.%20National%20Policy%20for%20Disaster%20Preparedness%20%26%20Management.pdf

[2] EM-DAT: The Emergency Events Database - Universite catholique de Louvain (UCL) - CRED, D. Guha-Sapir, Brussels, Belgium. http://emdat.be/emdat_db/

[3] The World Bank (2020). GFDRR – Uganda Country Profile. URL: https://www.gfdrr.org/en/uganda

[4] Department of Disaster Preparedness and Management (2011). The National Policy for Disaster Preparedness and Management. URL: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/1732.pdf

[5] The World Bank (2020). GFDRR – Uganda Country Profile. URL: https://www.gfdrr.org/en/uganda

[6] Department of Disaster Preparedness and Management (2011). The National Policy for Disaster Preparedness and Management. URL: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/laws/1732.pdf

thus applying a mix of tools would attempt to overcome these challenges. In this evaluation, I adopted the following approaches to justify the value of climate services:

(1) Avoided asset losses method and data sources.

This approach is a straight forward measure, where the data on losses associated with events are routinely collected. The ICPAC has created a weather dashboard under 'East Africa Watch' a multi hazard warning systems to collect data on climate change impacts in IGAD region. The IPCC through NASA also has earth data on predicted losses to climate change, Gross Domestic Product (GDP) under different emission pathways at country levels, which could support this estimation. The four different IPCC Scenarios (RCP2.6, RCP4.5, RCP6 and RCP8.5), which means four different increases in mean global temperature by the end of the century (1°C, 2°C, 3°C and 4°C, respectively). The Representative Concentration Pathways (RCP) of the IPCC are define along the following levels; the first scenario (RCP 2.6) assumes mitigation policies and measures that keep the rise in temperatures at 1° C are taken. The two scenarios (RCP 4.5 and RCP 6) assume less efficient GHG emission reduction that results in temperature rises of 2°C and 3°C. The fourth scenario (RCP 8.5) assumes continuing GHG emissions and a rise in mean global temperatures of 4°C. Apparently countries are operating with emission levels that could result into a 3^0C rise by the end of the Century (2100).

Therefore, improvement in services is expected to guide stakeholders to reduce / avoid future damages/losses from climate change, translating into economic benefits. For example, climate change is causing significant losses to national economy, and thus upgrading hydro-met services are predicted to reduce further losses through improved decision makings and planning among stakeholders. For instance in agricultural sector, benefit estimation from climate services using an 'avoid loss' methodology , will expressed in form of reduce crop failures, livestock losses (death and reduced productivity) from weather extreme events (WMO, 2015).

Many scholars have praised 'avoided asset loss' method as data less demanding and less time consuming, easier to implement both ex-ante and ex-post; compared to other evaluation methods such as economic modelling and stated preference (Tesfaye et al., 2018). However, it has be blamed for a general lack of rigor to estimate production gains and income changes at household and farmer levels for use of climate services, despite enormous contribution to humanitarian and disaster response programmes. Its assumed that upgrading hydromet services is capable of reducing climate related losses in low income/developing countries (e.g. Uganda) by approximately 10%, while in lower middle income countries (in this case Kenya) by 20%; 50% in upper middle income, and 100% in high income countries i.e. in the OECD (World Bank, 2012, see also Hallegatte, 2012). This estimation takes note of this important assumption to control for structural differences across countries to determine benefit outcomes from upgrading climate services.

(2) Benefit Transfer (BT) approach

This is particularly useful in situation where there is a limited or no available data as in this study. The Benefit transfer technique takes into account, the consideration of similar monetary valuations conducted i.e. '*willingness-to-Pay'* values for climate services done in similar countries (locations) and applying the results outside the site context where the study was originally conducted (Pearce and Howarth, 2001). The BT was supplemented with other methods such as the 'Avoided loss' and Contingent Valuation technique to ensure consistency in the evaluation results. We need to bear in mind that there are few literature analyzing the validity of 'transfer' techniques in most economic valuations (Pearce and Howarth, 2001).

The underlying assumptions in this evaluation is that people value their production activities/ sources of livelihoods and would be willing protect the state of their environment through paying for any services that could help them achieve their wellbeing goals. Environmental goods in our case climate services provide services which have no apparent markets or very imperfect markets but have direct bearing on people's livelihoods and wellbeing. Bad weather when not noticed early can affect the crop/livestock yields, people's income, health, damage to buildings and infrastructures. Unlike other marketed products, climate services cannot be priced, and their monetary values to the population cannot easily be observed.

Therefore, it possible to value this non-priced goods/services using peoples *willingness-to-pay* (WTP) to enjoy the environmental benefits, or their *willingness-to- accept compensation* (WTA) to avoid the degradation and losses associated with the environmental problem, in this cases weather related extreme events such as droughts and floods. If we can obtain this WTP, as benefits to climate services, and the knowledge on financial costs in generating and dissemination, it is possible to analyze the 'Benefit Cost Ratio' (BCR) under different scenarios and restricted assumptions. The simplest way to implement Benefit Transfer is to transfer average WTP from a single study to another site which has no study. The idea here is that an evaluator borrows an estimated WTP in a context i, and applies it to a context j, but taking consideration of the differentials in the two areas, such as income differences which may vary across locations. Takes for instance where per capita income varies in two different countries, then the WTP in the policy site (j) will be estimated as (Pearce and Howarth, 2001).

$$WTP_j = WTP_i \, (Y_j / Y_i)^e \qquad (1)$$

Y denotes income per capita, WTP is the willingness to pay, and 'e' the income elasticity of demand, i, being the study site (where WTP was initially done), and j, the policy site (new location) where results from i will be transferred to in order to estimate its WTP. A similar approach has been successful in Europe where WTP health studies were transferred from USA, assumed to be in similar context to estimate WTP in Eastern Europe, at income elasticity of demand pegged to 0.035. (Krupnick et al., 1996).

Also evaluator can make controls through adjustments based on population size, Purchasing power and currency, Year of value and general price levels, Year of value and general price levels (Brander , 2013); but less often basing on population distribution such as age. Note that the transfer is 'assumed' to be correct: and no separate validation is carried out. For example where, a year of value and general price levels approach is used for adjustment controls, then the formula, used:

$$WTP_P = WTP_S\,(D_P / D_S) \qquad (2)$$

Where: WTP_P = willingness to pay at the policy site
WTP_S = willingness to pay at the study site
D_P = GDP deflator index for the year of the policy site assessment
D_S = GDP deflator index for the year of the study site valuation

The GDP deflators measure the annual rate of price change in an economy, and are available at the World Bank World Development Indicators[1]. When you choose to use purchasing power parity of the currency using exchange rates across countries, which are also available in the World Bank Development Indicators, then the formula becomes:

$$WTP_P = WTPS \times E \qquad (3)$$

Where: WTP_P = willingness to pay in currency of the policy site
WTP_S = willingness to pay in the currency of the study site
E = purchasing power parity adjusted exchange rate between policy and study site currencies

In this study purchasing power of a unit of US$ is assumed to have equal weight across the study and policy sites, and there was no need to control through this parameter. In order to ensure validity of the transfer, it is recommended that the WTP estimate from i (study site) and applied to j (policy site), one would need to conduct a full WTP study in in j and the mean WTP result would be compared with the 'transferred' WTP.

(3) Contingent valuation and impact of climate services from household survey.

The Intergovernmental Authority on Development (IGAD) through the Climate Prediction and Applications Center (ICPAC) provides seasonal forecasts on rain onsets, anomalies in relation to the long term climate averages. This effort helps to inform farmers on what crops to plant, when to plan them, guide livestock production mobility for better matching forage conditions, and when to use crops reservoirs (Zhongming et al., 2019). This is likely to increase crop yield and higher livestock body conditions scores in form of weigh gains and well targeted marketing, leading to higher household income for those who can access and also actively apply these forecasts in their production decisions unlike those not using such services. Literature has shown that climate services lead to better informed decision making, generating for value for smallholder farmers (Zhongming et al., 2019). An average of US$ 30 billion annually in household productivity and US$ 2billion per year in reduced asset losses is attained through an improved weather, climate, water observations and forecasting (Zhongming et al., 2019).

In this assessment, I adopt the household survey in locations in the ClimSA pilot countries (Uganda and Kenya) where farmers are receiving seasonal forecasts i.e. (the treatment group), and how it has impacted their yields / income; compared to the counterfactual group i.e. those not receiving or using the forecasts in farming production decisions. Some sections of the survey will elicit farmers' willingness to pay for seasonal forecasts inform contingent valuation through stated preference. This approach can help us estimate the value to be generated from climate services Vis-à-vis the costs of investment on climate services to generate the Benefit Cost Ratio (BCR). This result is equality important to validate the consistency in the Benefit Transfer analysis.

Contingent valuation (Stated preference method)

Contingent valuation in household survey helps to create a market price for a non-market good such as climate services. This is attained through creating hypothetical market, by asking potential users of CS to elicit whether they are willing to pay for climate forecasts, and by how much? In addition, other variables such as socio-economic characteristics are collected to determine factors behind willingness to pay. The maximum amount respondents are willing to pay analyszed through STATA software demonstrates the values households attach to climate services to avoid the pain and suffering (losses) they want to avoid from the effects of climate change. The household value can then be extrapolated/projected at national level, depending on adoption of climate information i.e. total number of farmers adopting, using the services, a figure normally obtained from expert opinion.

Many economists agree that CV if carefully designed and administered can yield accurate and useful information on household's preferences (Cummings et al., 1986), for economic valuation of non-market goods. The CV method has been proven attractive in a number of evaluation studies, including cost benefit analysis and environmental analysis across literature (Verbicˇ et al., 2016; Venkatachalam, 2004; Ndebele and Forgie, 2017; Latinopoulos et al., 2016; Giudice and Paola, 2016; Guo et al., 2014; Abdullah and Jeanty, 2011)). However, its

[1] http://data.worldbank.org/data-catalog/world-development-indicators

reliability and validity has been questioned, when they survey questions are not properly designed and asked to the respondents (Venkatachalam, 2004)

3.0 Observations and Main Results

3.1. Benefit Transfer Results

The Consultative Group on International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture and Food Security (CCAFS) had recently conducted willingness to pay study for improved climate services information in Rwanda and thus feasible to apply in the IGAD region after controlling for countries' differences in key development indicators, in line with BT methodology and guidelines. Rwanda, a low income country and also a member of East African community was selected as the 'study site' and the results transferred to 'policy sites' (Kenya and Uganda) as it shares many similarities within East African region, thus making transferring results suitable for Benefit Transfer analysis into the policy locations under investigation. The results from Rwanda was transferred to help estimate those of Kenya and Uganda, considered (policy sites), after controlling for differences in country specific development indicators, e.g. based on income differentials, measured by each respective GDP per capita, adjusted through income elasticity of demand (e) .
Recalling earlier equation (1) from the BT model, above i.e.

$$WTP_j = WTP_i \, (Y_j / Y_i)^{e} \qquad (1)$$

Where: Y denoting the income per capita, WTP is the willingness to pay, and 'e' the income elasticity of demand, i, being the study site, and j, the policy site (new location) where results from i will be transferred to site j, in order to estimate its WTP. Farmers in Rwanda just like other parts of the World value very high accuracy in the quality of information disseminated from weather forecasts, which are user friendly and accessible, and thus willing to pay an amount estimated at US$ 1.63 monthly for farmers who have not received climate information and not using in their farming systems. This approximates to about US$ 19.56 per farmer /year (WTPi = US$ 19.56 per farmer/ year). The income elasticity of demand (e) in Sub-Saharan Africa is more responsive to changes in food prices than other commodities, with the regional average ranging for cereals (0.60), dairy products (0.66), fruits and vegetables (0.84), meat and beef products (0.80); and oils and fats (0.61) (Femenia, 2019). Therefore, 'e' average for the SSA region estimates to 0.702.

Box 1.
The GDP per capita (current US$) for Rwanda (Yi) = US$ 822.3 (2021 estimate)[1]
The GDP per capita (current US$) for Uganda (Yj) = US$ 883.9 (2021 estimate)[2]

An estimate of the price elasticity of WTP with respect to income is obtained from a published meta-analysis of price and income elasticities of food demand (Femenia, 2019). This estimate is 0.702, which indicates that WTP increases with income but at a less than proportional rate (i.e. for every 1% increase in income, WTP increases by 0.702%).

Using equation 1, the unit value adjusted for the difference in average household incomes between the study and policy site-1 can be calculated as:

$WTP_{j(Uganda)}$ = US$ 19.56 $(883.9 / 822.3)^{0.702}$
$WTP_{j(Uganda)}$ = US$20.58 per farm household /year

The adjustment for the difference in income therefore results in a 5.2% higher WTP value for Uganda (1st Policy site) compared to the study site (Rwanda).

Considering, Uganda, a country with about 7 million households who are farmers, representing 80% of the total households (UBOS 2022), and assuming that all begin utilizing climate information in their farming systems, the revenue generated from these services would yield about US$20.58 x 7,000,000 (US$ 143,920,000) annually. By BT methodology, this approximates to about US$ 143.92 million per year at national level in revenue gains from smallholder farmers alone. Which is about 0.35% of GDP in revenue gains at current GDP of (US$ 40.53 billion)[3] for Uganda. This amount is just enough to service almost 0.6% (US$ 143.7 million) of the country's current, public debts burden estimated at US$ 23.95 billion (2022 est.)[4]. The gains would even be higher if fisheries and pastoralists, other sectors of the economy like tourism, infrastructure, and aviation among others are included in the estimation. However, caution must be taken that collecting such money directly from farmers may prove politically contested due to the public nature of the good problem, and thus we recommended more policy instruments like indirect tax levy to achieve the same results. The total benefits were not captured fully at this

[1] https://data.worldbank.org/country/RW
[2] https://data.worldbank.org/country/UG
[3] https://data.worldbank.org/country/UG
[4] https://www.statista.com/statistics/531996/national-debt-of-uganda/

stage by this methodology as it restricted to only smallholder farmers where data was available. Thus limiting the estimation of Benefit Cost Ratio (BCR) of investment in climate services at only to farmer level. The 'avoid asset losses' approach would improve this estimation, as it has rigor to capture full benefits and costs of valuation.

Box 2

The GDP per capita (current US$) for Rwanda (Yi) = US$ 822.3 (2021 estimate)[1]
The GDP per capita (current US$) for Kenya (Yj) = US$ 2,081.8 (2021 estimate)[2]

An estimate of the price elasticity of WTP with respect to income is obtained from a published meta-analysis of price and income elasticities of food demand, Sub-Saharan Africa (Femenia, 2019). This estimate is 0.702, which indicates that WTP increases with income but at a less than proportional rate (i.e. for every 1% increase in income, WTP increases by 0.702%).

Using equation 1, the unit value adjusted for the difference in average household incomes between the study and policy sites can be calculated as:

$WTP_{j(Kenya)}$ = US$ 19.56 $(2{,}081.8 / 822.3)^{0.702}$
$WTP_{j(Kenya)}$ = US$ 37.55 per farm household /year

The adjustment for the difference in income therefore results in a 92% higher WTP value for Kenya (2^{nd} Policy site) than the study site (Rwanda).

In the same way, the number of farmers in Kenya are estimated to 7.5 million smallholders, contributing 75% of total agricultural output.[3] While taking consideration climate services should reach all farmers and they begin to use actively in the production decisions, this would generate approximately US$ 37.55 per farmer /year x 7,500,000 farmers (US$ 281,625,000). Therefore investment in CS would on average generate about US$ 281.6 million annually in revenue gains from smallholders alone; when other sectors are not included. On average, this estimates to about 0.26% of the Kenya's GDP at current prices (US$ 110.35 billion)[4] in revenue gains per year from smallholder farmers only, from climate services. The revenue is equally good enough to service almost 0.36% (US$ 279.5 million) of the country's public debts burden, currently standing at US$ 77.65 billion (2022 est.)[5]. This result is very important, at a time where greater efforts are needed from developing countries to mobilize domestic revenue, particularly to finance their development, to rebuild better and stronger economies while recovering from the socio-economic impacts of the COVID-19 pandemic, and global crises like Russia-Ukraine war, couple with already rising macroeconomic fiscal imbalances, and donor fatigue in supporting development finance.

3.1.1. Benefit Cost Ratio (BCR) from Benefit Transfer Results

The BCR measures the ratio of project benefits versus project costs. It involves summing the total discounted benefits for a project over its entire duration/life span and dividing it over the total discounted costs of the project.

Mathematically expressed as,

$$\text{BCR} = \sum_i \sum_t [\text{B}_{\text{it}} - \text{C}_{\text{it}}] / \; [1 + r]^t \qquad (6)$$

Where B_{it} are the project's benefits to the ith agent in time period t; Cit are the project's costs to the ith agent in time period t, r is the discount rate. The project benefits and costs are summed from time (t=0) to time (t = n, i.e. the life span of the project). In this analysis, t is set at 0, as investment in CS are being done yearly and the benefits are realized the same year, implying a no need for considering the time value of money through discounting. In this case, when't' is set at '0' the expression $(1+ r)^0 = 1$. Therefore the BCR in the ClimSA pilot countries are estimated as in box 3 below.

Alternatively, this expression can be expanded as below to become:

$$BCR = \frac{|PV\;[Benefits]|}{|PV[Cost]|} = \frac{\sum_{t=0}^{N} \frac{|CF_t[Benefits]|}{(1+i_t)^t}}{\sum_{t=0}^{N} \frac{|CF_t[Costs]|}{(1+i_t)^t}}$$

Where: BCR = Benefit Cost Ratio, PV = Present Value, CF = Cash Flow of a period (classified as benefit and cost, respectively); i = Discount Rate or Interest Rate; N = Total Number of Periods t = Period in which the Cash Flows

[1] https://data.worldbank.org/country/RW
[2] https://data.worldbank.org/country/KE
[3] https://www.ifad.org/en/web/operations/w/country/kenya
[4] https://data.worldbank.org/country/KE
[5] https://www.statista.com/statistics/531654/national-debt-of-kenya/

occur.

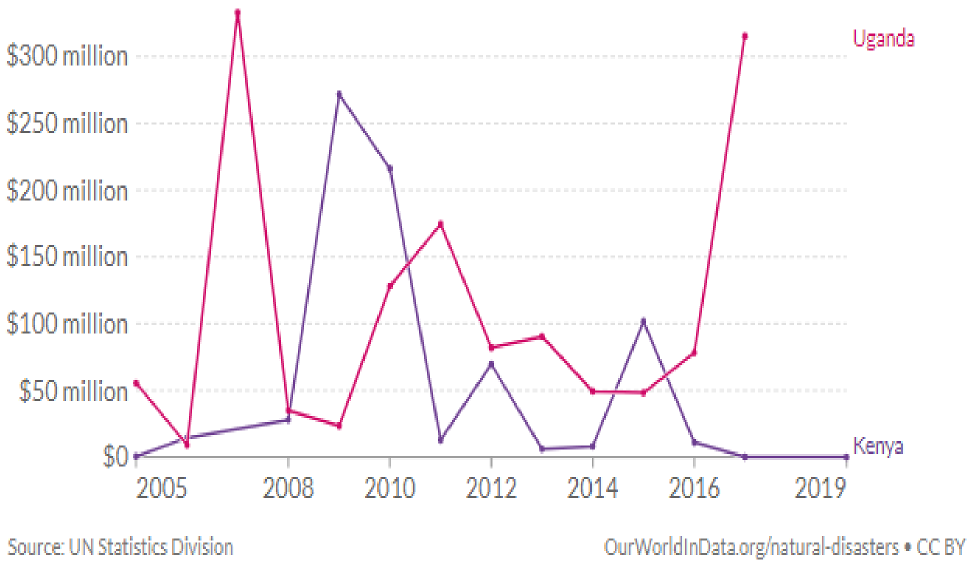
Box 3
Costs of Climate Services (ICPAC level)
ICPAC budget in 2022 was about US$ 29,704876.95 ; and US$ 32,711,948.52 in year 2021
Average annual costs of delivering climate services from ICPAC is estimated as
Average annual costs = (US$ 29,704876.95 +US$ 32,711,948.52)/ 2
Average Costs = US$ 31,208,412.735 per year

Benefits of CS, inform of revenues at farmer level
Uganda = US$ 143,920,000
Kenya = US$ 281,625,000).
BCR results,
Uganda = (US$ 143 920,000/ US$ 31,208412.74) = 5:1 (about 5/1)
Kenya = (US$ 281,625,000/US$ 31,208,412.74) = 9:1 (about 9/1)

The decision rule here is that implement the project if BCR > 1; and stop funding if BCR < 1; while BCR = 1 (the investment is neither profitable nor lossy) but the project may be taken if there are perceived social benefits likely not captured through monetary values. The BCR results shows that for every one (1) unit of US$ invested at IGAD level, yields in returns approximately US$ 5.0 in Uganda, and US$ 9.0 in Kenya, annually. This is about X5 and X9 times the costs of investment in the policy countries (Uganda and Kenya) respectively. Therefore, this is a clear indication that investing in CS is worth putting tax payers' money. Due to limited data to carry a full analysis, this estimation was only restricted at farmer level which would have otherwise been higher if other sectors of economy were considered. We assumed that the costs of generating CS is fixed irrespective of how many farmers being reached, and therefore, the more the farmers accessing and using the services, the lower the costs/ farmer.

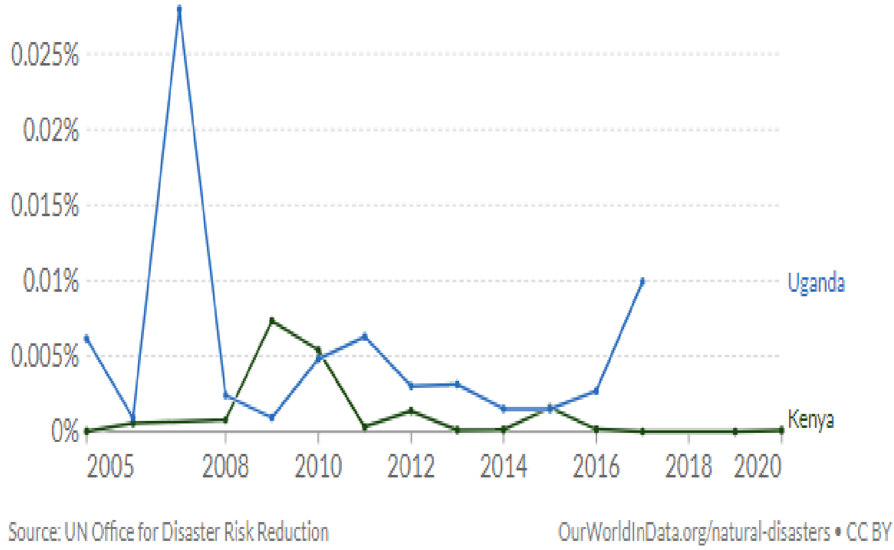
3.2. Estimated losses avoided from climate disasters through Climate Services.

Figure 1: Trends in direct disaster economic losses in pilot countries (US$ million)[1]



[1] Shows the monetary value of the total or partial destruction of the physical assets existing in the natural disaster affected area. This direct economic loss is nearly equivalent to physical damage.

Figure 2: Trends in direct disaster economic losses in pilot countries as share of GDP (%)[1]



This is a very good estimate since it values all the economic losses attributed to natural disasters ranging from damages related to glacier lake outburst (not a problems in IGAD area), fog, dry mass movement, landslides, volcanic activities, extreme temperatures, wildfires, droughts, floods, earthquake, and extreme weather. All these events are capable of being predicted through climate information. A reliable early warning systems would help reduce exposure to these incidences, significantly avoiding the losses that would have occurred without these information. For details of economics losses, by total and share of GDP, please refer to table 11, below.

Table 11: Direct economic losses to natural disasters, studied ClimSA countries

Year	Economic Losses			
	Kenya		**Uganda**	
	Losses (US$ million)	Share of GDP (%)	Losses (US$ million)	Share of GDP (%)
2005	0.581	<0.01	55.47	<0.01
2006	14.47	<0.01	9.19	<0.01
2007	**	**	332.92	0.03
2008	27.99	<0.01	34.9	<0.01
2009	271.61	<0.01	23.44	<0.01
2010	216.06	<0.01	127.98	<0.01
2011	12.85	<0.01	174.47	<0.01
2012	69.54	<0.01	81.98	<0.01
2013	6.19	<0.01	90.36	<0.01
2014	8.29	<0.01	49.28	<0.01
2015	101.59	<0.01	48.23	<0.01
2016	11.12	<0.01	78.30	<0.01
2017	0.122	<0.01	315.23	<0.01
2018	**	<0.01	**	**
2019	0.068	<0.01	**	**
Annual Average (US$)	**56.96**		**113.857**	

Source: UN office for Disaster Risks Reduction with authors modifications[2]
** Where there was no data

3.2.1. Estimated avoided asset losses from climate services (past trends)

Annually Kenya and Uganda, loses on averagely US$56.96 million and US$ 113.86 million respectively to natural disasters related damages such as from droughts, mudslides, floods among others, from available data. Upgrading hyromet services to strengthen climate services inform of early warnings would help reduce the levels of these losses. Recalling the earlier assumption that the share of losses avoided by upgrading hydro-met services would

[1] https://ourworldindata.org/grapher/direct-disaster-loss-as-a-share-of-gdp?tab=chart&region=Africa&country=KEN~UGA
[2] https://ourworldindata.org/grapher/direct-disaster-loss-as-a-share-of-gdp?tab=chart&region=Africa&country=KEN~UGA

reduce these losses to about 10% of these benefits in low-income countries (where Uganda falls); 20% in lower middle income (Kenya), 50% in upper middle income, and 100% in high income countries (World Bank, 2012, see also Hallegatte, 2012).

The structural issues which affect developing countries limits the attainment of full value for money for investment in services relative to developed countries such as the European Union and Organisation for Economic Cooperation and Development (OECD) countries. In our scenario, Uganda would avoid economic losses to natural disaster to about (0.1 x US$ 113.857) annually by strengthening early warning systems. This approximates to about US$ 11.39 million losses avoided per year, with the current hydromet system. This gain is even higher where the systems are upgraded to European standards (100%), saving the country almost US$ 113.86 million annually to economic loss avoidance.

Therefore, by Ugandan GDP (current US$) estimated at US$ 40.53 billion)[1], the country will avoid 0.028% of its GDP losses per year, which would have been otherwise been eroded by climate related disasters. In Kenya, a lower middle income country is able to avoid 0.2 x US$ 56.96, equally about US$ 11.392 million per year (a 20% gain) from hydromet services. By the World Bank assumption, this figure will grow to 100% (US$ 56.96 million) per year of losses avoided, if the services are upgraded to European Standards in Kenya. At the country GDP (current US$) of about US$110.35 billion (2021 est.)[2], the avoid losses from climate services approximates to about 0.01% of the GDP /year saved. Note that the current valuation only measured the direct economic losses avoided to natural disasters while ignoring other indirect losses associated with weather extreme events e.g. the loss labour productivity such as inability to work in hot weather and episodes of water borne diseases such as cholera and malaria, social costs avoided such as incidences of gender based violence (GBV) reduced due to improved household food security are not included, which would increase the gains further if factored in these estimations.

3.2.2. Estimated avoided asset losses from climates services (the future trend)

This analysis was based on the "Shared Socioeconomic Pathways (SSPs", a scenario compact developed by the climate change research community in order to facilitate the integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation (Riahi, et al., 2017). The SSPs are based on five narratives describing alternative socio-economic developments, including sustainable development, regional rivalry, inequality, fossil-fueled development, and middle-of-the-road development, i.e. estimating the long term implications /projections on the demographic and economic changes under different emission pathways /climate policy regimes adopted in climate change adaptation and mitigation efforts ((Riahi, et al., 2017). The country gains from successful implementation of the Paris agreement is tagged to when countries restrained temperature rise to 20C target (Represntative Concentration Pathway, RCP 4.5). The failure to meet the RCP 4.5 pathway, implies severe climate damages in Sub-Saharan Africa, where Uganda and Kenya equally fall. Climate change policies under different Representative Concentration Pathways (RCP) are as follows:

1) The case of 1◦C is likely to reflect the lowest emission scenario with the most stringent mitigation policies (or approximately RCP2.6).
2) Implementation of a climate change agreement (e.g., the Paris Accord) would slow global warming to around 2◦C by 2100 (or approximately RCP4.5).
3) A medium baseline case with less stringent mitigation policies will push global surface temperatures up to 3◦C by 2100 (approximately RCP6).
4) Without any countervailing action to reduce emissions, global warming could increase up to 4◦C (or approximately RCP8.5).

The table 12 below, shows the projected global temperature rises on the country's economic performance, measured by the fall in Gross Domestic Products (GDP).

Table 12: Long run impacts of climate change on the GDP, study countries (% change/ year)

	% Annual GDP changes by 2100	
Climate policy regimes	**Kenya**	**Uganda**
1^0C	−2.331	−1.743
2^0C	−4.706	−3.652
3^0C	−7.238	−6.328
4^0C	−10.506	−10.404

Source: Kompas et al., 2018; with data retrieved initially from GTAP-INT[3]

[1] https://data.worldbank.org/country/UG
[2] https://data.worldbank.org/country/KE
[3] GTAP is the Global Trade Analysis Project.

Table 13: Impacts of global warming under Business-as-usual (3˚C) (% GDP losses /Year)

Period	% GDP losses Kenya	Uganda
2027	−0.744	−0.635
2037	−1.492	−1.268
2047	−2.254	−1.912
2067	−3.813	−3.232
Long run (2100)	−7.238	−6.328

Source: Kompas et al., 2018, with data retrieved initially from GTAP-INT

The country GDP and downscaled projection were based on the Special Report on Emissions Scenarios (SRES) A1, A2, B1 and B2 marker scenarios, 1990 – 2100 with 1990 as the bases year GDP); extracted from the national accounts of the UN Statistics Divisions. The SRES regional GDP growth rates were estimated from 1900 -2100 basing on the SRES marker model for the region, applied uniformly to each country within the SRES defined region (Gaffin et. al., 2002). Under the SRES markers, economic growth rates are assumed "very high" for the A1 family, "medium" for the A2 family, The A1 scenario assumes a very-rapid economic growth, in which the rapid growth of the global economy and population peaks in 2050 and declines thereafter, in which then new efficient technologies are introduced (Kim, Chang-Gil and et al., 2009: p.21).. It is divided into three groups according to the alternative development of energy technology, i.e. a fossil intensive energy scenario (A1F1), non-fossil energy scenario (A1T), and balanced-energy source scenario (A1B). The A2 is the scenario for a heterogeneous world with a high population growth rate, a low economic growth rate, and the most diversified but slowly developing technologies (Kim Chang-Gil and et al., 2009: p.21). The results of the GDP projections for the two countries under different development pathways, are provided in table 14 and 15, below.

Table 14: Downscaled GDP Projections for Kenya (1990 US$ Market Exchange Rates)

Year	Development pathways (Scenario Markers) SRES A1	SRES A2	SRES B1	SRES B2
2025	58,125,412,349	39,814,327,470	66,476,497,004	35,945,868,382
2030	74,260,238,631	53,085,920,127	96,503,902,795	48,828,780,395
2035	149,847,829,508	66,357,512,784	135,995,769,116	68,889,040,087
2040	225,435,420,384	79,629,105,441	189,105,876,162	97,190,628,268
2045	301,023,011,261	92,900,698,099	252,626,606,228	133,462,793,859
2050	376,610,602,137	106,172,290,756	327,079,789,844	183,271,964,202
2055	509,122,383,833	130,481,269,363	403,714,190,218	235,202,842,212
2060	641,634,165,529	154,790,247,970	489,206,984,789	301,848,551,827
2065	774,145,947,225	179,099,226,576	582,464,089,409	363,566,323,346
2070	906,657,728,921	203,408,205,183	695,289,946,068	437,903,281,864
2075	1,039,169,510,617	227,717,183,790	808,219,284,100	497,562,897,146
2080	1,186,455,493,212	262,258,724,586	930,579,088,086	565,350,493,748
2085	1,333,741,475,807	296,800,265,381	1,042,128,038,266	616,477,584,932
2090	1,481,027,458,402	331,341,806,176	1,160,223,626,089	672,228,320,178
2095	1,628,313,440,997	365,883,346,972	1,264,104,418,323	719,225,894,874
2100	1,775,599,423,591	400,424,887,767	1,375,849,913,537	769,509,216,333

Source: Earth Data, accessible at https://search.earthdata.nasa.gov/downloads/8434560176

Table 15: Downscaled GDP Projections for Uganda (1990 US$ Market Exchange Rates)

Year	Development pathways (Scenario Markers)			
	SRES A1	SRES A2	SRES B1	SRES B2
2025	29,320,579,372	20,083,799,866	33,533,171,259	18,132,407,916
2030	37,459,574,616	26,778,475,571	48,680,090,640	24,631,018,919
2035	75,588,714,149	33,473,151,276	68,601,229,334	34,750,146,040
2040	113,717,853,682	40,167,826,981	95,391,905,669	49,026,500,032
2045	151,846,993,215	46,862,502,686	127,434,080,209	67,323,504,169
2050	189,976,132,747	53,557,178,391	164,990,983,318	92,449,067,558
2055	256,819,911,673	65,819,514,397	203,648,171,766	118,644,897,730
2060	323,663,690,598	78,081,850,403	246,773,857,549	152,263,426,006
2065	390,507,469,523	90,344,186,409	293,816,144,693	183,396,122,452
2070	457,351,248,448	102,606,522,415	350,729,624,559	220,894,397,380
2075	524,195,027,373	114,868,858,421	407,695,304,205	250,988,884,705
2080	598,491,452,440	132,292,872,249	469,418,055,060	285,183,422,452
2085	672,787,877,508	149,716,886,077	525,687,416,695	310,973,793,213
2090	747,084,302,575	167,140,899,905	585,259,141,288	339,096,498,787
2095	821,380,727,643	184,564,913,733	637,660,404,193	362,803,790,718
2100	895,677,152,710	201,988,927,561	694,028,910,316	388,168,533,235

Source: Earth Data, accessible at https://search.earthdata.nasa.gov/downloads/8434560176

The economic growth is considered "high" for B1 family and "medium" for the B2 family. The B1 scenario assumes that there will be a same population growth rate as that of the A1 scenario but at a slower economic growth rate. In this scenario, the economic structure changes toward a service and information economy and the sustainable development is pursued with an emphasis on clean and resource-efficient technologies. B2 is a scenario for a world where regions coexist with each other in harmony. This scenario assumes the intermediate level of population and economic growth between A1 and B1, and focuses on regional solutions for economic, social and environmental sustainability (KIM, 2012). For details of the GDP projections under A1 marker, refer to Tsuneyuku Morita and Kejun Jiang (National Institute for Environmental Studies (NIES), Tsukuba, Japan; A2 model (Alexei Sankovski and William Pepper, ICF Consulting, Washingtom, DC, USA; and for B2, Nebojsa Nakicenovic Arnulf Grubler, R Alexander Roehrl, and Keywan Riahi, International Institute for Applied System (IIASA), Laxenburg, Austria.

3.2.3. Key assumptions on climate policy regimes/ development paths in the estimations

We assumed that countries like Uganda and Kenya are likely to face the following climate policy along its development trajectory i.e. a situation where

1) Implementation of a climate change agreement (e.g., the Paris Accord) would slow global warming to around 2◦C by 2100 (or approximately RCP4.5).
2) A medium baseline case with less stringent mitigation policies will push global surface temperatures up to 3 ◦C by 2100 (approximately RCP6).
3) The countries adopts A2 scenario in their development trajectory where there is a heterogeneous world with a high population growth rate, a low economic growth rate, and the economy most diversified but slowly developing technologies

In terms of development, Uganda is assumed to be a lower middle income by 2040 conforming to Vision 2040; while Kenya will be a upper middle income by 2065, in line with the African Union (AU) Agenda 2063 agenda, a continental blueprint to achieve inclusive and sustainable socio-economic development over 50 –year period

4) By World Bank guideline, the share of losses avoided by upgrading hydro-met services (CS) in future is estimated at 10% for Uganda (a low-income country) apparently for period 2025 to 2040. The country is currently implementing Vison 2040 and therefore is assumed to attain a lower middle income status; in which case the implementation of climate services expected to reduce climate related losses at 20% from period 2040 and beyond.
5) Kenya (a lower middle income country) is currently implementing Vision 2030 of creating "a globally competitive and prosperous country with a high quality of life by 2030", aimed at transforming the country into "a newly-industrialising, middle income country providing a high quality of life to all its citizens in a clean and secure environment" (GoK, 2007). In this estimation, we assumed that Kenya will remain a lower middle income by this period, but by 2065; the country is assumed to attain a upper middle income status. Going by the World Bank estimation on expected gains from climate services, upgrading hydro-met and climate services would reduce/avoids approximately 20% of climate related losses in a lower middle income level, but would increase to 50% if upper middle income status is achieved (World Bank, 2012, see also

Hallegatte, 2012).

With these in mind, it is now feasible to estimate the losses in country's GDP "with" and "without" climate services from the available data, while taking consideration of the projected changes in GDP losses in the respective country. The details of the estimation for Kenya are provided in the table 16 and Figure 3, below.

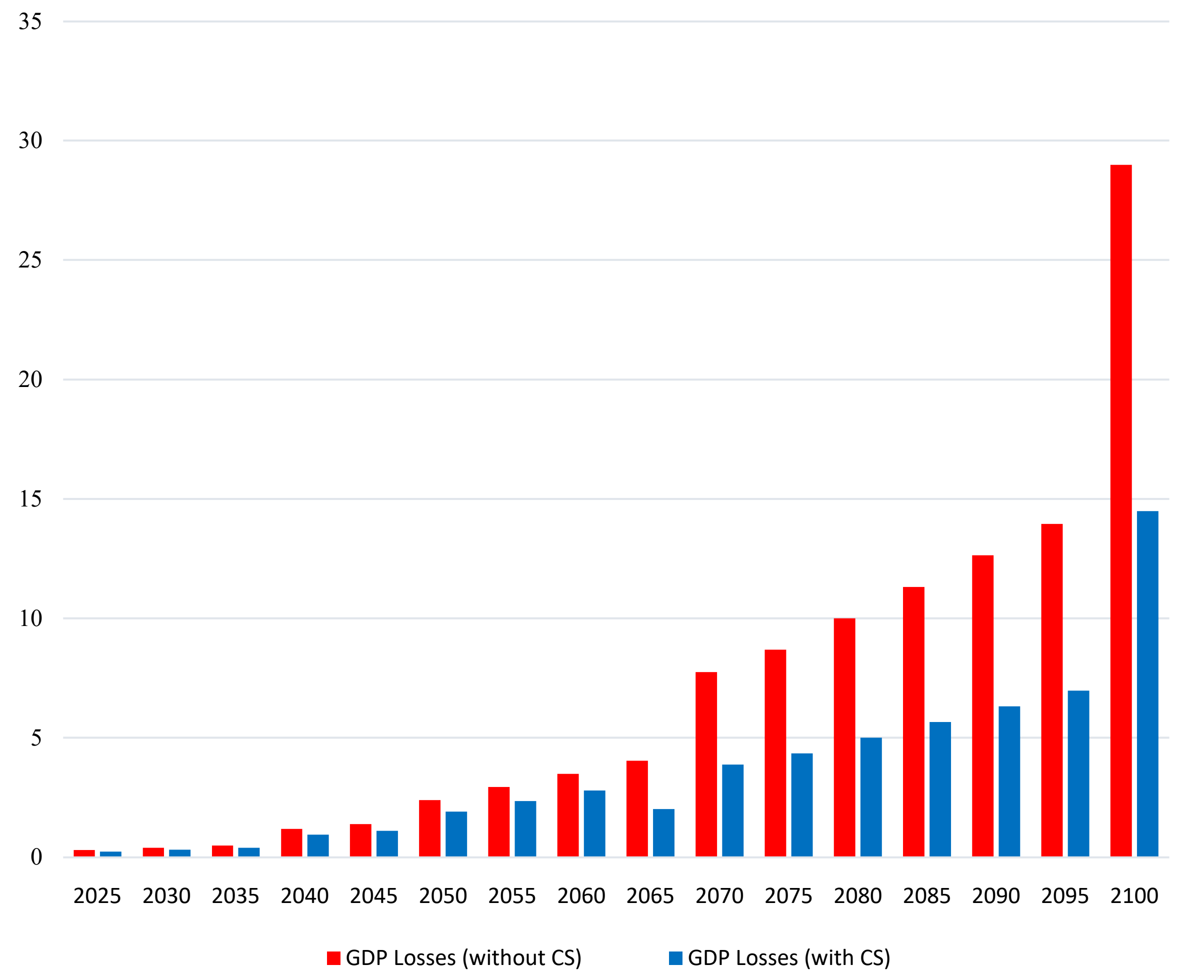
Table 16: Projected GDP losses "with "and "without" Climate Services, Kenya

	GDP loss (US$)		
Year	**Without CS**	**Losses avoided**	**With CS**
2025	296,218,596.4	59,243,719.3	236,974,877.1
2030	394,959,245.7	78,991,849.1	315,967,396.6
2035	493,699,895.1	98,739,979.0	394,959,916.1
2040	1,188,066,253.2	237,613,250.6	950,453,002.5
2045	1,386,078,415.6	277,215,683.1	1,108,862,732.5
2050	2,393,123,433.6	478,624,686.7	1,914,498,746.9
2055	2,941,047,811.4	588,209,562.3	2,352,838,249.2
2060	3,488,972,189.2	697,794,437.8	2,791,177,751.4
2065	4,036,896,567.0	2,018,448,283.5	2,018,448,283.5
2070	7,755,954,863.6	3,877,977,431.8	3,877,977,431.8
2075	8,682,856,217.9	4,341,428,109.0	4,341,428,109.0
2080	9,999,925,168.5	4,999,962,584.2	4,999,962,584.2
2085	11,316,994,119.0	5,658,497,059.5	5,658,497,059.5
2090	12,634,063,069.5	6,317,031,534.7	6,317,031,534.7
2095	13,951,132,020.0	6,975,566,010.0	6,975,566,010.0
2100	28,982,753,376.6	14,491,376,688.3	14,491,376,688.3
2100 (Paris Accord)	18,843,995,218.3	9,421,997,609.2	9,421,997,609.2

Source: Earth Data (2023), with author own calculations

In a long run (2100), under "business-as –usual" scenario i.e. where global warming will be at 3^0C (RCP6), the country will lose approximately US$ 28.98 billion per year without using Climate Services against US$ 14.49 billion, saving the country 50% of the total amount which would have been lost (US$ 14.49 billion) where economic decisions and policy processes are actively guided by climate information services. However, where Paris Agreement is achieved i.e. the global temperature rises are restricted to maximum of 2^0C (RCP4.5), the losses to GDP will be lowered to US$ 18.84 billion in the coming century (2100). The combined benefits /losses avoided are even higher where the global attainment of the Paris Accord targets are achieved leading to an estimated US$ 23.9 billion per year

Figure 3 : GDP Losses "With" and "Without" Climate Services, Kenya (US$ Billion)



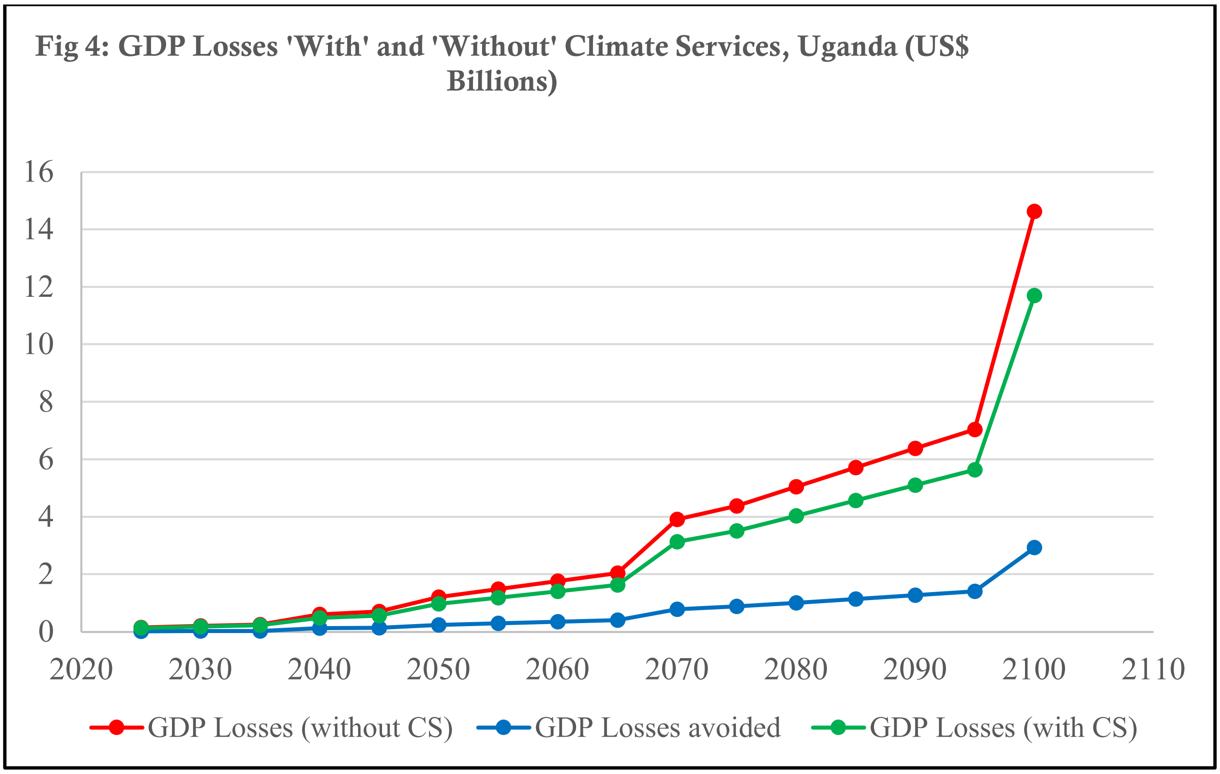
Source: Earth Data (2023), with author own calculations

In a long run (the coming Century, 2100); where the "business-as-usual" is the trend in climate adaptation and mitigations, in which case the global warming will reach 3^{0}C (RCP6), Uganda will lose approximately US$ 14.62 billion per year without using CS against US$ 11.7 billion, saving the country about US$ 2.92 billion where the CS are actively used in future economy decision making and policy processes. However, where Paris Agreement is achieved i.e. the global temperature rises are restricted to below2^{0}C (RCP4.5) to pre-industrial level, the losses to GDP in the country will be lowered to US$ 9.51 billion in the coming century (2100). The benefits of successful attainment of the Paris Accord targets will lead to US$ 5.11 billion per year of GDP damages avoided from climate change impacts in the next Century. The gains from CS implemented together with Paris Accord target is even remarkable, relieving the country approximately US$ 4.82 billion per year in the next Century ahead.

Table 17: Projected GDP losses "with "and "without" Climate Services, Uganda

Year	GDP Losses (US$) Without CS	Avoided with CS	With CS
2025	149,423,471.0	14,942,347.1	134,481,123.9
2030	199,231,858.2	19,923,185.8	179,308,672.4
2035	249,040,245.5	24,904,024.5	224,136,220.9
2040	599,303,978.6	119,860,795.7	479,443,182.8
2045	699,188,540.1	139,837,708.0	559,350,832.1
2050	1,207,178,800.9	241,435,760.2	965,743,040.8
2055	1,483,571,854.5	296,714,370.9	1,186,857,483.6
2060	1,759,964,908.1	351,992,981.6	1,407,971,926.5
2065	2,036,357,961.7	407,271,592.3	1,629,086,369.3
2070	3,912,386,699.7	782,477,339.9	3,129,909,359.7
2075	4,379,949,571.6	875,989,914.3	3,503,959,657.3
2080	5,044,327,218.8	1,008,865,443.8	4,035,461,775.1
2085	5,708,704,866.1	1,141,740,973.2	4,566,963,892.9
2090	6,373,082,513.4	1,274,616,502.7	5,098,466,010.7
2095	7,037,460,160.6	1,407,492,032.1	5,629,968,128.5
2100	14,619,958,576.9	2,923,991,715.4	11,695,966,861.5
2100 (Paris Accord)	9,505,598,931.0	1,901,119,786.2	7,604,479,144.8

Source: Earth Data (2023), with author own calculations



Source: Earth Data (2023), with author own calculations

For now, both countries are losing in terms of US$ millions annually to climate related disasters but increasing as years pass-by. However, by 2040, Kenya would reach beyond US$ billion; while Uganda by 2050 where more than a US$ billion will be lost to climate related natural disasters yearly. Therefore, the year 2040 for Kenya; and 2050 for Uganda will mark the threshold where losses will reach US$ billions and beyond to disaster damages, from data analyzed.

4.0: Recommendations and Conclusions

The analyses re-affirmed that the economy of IGAD region remains very vulnerable to climate change. The vulnerability of its population is exacerbated by the structural challenges that reinforces poverty, inequality and deprivation in the region, making the poor especially the smallholders and urban poor most impacted. Climate variability, ranging from unpredictable, intense and at times extreme weather events such as droughts, floods and landslides, are on the rise, and a likely trend for years ahead, threatening ecosystems and livelihoods at alarming rates. The region is experiencing increase in the frequency and intensity of droughts and floods, putting the livelihoods of many and legitimacy of governments to providing social services at risks. Repeated failed weather inform of prolonged droughts are becoming a regional new normal, a trend that is worrying for poverty alleviation efforts of achieving the national social economic transformation such as ongoing Sustainable Development Goals (SDGs), working towards African Union (AU) agenda 2063, and sometimes reversing past gains across member states.

Evidently, Kenya and Uganda (the pilot countries) targeted in this assessment, lose annually on average of US$56.96 million and US$ 113.86 million respectively to natural disasters related damages resulting from droughts, mudslides, and floods among others. In the coming century (2100), Kenya is projected to lose about 7.2% of its GDP (US$ 18.8 billion), while Uganda 6.3% of GDP (US$ 9.5) annually to climate related disasters. However, the provision of climate services through upgrading /strengthening hydro-met services for early warnings would significantly reduce the levels of these losses across all sectors. For example, the World Bank estimates that upgrading CS alone could reduce the levels of disaster losses by about 10% for low-income countries, such as Uganda; a 20% reduction in lower middle income (e.g. Kenya), 50% in upper middle income, and 100% in high income (OECD) countries.

With this approximation, in a short and medium run, Uganda is capable of avoiding about US$11.39 million per year to economic losses from natural disasters by strengthening early warning systems through climate services. This is about 0.028% of its GDP losses avoided per year to climate disasters. These gains are even higher, where the systems are upgraded to European standards (100%), saving the country almost US$ 113.86 million annually to economic loss avoidance. In Kenya, a lower middle income country is able of avoiding losses equally to about US$ 11.392 million per year from provision of climate services. This is about 0.01% of the GDP saved per year. These gains are higher if the systems are developed to European Standards, saving the country almost US$ 56.96 million per year in avoiding disaster losses.

Results of Benefit Transfer showed that at smallholder farmer level alone in Uganda, the provision of CS could generate approximately US$ 143.92 million per year in revenue gains through payments to climate services. Which is about 0.35% of GDP in revenue gains at current GDP of (US$ 40.53 billion) for Uganda. This amount is just enough to service almost 0.6% of the country's current, public debts burden estimated at US$ 23.95 billion (2022 est.). Similarly, Kenya, investment in climate services is projected to generate about US$ 281.6 million annually in revenue gains from smallholders alone; when other sectors are not included. This approximates to about 0.26% of the country's GDP at current prices (US$ 110.35 billion) in revenue gains per year from smallholder farmers. The revenue is equally good enough to service almost 0.36% of the country's public debts burden, currently standing at US$ 77.65 billion (2022 est.). This result is very promising, at a time where greater efforts are needed from developing countries to mobilize domestic revenue, particularly to finance their development, to rebuild better and stronger economies while recovering from the socio-economic impacts of the COVID-19 pandemic, and global crises like Russia-Ukraine war, couple with already rising macroeconomic fiscal imbalances, declining fiscal space to access finance and donor fatigue in supporting development finance.

With this result, we are confident that every (1) unit of US$ invested at IGAD level, yields in returns approximately US$ 5.0 in Uganda, and US$ 9.0 in Kenya, annually. This is about X5 and X9 times the costs of investment in the policy countries (Uganda and Kenya) respectively. These benefits would be higher where more people and sectors are served due to non-rivalry and non-exclusivity nature of the services, and climate services are improved to effective and efficient levels.

In a long run, the benefits of climate services are even greater where the Paris Accord targets are achieved, i.e. the global temperature rise is restrained to a 2^0 C. In a the coming Century, 2100); with "business-as-usual" in climate adaptation and mitigations, where the global warming will reach 3^0C (RCP6), Uganda on average will lose an estimated US$ 14.62 billion per year of GDP to climate damages in absence of CS against US$ 11.7 billion where climate services are actively used in future economy decision making and policy processes, saving the country almost US$ 2.92 billion annually. In Kenya, by year 2100, an estimated US$ 28.98 billion per year will be lost to climate related damages where Climate Services not used versus US$ 14.49 billion with CS, saving the country 50% of the total amount which would have been lost (US$ 14.49 billion).

Implementation of climate services concurrently with Paris targets i.e. where the global temperature rises are restricted to below 2^0C (RCP4.5) to pre-industrial level is even more attractive. In Uganda, the losses to GDP avoided with climate services will accrued to average of USD$ 2.92 billion per year when 3^0C temperature is the trend (business-as-usual, RCP6) scenario in the coming century (2100). The benefits of successful attainment of the Paris Accord targets will lead to additional US$ 1.9 billion per year of GDP losses avoided from climate change impacts, where climate services are implemented together with the Paris target of a 2^0C global temperature (RCP4.5) scenario. Therefore, the gains from CS implemented alongside the Paris Accord is remarkable, relieving the country approximately US$ 4.82 billion per year in the next Century ahead. Similarly, in Kenya, the losses to GDP avoided in the coming century from climate services will yield to about US$ 14.5 billion in the coming century (2100), but also creating additional US$ 9.4 billion when implemented under Paris targets, i.e. keeping a below 2^0C temperature globally. These combined benefits /losses avoided to GDP are even greater with Climate Services are jointly implemented under the Paris targets leading to an estimated US$ 23.9 billion per year of losses avoided to climate change impacts.

In light of this context and above findings, the consultant recommends that investing and ensuring access climate services to all citizens is a human right issue and shouldn't be treated as an expense but rather investment capable of life safety and unlocking the well-being of millions of vulnerable people out of poverty towards 2030 Sustainable Development Agenda; and African Union Agenda 2063. Investment in climate services should be urgent and rated a high priority in the countries' budgeting processes at both local, sub-regional and national level, now that climate change has turned to be a global new normal, challenging nearly all adaptation measures. There is a need to upscale resource mobilization while exploring other climate finance avenues with both public and private sources playing active roles to improve the generation, dissemination and support policy and decision making environment for accurate and real time access to climate information to the end-users.

Finally and most importantly, Climate Services just like any other transformative actions in climate adaption programmes are more effective and welfare enhancing where member countries scale up efforts to address structural issues reinforcing poverty, inequalities and vulnerability of the smallholder / urban poor population by ensuring strong governance and functional pro-poor institutions.

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