CTCN assistance in Uganda

Adaptation to climate change through improved information and planning tools for Lake Victoria

Deliverable 6 (activity 2.2) Testing and demonstration report

Report / Technical Note

April 2018

The expert in **WATER ENVIRONMENTS**

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Deliverable 6 (activity 2.2) Testing and demonstration report

Prepared for	UNEP
Represented by	Mr. Manfredi Caltagirone

Project manager	Oluf Zeilund Jessen
Quality supervisor	Per Bøgelund Hansen
Prepared by	Nisha Gill Hansted, Sílvia Leirião, Niels Riegels and Oluf Z.Jessen

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DHI • Agern Allé 5 • • DK-2970 Hørsholm • Denmark
Telephone: +45 4516 9200 • Telefax: +45 4516 9292 • dhi@dhigroup.com • www.dhigroup.com

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Acronyms and Abbreviations

ASI	Agricultural Stress Index
CFS	Climate Forecast System
CGLS	Copernicus Global Land Service
CIESIN	Intergovernmental Panel on Climate Change Science Information Network
CORDEX	Coordinated Regional Climate Downscaling Experiment
CTCN	Climate Technology Centre & Network
EAC	East African Community
EDI	Effective Drought Index
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GDP	Gross Domestic Product
GFSAD	Global Food Security Support Analysis Data
IUCEA	Inter-University Council for East Africa
JAXA	Japanese Aerospace Exploration Agency
LMCS	Land Monitoring Core Service
LVBC	Lake Victoria Basin Commission
LVEMP	Lake Victoria Environmental Management Project
MUST	Mbarara University of Science Technology
MWE CCD	Ministry of Water and Environment Climate Change Department
MWE SSD	Ministry of Water and Environment Support Services Department
MWE DWRM	Ministry of Water and Environment Directorate of Water Resources Management
NAPE	National Association of Professional Environmentalists
NASA	National Aeronautics and Space Administration
NBI	Nile Basin Initiative
NCEP	National Centers for Environmental Prediction
NDE	National Designated Entity
NDVI	Normalized Difference Vegetation Index
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NOAA	National Oceanic and Atmospheric Administration
MEaSUREs	Making Earth System Data Records for Use in Research Environments
MGLSD	Ministry of Gender Labour and Social Development
RAN	Resilient Africa Network
RCP	Radiative Concentration Pathway
SEDAC	Socioeconomic Data and Applications Center
SPI	Standardised Precipitation Index
SRES	Special Report on Emissions Scenarios
STEPUP	STEPUP Standard Limited
SVI	Standardised vegetation index
SWI	Soil Water Index
TRMM	Tropical Rainfall Measuring Mission
UNCST	Uganda National Council for Science and Technology
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNMA	Uganda National Meteorology Authority
VCI	Vegetation Condition Index
WCRP	World Climate Research Programme
WRIS	Water Resources Information System

Testing, validation and demonstration report

The technical assistance is being implemented through three main activities forming the scope of work and key deliverables: Activity 1 – Stakeholder outreach; Activity 2 – Data access, model refinement, and development of guidelines for decision support; and Activity 3 – Dissemination and outreach. For more background information please refer to Activity 1 Deliverables 4 & 5 (activity 1.2) **Technology specification report and methodology for testing and demonstration report** (January 2018).

This deliverable brings Activity 2 to completion with the delivery of technical outputs, testing validation and demonstration on specific use cases:

- In Activity 2.1 we implemented the technical components, including setting up the web portal, data access, impact assessment model refinements, and guidelines for decision-making.
- In Activity 2.2 we tested developments taking place in Activity 2.1 and carried out validation activities on relevant case studies, received feedbacks from LVBC, and delivered a user guide.

The first chapter provides background to the Climate Technology Centre and Network (CTCN) technical assistance. The second chapter describe the results from testing and validation including feedback from the Lake Victoria Basin Commission (LVBC). The third chapter presents the procedure for update of the LVBC's Water Resources Information System (WRIS), and chapter four concludes with the next steps towards Activity 3 that is the capacity and dissemination part of the technical assistance. Chapter five lists the relevant bibliography.

1 Introduction

1.1 Background

Upon a request by the Lake Victoria Basin Commission (LVBC), the CTCN funded technical assistance on "Adaptation to climate change through improved information and planning tools for Lake Victoria". The objective of this technical assistance is to strengthen planning in the water resources and energy sectors in Uganda, at both long-term and seasonal timescales. The specific objectives of this technical assistance are to:

- Provide access to state-of-the-art ensemble climate projections, seasonal forecasts, and satellite-based historical data through a web based interface.
- Refine the existing impact model used for simulating hydrology and water use in the Lake Victoria basin in order to maximize the utility of the model for estimating climate impacts on the water and energy sectors.
- Provide guidelines for using ensemble projections of climate variables and other drivers in decision-making,
- Demonstrate the utility of the technologies and guidelines through applications to local case studies.
    - Enable decision makers and stakeholders to use the transferred knowledge, practices and technologies through dissemination and outreach activities.

In February 2018 a web portal was deployed making the data, information, tools and guidelines produced freely accessible online to all national stakeholders. The web portal titled ***Adaptation***

to Climate Change portal – Lake Victoria and Uganda[1], constitutes the platform provided by the technical assistance used to deliver embedded applications, namely:

Data and information – application providing free access to near real time data and information of relevance for the CTCN assistance

Reporting – application to support dissemination of reports or bulletins to stakeholders

Basin planning – supporting basin planning through evaluation of existing and new investments, climate change and population pressure

Drought assessment – supporting the identification of areas with drought hazard and evaluating the impact on vulnerable sectors or areas

Decision making guidelines –supporting the decision process taking the uncertainty associated with climate change into consideration

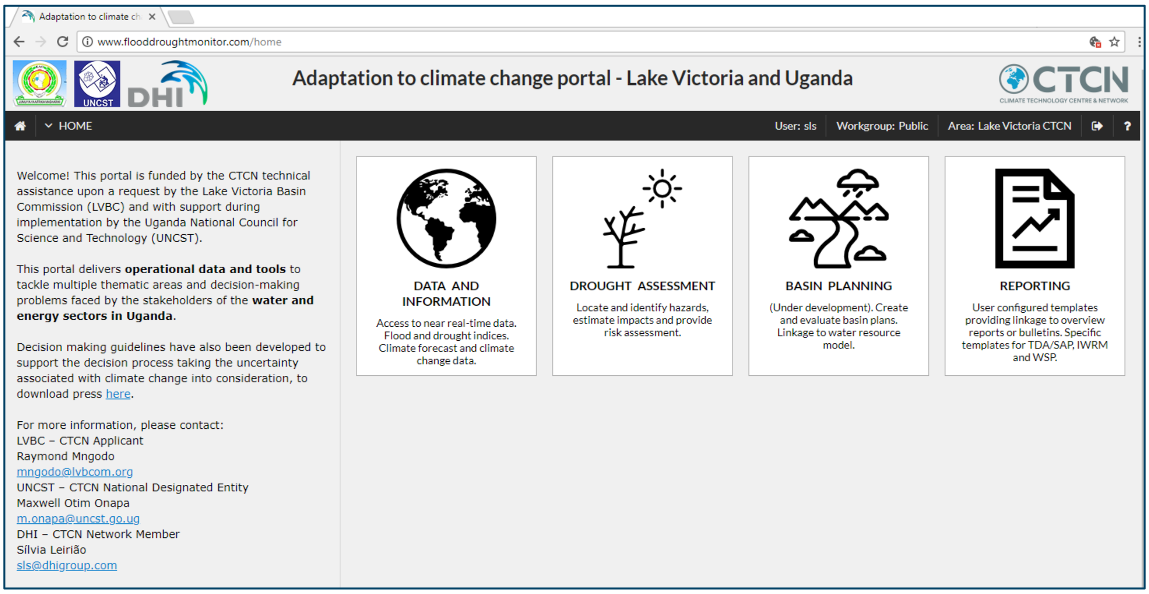


Figure 1 Screenshot of the home page of the web portal displaying the introductory welcome message, the link to the guidelines document and the four data and tool applications.

Simultaneously, the LVBC Water Resources Information System has been updated with static data consisting of climate change projections, and a procedure has been put in place to outline the import of seasonal forecast data monthly (for more information please see chapter 3).

The deployment of the web portal was preceded by engagement and preparation meetings with stakeholder institutions in Uganda – 5th to 9th of February 2018 – for the testing and demonstration; and was succeeded by a testing, validation and demonstration workshop – 21st and 22nd of March 2018 – with LVBC staff held at the UNCST premises. The results from the workshop are incorporated into the report presented herein.

[1] Portal address: http://www.flooddroughtmonitor.com

1.2 Objective

The objective of testing and demonstration was to ensure that the outcomes of the technical assistance are relevant and their utility demonstrated for decision-making processes of the participating stakeholders.

The steps taken in the testing and demonstration phase were the following:

1. Identify outcomes to be validated;
2. Meetings with the stakeholders to allow the institutions to further assess and nominate participants in validation outlined in the work plan;
3. Collect information to be used for the validation e.g. planned interventions, scenarios, observed data or historical information, reporting templates;
4. Validation of data and information, remotely and via working sessions outlined in the work plan;
5. Demonstration using case studies, for an assessment of how the outcomes from the CTCN assistance correlates with the actual processes and reporting of stakeholders;
6. Adjustment of the CTCN outcomes aiming at refining the data, tools and guidelines provided.

The following chapters present the results from the testing of the data and tools as well as demonstration with study cases. Demonstration includes inputs by the following institutions:

- **Lake Victoria Basin Commission**
- **Uganda National Meteorological Authority**
- **Ministry of Water and Environment, Climate Change Department**
- **Ministry of Energy & Mineral Development, Energy Resources Development**
- **Ministry of Energy & Mineral Development, GIS Unit**

The team worked together with these stakeholders, who contributed not only with comments to the deliverables, but also their own data, analysis and information (attendance register in Appendix B).

1.3 Infosheets

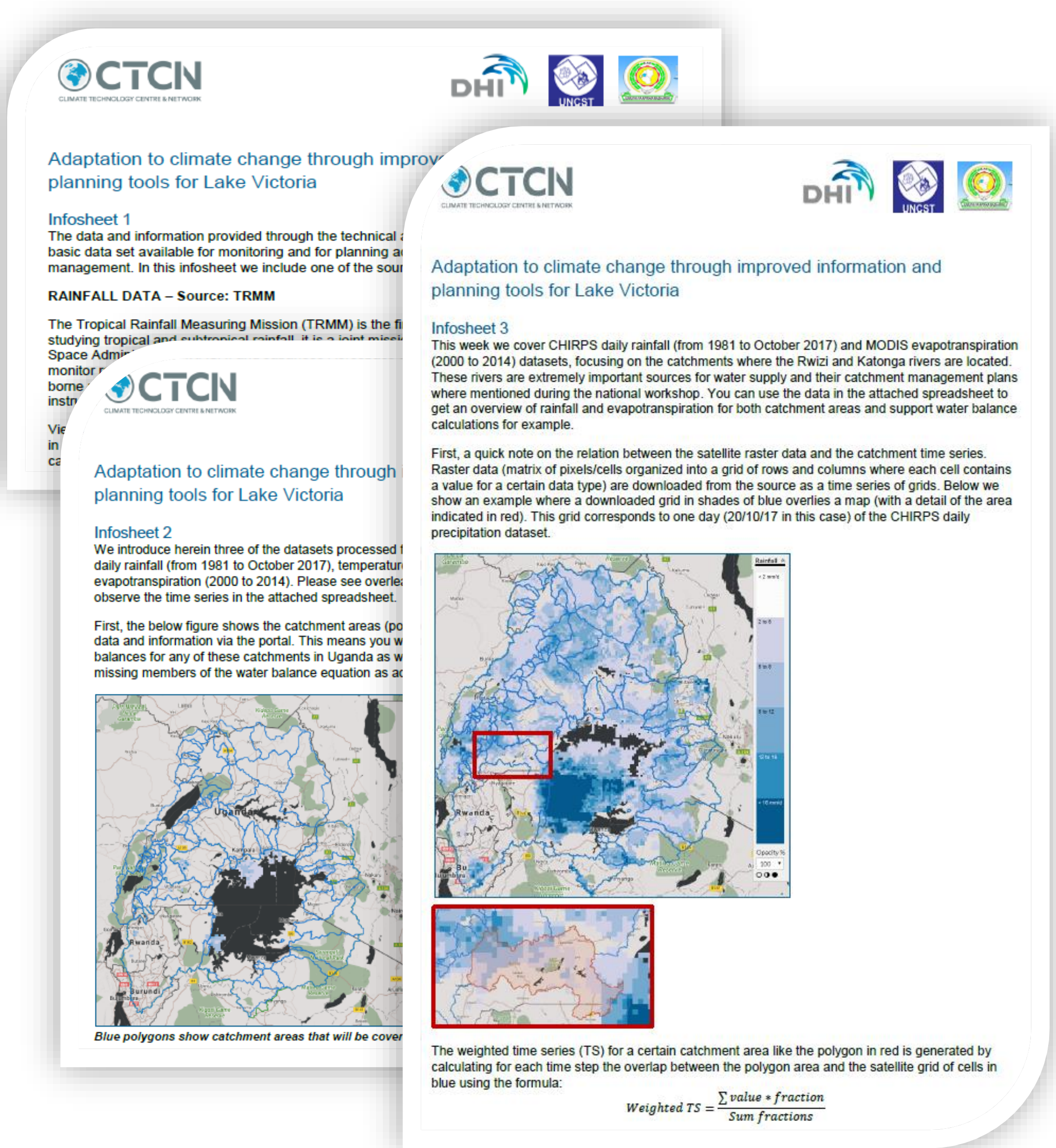
Since Activity 1.2 and the conclusion of the Technical specifications report, a series of information sheets are sent off weekly, about the data provided under this technical assistance freely over the internet to all the stakeholders. Each information sheet or **Infosheet** for short, consists of a two-page note on different aspects related to the deliverables such as: access to the time series and spatially distributed data for Uganda and the Lake Victoria Basin area, in near real time; climate data, seasonal forecasts and a variety of indicators; or applications such as the drought assessment, reporting and basin planning. Others regarding the functioning of the web portal. The infosheets were used as a tool for demonstration on usage of and decision-making based on data and tools delivered by the technical assistance.

The Monday emails started with the send out of spreasheets with actual data together with the respective infosheet, prior to the official deployment of the web portal which took place on the 15th of February 2018. After that, the infosheets were sent with descriptions of data, tools and How-to information regarding the portal.

The topics covered to date are the following:

- **Infosheet 1** - Basic data set available for monitoring and for planning activities related to water resources or drought management. In this infosheet we include one of the sources of rainfall, TRMM.
- **Infosheet 2** - Three of the datasets processed from freely available remote sensing sources: daily rainfall (from 1981 to October 2017), temperature (1981 to November 2017) and evapotranspiration (2000 to 2014).
- **Infosheet 3** - CHIRPS daily rainfall (from 1981 to October 2017) and MODIS evapotranspiration (2000 to 2014) datasets, focusing on the catchments where the Rwizi and Katonga rivers are located; the relation between the satellite raster data and the catchment time series.
- **Infosheet 4** - Indices to be used in drought assessment, the Standardised Precipitation Index (SPI) based on the probability of precipitation for any time scale transformed into an index; note on the catchments with data coverage under this technical assistance.
- **Infosheet 5** - Indices generated from remote sensing data that can be used for the short-term management of water resources and drought management: the Soil Water index (SWI), and SWI percentile. Districts Abim, Kaabong, Kotido, Moroto and Nakapiripirit in Northern Uganda.
- **Infosheet 6** - Satellite observed water level for lakes and reservoirs; water level observations can be used to better understand and close the water balance of the system and to assess droughts, especially when combined with other datasets; complete record of remote sensing water level values for lakes Victoria, Kyoga and Kwania (record from 1993 to present) from source JASON.
- **Infosheet 7** - Ensemble of rainfall seasonal forecasts for a time period of 9 months ahead; forecasts of the Standardized Precipitation Index 1- and 3- month.
- **Infosheet 8** - Seasonal forecasted rainfall and Standardized Precipitation Index datasets produced; focus on catchments where the Rwizi and Katonga rivers are located.
- **Infosheet 9 -** Satellite dataset, Normalized Difference Vegetation Index (NDVI). We obtain and process this dataset for our focus area and calculate another variable based on it: the NDVI deviation. This data has a spatial resolution of 5.6 by 5.6 km and the time period starts from year 2000 until present; focus on Kiboga and Nakaseke districts.
- **Infosheet 10 -** Focus on climate change projections, which together with rainfall seasonal forecast data, form one of the main milestones of this response to the technical assistance request; temperature delta change factors from Coordinated Regional Downscaling Experiment (CORDEX), a program sponsored by World Climate Research Program (WCRP).
- **Infosheet 11 -** Precipitation and potential evapotranspiration delta change factors from CORDEX.
- **Infosheet 12 -** Focus on water quality with chlorophyll concentration for Lake Victoria and the other large surface water bodies in our focus area.
- **Infosheet 13** - Group of datasets related to socio-economic and agricultural information, needed for designing purposes and to estimate the impact of planning measures in the water and energy sectors; Population projections from the Country-Level Population and Downscaled Projections Based on Special Report on Emissions Scenarios (SRES) A1, B1, Scenarios, 1990-2100; The Intergovernmental Panel on Climate Change Science Information Network (CIESIN); Gross Domestic Product (GDP) from the World Bank; Urban expansion by NASA Socioeconomic Data and Applications Center (SEDAC); Night light by the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center (NGDC); Irrigated areas by Food and Agriculture Organization (FAO); Crop dominance from the NASA Making

Earth System Data Records for Use in Research Environments (MEaSUREs) Global Food Security Support Analysis Data (GFSAD).


Adaptation to climate change through improved information and planning tools for Lake Victoria

Infosheet 3

This week we cover CHIRPS daily rainfall (from 1981 to October 2017) and MODIS evapotranspiration (2000 to 2014) datasets, focusing on the catchments where the Rwizi and Katonga rivers are located. These rivers are extremely important sources for water supply and their catchment management plans where mentioned during the national workshop. You can use the data in the attached spreadsheet to get an overview of rainfall and evapotranspiration for both catchment areas and support water balance calculations for example.

First, a quick note on the relation between the satellite raster data and the catchment time series. Raster data (matrix of pixels/cells organized into a grid of rows and columns where each cell contains a value for a certain data type) are downloaded from the source as a time series of grids. Below we show an example where a downloaded grid in shades of blue overlies a map (with a detail of the area indicated in red). This grid corresponds to one day (20/10/17 in this case) of the CHIRPS daily precipitation dataset.

The weighted time series (TS) for a certain catchment area like the polygon in red is generated by calculating for each time step the overlap between the polygon area and the satellite grid of cells in blue using the formula:

$$Weighted\ TS = \frac{\sum value * fraction}{Sum\ fractions}$$

Figure 2 Examples of infosheets.

- **Infosheet 14** - The reporting application the stakeholders can use to disseminate the data and information. Dissemination in the form of reports or bulletins is critical in relation to planning as this enables the decision or policy makers to disseminate the actual plans or the background for the decision process to stakeholders.

- **Infosheet 15** - The drought assessment application that can be used to set up warnings also to carry out simple risk assessments at catchment level; defining droughts; and How to use the drought application.

- **Infosheet 16** - Application of the drought assessment to Uganda by setting set up a drought warning.

- **Infosheet 17** - Application of the drought assessment tool to Uganda by locating areas at risk.

- **Infosheet 18** - The purpose and difference between workgroups and how to switch from one to the other. We also exemplify how to create a new workgroup and manage users within it.

Finally, the infosheets assisted demonstration but also with testing of the datasets and applications, as each week stakeholders were invited to apply these on their own daily tasks and revert with feedback and comments. Stakeholders were also invited to suggest items to be covered by infosheets each week. They will continue until the final workshop and training marking the closure of the technical assistance.

2 Testing and validation of data

Given the focus on Lake Victoria and the importance to the applicant, the LVBC, the testing and validation process focused on the lake catchment area. The analysis presented in the following chapters can be reproduced to any of the catchments within the area of focus in Uganda by the stakeholders as the same datasets are made available via the web portal.

2.1 Focus area

Lake Victoria is the second largest freshwater body in the world covering an area of 68,800 km^2, but in comparison is relatively shallow with an average depth around 40 m. The lake area is divided mainly between Tanzania (49 %) and Uganda (45 %), with 6 % of the area being situated in Kenya. The catchment area additionally covers parts of Rwanda and Burundi and has a size of 184,000 km^2 (Thiery, et al., 2016).

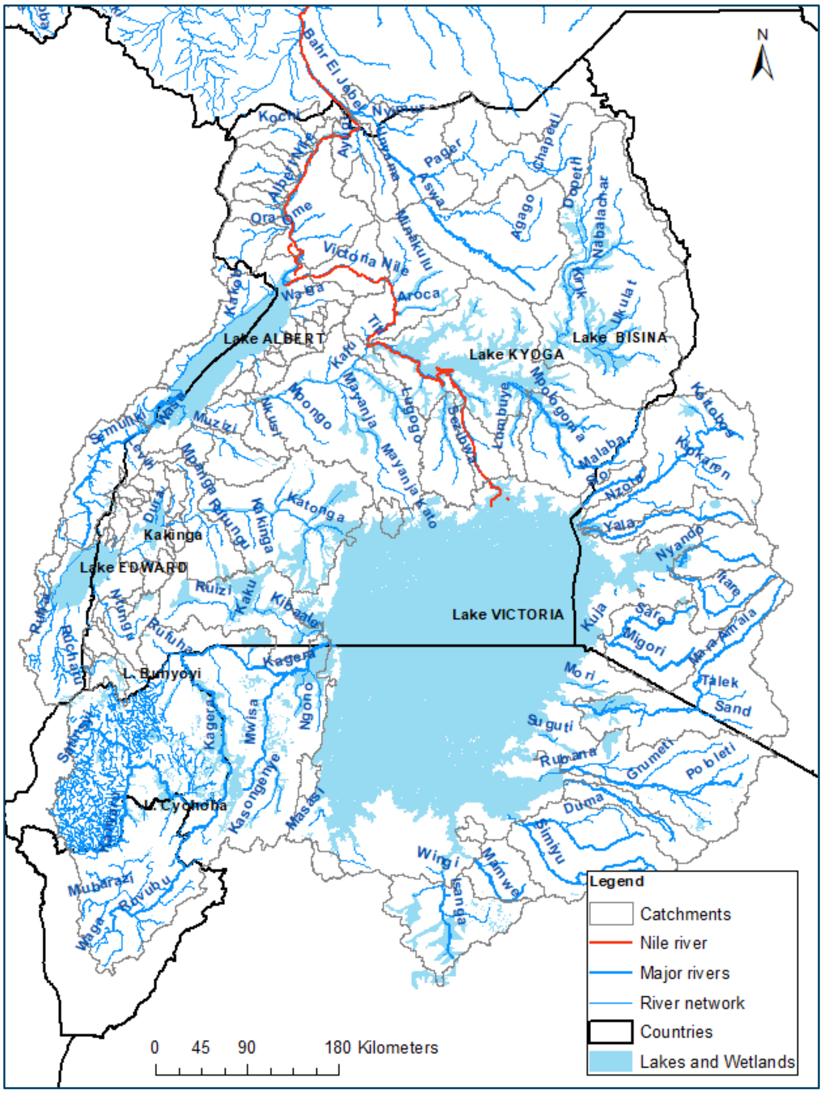


Figure 3 Map of the focus catchment areas, rivers and lakes of the technical assistance

82% of the lake inflow comes directly from rainfall on the lake surface, while the remaining 18% are covered by discharge from the basin. This indicates that the lake will be very sensitive to changes in precipitation. Furthermore, the large area compared to its depth results in high evapotranspiration, making it sensitive to changes in temperature (Lørup, Jessen, & Butts, 2014). Lake level fluctuations are controlled by the operation rules of Kiira and Nalubaale power stations keeping it at a band of 3 meters and live storage volume of 200 km^3. The outflow released from the lake is controlled by the "Agreed curve", which is an agreement that links the allowed outflow from the lake to the lake water level (UNEP & DHI, 2013).

Environmental problems in the lake include pollution and eutrophication as untreated wastewater is led directly into the lake. Additionally, the sediment load in the inflowing rivers is increasing as a result of deforestation and farming. The area surrounding Lake Victoria is estimated to be among the three most densely populated areas in Africa as well as having a rapidly growing population. This leads to water scarcity and environmental degradation (UNEP & DHI, 2013). The livelihoods of 30 million people are dependent on the lake, including 200,000 fishermen. Of these, it is estimated that 3,000-5,000 die every year on the lake, many due to known severe nightly thunderstorms, that are expected to increase in intensity with climate change (Thiery, et al., 2016).

In this analysis, we will investigate the water balance of Lake Victoria using remote sensing data from the portal and data available from the water resources model setup. Furthermore, the daily variations in precipitation will be studied, with the objective of finding out if the day-time night-time rainfall patterns are captured.

2.2 Input data

This study incorporates several different types of data, all summarised in Table 2 below. This section introduces and compares the different data types/sources.

Table 1 Data used in this study, including units, time period, and sources

	Name	Parameter	Unit	Time period	Temporal resolution	Source
Remote sensing	TRMM 3-hourly	Precipitation	mm/hr	1998-2017	3 hours	Portal
	TRMM daily	Precipitation	mm/hr	2000-2017	Daily	Portal
	CHIRPS	Precipitation	mm/day	1981-2017	Daily	Portal
	GPM	Precipitation	mm/day	2014-2017	Daily	Portal
	Temperature	Temperature	ºC	2000-2017	8-daily	Portal
	JASON	Lake level elevation	m.a.s.l.	1993-2017	10-daily	Portal
Extrapolated	Precipitation	Precipitation	mm/day	1950-2004	Daily	MWE, 2013
	Evaporation	Evaporation	mm/day	1950-2004	Daily	MWE, 2013
Observed	Flow Jinja	Discharge	m^3/s	1950-2004	Daily	MWE, 2013
	Flow Kamdini	Discharge	m^3/s	1950-2006	Daily	MWE, 2013
	Flow Semliki	Discharge	m^3/s	1950-1979	Daily	MWE, 2013

	Name	Parameter	Unit	Time period	Temporal resolution	Source
	Rainfall Mwanza	Precipitation	mm	2005-2014	Daily	LVBC WRIS
	Lake water level elevation	Water level	m.a.s.l.	1950-2000	Daily	MWE, 2013
Simulated	Flow Jinja	Discharge	m^3/s	1960-1979	Daily	Model
	Flow Kamdini	Discharge	m^3/s	1960-1979	Daily	Model
	Flow Semliki	Discharge	m^3/s	1960-1979	Daily	Model

The following map was prepared based on information from the Nile Equatorial Lakes Multi Sector Investment Opportunity Analysis, NEL Indicative Investment Strategy and action plan by NBI (2012). It presents the l hydrometric stations in the focus area. However, data for these stations is not available in the LVBC WRIS in most instances, and hence only few observed records were available to the team.

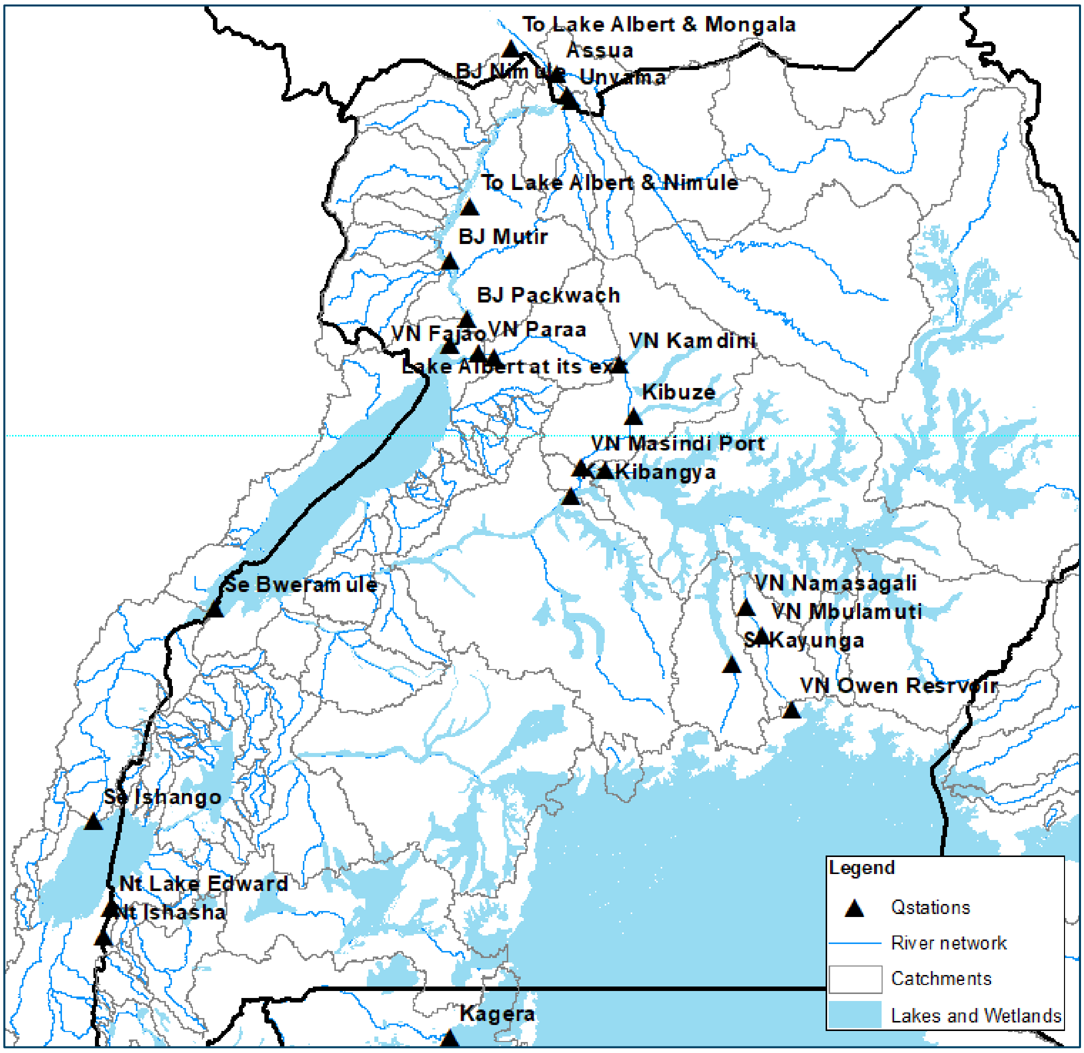


Figure 4 Location of hydrometric stations in the focus area (from NBI, 2012).

2.3 Comparison of rainfall data sources

2.3.1 Rainfall over Lake Victoria

This section compares the four different sources of precipitation data: TRMM, CHIRPS, GPM from the portal, and, extrapolated data obtained from the analysis carried out during the preparation of the model for the Nile Basin Adaptation to Water Stress, UNEP and NBI (2013). Of the four data sources, the first three are remote sensing data. The rainfall for the entire lake catchment has been obtained through a weighted averaging of the pixels of raw data. Regarding the area, the extrapolated data covers exactly the area of the lake, estimated to 68,800 km^2 from literature (MWE DWRM, 2013). The remote sensing data also covers some of the lake shore and as such covers an area of approximately 98,900 km^2. This last value was scales by 70% to include only the area that covers the lake.

As TRMM is only available from 2000 and the extrapolated data ends in 2004, the time period where both of these are available is quite short. This means that the conclusion drawn from comparisons between these two data sources should not be given too much weight. The same is true for GPM data which starts in 2014 and for this reason has not been compared with the extrapolated data. Therefore, while all data sources are compared, the main effort has been put into comparing CHIRPS and extrapolated, and CHIRPS and TRMM.

2.3.1.1 CHIRPS and extrapolated precipitation data

There is extrapolated precipitation data available from 1950-2004 and CHIRPS precipitation data from 1980-2017. This gives a comparable time period of 1981-2004. Figure 5 shows the accumulated monthly precipitation for the two data sources in this time period. As seen, there is good agreement between the two data sets as to when there are peaks and lows. However, the peaks are generally higher for the extrapolated data. This is especially clear in Figure 6, where the yearly mean of the two data sources are plotted. The mean values are clearly lower for the CHIRPS data than for the extrapolated data, although there is still overall agreement between the two data sets regarding the temporal positions.

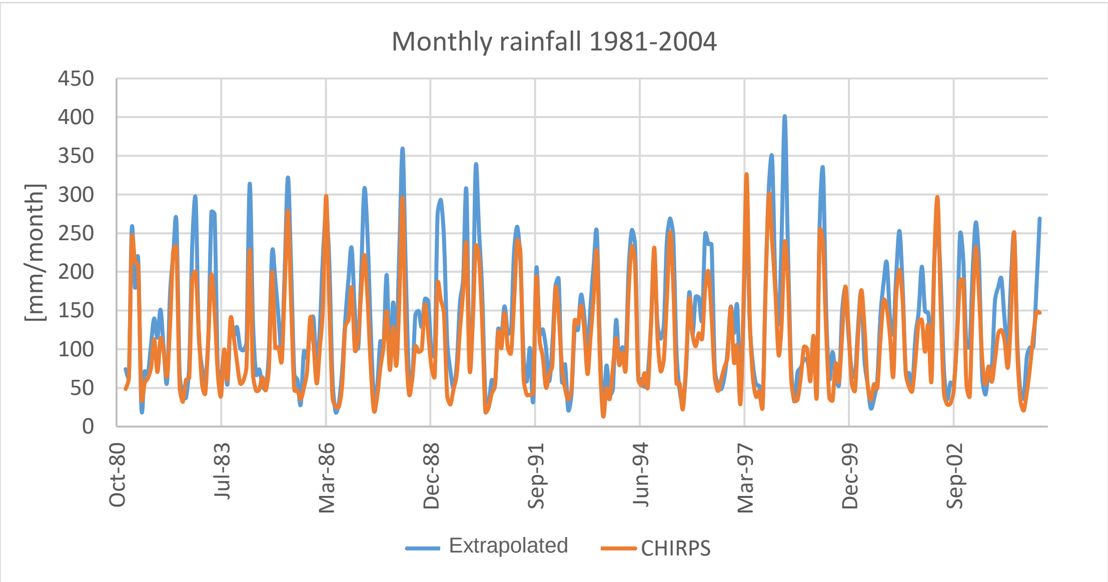


Figure 5 Monthly precipitation for the extrapolated data and the CHIRPS data

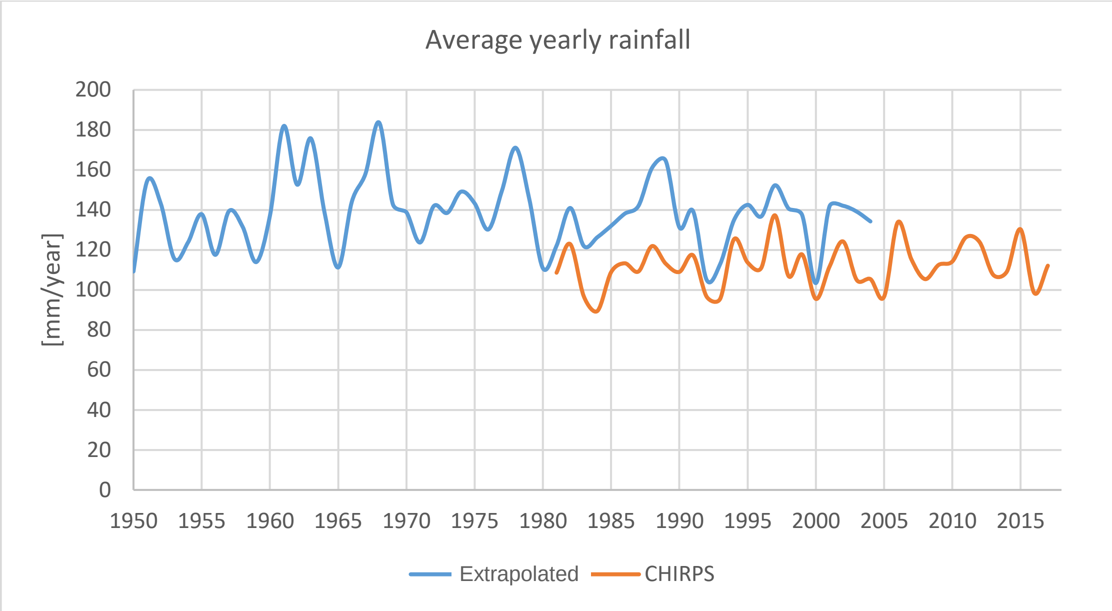


Figure 6 Average yearly rainfall for the extrapolated data and CHIRPS data.

When considering the daily patterns, it is calculated how many days are rainy days for the two different data sets. Rainy days have been defined as days where the rainfall is above 0.2 and the percentages are shown in Table 4. As could be expected considering the conclusions made above, there are more rainy days in the extrapolated data set than in CHIRPS, with almost 98 % of the days having rainfall, while there are only 86% of the days with rainfall for the extrapolated data.

Furthermore, in the period 1981-2004, the total rainfall for the CHIRPS data is 31,875 mm while it is 38,913 mm for the extrapolated data, which is an increase of 22%. Averaging these values out over the 24 years in the period gives a yearly rainfall of 1,328 mm for CHIRPS and 1,621 mm for extrapolated. This means that the yearly extrapolated rainfall is higher than CHIRPS by almost 300 mm.

Table 2 Percentage of rainy days for extrapolated and CHIRPS data (1981-2004).

	% days with P > 0.2 mm
Extrapolated	97.64
CHIRPS	85.80

Figure 7 shows the average monthly rainfall in the time period 1981-2004. When averaging over the entire available time period for the two data sources, the result is largely similar and has not been presented here. Considering the plot shown in the figure, the extrapolated data is once more higher than the CHIRPS data. Apart from this, the two data sources display the same seasonal trends; there are two wet periods, both covering around 3 months and with one period having higher precipitation than the other. The season with the heaviest rainfall covers March-May, peaking in April, while the other period covers October to December. This is to an extent comparable with the seasonal patterns described by Awange, et al. (2008), who defines a “long-rains” season from March to May and a “short-rains” season from September to November. This first season can compare exactly with the first rainy season in the plot, while the short-rains season seems to start one month later than what is stated in the paper.

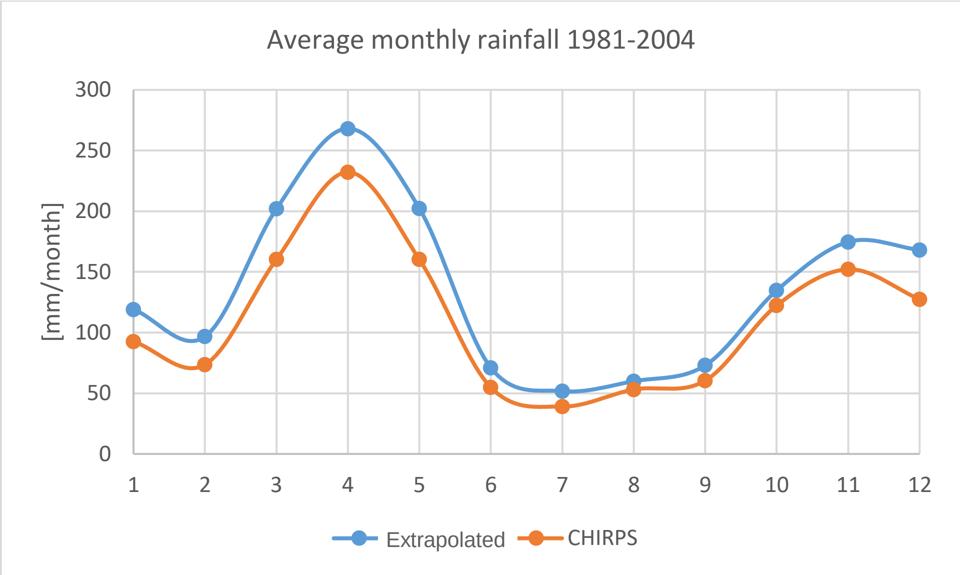


Figure 7	Average monthly averages considering only the time period 1981-2004

Figure 8 shows the correlation between extrapolated and CHIRPS data for the period 1981-2004. There is a correlation between the two datasets, but with a relatively low R^2-value. The correlation is best for the smaller rainfall events.

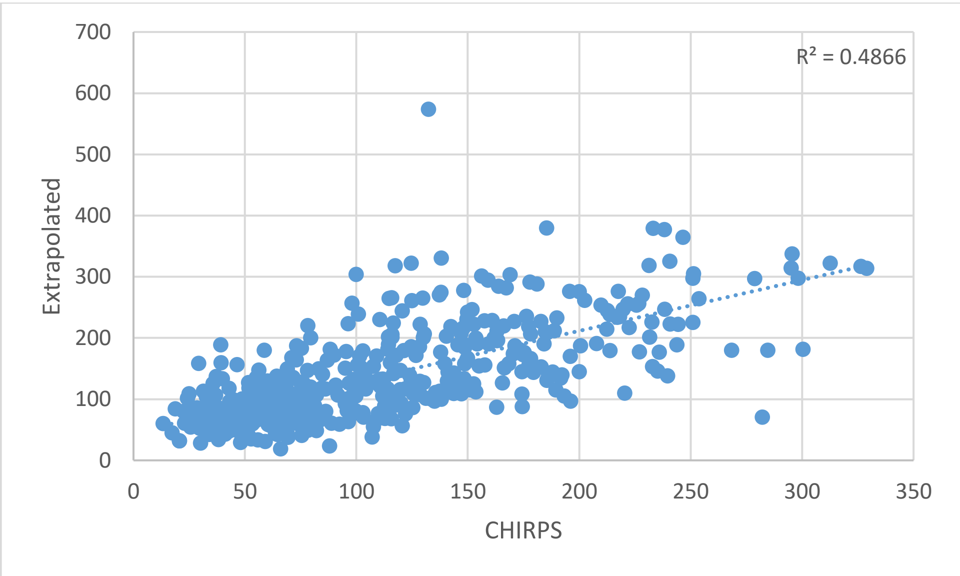


Figure 8	Plot of monthly CHIRPS ("SIM") data versus extrapolated data for the time period 1981-2004

2.3.1.2 CHIRPS and TRMM precipitation data

TRMM and CHIRPS data are both available from March 2000 to September 2017. In this period, when considering monthly data, the mean absolute error is 30.5%. When considering the magnitude of the data, as presented in Figure 9, it is evident that the CHIRPS data is generally lower than the TRMM data. This is similar to the conclusions above, where it was found that CHIRPS is generally lower than the extrapolated data.

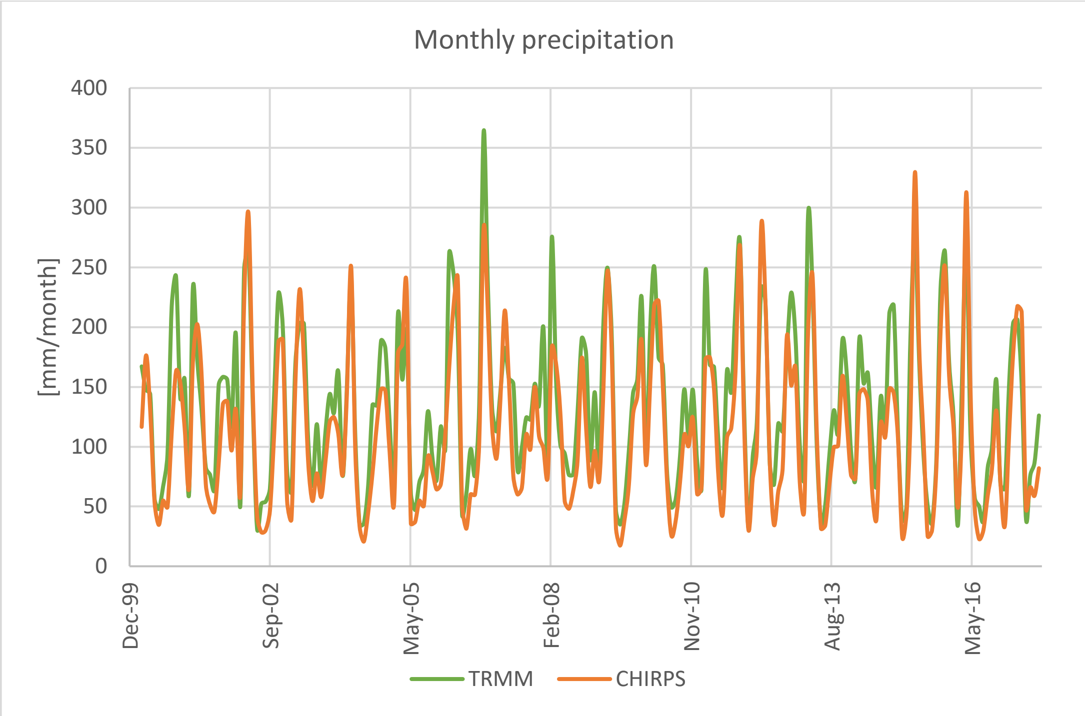


Figure 9 TRMM and CHIRPS monthly precipitation data in the period 2000-2017.

As seen in Table 5, there is also a higher percentage of days with rainfall for the TRMM data than for the CHIRPS data. This is once more comparable with the differences between CHIRPS and extrapolated data. This especially could give potential modelling errors as one input data set states that there is rainfall occurrence, while in the other there is not. To investigate the impact of this, and to find which data set best represents reality, a model could be run with the different precipitation data sets as input. The results could be compared to a known parameter, such as the runoff at a station with good observed data.

Table 3 Percentage of days with rainfall when considering TRMM and CHIRPS data (2000-2017).

Num. days with rainfall		% days with rainfall	
TRMM	CHIRPS	TRMM	CHIRPS
5,929	5,492	91.88	85.11

2.3.1.3 CHIRPS, TRMM, and GPM data

GPM is only available after 2014. This gives a very short time period for data comparison. As seen in Figure 10, GPM is much higher than CHIRPS and TRMM which are in good agreement with each other. There is generally agreement between the three data sources as to the temporal positions of peaks and dips, but the magnitude is much higher for GPM. The conclusions from the figure are supported by the average percentage differences between the data sources, shown in Table 6.

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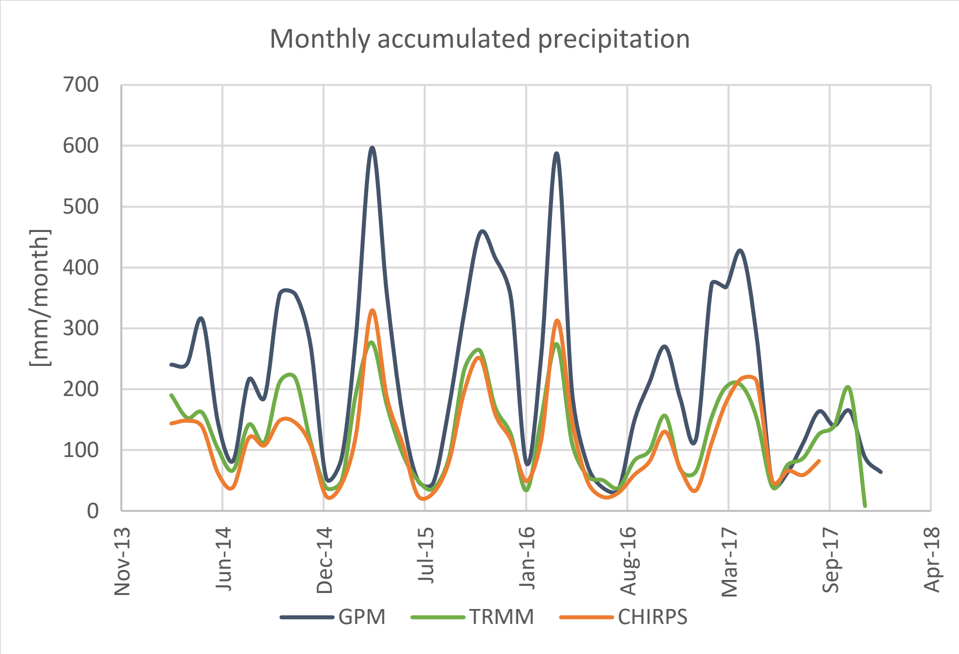


Figure 10 Monthly accumulated values for GPM, TRMM, and CHIRPS

Table 4 Mean percentage differences between the monthly values of precipitation data from CHIRPS, TRMM, and GPM (2014-2017).

Mean difference CHIRPS - TRMM	24.92551
Mean difference CHIRPS - GPM	63.44186
Mean difference GPM - TRMM	47.82234

Figure 11, Figure 12, and Figure 13 show the correlation between the monthly values of the three data sources. The correlations are quite good in all cases, as was also seen previously, where there is clearly correspondence between high and low rainfall events.

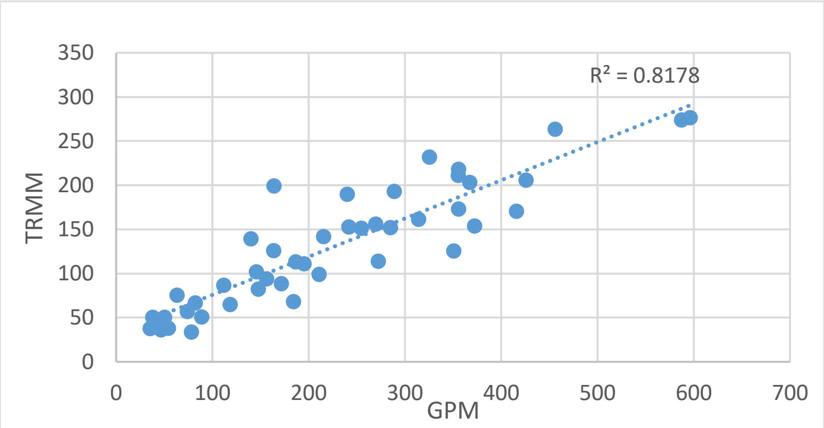


Figure 11 Correlation between monthly values of TRMM and GPM.

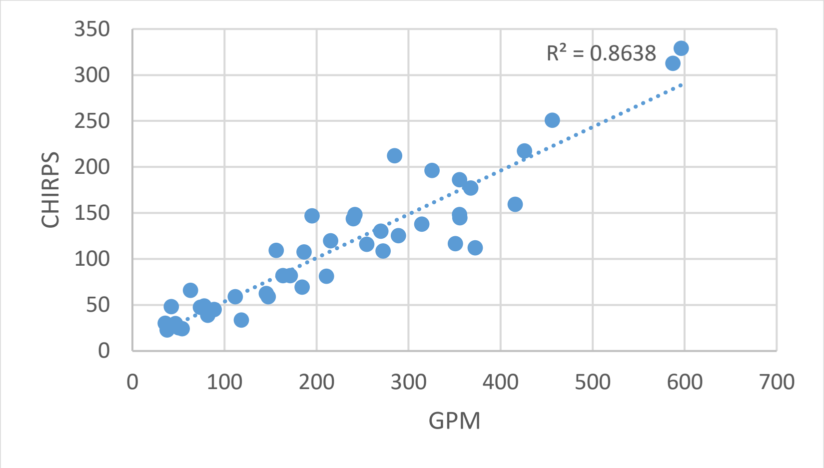


Figure 12 Correlation between CHIRPS and GPM.

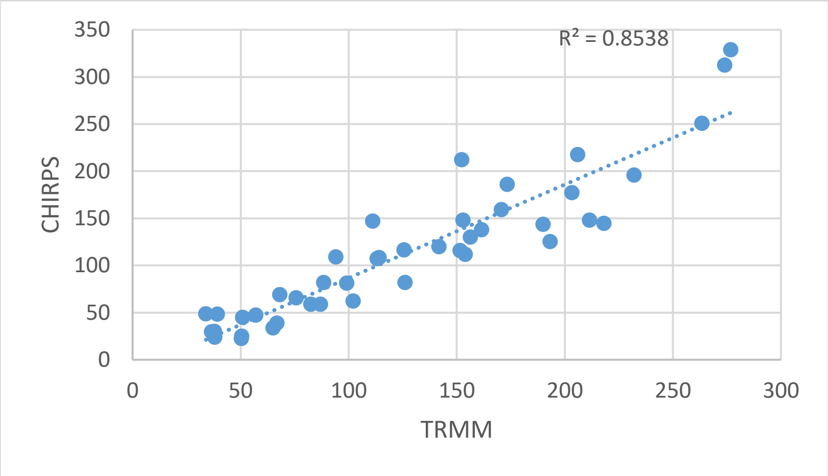


Figure 13 Correlation between CHIRPS and TRMM.

When considering the number of days with rainfall for the period, presented in Table 7, GPM and CHIRPS correspond well to one another, while TRMM has a higher number of rainfall events. This shows that the rainfall events are more extreme for GPM as the precipitation here is much higher than for the other two data types, while the number of rainfall events is comparable with the other data types.

Table 5 Days with rainfall for the TRMM, CHIRPS, and GPM (2014-2017).

	TRMM	CHIRPS	GPM
Num. days	1,244	1,120	1,107
% days	93.6	84.3	83.3

2.3.1.4 Duration curves

The duration curves for both periods, 1981-2004 (CHIRPS and extrapolated) and 2000-2017 (CHIRPS and TRMM), are shown in Figure 14 and Figure 15, respectively. Considering the duration curves shown here, the shape is overall similar. This means that although the data displays different values, their information about the magnitude distribution is the same. As concluded above, CHIRPS is generally lower than the extrapolated and TRMM data. A duration curve was also made for 2000-2004, incorporating all three data types, but did not give meaningful results.

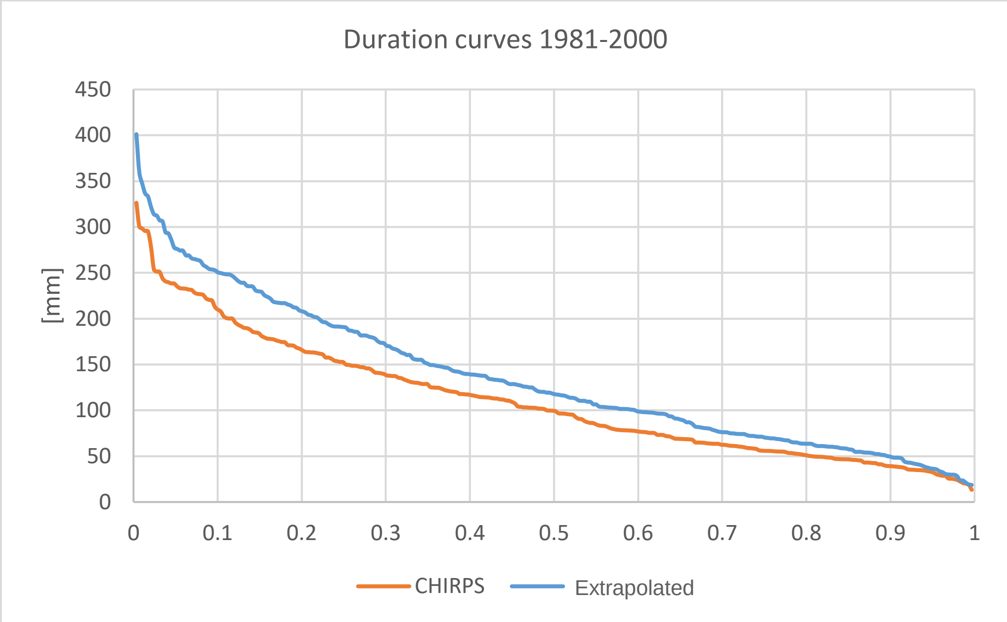


Figure 14 Duration curves for the period 1981-2004, displaying CHIRPS and extrapolated precipitation data.

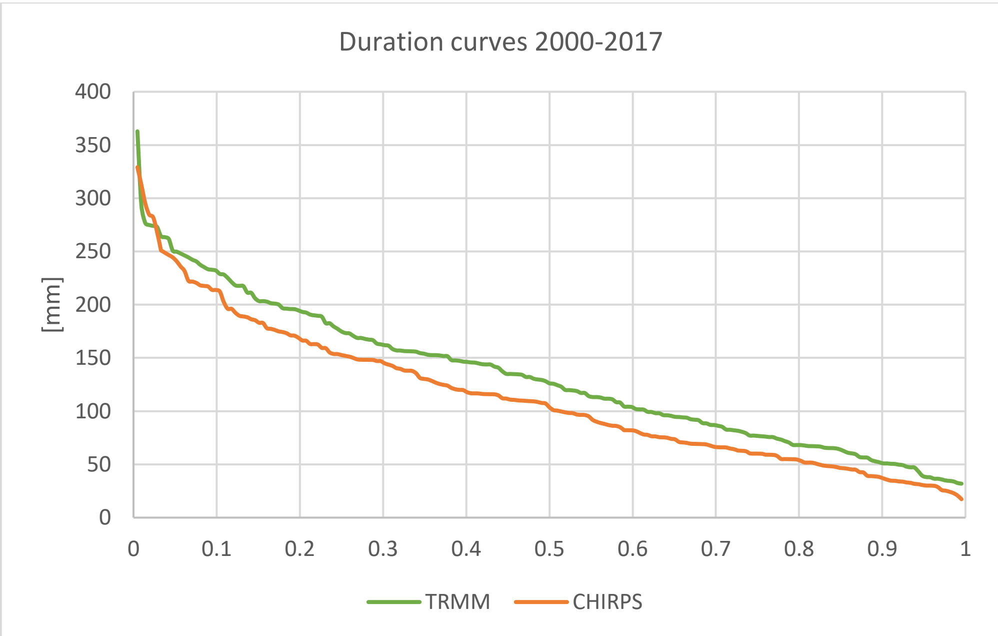


Figure 15 Duration curves for the period 2000-2017, displaying CHIRPS and TRMM precipitation data.

Figure 16 shows the duration curves for TRMM, CHIRPS, and GPM. There is generally good agreement between TRMM and CHIRPS, while GPM has a higher values than the other two data sources. As the percentiles grow higher, GPM comes closer to the other two.

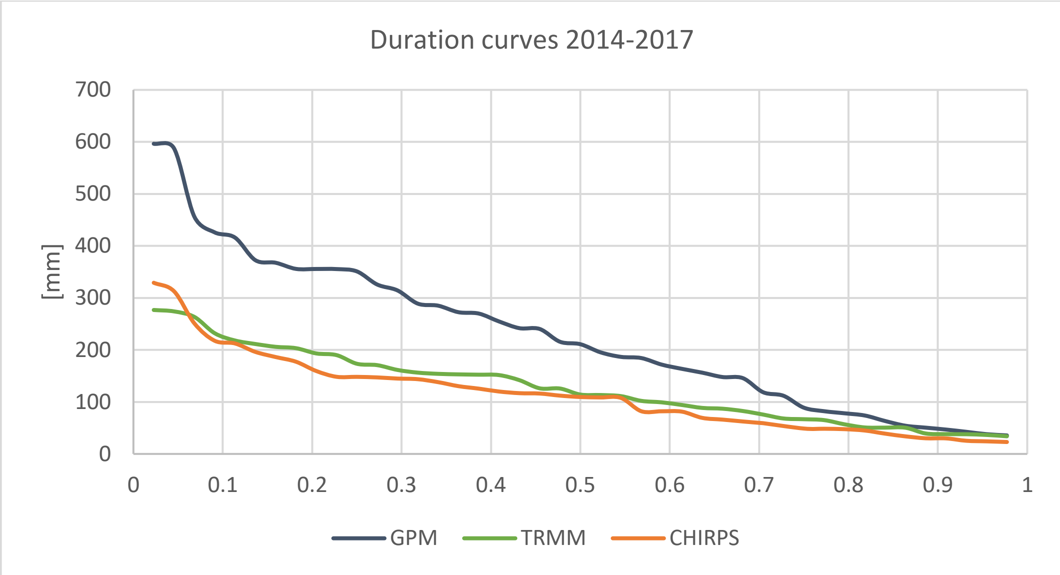


Figure 16 Duration curves for GPM, TRMM, and CHIRPS for the period 2014-2017 (monthly data)

The differences in the selected percentiles are presented in Table 8. The difference between TRMM and CHIRPS is generally more constant, as is also evident of the plotted curve; the differences are smaller at either end and almost constant in the central part. Between CHIRPS and the extrapolated data, the differences are large for high flows and then become smaller with higher percentiles representing low flows. For GPM, TRMM, and CHIRPS, as expected, TRMM and CHIRPS are closer to each other than the two values are to GPM. It is also clear that the difference between GPM and the others become smaller with lower flows and discussed above.

Table 6 Differences between CHIRPS, TRMM, extrapolated data, and GPM for selected percentiles. Note that the time periods are not comparable.

Percentile \ [mm]	TRMM – CHIRPS	Extrapolated – CHIRPS	GPM – TRMM	GPM – CHIRPS	TRMM – CHIRPS
Q_{25}	22.11	38.19	177.59	202.76	25.16
Q_{50}	22.53	18.31	96.86	101.59	4.72
Q_{75}	16.63	14.43	22.19	40.13	17.95

2.3.1.5 Accumulated volumes

The monthly accumulated volumes are shown in Figure 18 to Figure 20 for the different time periods. Once more, the pattern is as seen before with lower precipitation in CHIRPS than for TRMM and extrapolated, and higher precipitation for GPM than for TRMM and CHIRPS. It is interesting to note that in the period 2000-2004, the accumulated volumes for extrapolated and TRMM data are almost identical. The time period may be too short to draw definitive conclusions, but these results indicate that there may be a better agreement between TRMM and the extrapolated data than between CHIRPS and the extrapolated data. It has been assumed that the extrapolated data is the most accurate, thus giving the highest credibility to the TRMM data. However, it is known that the rainfall over the lake is higher than the surrounding land, but there are no stations on the lake to give exact data. As GPM is higher than both TRMM and CHIRPS, it is possible that this may be the best representation of the rainfall over the lake, but there is no observed data to verify this.

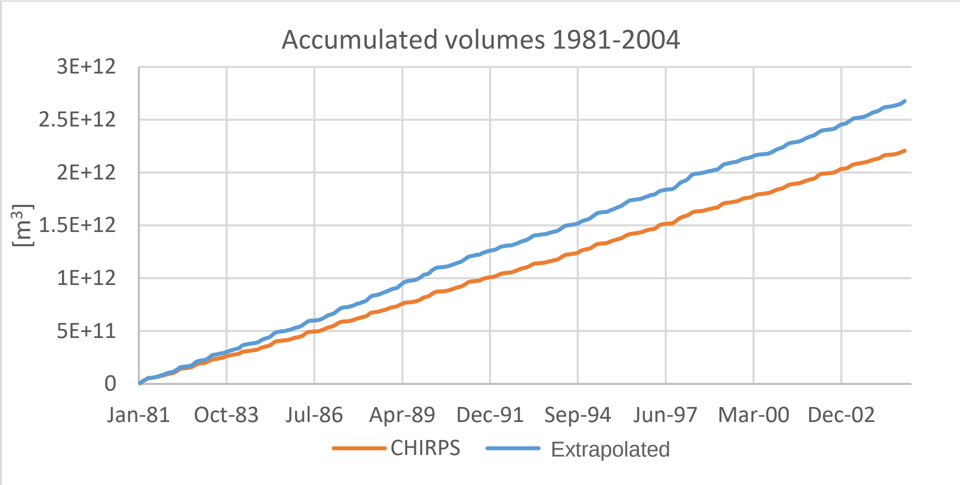


Figure 17 Accumulated volumes for the period 1981-2004, incorporating extrapolated and CHIRPS precipitation data.

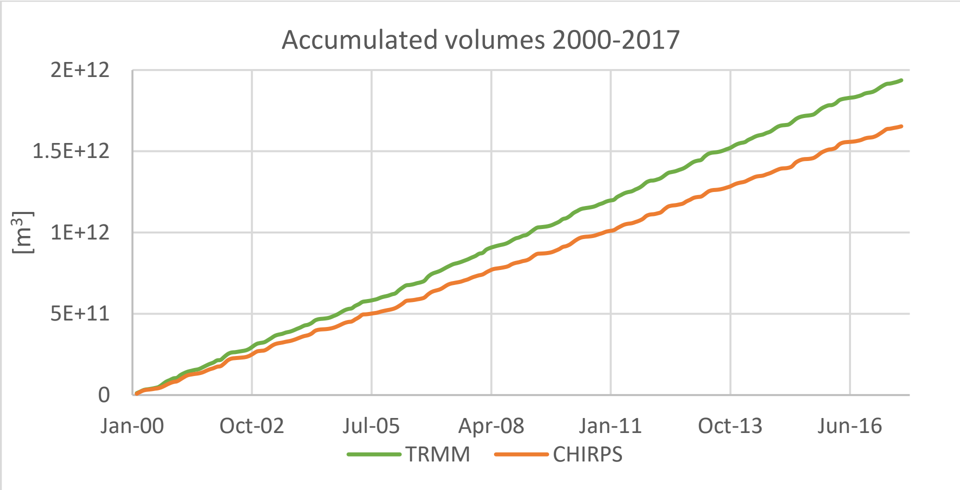


Figure 18 Accumulated volumes for the period 2000-2017, incorporating TRMM and CHIRPS precipitation data.

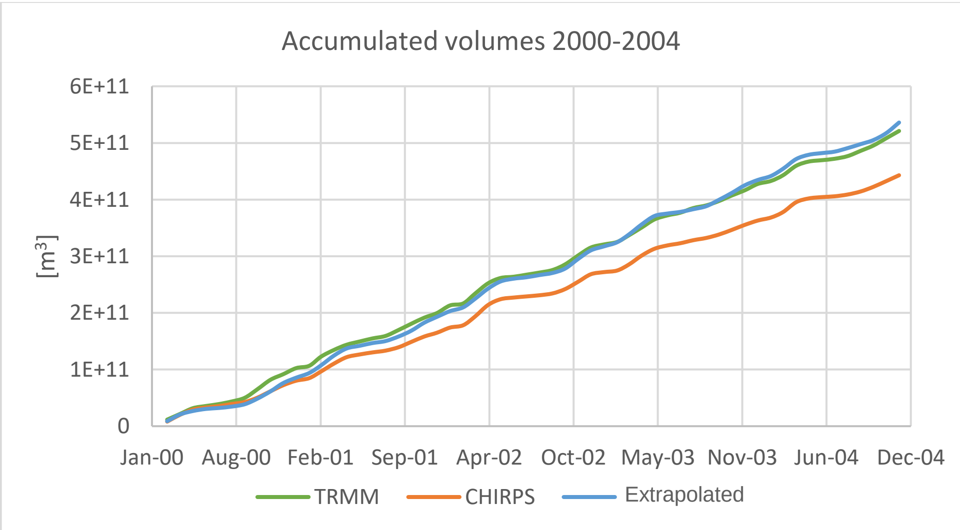


Figure 19 Accumulated volumes for the period 2000-2004, incorporating TRMM, CHIRPS, and extrapolated precipitation data.

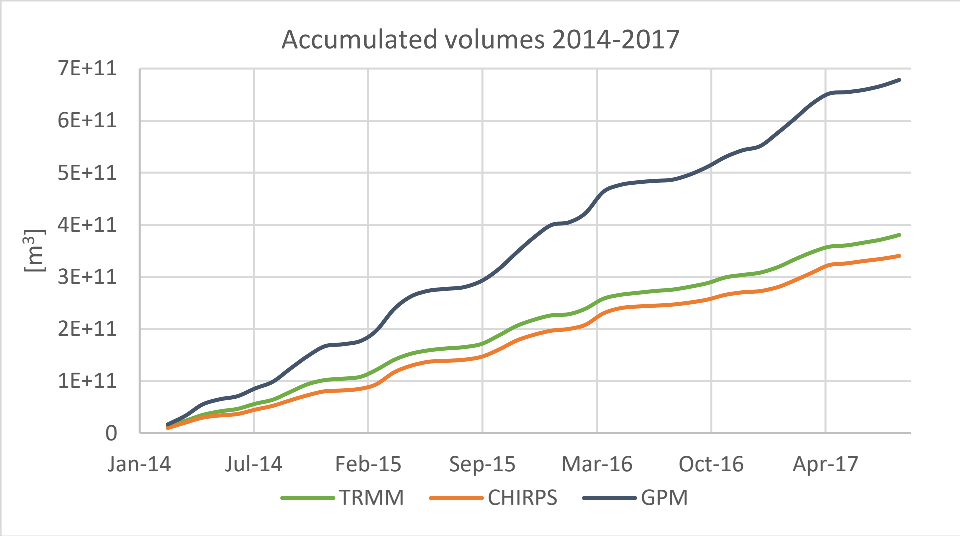


Figure 20 Accumulated volumes for the period 2014-2017, incorporating TRMM, CHIRPS, and GPM.

Table 9 summarises the information from the plots. The percentage differences between CHIRPS and extrapolated and CHIRPS and TRMM are comparable in magnitude.

Table 7 Percentage differences between accumulated volumes for CHIRPS, TRMM, GPM, and extrapolated precipitation data in the different time periods.

Time period	Data	Difference, total accumulation [%]	Mean absolute difference [%]
2000-2017	CHIRPS, TRMM	15.8	16.7
1981-2004	CHIRPS, extrapolated	19.3	19.0
2000-2004	TRMM, extrapolated	2.8	6.4
	CHIRPS, extrapolated	19.0	13.7
2014-2017	GPM, CHIRPS	66.4	65.8
	GPM, TRMM	56.2	51.3
	TRMM, CHIRPS	11.2	15.7

2.3.1.6 Rainfall spatial distribution

Seasonal and annual spatially distributed maps of the three different sources have been done to compare distribution patterns of rainfall, particularly over the lake. Below, only the annual maps are shown.

All three isoline maps clearly indicate the dramatic increase of slope and magnitude of rainfall over the lake, almost resembling a mountain of rainfall raising over a lake surface. Minimum and maximum yearly rainfall values differ between, the latter being 2.342 mm (CHIRPS) and 3,284 mm (TRMM). As expected 7,226 mm (GPM) falls very much apart from the other two sources.

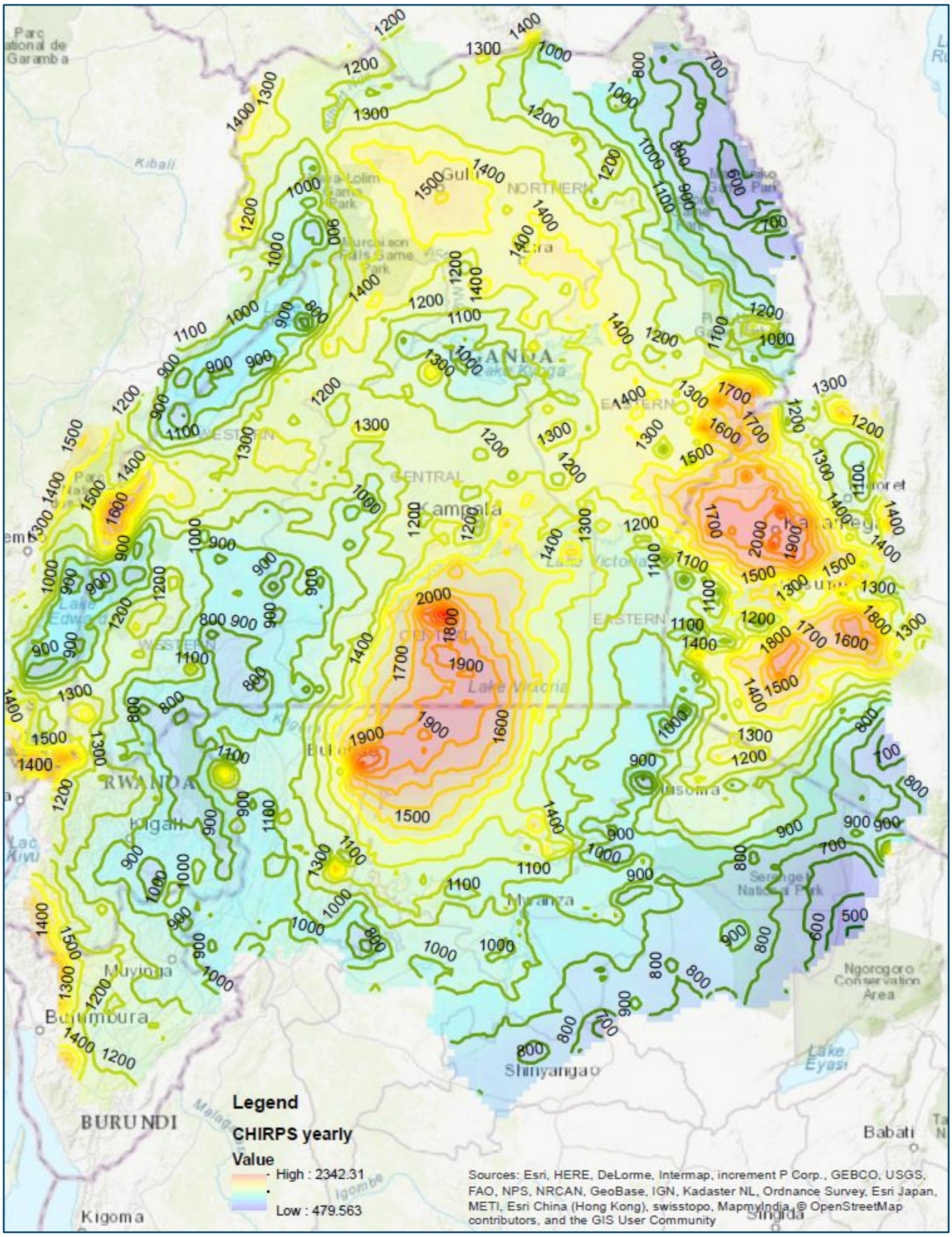


Figure 21 CHIRPS annual precipitation isolines over a map of the focus area.

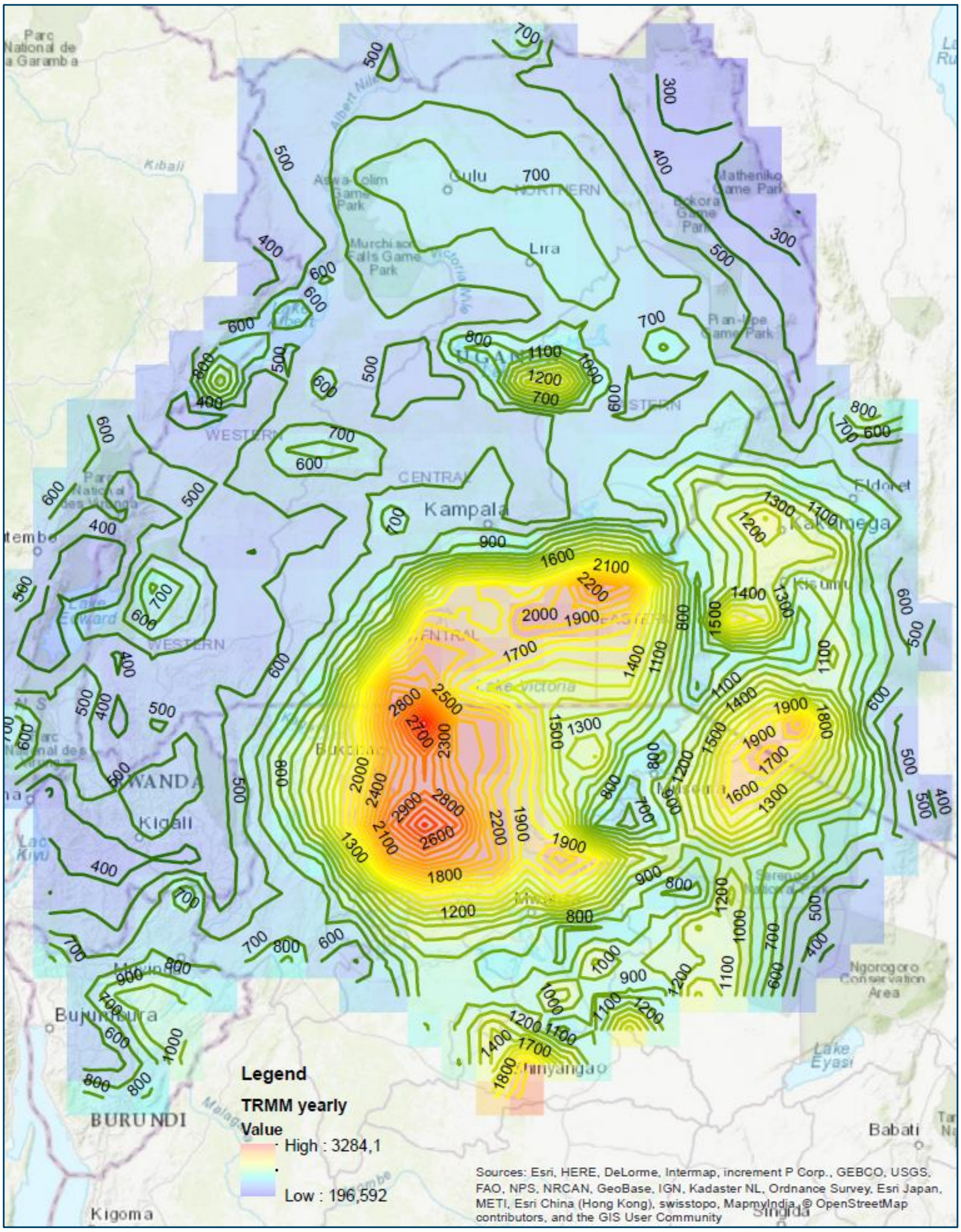


Figure 22 GPM annual precipitation isolines over a map of the focus area.

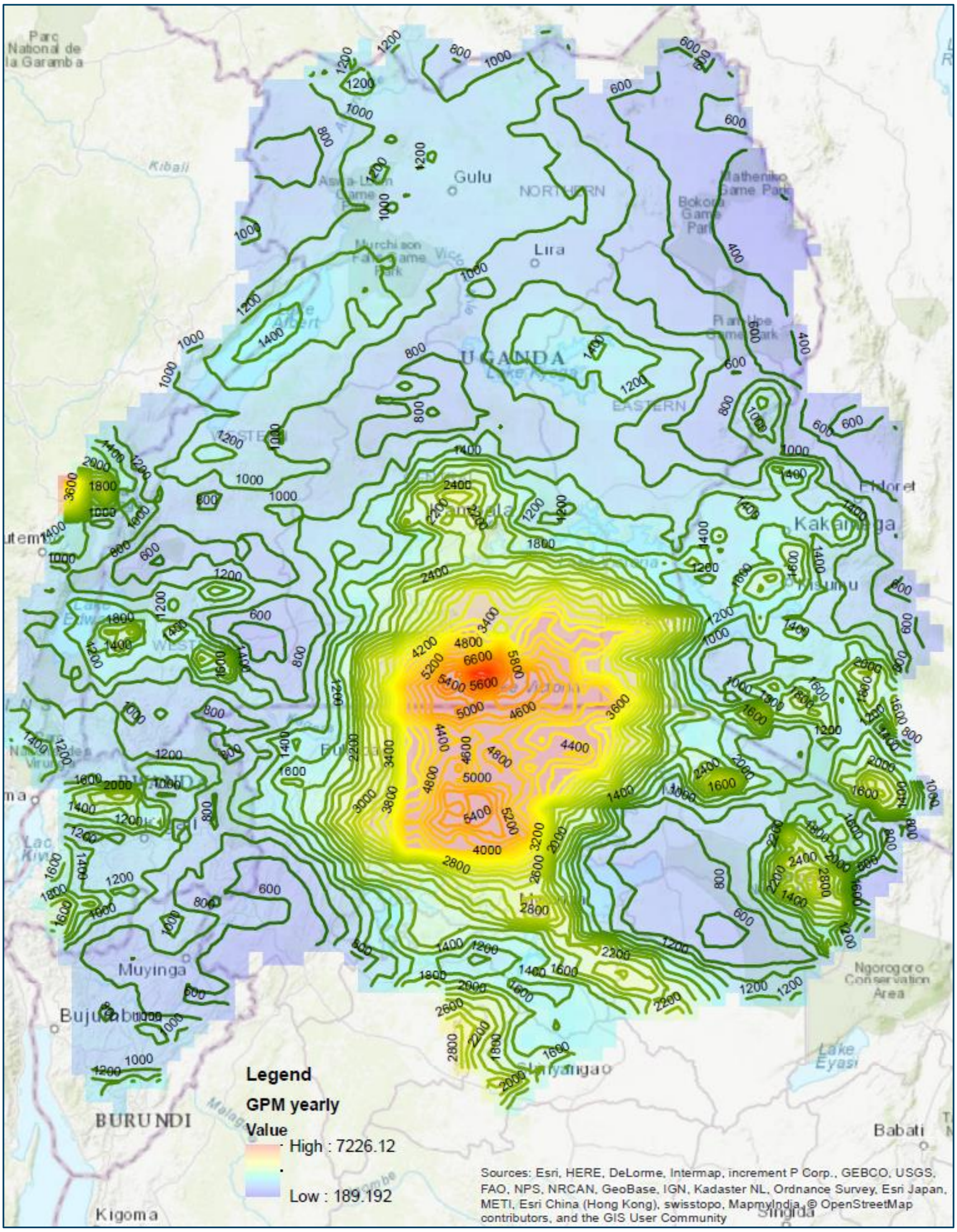


Figure 23 GPM annual precipitation isolines over a map of the focus area.

2.3.2 Rainfall on land

There is limited observed precipitation data for the time period in which there is also remote sensing, but for the station Mwanza there is a record of 15 years (2005-2014), which gives a good time period for comparing with TRMM. When plotting the daily precipitation, the result is not very meaningful, but accumulating to monthly values, as shown in Figure 21, gives a clearer picture of the agreement between the two datasets. There is a quite good agreement as to the temporal positions of the peaks and lows, but not the magnitudes. The agreement between the data sets seem to be best until around 2009. After this, the differences in magnitudes seem to be larger, and the peaks are more often displaced compared to each other. The mean difference between the two data sets is 45%. From 2005-2008 the mean difference is 39% and from 2009-2004 the mean difference is 49%. While there does seem to be a larger difference after 2009, the difference before 2009 is also quite large, and both values are relatively closely to the average for the entire period.

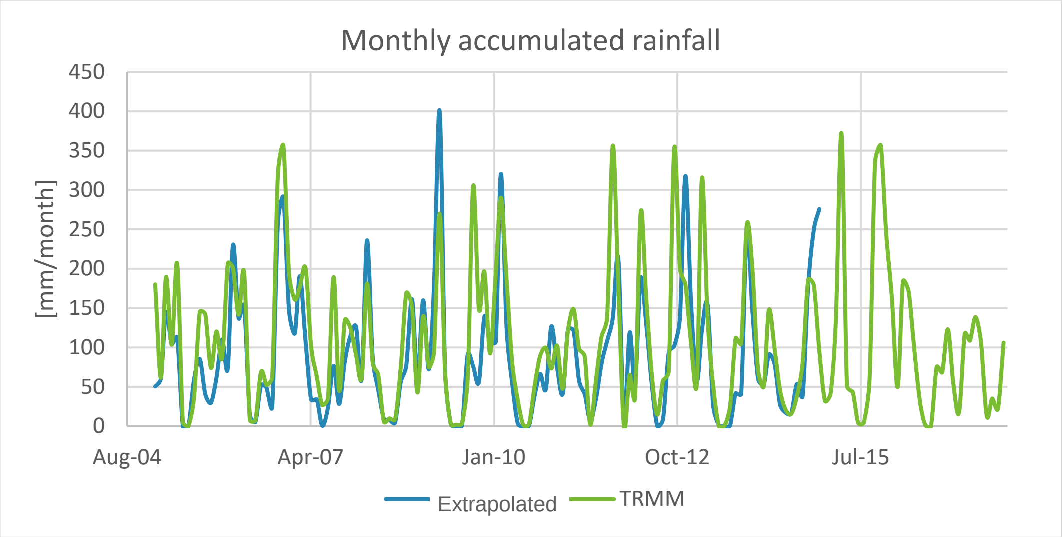


Figure 24 Monthly accumulated precipitation values for TRMM and observed at the station Mwanza.

2.3.3 Water level

There are observed water levels available as well as the remote sensing product JASON. Figure 22 shows the observed water levels plotting alongside the water levels from JASON. As seen, there is a displacement of about 1 m, with the observed data being the lower. However, the fluctuations are almost the same within the two data sets, so the performance of JASON seems to be very good and depending on the purpose, could be used to substitute the observed data when this is not available for this period with prior adjustment.

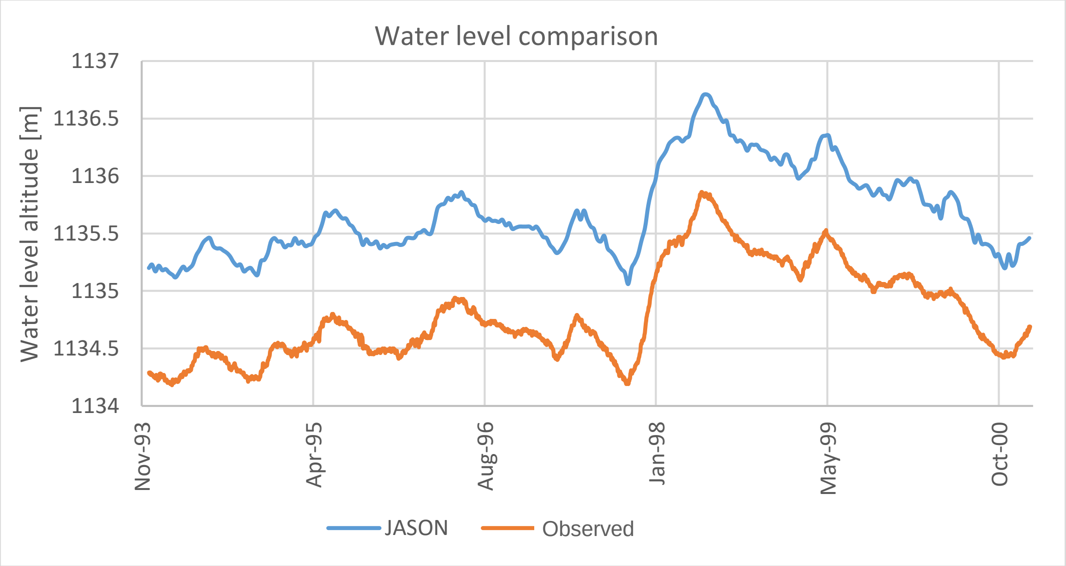


Figure 25 Observed water levels and water levels from JASON, presented as altitude of the water table.

2.4 Water balance analysis

From the data discussed above, three different water balances have been made to further the drawing of conclusions. The upper boundary of the time period is constrained by the extrapolated data (for flow and evaporation) which is only available until 2004. This gives the following time periods for the water balances:

- 1950-2004 (extrapolated),
- 1981-2004 (CHIRPS), and
- 2000-2004 (TRMM).

GPM data has not been included. Evaporation is from a time series of extrapolated data, while outflow is the observed outflow at Jinja. There was no observed data for the inflow, so this has been given as a constant value of 788 m^3/s, as used by Lørup, et al. (2014). The water balances are presented as the annual mean for the given time periods. For each separate year, Q is given as the mean of all values, while precipitation and evaporation are summed up, multiplied by the area of the lake and divided by the number of seconds per year. A year is considered to have 365.25 days. Note that for TRMM, the first data is from March 2000, so here the first year has been calculated as having 305 days. The change in storage is calculated as

$$\Delta S = P + Q_{in} - (E + Q_{out})$$

where all inputs are in m^3/s.

The results of the water balance are shown in Table 10 including the mean absolute errors in storage change between the different water balances. The water balance in all cases, except for the extrapolated data, are negative, which is not expected. The most likely reasons for this is that precipitation is underestimated or evaporation is overestimated due to the lack of observed data on the lake itself. However, it is also a possibility that the weather patterns have changed and that the water balance may be turning negative.

While it seems surprising that the error between the extrapolated data and TRMM is this large, considering that the two data sources were found to be largely similar, the mean storage change for the extrapolated data in the period 2000-2004 is -300 m^3/s, which is comparable in magnitude with the value for TRMM in the same period.

Table 8 Water balances with three different precipitation inputs (extrapolated, TRMM, and CHIRPS). The values are the annual means of the given time period. All values are in m3/s.

	P	E	Q_{in}	Q_{out}	ΔS	Time period
Extrapolated	3613.8	3330.3	788	1057.6	13.9	1950-2004
CHIRPS	2895.5	3321.5	788	1067.1	-705.0	1981-2004
TRMM	3395.9	3358.1	788	1185.3	-359.5	2000-2004
Extrapolated	3456.3	3358.1	788	1185.3	-300.8	2000-2004

Using extrapolated data, Lørup, et al. (2014), found that the annual storage change for the period 1953-1978 was 90 m^3/s. Considering the extrapolated data for only this time period gives a comparable result (97 m^3/s). This could indicate that climate changes have affected the lake in the later years, as the storage change has changed a lot and is negative for the later years, both when considering remote sensing data (-705 m^3/s for CHIRPS) and extrapolated data for the whole period (13.9 m^3/s).

2.4.1 Water balance solved for evaporation

To further investigate the evaporation, it has been calculated used the Thornwaite equation:

$$PET = 16\left(\frac{day\ length}{12}\right)\left(\frac{no.of\ days}{30}\right)\left(\frac{T_a}{I}\right)^{\alpha}$$

where T_a is the average temperature for that month. I is defined as

$$I = \sum_{i=1}^{12}\left(\frac{T_{a,i}}{5}\right)^{1.514}$$

and α as

$$\alpha = (6.75 \cdot 10^{-7})I^3 - (67.71 \cdot 10^{-5})I^2 + (1.792 \cdot 10^{-2})I + 0.49239$$

The temperature is found from remote sensing, and one value is used for the basin and one value for the lake. The precipitation data is from TRMM and the time period is 2000-2004.

In addition, the water balance was set up to take as input lake water levels changes rather than storage change, as suggested by Vanderkelen, et al. (2018):

$$\frac{dL}{dt} = P - E + \frac{Q_{in} - Q_{out}}{A}$$

A is the area of the lake. In this equation, the input parameters have the unit m/time (either monthly or yearly). The precipitation is known from TRMM, the flows from observed data/assumptions, and the lake water level change from JASON. This leaves the evaporation as the only unknown and it can then be found from the equation.

Figure 23 shows the evaporation from 2000-2004 found using three different methods. The value found from the water balance is significantly lower than the other two, and may be the most accurate. However, it should be kept in mind that there are several uncertainties to this method. There is no observed data over the lake to verify the TRMM data and there is limited information about the flow, especially inflow.

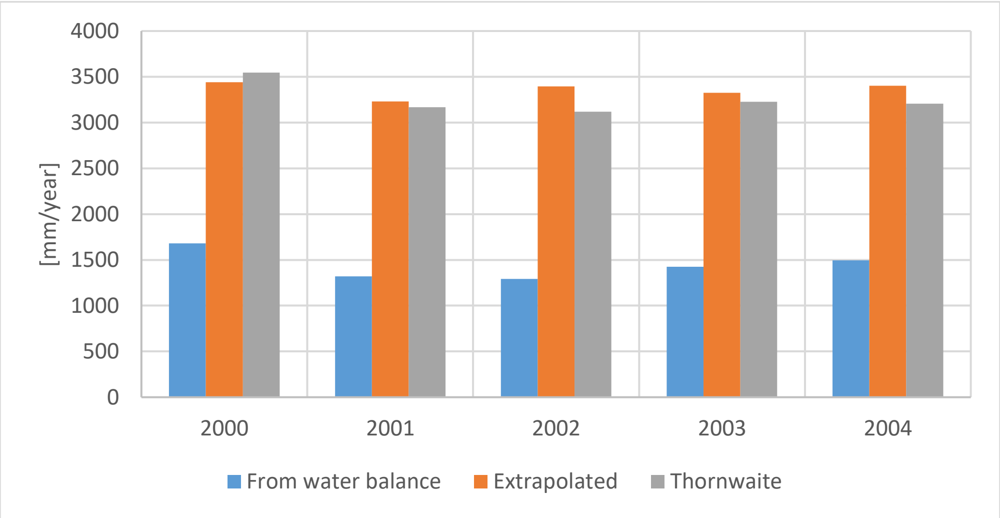


Figure 26 Evaporation for Lake Victoria found using three different methods.

Using the water balance equation from above, E was found during period with large drops or rise in water level. The selected periods can be seen in Figure 24. P1 is the continuation of a drop starting in 1998, but as the daily TRMM data is not available before March 2000, the water balance for this period starts in May 2000 which is the highest point in the included time period.

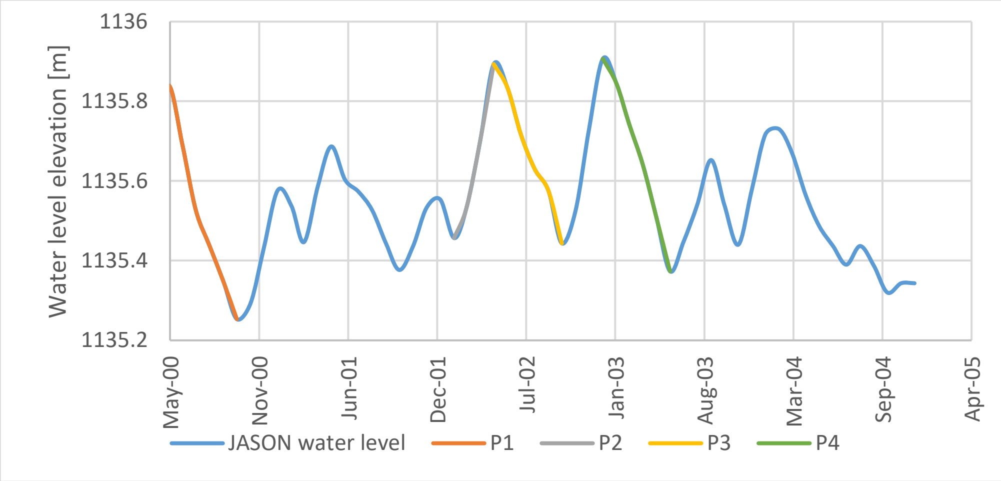


Figure 27 Selected periods in which the evaporation was calculated based on water level. The period is March 2000-December 2004.

The results are summarized in Table 12 below. As the time periods are different, only E in m^3/s is comparable. The water balance is visualized in Figure 28, where all elements are in mm per month. The flows have not been included as they are largely similar every month and as so are not the drivers for the changes in water level.

Table 9 Water balance for selected periods with changes in lake water level. E is calculated from the water balance. All values are in m/month-

	Period	Water level changes	Outflow/A	Inflow/A	P	E
P1	May 2000 - Oct 2000	-0.10	0.04	0.03	0.10	0.19
P2	Feb 2002 – May 2002	0.11	0.04	0.03	0.17	0.05
P3	May 2002 – Oct 2002	-0.07	0.04	0.03	0.08	0.14
P4	Jan 2003 – Jun 2003	-0.09	0.04	0.03	0.14	0.21

There are large variations in precipitation and evaporation between the different periods. In P2, the only period with rising water levels, the precipitation is very high, while the evaporation is the lowest of all the periods. In the other periods, evaporation is controlling the falling water levels, as it is higher than the precipitation. P1 shows the largest drop. While it has only the second highest evaporation rate, the precipitation is also relatively low. In P3, the evaporation is the second-lowest, but as the precipitation rate is the lowest of all the periods, there is still a drop in lake water level. P4 shows the second-highest drop in water level, which is caused by the high evaporation, as the precipitation is the second-highest of the included periods.

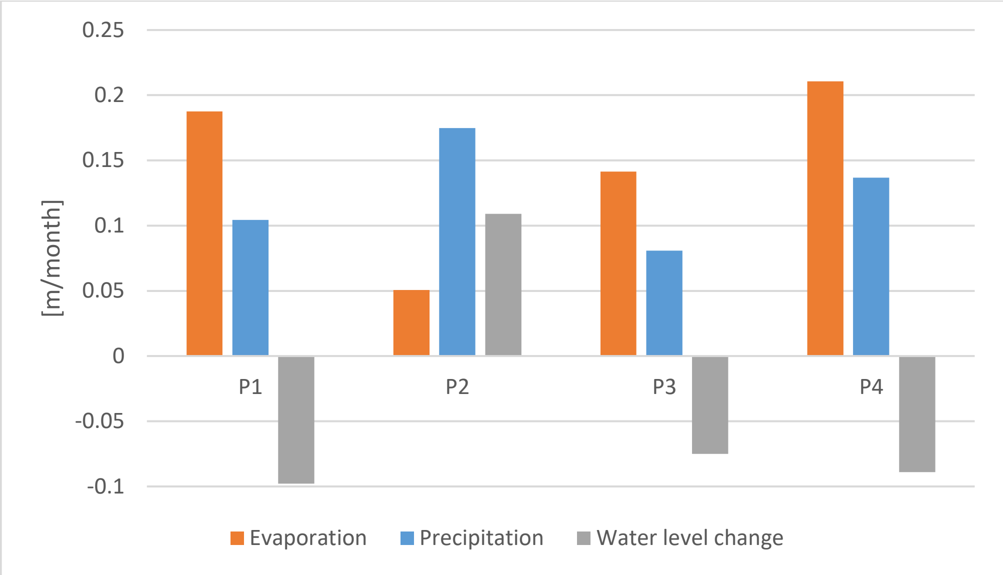


Figure 28 Water balance elements for the four different periods, all in m/month. Inflow has not been shown as this is the same for all periods.

Table 13 presents the evaporation for the four periods, calculated from Thornwaite, from the water balance, and from the extrapolated, visualised in Figure 26. Generally, the value found from the water balance is the highest, except for P2 where is less than half of the other values. This is the only period with rising water levels. This could indicate that the extrapolated and Thornwaite evaporation do not capture the variation in evaporation. However, there are uncertainties in the data, especially regarding the flows, therefore the evaporation calculated from the water balance may not be the most accurate.

Table 10 Evaporation for the four periods found using three different methods. All values are in mm/period

	Period	Extrapolated E [mm]	Thornwaite E [mm]	Water balance E [mm]
P1	May 2000 - Oct 2000	822.65	898.98	1125.57
P2	Feb 2002 – May 2002	496.70	451.32	202.80
P3	May 2002 – Oct 2002	793.18	841.19	849.34
P4	Jan 2003 – Jun 2003	763.80	705.97	1264.29

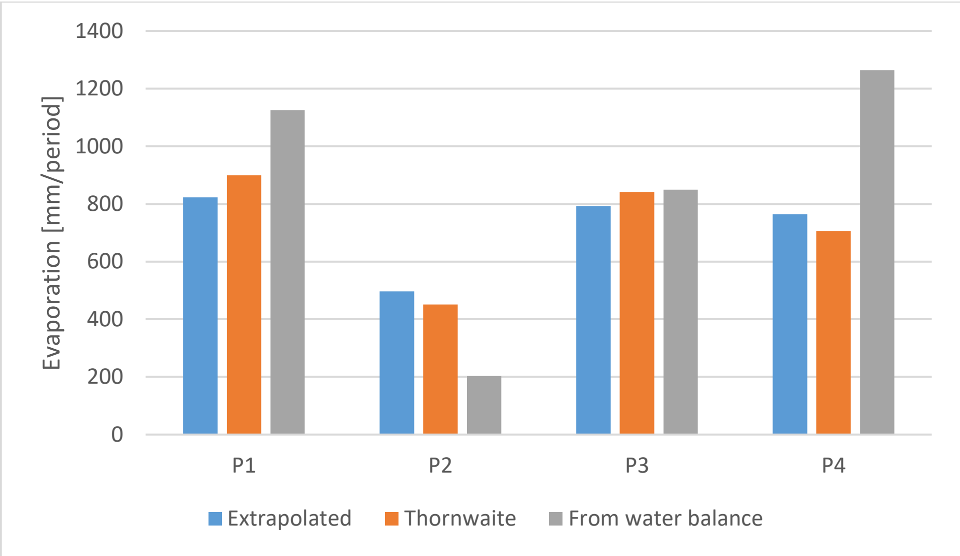


Figure 29 Evaporation for the four periods found using three different methods.

2.5 Day and night time variation of rainfall

2.5.1 Catchment rainfall

TRMM is available as 3-hourly weighted time series data for the Lake Victoria catchment. It has been separated into day and night data. The time periods are defined with the night-time from 21:00 to 06:00. Note that when using this data source, the value time tags are the middle of the time that the sample covers – that is, the value for 21:00 covers the time period 19:30 to 22:30. Therefore, we will consider the night-time as being from 19:30 to 7:30 (GES DISC, 2017).

Firstly, there is clearly higher rainfall by night, accumulating the 3-hourly values into monthly values gives an average percentage difference of 51%. The average percentage of the total rainfall that falls at night is 61% when looking at the monthly data.

Figure 27 shows the accumulated values for each date separated into night and day. Here it is clear that the night values are generally higher than the day values and experience more extreme events.

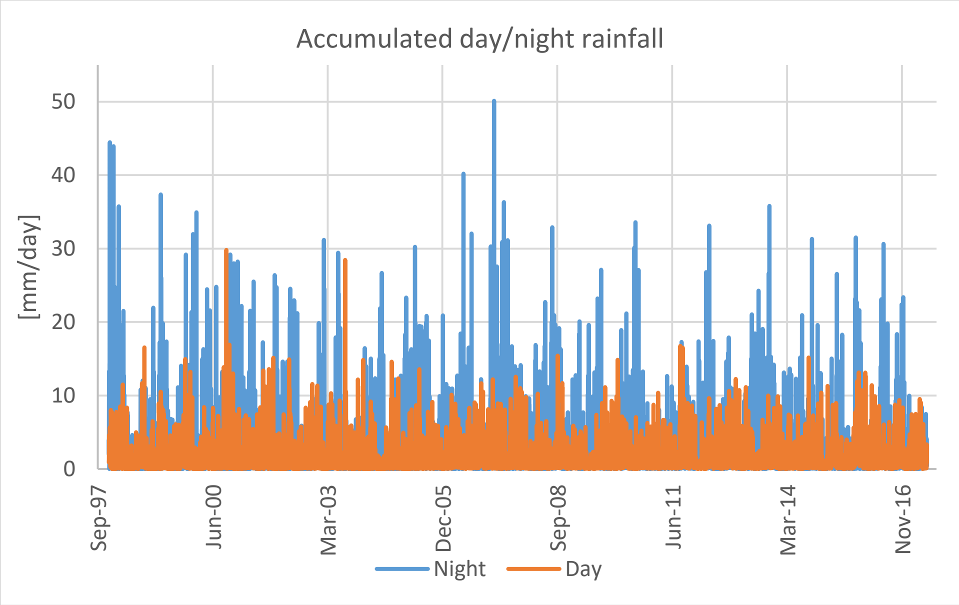


Figure 30 Accumulated values for each date, separated into night and day values.

Figure 28 shows the monthly accumulated values for the entire period, given an even clearer indication of how the night values are significantly higher than the day values.

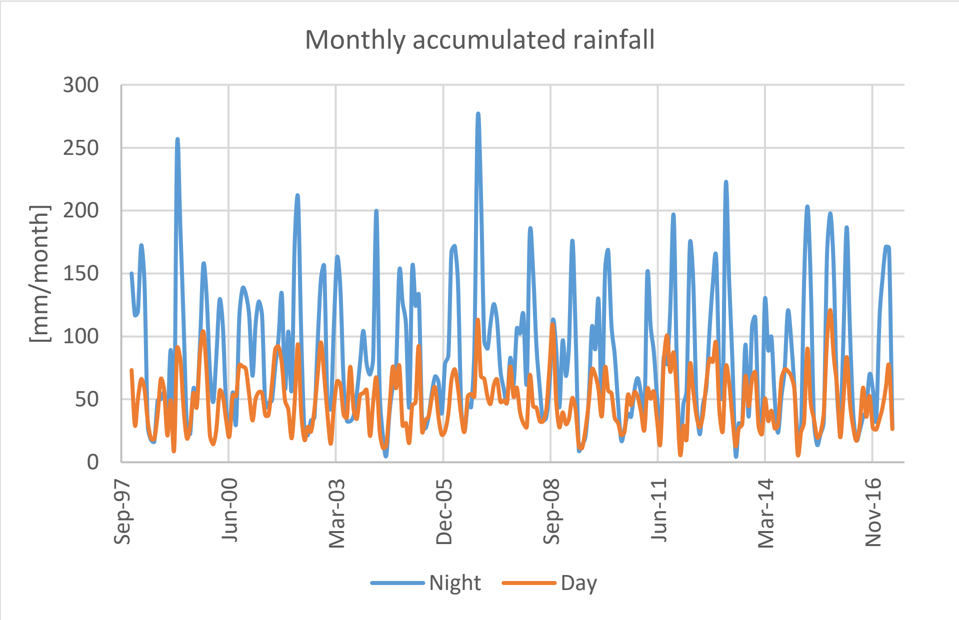


Figure 31 Monthly accumulated values for Lake Victoria, separated into night and day.

It has been investigated how many storms there are at day and at night. Williams et al. (2014) have studied the performance of regional climate models over Lake Victoria; as the heaviest rainfall they use 16 mm/day (7 mm/hr). Defining storms as rainfall events of this value or higher, gives 3032 storms at night, corresponding to 11% of the night-time data points, while there are only 1069 storms at day, corresponding to 4% of the data points. Another definition of storms has been found in Thiery et al. (2016), who look at future projections of extreme rainfall events in the face of climate change. They state that the 99th percentile precipitation at night over Lake Victoria is 4-8 mm/h. Using 4 mm/hr as a somewhat higher definition for a storm than before gives 50 storm events at night (0.18% of all night data points) and only one event during the daytime.

2.5.2 Jinja station and Lake Victoria

Figure 29 shows the nightly and daily monthly averages for the period 1998-2017 of TRMM 3-hourly data. Note that the comparison is between averages of the pixels for the entire lake basin and data from a single pixel at the location of Jinja station. Both time series show the same annual seasonality with two rainy seasons, once with heavier rainfall than the second, but the variation is more pronounced in the nightly data. Especially the peaks of the two rainy seasons show large differences, indicating that a significant part of the precipitation in the rainy seasons falls at night. The amount of precipitation is very similar during night and day from June to September, with the rainfall actually slightly higher during the day in August and September. The largest difference between night and day is found in April, which is the peak of the heaviest rainy season. The conclusions here are comparable to the findings of the monthly averages for CHIRPS and extrapolated data. The same seasonal pattern is found and the magnitudes when adding up day and night values are comparable to the extrapolated and CHIRPS values.

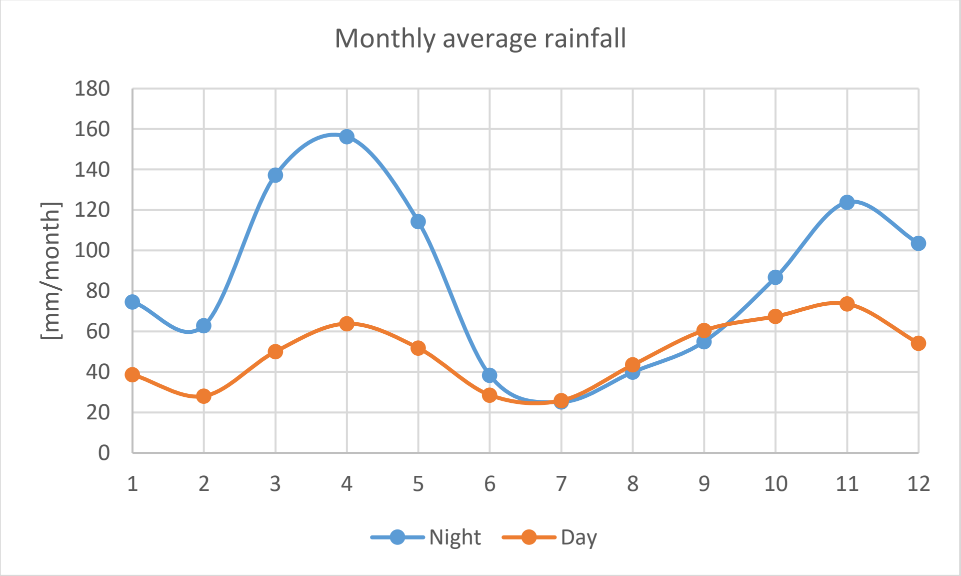


Figure 32 Monthly averages for day and night precipitation, considering 3-hourly TRMM data.

Figure 30 shows the monthly averages for the station Jinja (TRMM data). Here the pattern is very different, especially when considering the daily data. The seasons are not clearly displayed for the daytime data, and the peak for this data is in September which does not correspond to previous findings. From June to September, the daytime precipitation is higher than the night-time precipitation, once again opposing the findings so far. The night data is quite comparable with the plot for the entire lake, displaying the same seasonal trends and having values of similar magnitudes. Possibly the seasonal pattern is not the same for the lake as for the land-based Jinja. However, with Jinja being right on the shores of the lake, it would be expected to see similar trends here. Looking at only part of the lake closer to Jinja might also give more similar rainfall patterns, as the current value for the lake takes the entire area into account. It is not unreasonable to expect that there may be variations over the lake area itself.

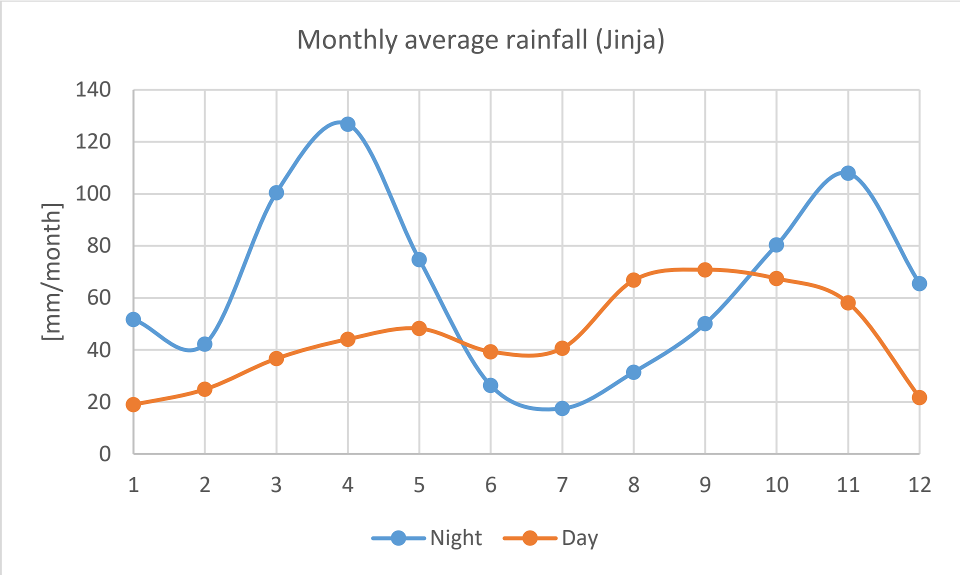


Figure 33 Monthly averages for 3-hourly TRMM at the station Jinja.

Figure 31 and Figure 32 show the accumulated monthly values for Jinja and Lake Victoria, separated into night and day, respectively. It is hard to draw definitive conclusions based on the plots. The positions of peaks and lows seem to agree. The agreement seems to be better in the night, although the percentage differences were similar during the night and during the day. The average percentage difference between accumulated monthly values for Lake Victoria and Jinja is 55% for both night time and daytime values.

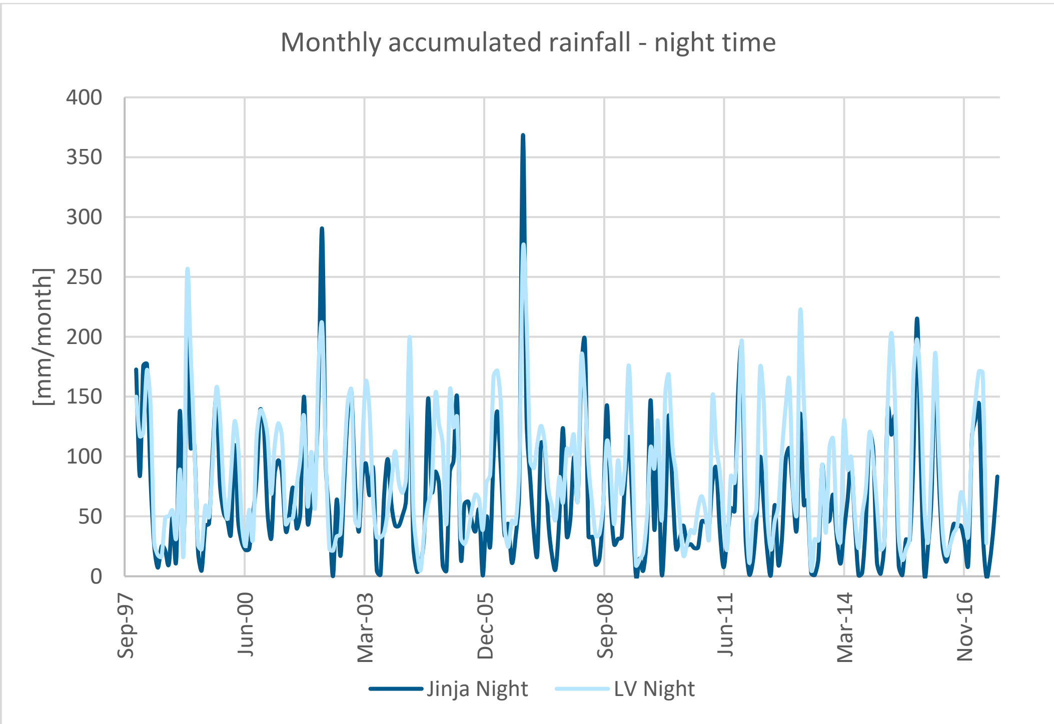


Figure 34 Monthly accumulated values of night time data for Jinja and Lake Victoria.

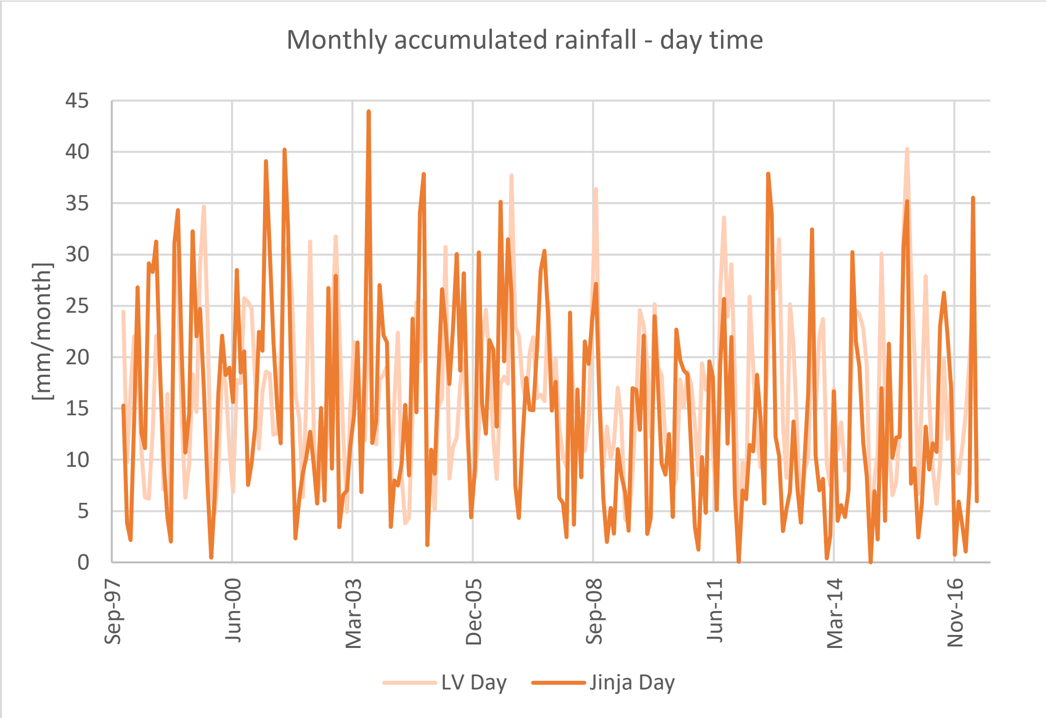


Figure 35 Monthly accumulated values of daytime data for Jinja and Lake Victoria.

The monthly averages, shown in Figure 33, show that the night time values are overall in agreement. They show the same trends, and the values are close to each other, although the values for Jinja are generally lower than those for Lake Victoria. The largest differences are found in March-May (the “long-rains” season) and in December. While the value for December is higher than that for November for LV, it is lower for Jinja.

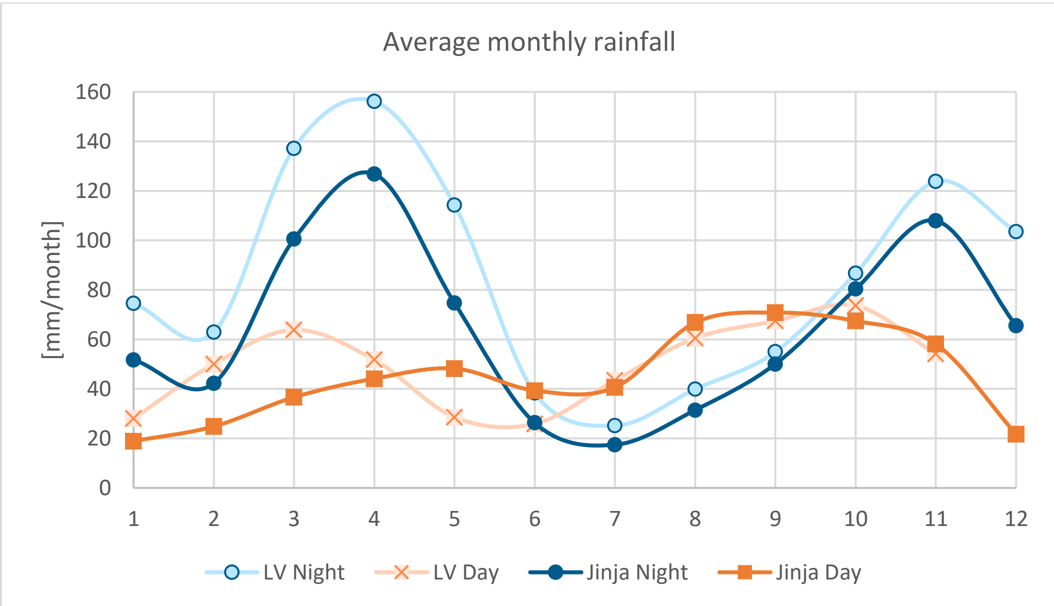


Figure 36 Monthly averages for Jinja and for Lake Victoria, separated into day and night values.

2.5.3 Maximum and minimum rainfall

It was considered how the extreme events looked during the day and during the night. To do this, the monthly minimum and monthly maximum were found for both day and night (considering daily accumulated values). The average monthly values are shown in Figure 34 and Figure 35. Both plots show the same seasonality. Interestingly, while the monthly maximum is much higher during the night than during the day, the opposite is the case for the minimum. This shows that while the night experiences the more extreme heavy rainfall, it also has lighter rainfall events than during the day.

The seasonal variations are clearer for minimum than for maximum. The reason could be that for the maximum, some months may have had very extreme events that affect the means strongly.

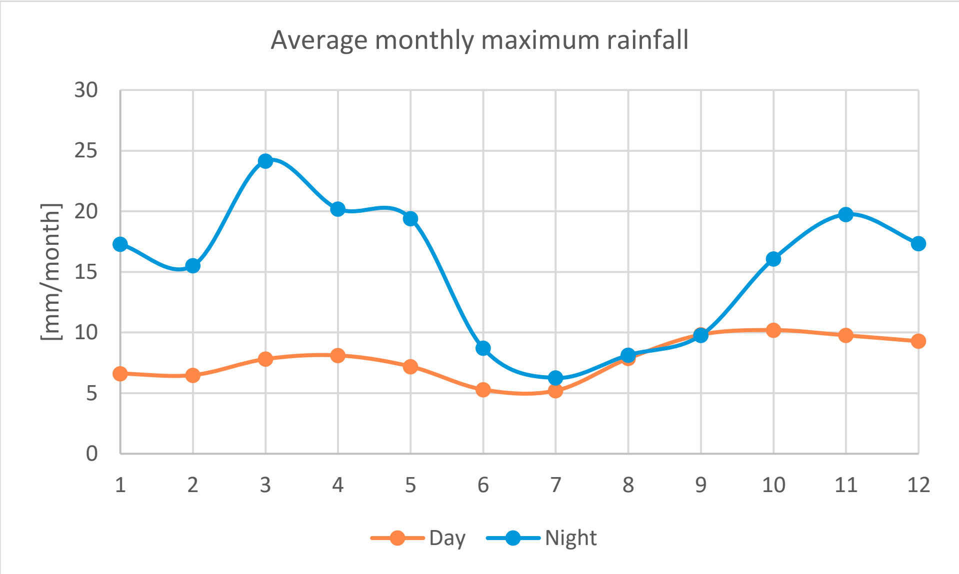


Figure 37 Average value of the maximum each month, separated into day and night.

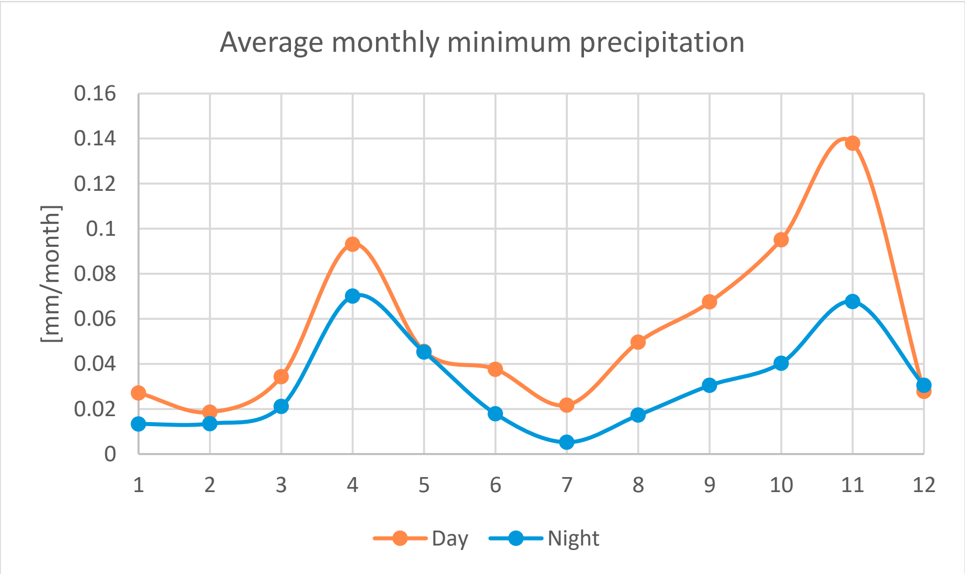


Figure 38 Average value of the minimum each month, separated into day and night.

The pattern is similar when considering percentiles, as seen in Figure 36 and Figure 37. The percentiles were found by separating the data by month, once more considering the daily values, and for each month finding the percentiles for night and day, respectively.

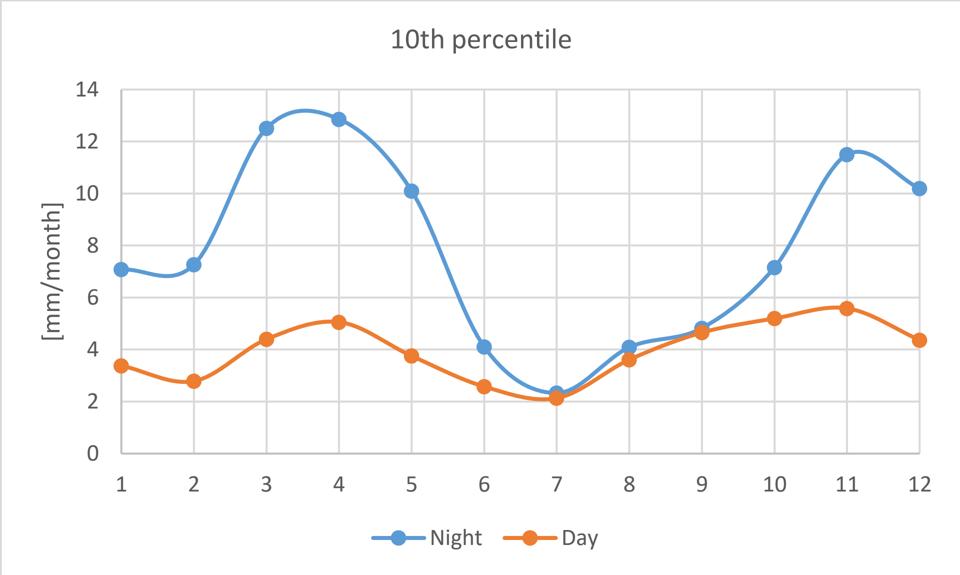


Figure 39 10th percentiles for every month, separated into night and day.

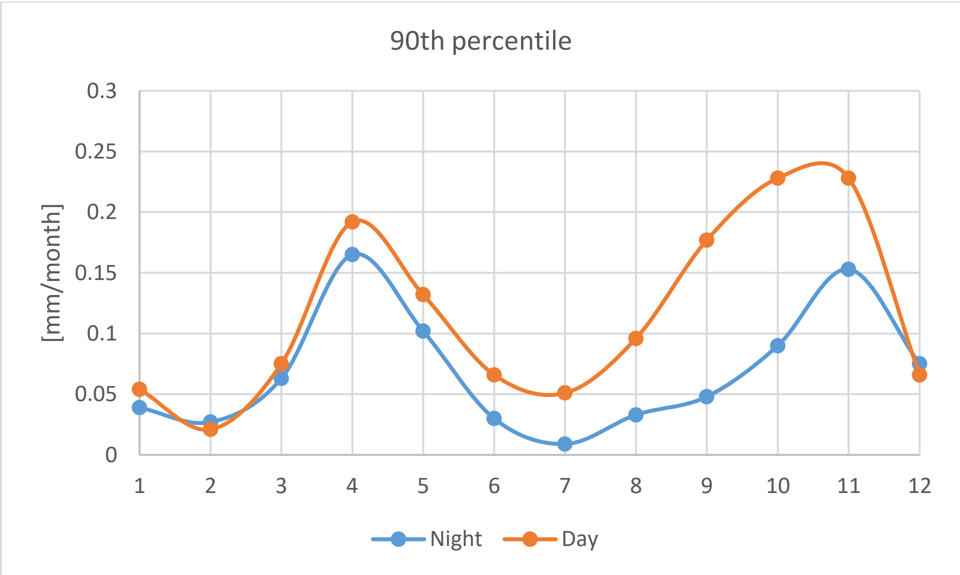
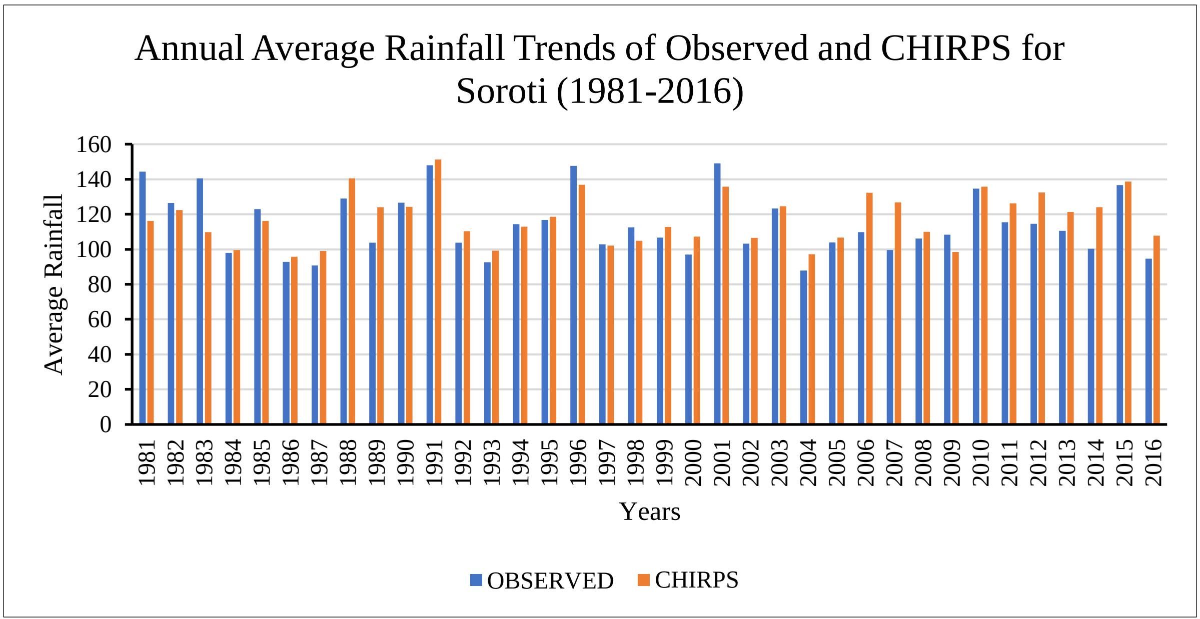


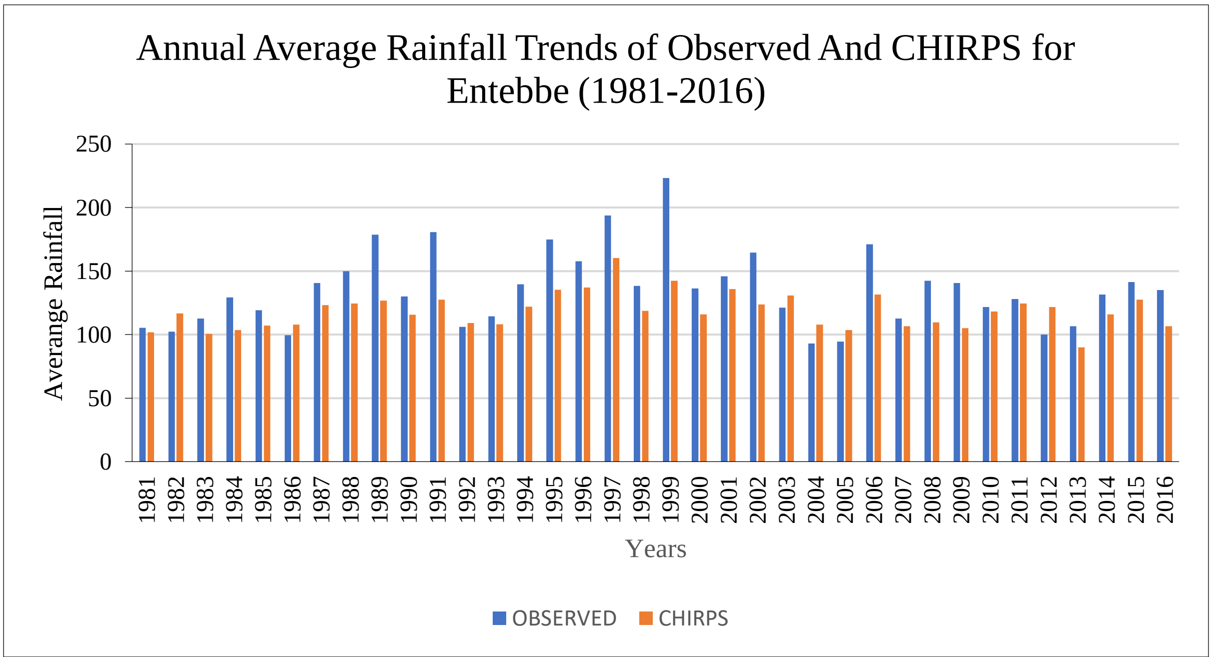
Figure 40 90th percentiles for every month, separated into night and day.

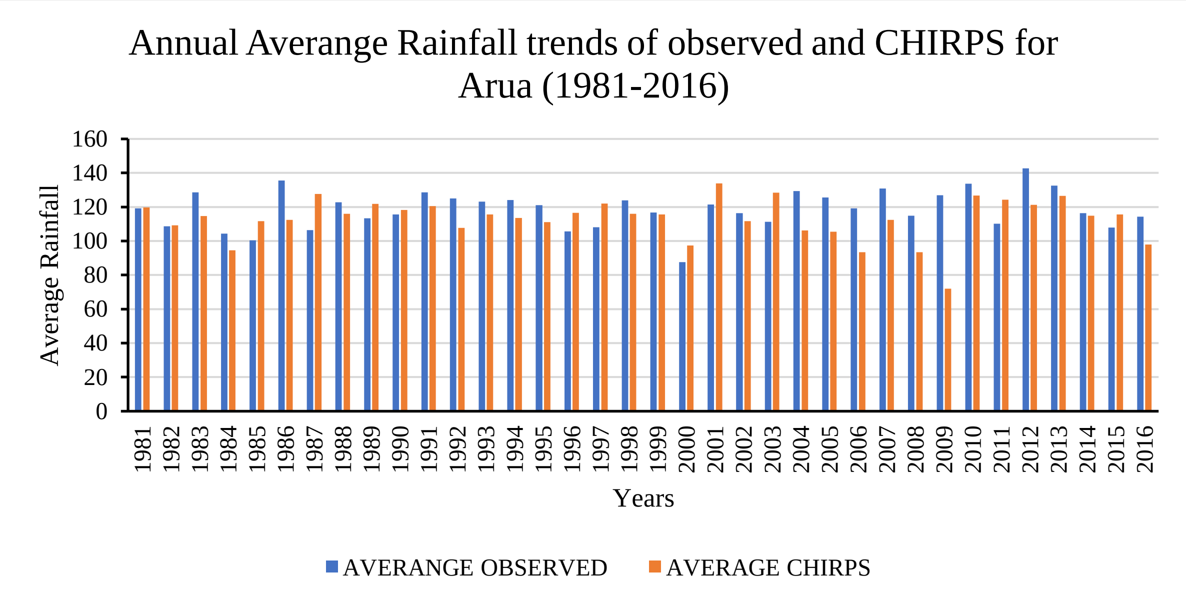
2.6 Testing of data by UNMA

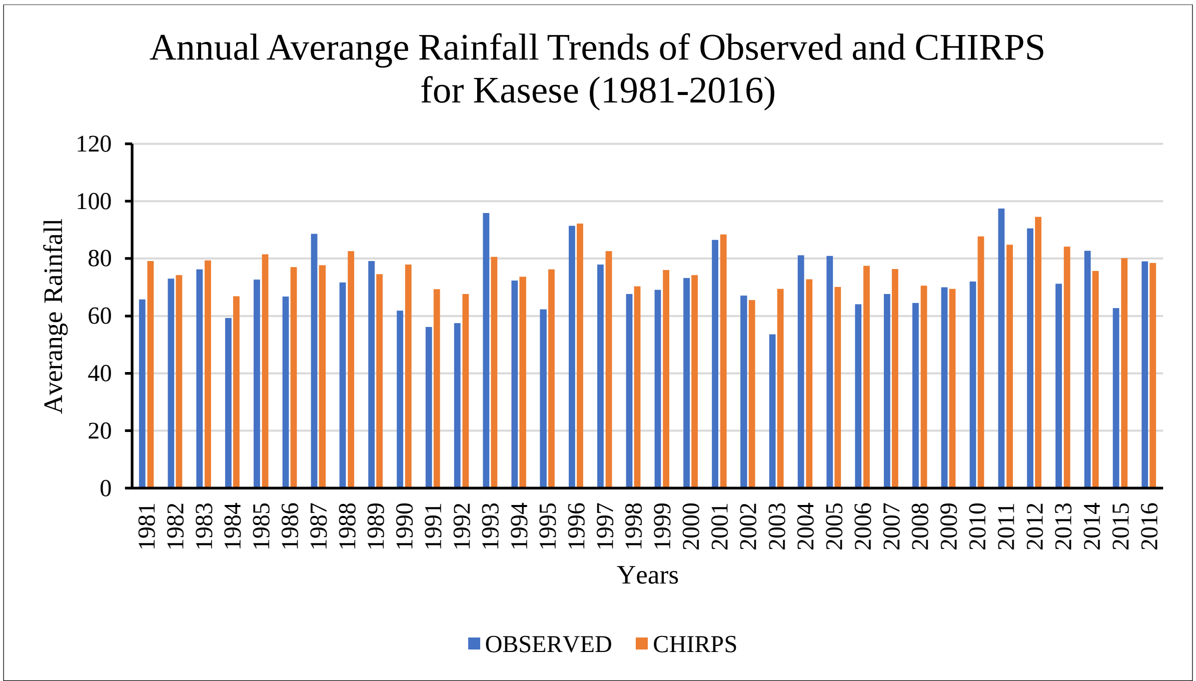
The Uganda National Meteorology Authority carried out their own analysis of the data from the portal. The UNMA provided a point layer of station locations which was added to the portal. This allowed the extraction of time series for the pixels underlying the station points.

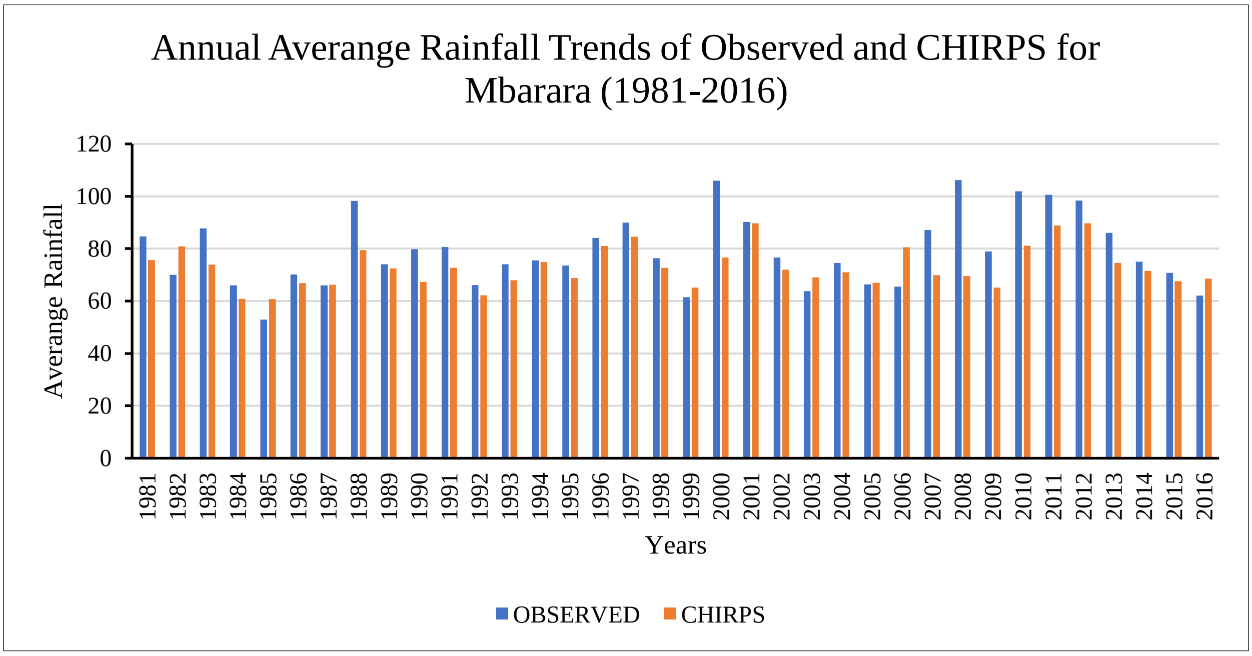
The UNMA calculated the mean annual rainfall analysis for both CHIRPS dataset and the UNMA observed station data. An analysis and correlation and the UNMA has found this dataset to be good data for use in research and analysis. The stations of Arua, Entebbe Soroti, Kasese,Tororo, Mbarara are showing good correlations as documented in the charts that follow.

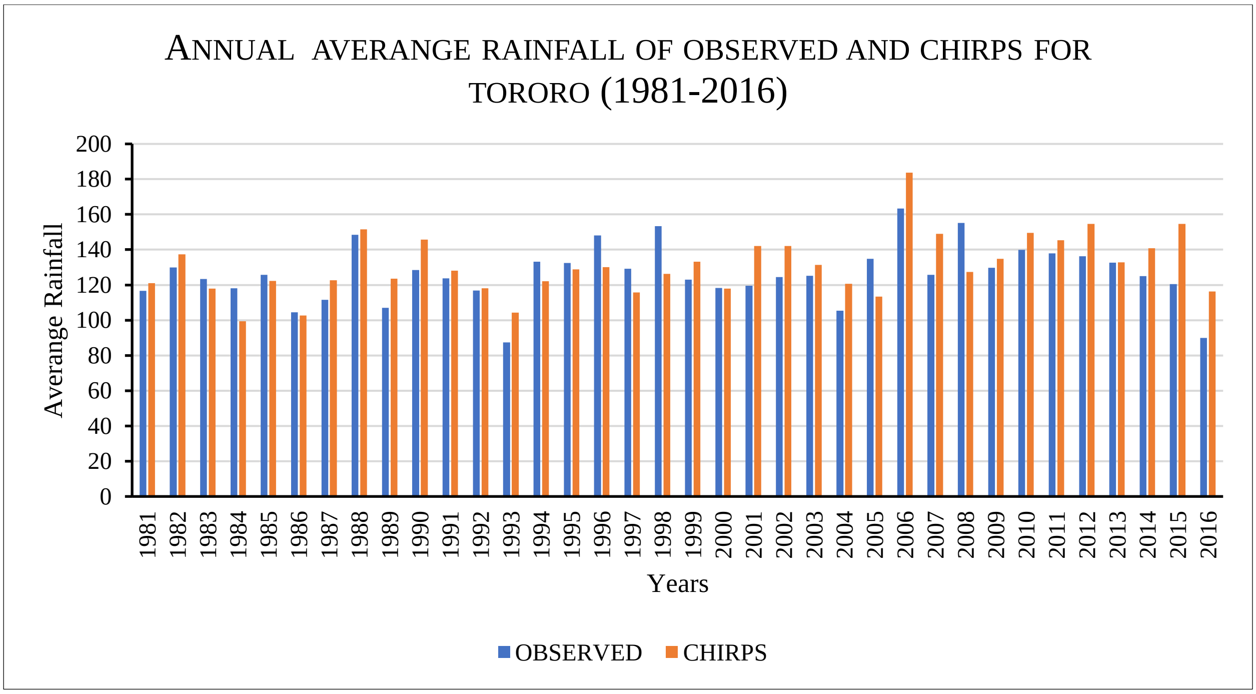


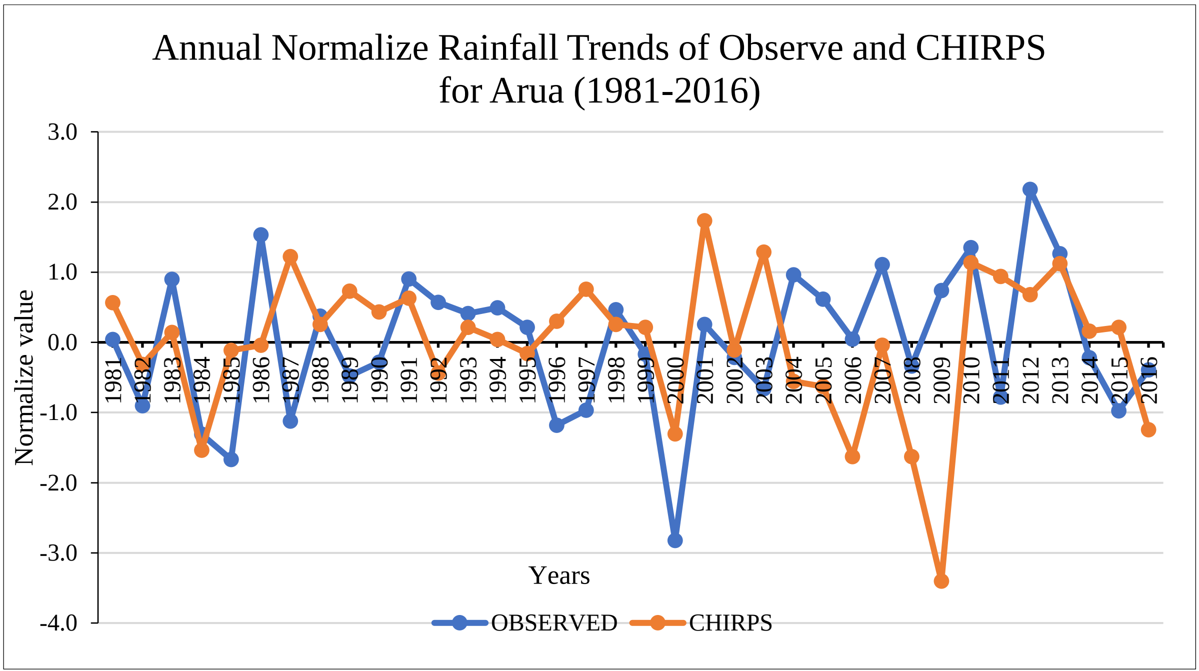


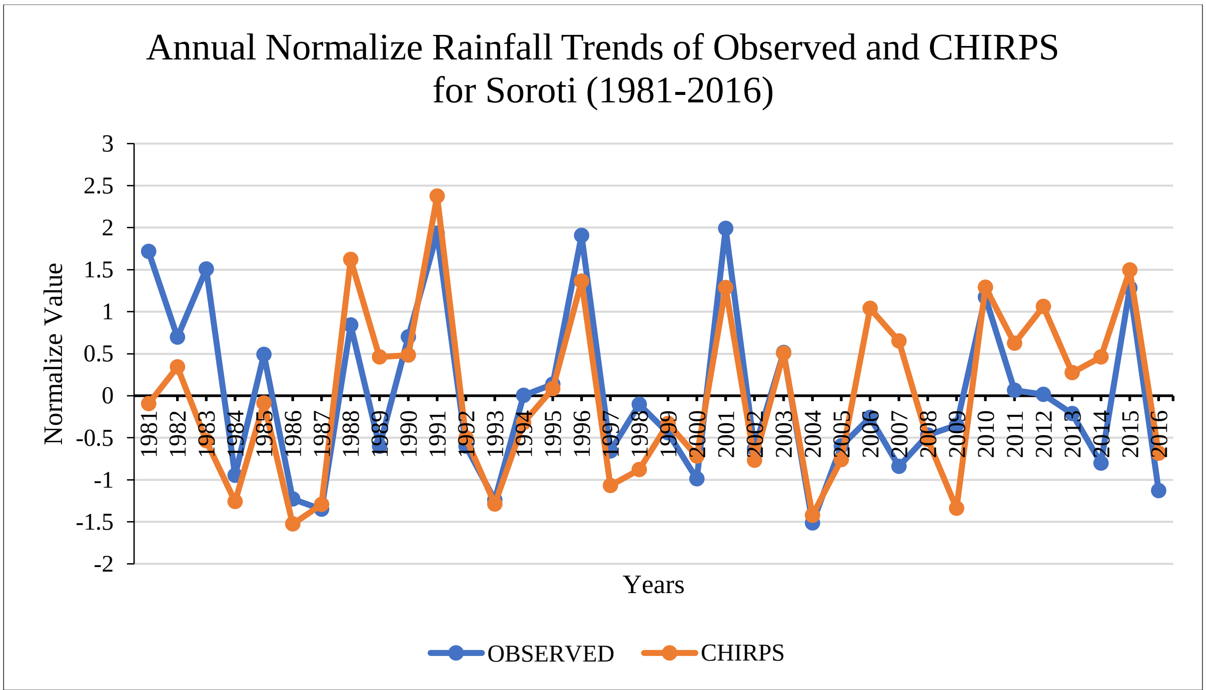

Annual Averange Rainfall trends of observed and CHIRPS for Arua (1981-2016)
Average Rainfall
160
140
120
100
80
60
40
20
0
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Years
AVERANGE OBSERVED
AVERAGE CHIRPS

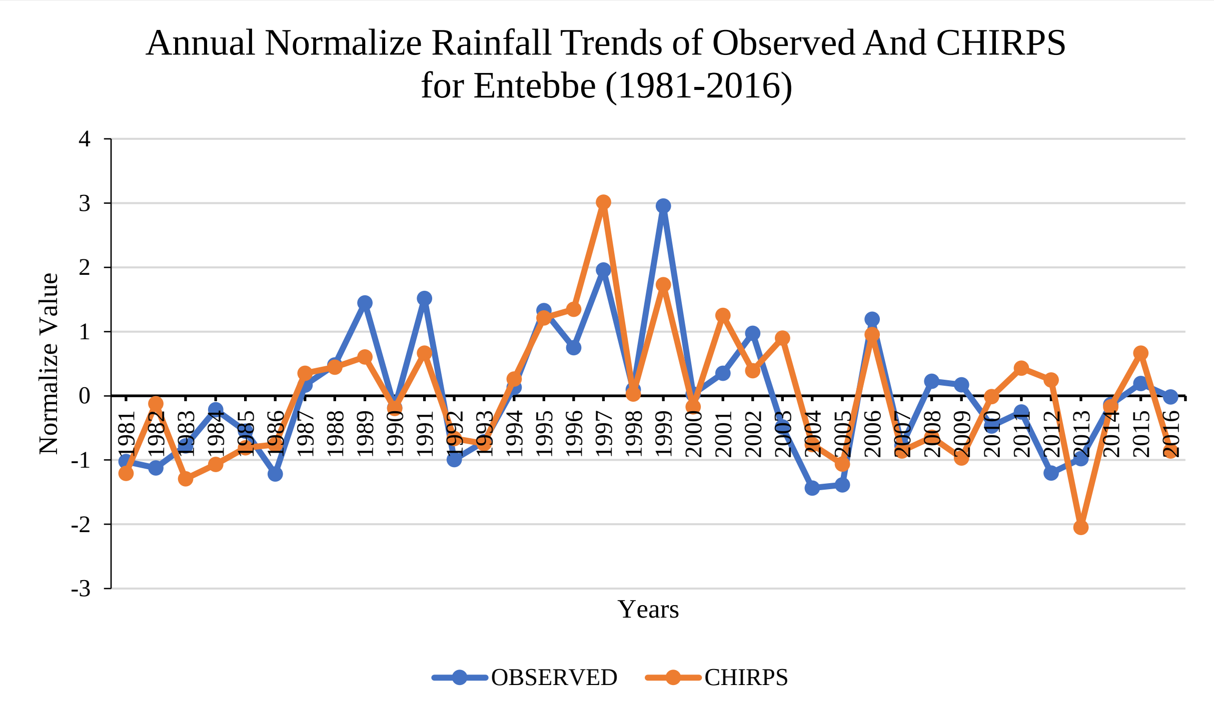

Annual Averange Rainfall Trends of Observed and CHIRPS for Kasese (1981-2016)
Averange Rainfall
120
100
80
60
40
20
0
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Years
OBSERVED
CHIRPS

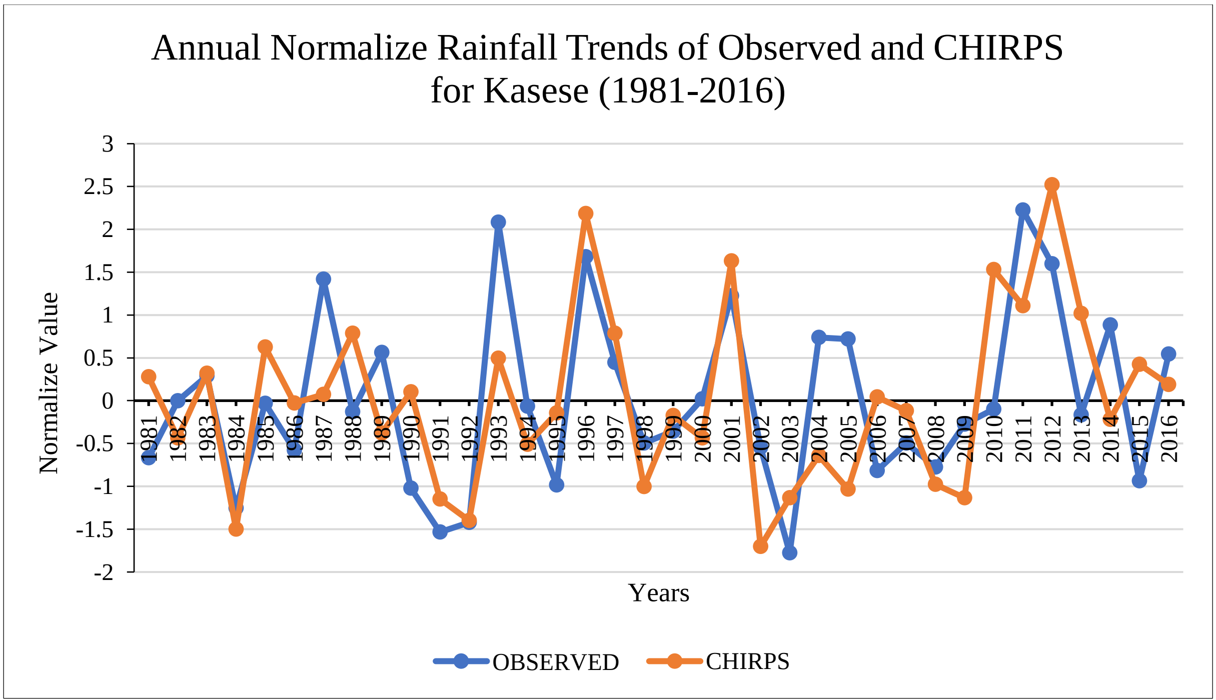

Annual Averange Rainfall Trends of Observed and CHIRPS for Mbarara (1981-2016)
Averange Rainfall
Years
OBSERVED
CHIRPS

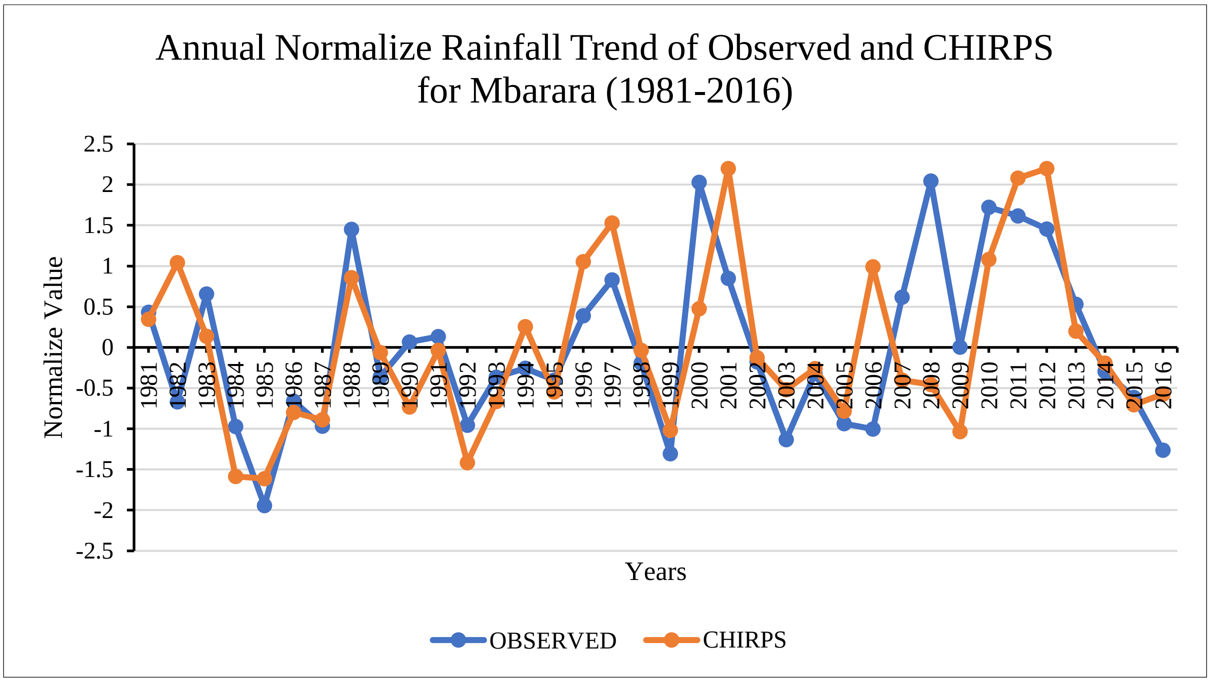

ANNUAL AVERANGE RAINFALL OF OBSERVED AND CHIRPS FOR TORORO (1981-2016)
Averange Rainfall
Years
OBSERVED
CHIRPS

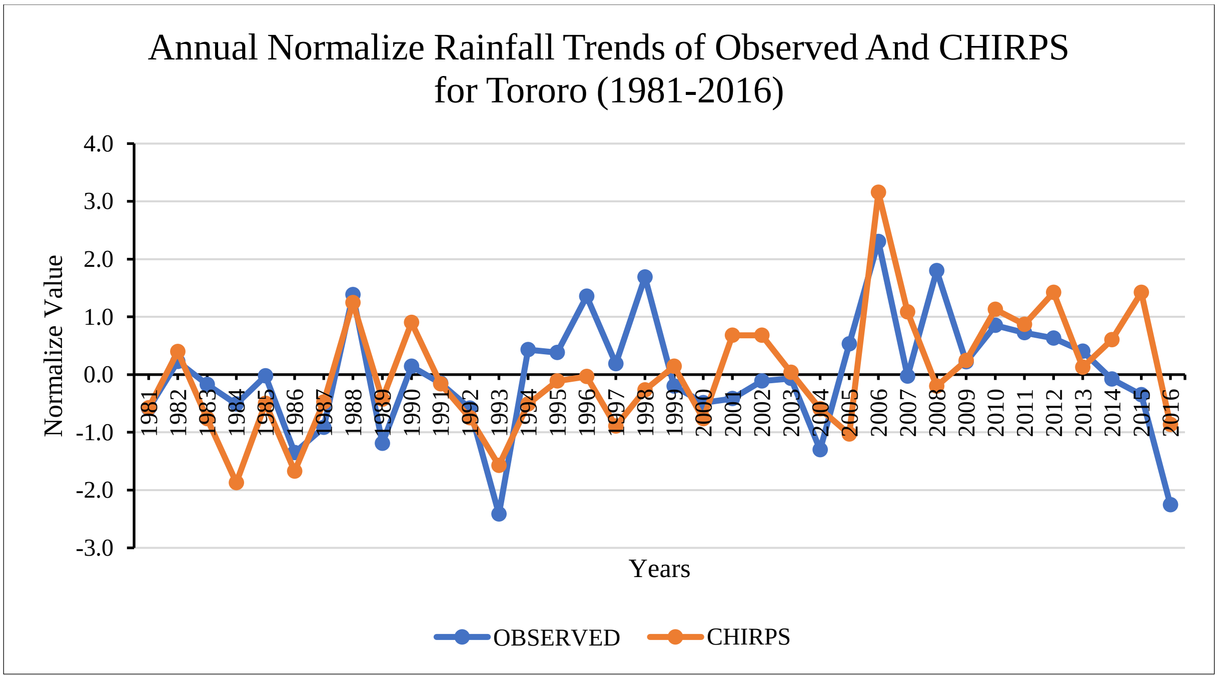

Annual Normalize Rainfall Trends of Observe and CHIRPS
for Arua (1981-2016)
Normalize value
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Years
OBSERVED
CHIRPS


Annual Normalize Rainfall Trends of Observed and CHIRPS
for Soroti (1981-2016)
Normalize Value
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Years
OBSERVED
CHIRPS


Annual Normalize Rainfall Trends of Observed And CHIRPS for Entebbe (1981-2016)
Normalize Value
4
3
2
1
0
-1
-2
-3
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Years
OBSERVED
CHIRPS


Annual Normalize Rainfall Trends of Observed and CHIRPS for Kasese (1981-2016)
Normalize Value
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Years
OBSERVED
CHIRPS


Annual Normalize Rainfall Trend of Observed and CHIRPS for Mbarara (1981-2016)
Normalize Value
Years
OBSERVED
CHIRPS


Annual Normalize Rainfall Trends of Observed And CHIRPS for Tororo (1981-2016)
Normalize Value
Years
OBSERVED
CHIRPS

3 Demonstration of data, information and tools

In accordance with the methodology set out for this technical assistance, demonstration was to be carried out by focusing on five selected use cases or case studies in total. The following chapters cover each of them describing them and presenting results.

3.1 Case Study 1: Management and dissemination of climate information

In this case study the stakeholder involved is the LVBC. Currently the management and dissemination of information and data is done using the **Water Resources Information System** (WRIS). The LVBC commissioned the development and implementation of the WRIS, between 2012 and 2015, to enable the monitoring of the environmental conditions in the Lake Victoria Basin based on shared information provided by the East African Community (EAC) Partner States. It was developed under the auspices of the Lake Victoria Environmental Management Project II (LVEMP II), World Bank funded project (LVBC, 2014).

The WRIS lacked climate change projection data as well as seasonal forecast data. Therefore, the team created an import procedure of the seasonal forecast data which was tested and approved during the March validation workshop in Kampala, by the LVBC System's Administrator, who is also operating the WRIS.

Additionally, to facilitate dissemination as well as reporting, a seasonal forecast report template was produced by team and setup on the portal and configured to be emailed automatically to the LVBC's email addresses weekly, to serve as demonstration for future reports that require frequent updating.

As a result, the WRIS now has the datasets it was lacking managed via the EAC States WRIS, as well as another complementing way for information dissemination by utilizing the reporting functionality of the portal.

Next, we describe both datasets, the procedure by which climate change and seasonal forecast data generated by the web portal are loaded into the LVBC WRIS, followed by the setup of automatic reporting for the LVBC.

3.1.1 Procedure to import data to the LVBC WRIS

Climate change data import

The climate change data is static and therefore has been added to the WRIS in a once-off loading step by the team. The data source is the Coordinated Regional Climate Downscaling Experiment (CORDEX), a World Climate Research Programme (WCRP) project. For each continent a model domain was defined to run a set of Regional Climate Models (RCMs). The RCMs are driven by the new generation radiative concentration pathway (RCP) scenarios at a horizontal resolution of 0.44 degree (for more information please see https://esg-dn1.nsc.liu.se/search/esgf-liu/).

The RCM outputs are processed into so-called delta change factors for monthly mean rainfall, potential evapotranspiration (PET) and temperature in order to indicate projected changes. The factors represent for each month the ratio between the average in the control model run 1986-2005 and the projection model runs for periods 2016-2035 and 2081-2100. Changes are estimated for the medium radiation forcing scenario RCP4.5 and the extreme radiation forcing scenario RCP8.5.

The outputs come as an ensemble of 10 members, which are processed by the portal backend and transformed into catchment scale median monthly values for rainfall, PET and temperature. These have been reformatted and imported into the WRIS database.

Seasonal forecasts import

The seasonal forecasts are a dynamic dataset updated on the web portal monthly, therefore, this dataset will be kept up to date by the LVBC WRIS operator.

The available dataset consists of an ensemble of rainfall seasonal forecasts with 9-month lead time. We obtain the raw rainfall seasonal forecast dataset and then bias correct it for the Lake Victoria and Uganda focus area. Based on the corrected rainfall seasonal forecasts we calculate forecasts of the Standardized Precipitation Index 1- and 3- month.

The source is the Climate Forecast System (CFS), sometimes called the Coupled Forecast System, is a medium to long range numerical weather prediction and a climate model. "Coupled" refers to the fact that the model couples atmospheric to oceanic modelling. The CFS is run by the National Centers for Environmental Prediction (NCEP) to bridge weather and climate timescales.

We downscale the data using historic rainfall (from Tropical Rainfall Measuring Mission) based on a monthly scale factor for the catchments of the focus area.

The team generated formatting and importing scripts consistent with the technology and backend functionality of the LVBC WRIS. The procedure to be followed monthly by the WRIS operator is outlined through a simple two-step process:

Step 1 – operator logs on to the web portal and downloads the data and unzips **envelope.zip** in a working directory on the WRIS server

Step 2 – operator runs **Import_run_all.bat**

During the second and last step this is the task performed:

- The **convert.bat** file will be called to convert from CSV files to TXT files inside the same directory
- An **import script** from the database is called, doing the following:
  - Reads the file name from a spreadsheet
  - Checks that the corresponding txt file exist
  - Imports the txt as time series using the import tool (if the same time series name exits it will be replaced)
  - If an error occurs during import, the script will send an email to the WRIS operator.

3.1.2 Seasonal forecast automatic reporting for the LVBC

The reporting application is based on reporting templates in the form of Word documents containing several tags, where the user is able to specify which type of content the reporting application should replace the tags with. For demonstration of the Reporting application of the portal, a report template was setup including the seasonal forecast data from the Data & Information application.

The template includes a description of the data sources and charts that are updated monthly by the reporting application and sent to the LVBC's, including the WRIS operator, email address.

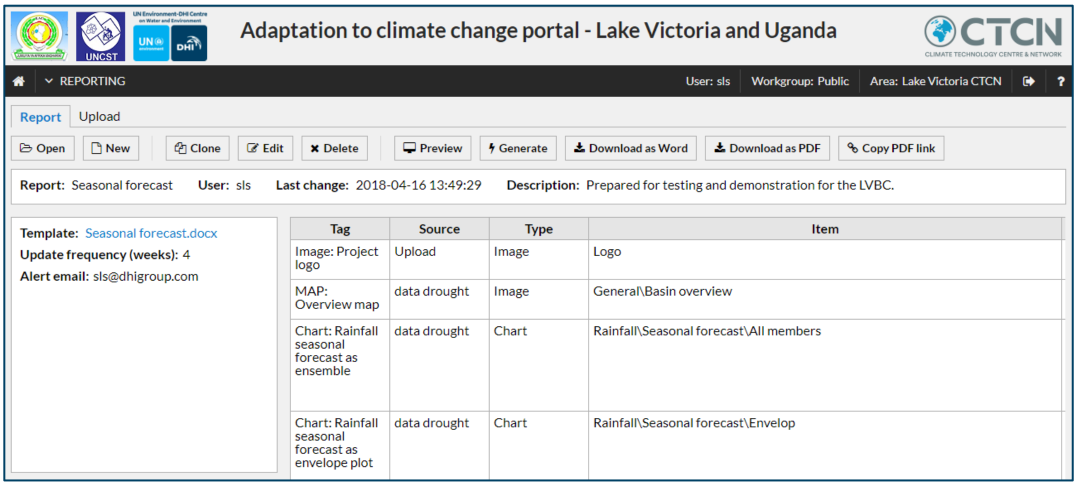


Figure 41 Report template configured from the reporting application in the public workgroup for all stakeholders to access and setup alert emails.

The stakeholders and the LVBC can use the template to disseminate climate information in the form of reports or bulletins.

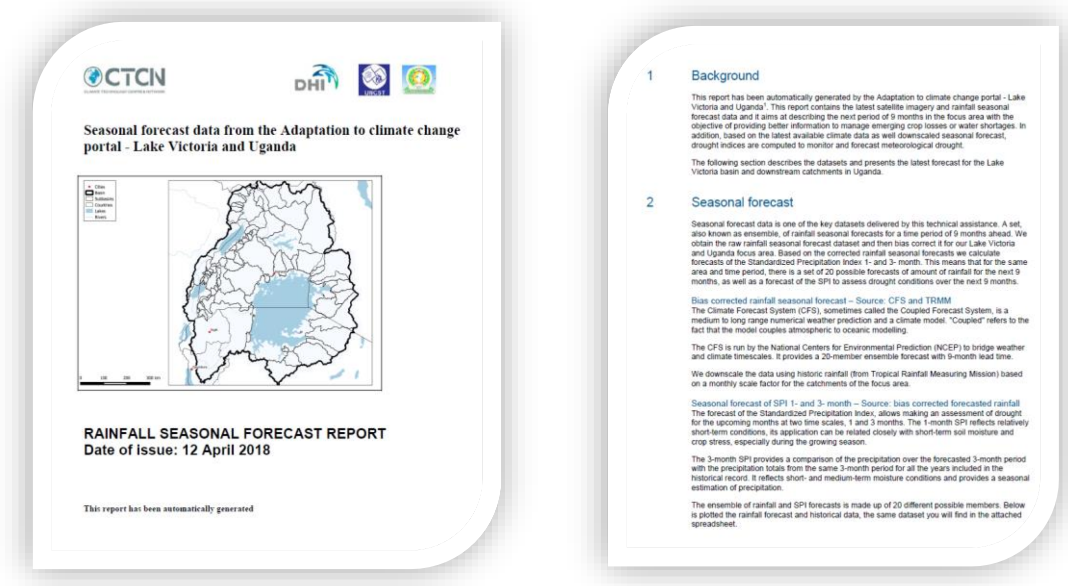


Figure 42 Image of the automatically generated report containing rainfall and SPI seasonal forecasts.

3.2 Case Study 2: Establishment of regional water resources assessment model for decisions related to the water or energy sectors

This case study served to produce a refined model as well as an agreement on the climate change scenarios of interest.

The departure point was the model developed through the Nile Basin Adaptation to Water Stress project (DHI and Met Office, 2013) carried out for UNEP and the NBI. The model was established of the whole Nile Basin, and the NBI and the MWE DWRM were part of the stakeholders involved in the model development. The model was calibrated and run for the period from 1953 to 1978, because it is the period with the best available hydro-meteorological records. The detailed model development is documented in DHI and Met Office (2013), UNEP (2013) and MWE DWRM (2013).

The LVBC reviewed the water resources model over a session (refer to Appendix B for agenda) during the testing and demonstration workshop, by examining its components together with the team as well as the results validation analysis produced by the team and presented in the following chapters.

3.2.1 Model setup and input data

The objective was to adjust the model to represent the water resources within the Lake Victoria itself (rainfall and evaporation) as well as the key components from the surrounding catchments, including:

- Lake Edward located on the border between Uganda and the Democratic Republic of Congo; it has a surface area of 2,325 km^2 and a mean depth of 33.5 m, with a catchment area of 12,000 km^2 drained by the Semliki River.
- Lake George which drains into Lake Edward through the Kazinga channel.
- Lake Albert shared by Uganda and the Democratic Republic of Congo, with most of its inflow coming from the Kyoga Nile followed by the Semliki; it has a surface area of 5,800 km^2 and mean depth of 20.5 m.

The data used in setting up the model came from different sources and was the subject of varied pre-processing procedures which will not be covered in this report. As background, the information in Table 11 has been taken from DHI and Met Office (2013) and is listed for informative purposes.

Table 11 List of data used to produce the model from DHI and Met Office (2013). This data is listed for informative purposes and has not been used by the team in this technical assistance.

Country	Area[2] / Catchments	Type of data[3]	Data sources[4]
Global	Model domain	P	GHCN
Global	Model domain	Ep	GDAS
Global	Model domain	Ep	CLIMWAT/FAO
Global	Model domain	P/Ep	CRU 3.1
Kenya	All	Q	LVEMP I

[2] WMZ: Water Management Zone (Uganda is now divided into 4 WMZs: 1) Albert, 2) Kyoga, 3) Upper Nile and 4) Victoria).

[3] Type of data: Q = Discharge, P = Precipitation and Ep = Potential Evapotranspiration

[4] Data sources: LVEMP I: Data generated in relation to Lake Victoria Environmental Management Project I, WRMA: Water Resources Management Authority, Kenya, DWRM: Directorate of Water Resources Management, Uganda, LVDB: Lake Victoria Database: Data primarily collected during the HYDROMET project.

CRU 3.1: Gridded monthly PET estimates for the period 1901-2009 over a 0.5 degree by 0.5 degree latitude-longitude grid (Harris et al., 2012). The CRU PET data are publicly available and information about permitted uses of the data is available at the CRU web-site.

CLIMWAT: Prepared according to the FAO Penman - Monteith method with limited climatic data as described in FAO Irrigation and Drainage Paper 56 (Allen et al, 1998).

GDAS: The Global Data Assimilation System that estimates PET from climate model variables on a spatial basis using Penman-Monteith equation (Shuttleworth, 1992).

GRDC: The GRDC discharge data are public and are downloaded from the GRDC web-page. For conditions for using and distributing these data please refer to the GRDC web-page. The GRDC data include both monthly and daily records.

GHCN: Global Historical Climatology Network is a publicly available data set which has daily rainfall data from a limited number of stations (approximately 70) throughout the region.

Country	Area[2] / Catchments	Type of data[3]	Data sources[4]
Kenya	All	P	LVEMP I WRMA
Kenya	All	Ep	CRU LVEMP I
Tanzania	Kagera	Q	LVDB /Hydromet
Tanzania	Kagera	P	NileDST
Tanzania	Kagera	Ep	CRU
Tanzania	Other TZ catchments	Q	LVEMP I
Tanzania	Other TZ catchments	P	NileDST LVEMP I
Tanzania	Other TZ catchments	Ep	CRU
Uganda	Lake Victoria Basin	Q	LVEMP I
Uganda	Lake Victoria Basin	P	DWRM LVEMP I
Uganda	Lake Victoria WMZ	Ep	CRU
Uganda	Kyoga WMZ	Q	DWRM
Uganda	Kyoga WMZ	P	DWRM
Uganda	Kyoga WMZ	Ep	CRU
Uganda	Albert WMZ	Q	DWRM
Uganda	Albert WMZ	P	DWRM
Uganda	Albert WMZ	Ep	CRU
Uganda	Upper Nile	Q	DWRM
Uganda	Upper Nile	P	DWRM
Uganda	Upper Nile	Ep	CRU
LV Basin	Lake Victoria	HVA curves	DWRM
LV Basin	Lake Victoria	P & Ep	LVEMP I
LV Basin	Lake Victoria	Releases	DWRM
LV Basin	Lake Victoria	"Agreed curve"	DWRM
Uganda	Lake Kyoga, Albert, George and Edward	P	DWMR
Uganda	Lake Kyoga, Albert, George and Edward	Ep	DWMR
Uganda	Lake Kyoga	HVA curve	DWRM
Uganda	Lake Kyoga	Rating curve outlet	DWRM
Sudan	Mongalla	Q	GRDC

In addition, the observed data used by this project is protected under confidentiality agreements between institutions and consultants, and the only information the team has had access to is the model itself and information from the LVBC WRIS.

3.2.2 Model refinements

The rainfall-runoff and water allocation model, was established using the MIKE BASIN software and is shown in Figure 43.

For each rainfall-runoff catchment, it was necessary to estimate a catchment-level precipitation time series that is used to represent average precipitation over the catchment. Station gauge records were used to develop catchment averages. To estimate catchment scale rainfall, the Thiessen polygon method has been used as the point of departure for estimation of the mean areal rainfall with adjustment of weighting applied carried out by the modeller.

Regarding discharge, most catchments in the basin are gauged, but for some of them there are large periods with gaps. The modellers estimated discharge from ungauged areas by rainfall-runoff modelling.

Finally, in the case of potential evapotranspiration, the CRU dataset is used for most rainfall-runoff catchments represented in the model. Directly over Lake Victoria the CRU data has set evapotranspiration to be zero, therefore the modellers derived PET over the lake from the LVEMP 1 data.

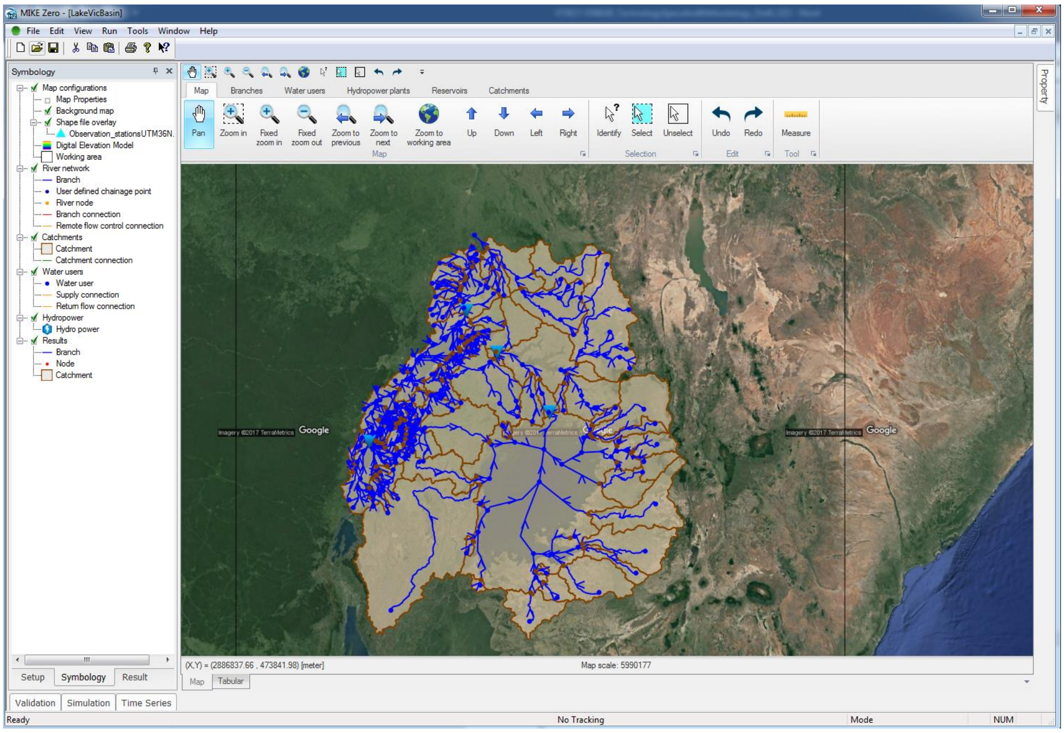


Figure 43 Screenshot of the MIKE HYDRO user interface for the Lake Victoria Basin displaying water network branches in blue and catchment polygons in brown over a satellite background map.

The technical workflow involved in the refinement of the model was the following:

1. Model domain reduced to the area covering the Equatorial Lakes system and the Nile system upstream of Mongalla in Southern Sudan. This includes almost the entire Uganda and those parts of Kenya, Tanzania, Burundi and Rwanda which drains into Lake Victoria.
2. Verification of calibration due to domain reduction implemented.
3. Updating with the latest information regarding hydropower plants by including in the model Nalubaale (180 MW), Kiira (200 MW) and Bujagali (250MW).
4. Upload of the model into the planning application and establishment of the baseline plan.

In the following figures, the alterations to the allocation model schematization are presented and properties and characteristics of the new model objects summarized. Other than its reduction in domain, the rainfall-runoff model has not undergone any changes.

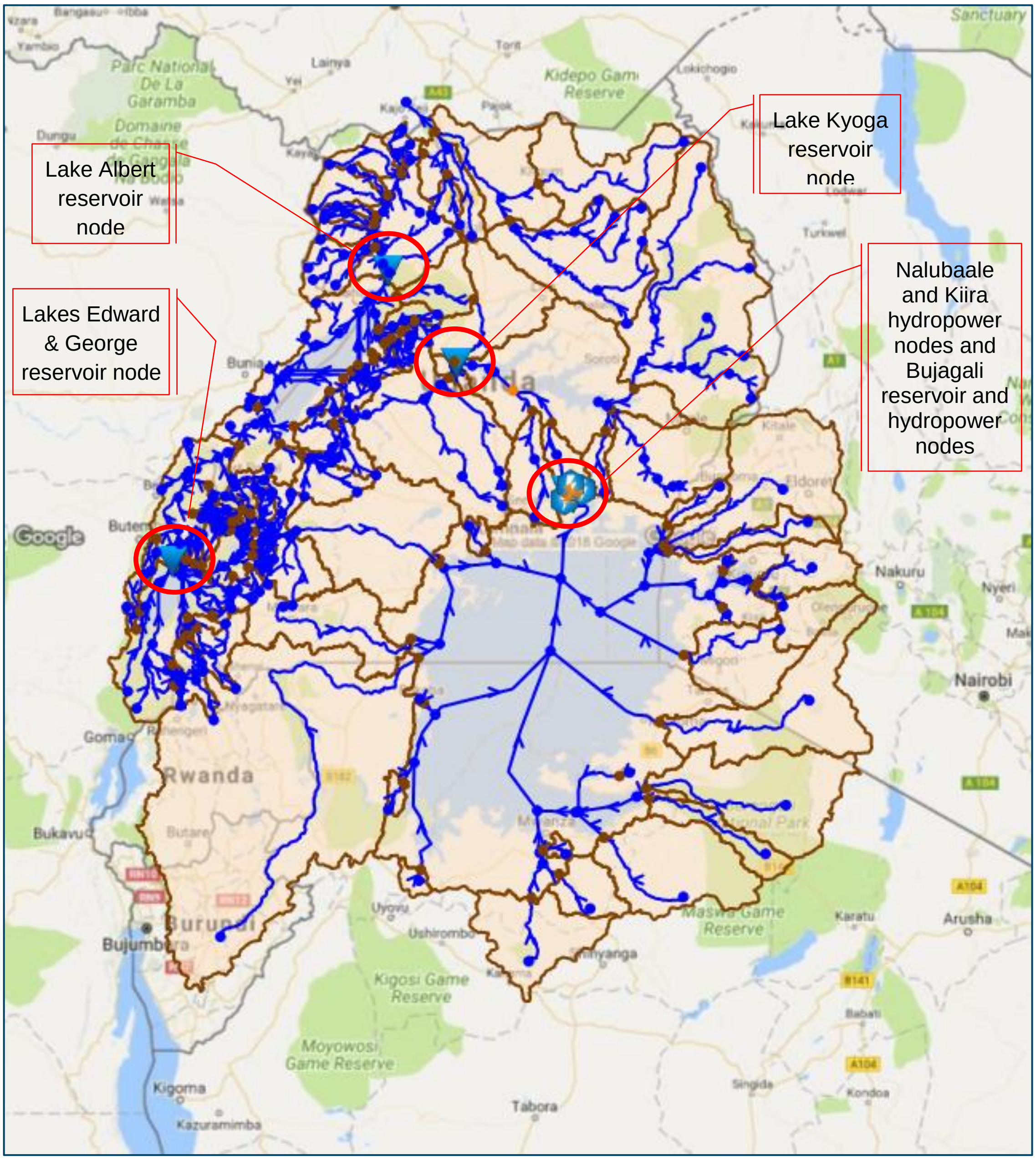


Figure 44 Schematization of the allocation model refinements.

In the following section, the results from the evaluation of the model performance are presented. As mentioned previously, the latter is needed prior to the upload of the model to the planning application, to ensure its calibration was not affected by the changes implemented.

3.2.3 Evaluation of model performance

To assist in verifying the performance of the refined model, water level and discharge analysis were carried out and are presented in the following subchapters. The period considered in the analysis is from 1960-1980.

3.2.3.1 Discharge

This section considers the available discharge data and compares observed data with simulated data by the model following the reference under chapter 2.2. The selected stations are all downstream, as there is limited data upstream.

The errors between observed and simulated data are summarised in Table 12 below. As seen, simulated data presents a very good fit with Jinja and Kamdini station data, when considering both flow and the accumulated volume.

Table 12 Percentage errors between observed and simulated data at different stations.

Station	Mean error, flow	Mean error, accumulated volume	Error, total accumulated volume
Jinja	4.18	2.07	1.11
Kamdini	7.70	5.78	1.91
Semliki	21.16	22.48	16.00

The flow comparison for the different stations is shown in the following figures: at Jinja (Figure 45) and Kamdini (Figure 46). Especially for Jinja, the comparison shows an extremely good match with the observed data. For Kamdini, the model data deviates especially in the beginning of the simulation period, but overall the performance is also very good.

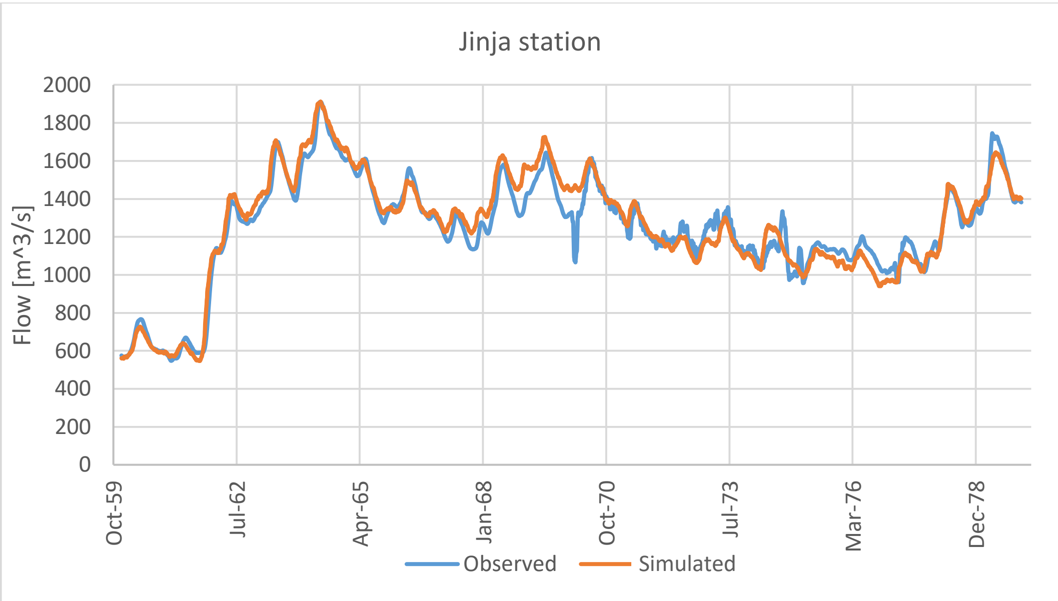


Figure 45 Observed and simulated flow for the station Jinja, the time period is 1960-1979.

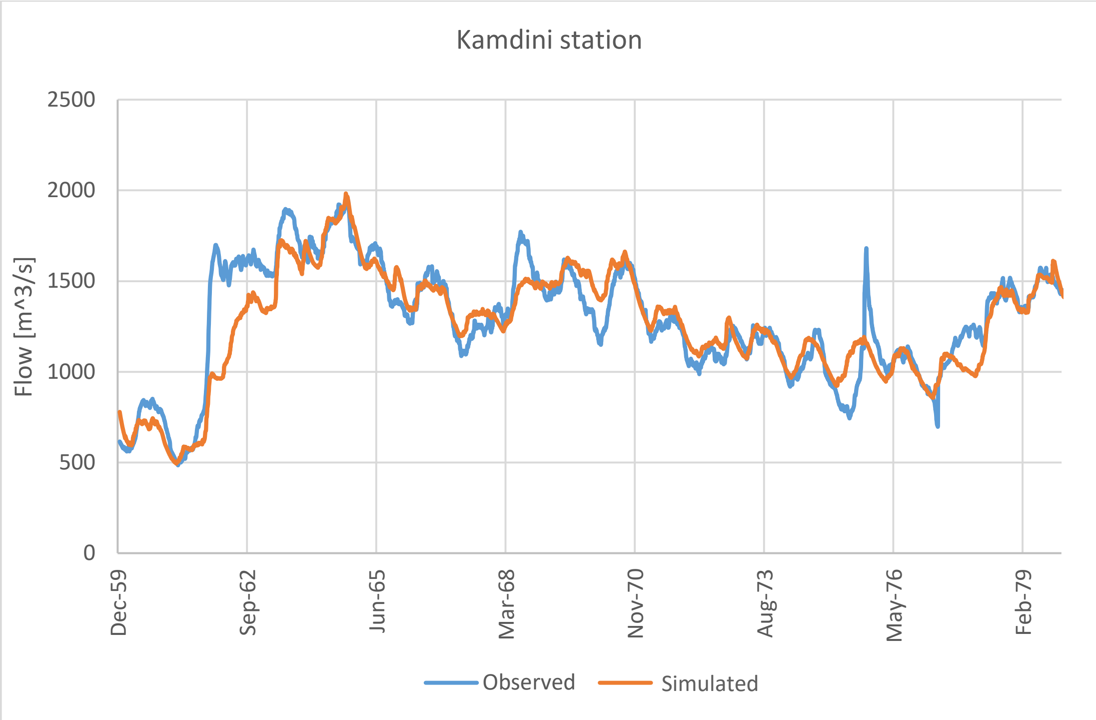


Figure 46 Observed and simulated flow for the station Kamdini, the time period is 1960-1979.

Semliki, shown in Figure 47, is not affected by new elements and therefore the results are the same. As seen in the figure, the modelled data follows the fluctuations in the observed data regarding the temporal position, but the observed data generally rises to higher peaks than the modelled data. Considering this figure, the error in the flow of approximately 20% seems reasonable.

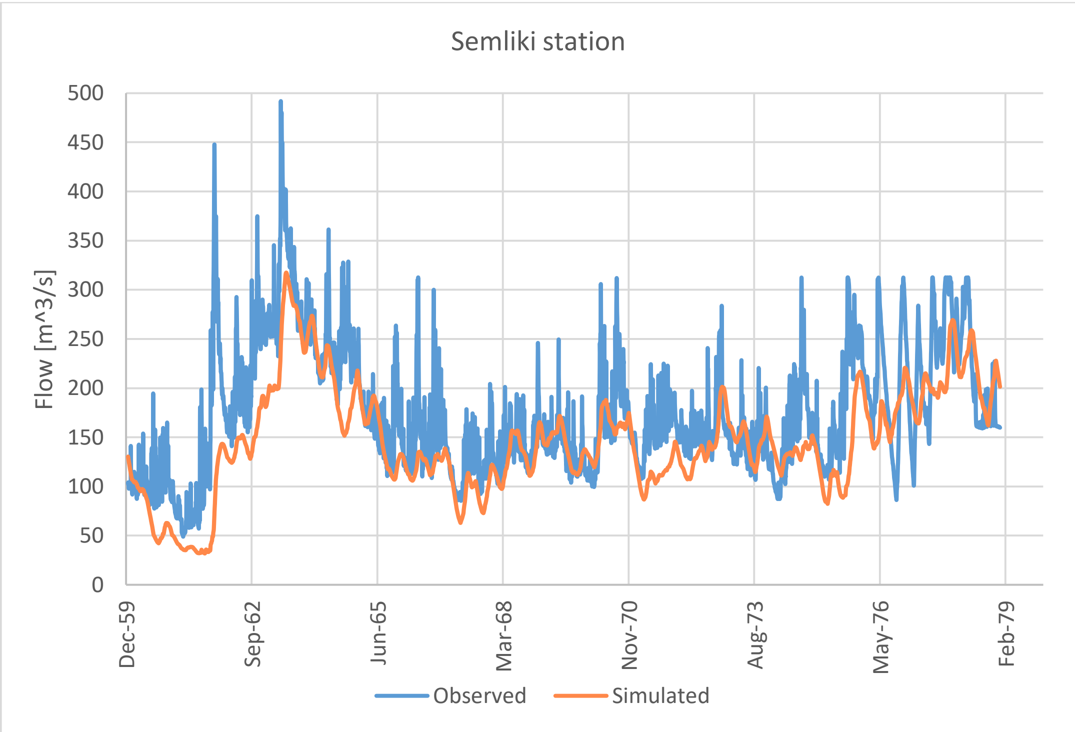


Figure 47 Observed and simulated flow for the station at Semliki, the period is 1960-1979.

3.2.3.2 Duration curves

As expected, the observed and simulated data for display very similar characteristics for Jinja and Kamdini. For Semliki, the displacement between modelled and simulated data is larger. However, the shapes of the two duration curves are similar and thus they display similar characteristics for the flow.

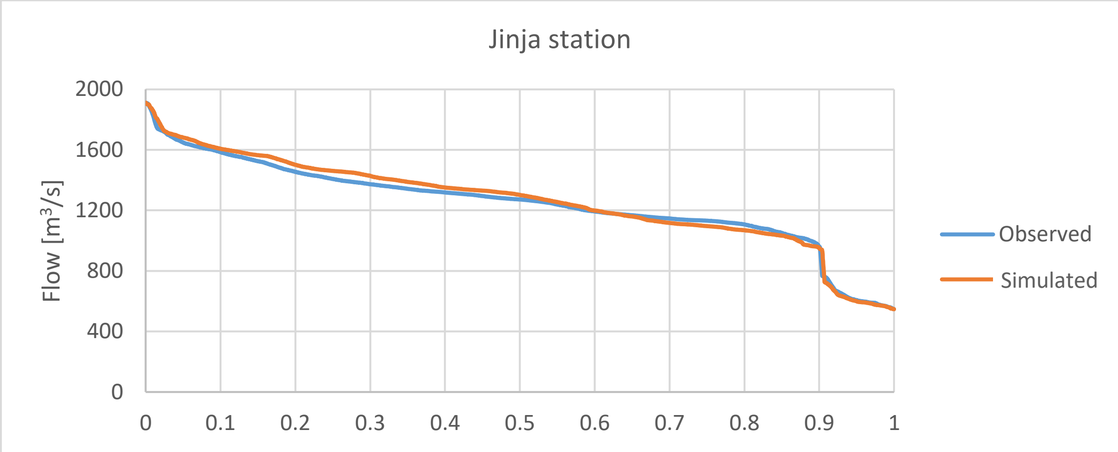


Figure 48 Duration curves for Jinja, including observed and simulated data (1960-1979).

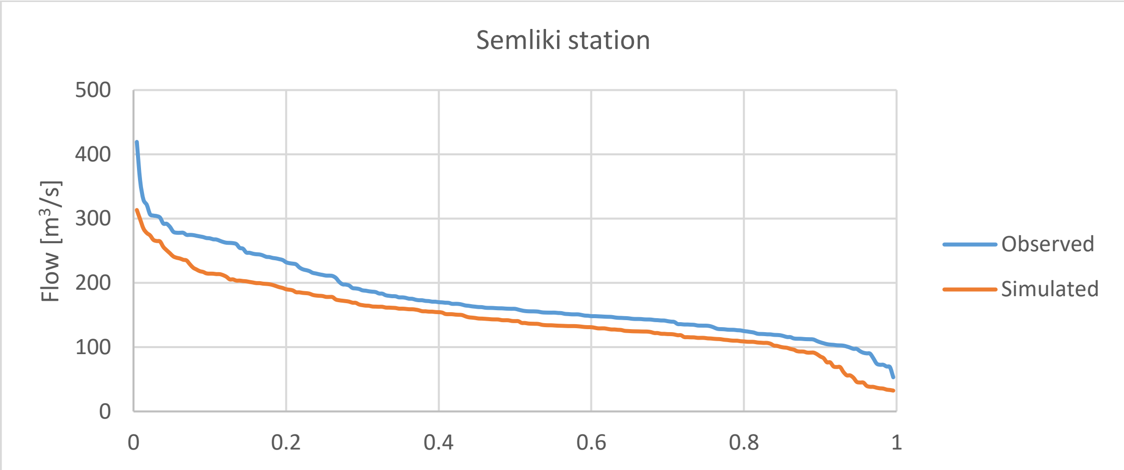


Figure 49 Duration curves for Semliki, including observed and simulated data (1960-1979).

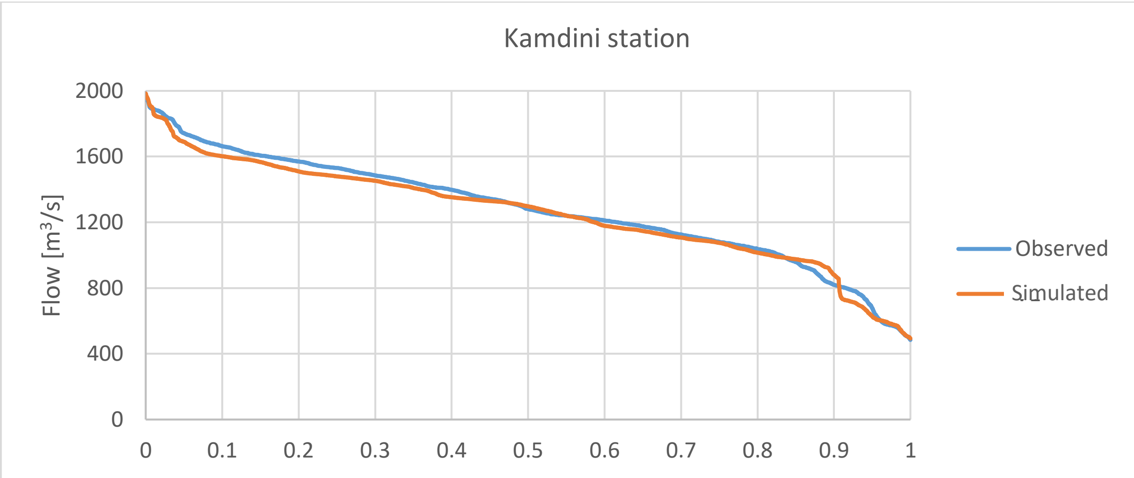


Figure 50 Duration curves for Kamdini, including observed and simulated data (1960-1979).

3.2.3.3 Monthly average discharge

The monthly averages of modelled and observed runoff at the three stations are shown in Figure 48 to Figure 50. There is a large variation in the seasonality between the three different stations. Jinja clearly has a peak in discharge in June and a much smaller peak in December. The low flow months for Jinja are January-March and October-November.

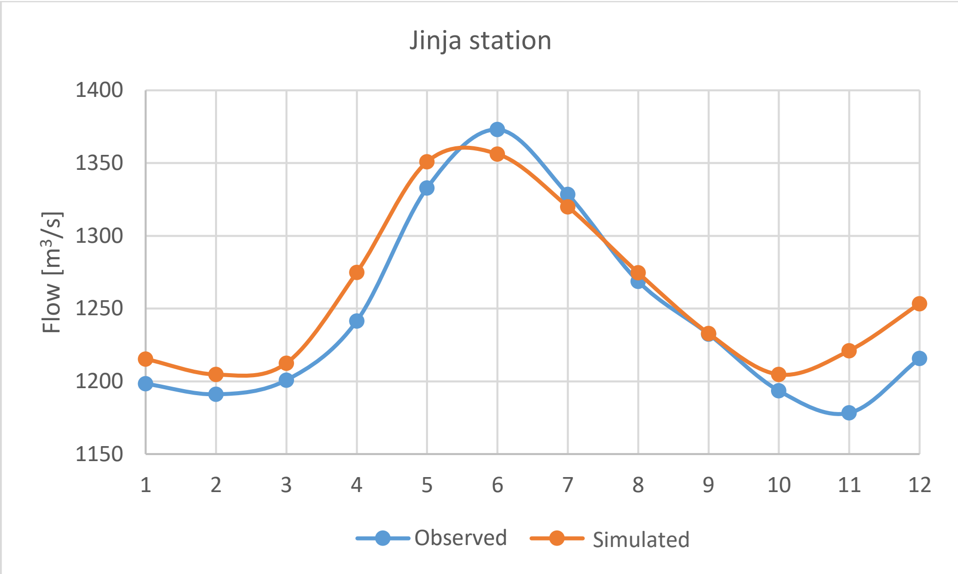


Figure 51 Monthly averages of simulated and observed discharge for Jinja.

Kamdini does not have single month that is a peak, but has high flow from June-December. The low flow period only incorporates February-April. The modelled data is generally a lower than the observed.

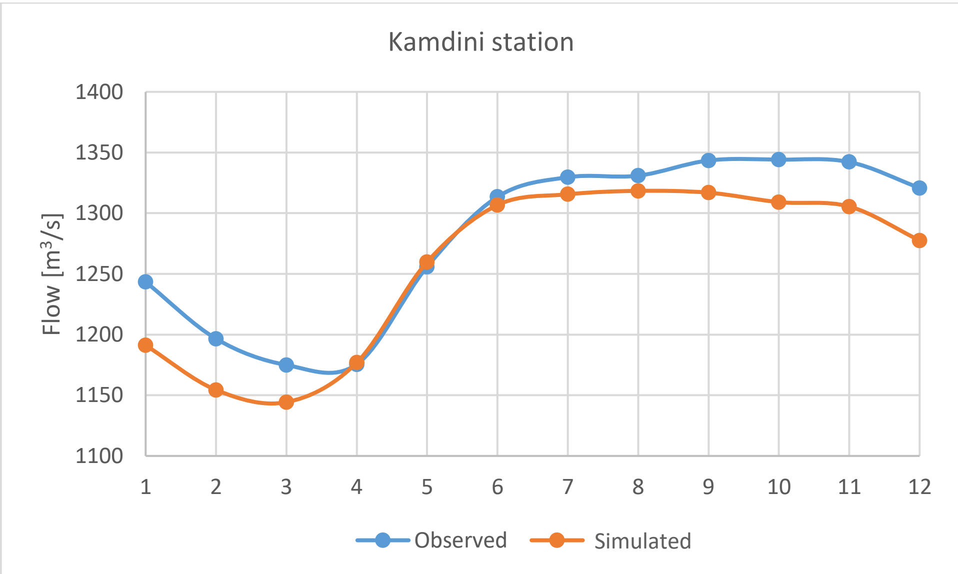


Figure 52 Monthly averages of simulated and observed discharge for Kamdini.

Semliki has smaller variations in the flow, but also generally a lower flow than the other two stations. There is not perfect agreement as to the seasonality between observed and simulated data. The observed data show two smaller peaks in May and in November. For the simulated data, the first period peaks in both May and June, while the second period peaks in December(/January). The low flow for the modelled data is clearly in March and August-

October, while February and March are the only two clear low-flow months for the observed data.

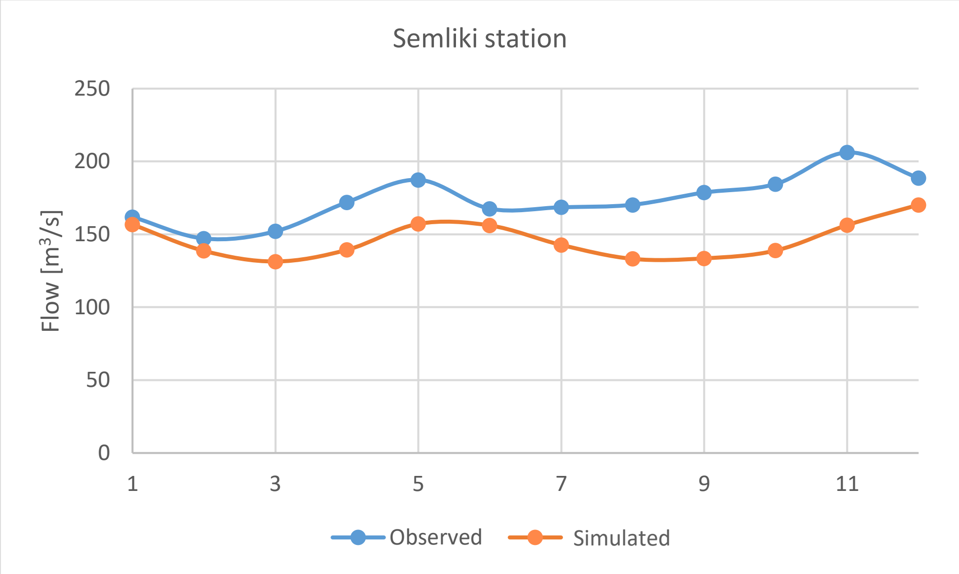


Figure 53 Monthly averages of simulated and observed discharge for Semliki.

3.3 Case Studies 3 & 4: Water resources planning and decision making

This use case demonstrates how the access to data and the basin planning application adds to capacity and knowledge for decision making in a future climate, specifically with regards to water resources planning at national and regional level. Firstly, we present the information collected from previous studies, and secondly, it is demonstrated how it can be used together with the portal to evaluate different decisions.

3.3.1 Scenario data collection

Our point of departure was established by linking to previous projects involving planning and strategy, namely, DHI and Met Office (2013) and UNEP (2013). The output from these projects was produced by official government documents such as Uganda Vision 2040, the National Development Plans, National Water Policy and other key documents such as: the National Water Resources Assessment (MWE, 2013); the National Irrigation Master Plan for Uganda (2010-2035) (MWE, 2011); and the Project for Master Plan Study on Hydropower Development in the Republic of Uganda (MEMD, 2011).

The baseline scenario includes the Nalubaale and Kiira hydropower plants at Owens Falls and the Bujagali hydropower plant located where Bujagali Falls used to be. Data for potential planning scenarios has been collected from UNEP & NBI (2013) Nile Basin Adaptation to Water Stress, Comprehensive assessment of Flood & Drought Prone Areas, and is summarized below. Most importantly, data collected during the testing and demonstration workshop is also presented.

The data and information relates to hydropower, water supply, irrigation and environmental flow.

(1) Hydropower

Table 13 Information received from the MEMD during the workshop from 2010 to 2015

Year	2010	2011	2012	2013	2014	2015
Uganda Maximum Domestic Demand (MW)	423.99	445.87	498.26	492.46	505.57	520.68
Total Domestic Energy Generation(GWh)	2,455.9	2555.1	2829.4	2993.0	3,171.33	3283.28
Total Kenya Net Energy Export / (Import) (GWh)	0.03	(-4.15)	6.43	4.87	78.05	11.38
Total Tanzania Energy Export / (GWh)	45.3	50.94	57.75	54.44	55.65	61.23
Total SNEL Energy (DRC) Export (GWh)	-	1.604	2.449	1.929	2.44	2.25
Total REG (Rwanda) Energy Export (GWh)	_	3.3	1.834	1.169	2.59	1.94
Total REG (Rwanda) Energy Import (GWh)		2.75	3.20	3.03	3.68	3.49
Eskom Hydro Energy (GWh)	1,254.8	1360.8	1275.37	1239.14	1,228.38	1303.85
Bujagali Hydro Energy (GWh)	-	-	972.46	1375.57	1,365.66	1456.61
Total Thermal Generation (Diesel &HFO) (GWh)	1,023.9	957.9	275.40	1.88	88.21	73.43
Total Co – Generation (GWh)	85.1	60.1	94.096	125.45	213.55	172.29
Domestic Energy Consumption-Constrained(GWh)	2410.6	2512.3	2765.8	2927.35	3,011.26	3209.97
Domestic Energy Consumption – Unconstrained (GWh)	2420.3	2639.2	2828.1	2929.12	3,012.26	3211.58
Peak time Maximum scheduled load shedding(MW)	45.1	162.3	132.30	0	0	0
Energy not supplied due to unscheduled Load shedding (GWh)	9.7	127.0	62.4	1.77	0.997	1.610
UETCL Transmission Losses Annual Average (%)	4.2	3.35	3.98	3.6	3.27	3.45
Average Annual System Load Factor	0.68	0.68	0.68	0.69	0.67	0.72
Average Annual Uganda Load Factor	0.68	0.70	0.70	0.70	0.68	0.72

Table 14 Data for hydropower generation sites dated 2018

Plant Name Label	Owen Falls Complex (Nalubaale & Kiira)	Bujagali	Nalubaale	Kiira
Plant Status	Operational	Operational	Operational	Operational
Construction Time		4.25 years	7 years	7 years
Plant Life		60 years		
Plant Unit Numbers		5	10	5
Plant Unit Size		51 MW	18 MW	40 MW
Plant Capacity Installed (MW)	380	255	180	200
District Name 2014	Jinja	Jinja	Jinja	Jinja
Plant Latitude	0.446476	0.49741	0.443521	0.44991
Plant Longitude	33.18404	33.14003	33.18503	33.18558
River_Name	Nile	Nile	Nile	Nile
Power_Plant	Eskom Complex	Bujagali		
Capacity_Installed_Mw	380	255		
Capacity_Licensed_Mw	380	250		
Capacity_Generated_Mw	164.5353	176.2947		
Capacity_Sold_Mw	162.7584	175.015		
Theoretical_Generation_Mwh	3337920	2196000		
Power_Generated_Mwh	1445278	1548573		

Plant Name Label	Owen Falls Complex (Nalubaale & Kiira)	Bujagali	Nalubaale	Kiira
Power_Sold_Mwh	1429670	1537332		
Power_Purchased_Uetcl_Mwh	1429744	1537332		
Power_Internally_Consumed_Mwh	2060	5867		
Power_Generation_Losses_Mwh	13540	5696		
Plant_Factor	0.432988	0.705179		
Availability_Factor	0.9609	0.853		

(2) Irrigation

The following information has been collected from UNEP & NBI (2013).

(a) 2040 Wetland irrigation: irrigation without need for storage infrastructure; representing conversion of existing wetland to irrigation

(i) Location: Lake Kyoga Basin
(ii) Area: 247,000 ha[5]
(iii) Crops: paddy rice
(iv) Planting dates: 01/02 and 01/08
(v) Average potential yield: 4,000 kg/ha
(vi) Distribution losses: 5%

(b) 2040 Upland irrigation: representing irrigated cultivated land

(i) Location: nation-wide
(ii) Area: total of 437,065 ha[6] divided per basin as,

Basin	Area (ha)	Basin	Area (ha)
Lake Victoria	126,149	Lake Albert	25,750
Lake Kyoga	130,504	Albert Nile	22,221
Victoria Nile	32,329	Aswa	13,197
Lake Edward	86,241	Kidepo	674

(iii) Crops: upland rice, maize, tomatoes and beans
(iv) Planting dates: 30/01 rice; 01/08 maize; 01/04 & 01/08 tomatoes; 01/03 beans
(v) Average potential yield: upland rice: 3000 kg/ha, maize: 5,000 kg/ha, tomatoes: 30,000 kg/ha and beans: 5,000 kg/ha

[5] This corresponds to about 9% of the total wetland area and 16% of the seasonal wetland area in Uganda. Wetland regulations stipulate that the area converted for cultivation should not exceed 25 of the total wetland area.

[6] This corresponds to 10% of the presently cultivated area in Uganda according to the National Development Plan (2010/11 – 2014/15).

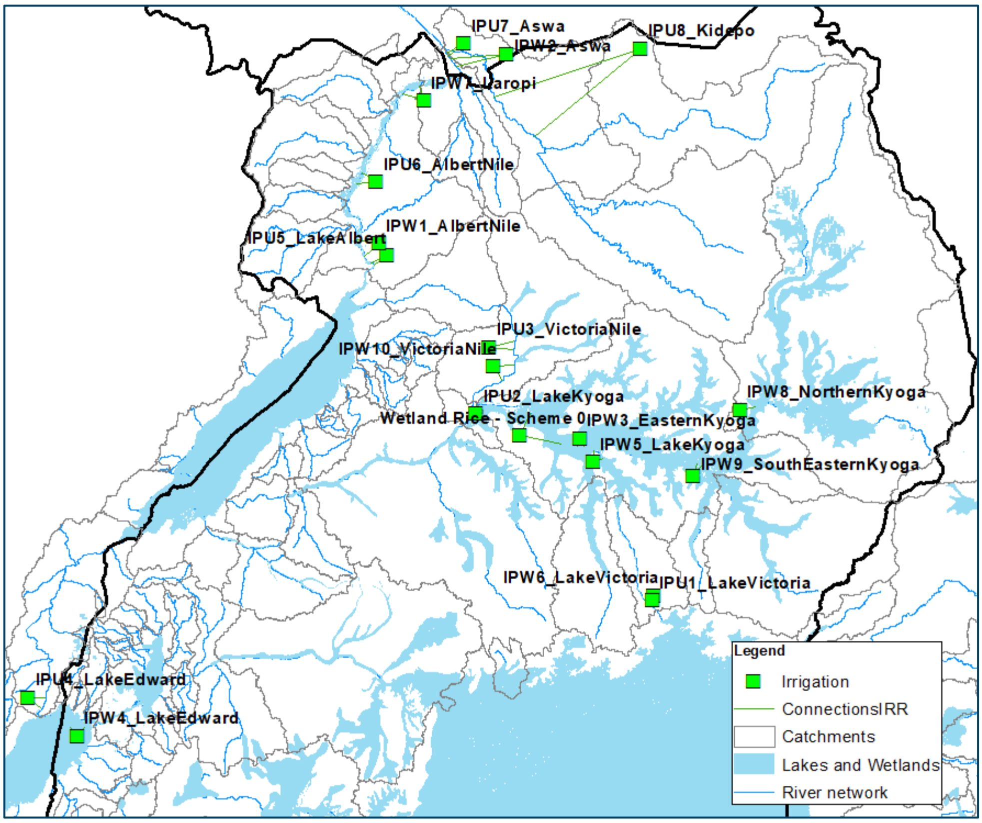


Figure 54 Distribution of water supply for irrigation in the study area from UNEP (2013).

(3) Water supply development by 2040

The following information has been collected from UNEP & NBI (2013). The total rural and urban water demand was estimated based on the following projections:

(a) Rural and urban population: 53.1 million and 22.4 million

(b) Rural and urban demand per capita: 25 L/day and 65 L/day

Amounting to a rural and urban total demand of 485 MCM/yr (15.4 m3/s) and 533 MCM/yr (16.9 m3/s). Below, the breakdown per catchment.

Table 15 Urban and rural water supply demand estimates from UNEP (2013).

Name	Demand (m^3/s)	Name	Demand (m^3/s)
Lake Kyoga (Rural WS)	5.2917	Victoria Nile (Rural WS)	1.5486
Lake Kyoga (Urban WS)	2.9257	Victoria NIle (Urban WS)	3.2359
Lake Victoria (Urban WS)	9.3883	Lake Victoria (Rural WS)	3.3618
Aswa (Urban WS)	0.0426	Lake Albert (Rural WS)	0.9104
Aswa (Rural WS)	0.8771	Kidepo (Urban WS)	0
KIdepo (Rural WS)	0.0544	Lake Edward (Rural WS)	1.9926
Albert Nile (Urban WS)	0.5886	Lake Edward (Urban WS)	0.6144
Albert NIle (Rural WS)	1.3458		
Lake Albert (Urban WS)	0.0653		

The national water demand for livestock production by 2040 was estimated as 6.8 m3/s, breakdown per catchment below.

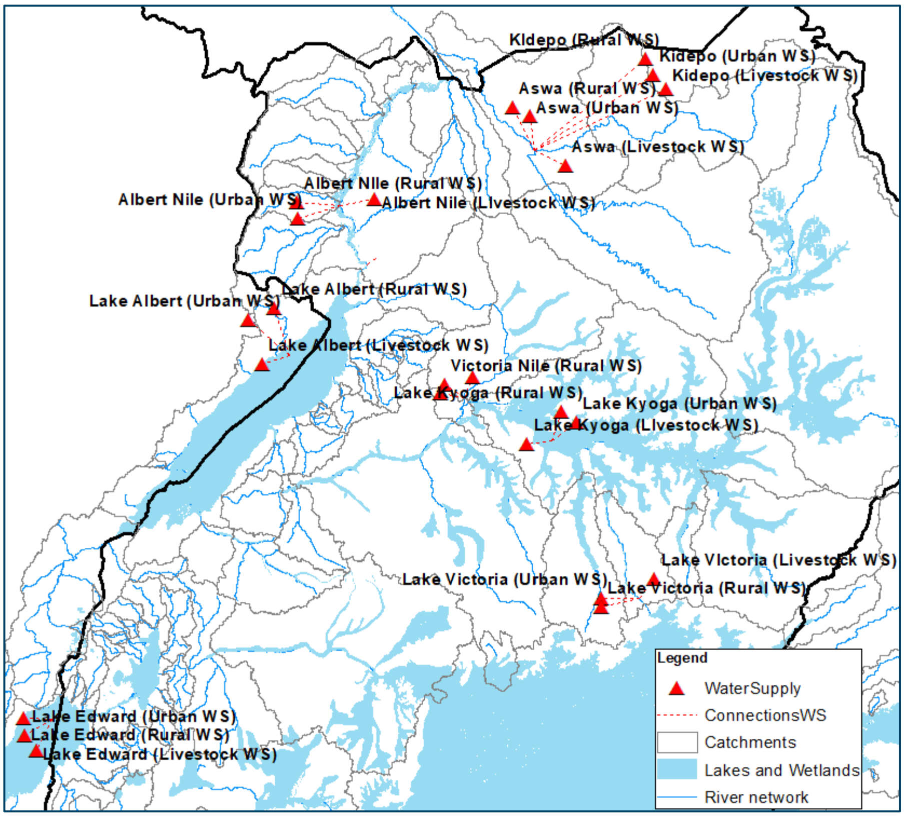


Figure 55 Illustration of urban and rural water uses in the study area from UNEP (2013).

Table 16 Water supply for livestock production estimates from UNEP (2013).

Name	Demand (m^3/s)	Name	Demand (m^3/s)
Aswa (Livestock WS)	0.4499	Victoria Nile (Livestock WS)	0.7343
Kidepo (Livestock WS)	0.0806	Lake Kyoga (LIvestock WS)	2.5924
Albert Nile (LIvestock WS)	0.4959	Lake VIctoria (Livestock WS)	1.4429
Lake Albert (Livestock WS)	0.3967	Lake Edward (Livestock WS)	0.5767

(4) Environmental flow assessment sites identified and flow requirements estimated

The following information has been collected from UNEP & NBI (2013).

(a) The sites identified by the study are located at the outflow of the major lakes and downstream of the main RAMSAR sites namely, Murchison Falls National Park, Lake Nakuwa, Lake George, Lake Mburo National Park and Musambwa – Sago Bay Wetland, Nabajjuzi Wetland.

(b) Inflow from Victoria Nile to Lake Kyoga captures flow alterations due to Hydropower development on Victoria Nile.

(c) Outflow from Uganda to Sudan: This EFA site is included to assess potential transboundary flow impacts of the proposed development scenarios in Uganda.

(d) Low flow requirement is the flow which must be exceeded 90 % of the time.

(e) High flow requirement is the flow that must be exceeded 10 % of the time.

Table 17 Low and high flow requirement estimates from UNEP (2013).

Site location	Low Q (m^3/s)	High Q (m^3/s)
Nile Inflow to Lake Kyoga	577	1592
Outflow from Lake Kyoga	563	1693
Murchison Falls	566	1715
Albert Nile	623	1680
Outflow to South Sudan	638	1766
Lake Bisina	0.5	29.4
Lake Nakuwa	0.3	97.3
Catchment 34	0.5	11.2
Katonga	0.7	8.7
Bukora	1.0	5.6
Lake George	3.7	39.0
Kafu	1.9	45.0

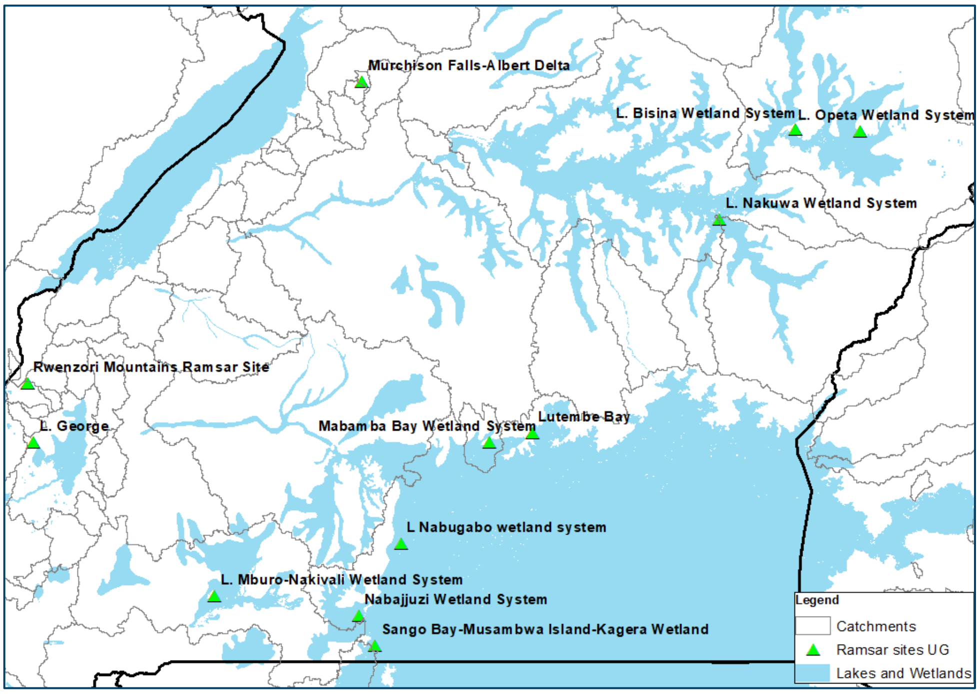


Figure 56 Location of RAMSAR sites and wetland systems in Uganda with environmental flow requirements taken from UNEP (2013).

3.3.2 Planning and decisions

During the stakeholder meetings in February and the testing and demonstration workshop in March 2018, and as interest and use of the portal grew, planning scenarios for these use cases were screened to result in the following:

- Baseline conditions with inclusion of existing large hydropower plants; trial of different power demands.
- Comparison of plans with different climate change scenarios, with inclusion of environmental flow sites.

This means new major hydro development was left out as well as large irrigation development. However, the number and scope of these well-defined decisions fit our demonstration purpose and laid the foundation for its success.

Table 18 Description of the baseline and plans used for demonstration

		B	P1	P2	P3	P4
Hydropower	Existing major hydropower plants in place	X	X	X	X	X
Environmental Flow	Environmental flow assessment sites identified and flow requirements estimated from UNEP & NBI (2013)		X	X	X	X
Climate change	RCP 4.5 2016 - 2035		X			
	RCP 4.5 2081 - 2100			X		
	RCP 8.5 2016 - 2035				X	
	RCP 8.5 2081 - 2100					X

These plans are available from the basin planning application and made accessible to all stakeholders. These can be cloned and different investments added to represent water uses in the area such as water supply or irrigation demands. Data from the previous chapter could be used as an example to set up new plans by stakeholders.

During the workshop, participants tested the tool and created new plans by setting the demand for existing hydropower plants and running climate change scenarios. These plans have been added to the portal and remain for continuous update and future use.

Workshop participants were asked about planning and decision support in order to solicit feedback on what types of information would be useful to include in the guidelines for decision making under uncertainty. To stimulate the discussion, a simplified version of a hypothetical planning problem was presented. The simplified problem concerned decision making about new hydropower and irrigation.

During the resulting discussion, we obtained feedback on the priorities of decision makers involved in water resources planning in Uganda. Energy security appears to be the most important priority, but rural development and fisheries are also important considerations. All of these objectives are motivated by the broader goals of economic growth and poverty alleviation.

Water resources development in Uganda is constrained by transboundary considerations. Upstream countries are concerned about the impact of Nile hydropower operations on Lake Victoria, while downstream countries are concerned about long-term changes to the Nile's flow. Any new development on the river need to account for how new developments will be perceived by other countries and how other countries will react.

When engaged in joint planning exercises with other countries, some participants noted that it can be difficult to agree on assumptions, including which data and models should be used to provide technical decision support. These participants indicated they would be interested in learning more about alternative planning approaches that do not require agreement on assumptions at the outset of the planning process.

Participants were also asked about the risk preferences of decision makers and how decision makers define failure. It was important to learn more about failure because of the importance of failure thresholds in the robust decision making methodology, which is a method for decision making under uncertainty that will be presented in the guidelines. Because the primary motivator of water resources development in Uganda is economic growth, decision makers are not necessarily risk averse, and may be willing to take risks to achieve economic development objectives.

3.4 Case Study 5: Providing data and interpretation of climate change data for management of agricultural impacts

Demonstration of the data & information, as well as the drought assessment application was carried out using the weekly infosheets by firstly, designing content based on stakeholder needs and request; and secondly, requesting feedback from stakeholders upon dissemination.

The stakeholders put forth their areas of interest within the topics being covered by the infosheets, and data as well as its application and interpretation was provided, through infosheets 3 and 5. Focus is on two catchments in Central Uganda and the eastern side of North Uganda (see Figure 57).

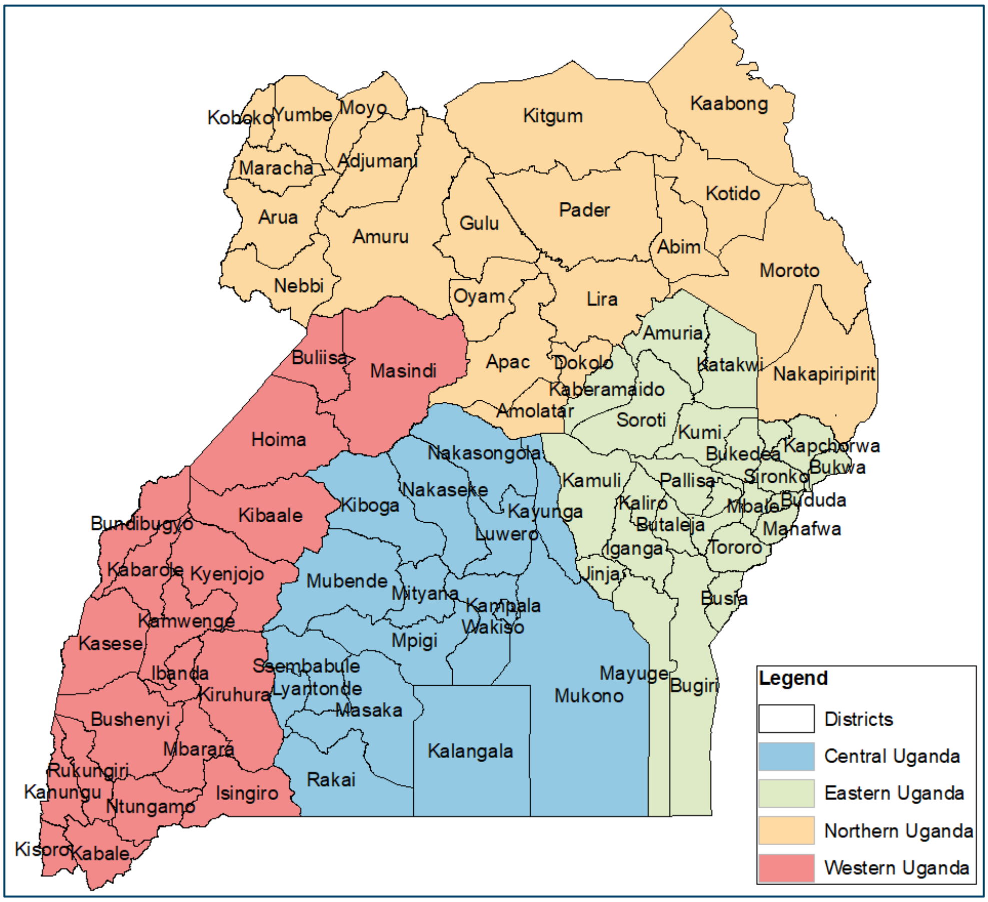


Figure 57 The four administrative regions and districts of Uganda.

A spreadsheet with CHIRPS daily rainfall (from 1981 to October 2017) and MODIS evapotranspiration (2000 to 2014) catchment average time series with relevant guidance were disseminated:

- the catchment weighted rainfall time series and long-term mean; by plotting this statistical measure together with the time series, it is possible to evaluate whether a certain month or year is above or below average considering the entire record available from this source, see Figure 58.

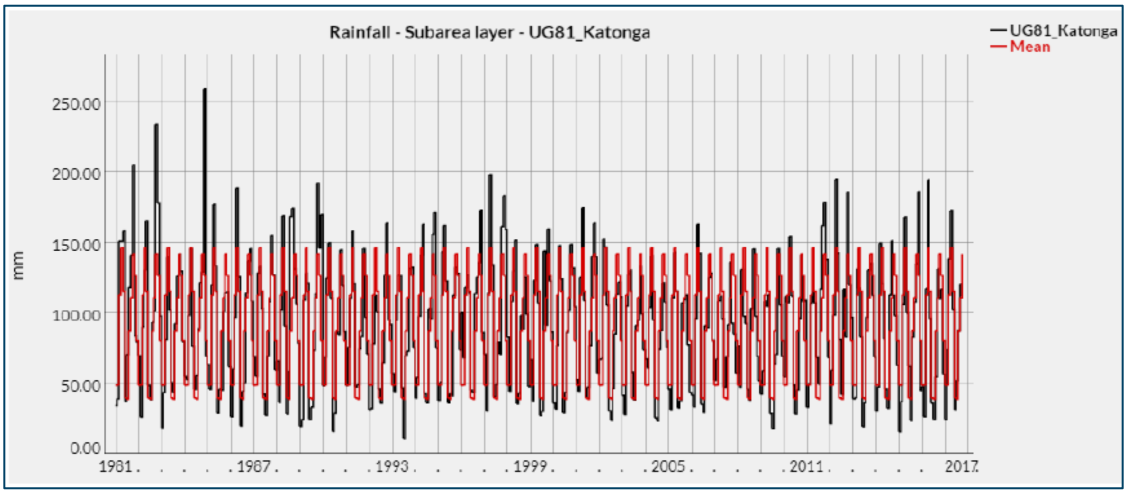


Figure 58 Location of the Katonga catchment (13,924 km2) and CHIRPS monthly accumulated rainfall in mm, from 1981 to 2017 (black line), plotted against the long-term mean in mm (red line).

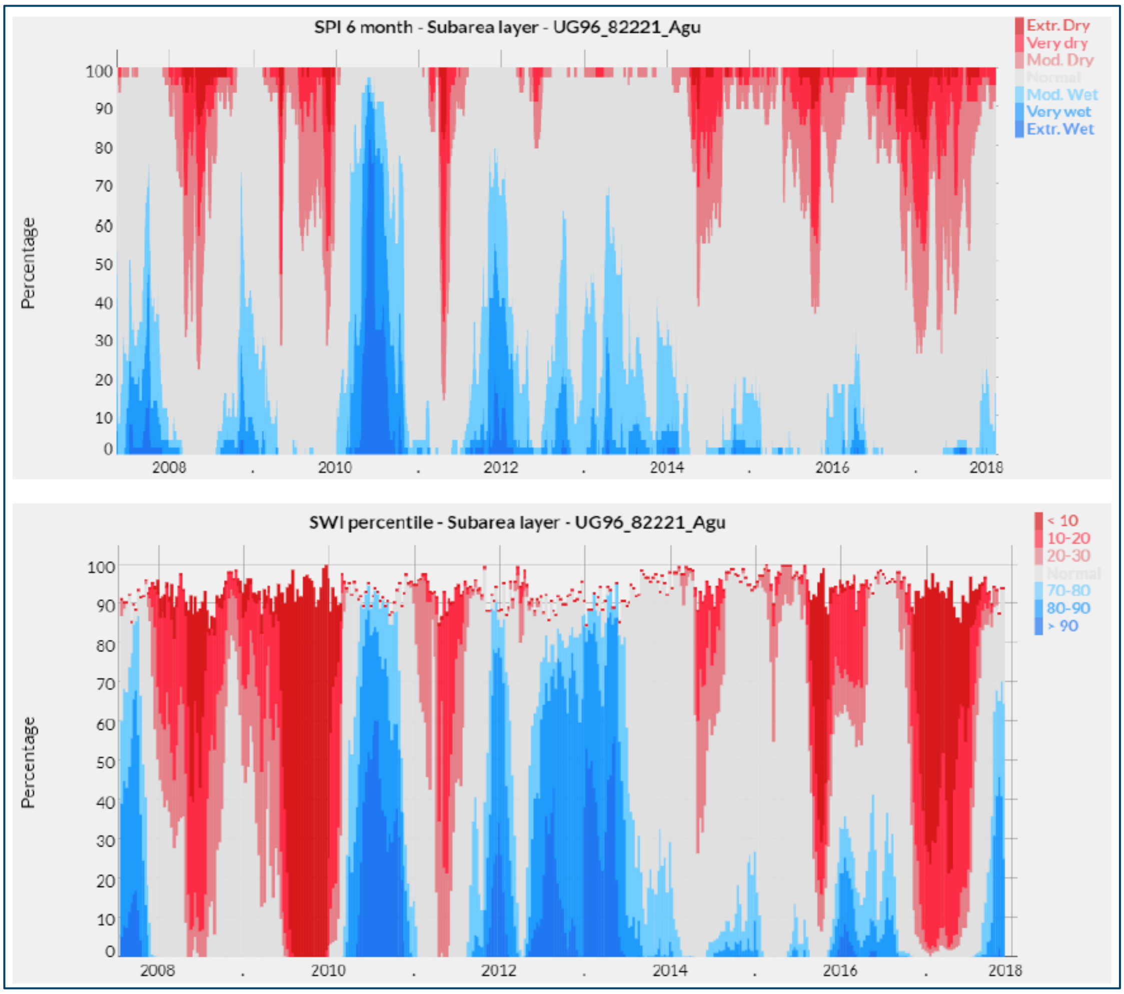


Figure 59 SPI 6-month an SWI percentile for the area of districts Abim, Kaabong, Kotido, Moroto and Nakapiripirit, most of it falling within the Agu catchment area, calculated based on the remote sensing product SWI from 2007 to present.

The Soil Water index (SWI) and SWI percentile average values for the catchments of districts Abim, Kaabong, Kotido, Moroto and Nakapiripirit in Northern Uganda, were disseminated as well as the interpretation of these two indices and their use in combination with SPI:

- The extremely dry soil moisture conditions between 2008 and 2010, and during 2017 are supported by the 6 month SPI. By observing these two indices together for example in 2017, the drought in this region can be verified: firstly the 6-monthly trend in precipitation from January to June 2017 always falls below normal conditions varying between moderate to extremely dry; and secondly, the soil moisture percentile drops below 20% and 10%, see Figure 59.

Drought warning and risk assessment was set up using the drought assessment application of the portal and shared through a series of infosheets 15, 16 and 17. Drought warnings rely on the categorized drought indices and a locally determined warning threshold expressed as a lower or upper threshold for the index value and a duration.

In this demonstration, the warning layer "Number of dry days (30d)" was used, corresponding to the number of days with less than 2 mm/d of rainfall in the last 30 days. The default duration is 10 days. This means on the map, areas will be highlighted in red where the threshold of 10 days without rainfall within the last 30 days has been exceeded. The threshold value might need some adjustment depending on the area and time of the year.

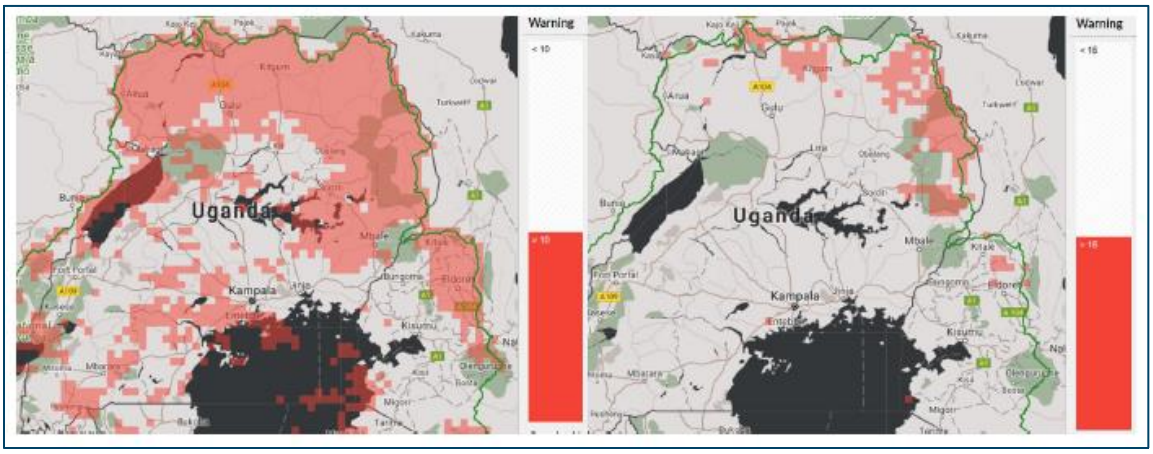


Figure 60 Demonstration of a drought warning configuration in the focus area using the drought assessment application; warning threshold varying from 10 to 15 days from left to right.

Moving on to risk, it is defined as the combination of hazard and vulnerability of exposed areas. By using this tool, this combination is realized by overlaying hazard and vulnerability areas on the focus area map. In this use case, focus was on lack of rainfall over cropland/pasture areas.

In this example, the hazard layer available "Days since rain" was applied, and is defined as the number of days since last rainfall event larger than 2 mm/day. The vulnerability indicators are mainly socio-economic or agriculture related layers, these can be added the same way as the hazard layers. In this infosheet, we focused on "Pasture (2000)" which we obtained from the Socioeconomic Data and Applications Center representing global agricultural lands in year 2000 (http://sedac.ciesin.columbia.edu/es/aglands.html). The grid values represent the proportion of pixel that is either under cropland or pasture. The vulnerability layer is meant to be overlaid with the hazard layer permitting the identification of areas with risk of drought considering areas of cropland and pasture with the highest number of days since the last rainfall event.

The result of the overlay allows the identification of a hazard taking place in a vulnerable area – this corresponds to a high risk.

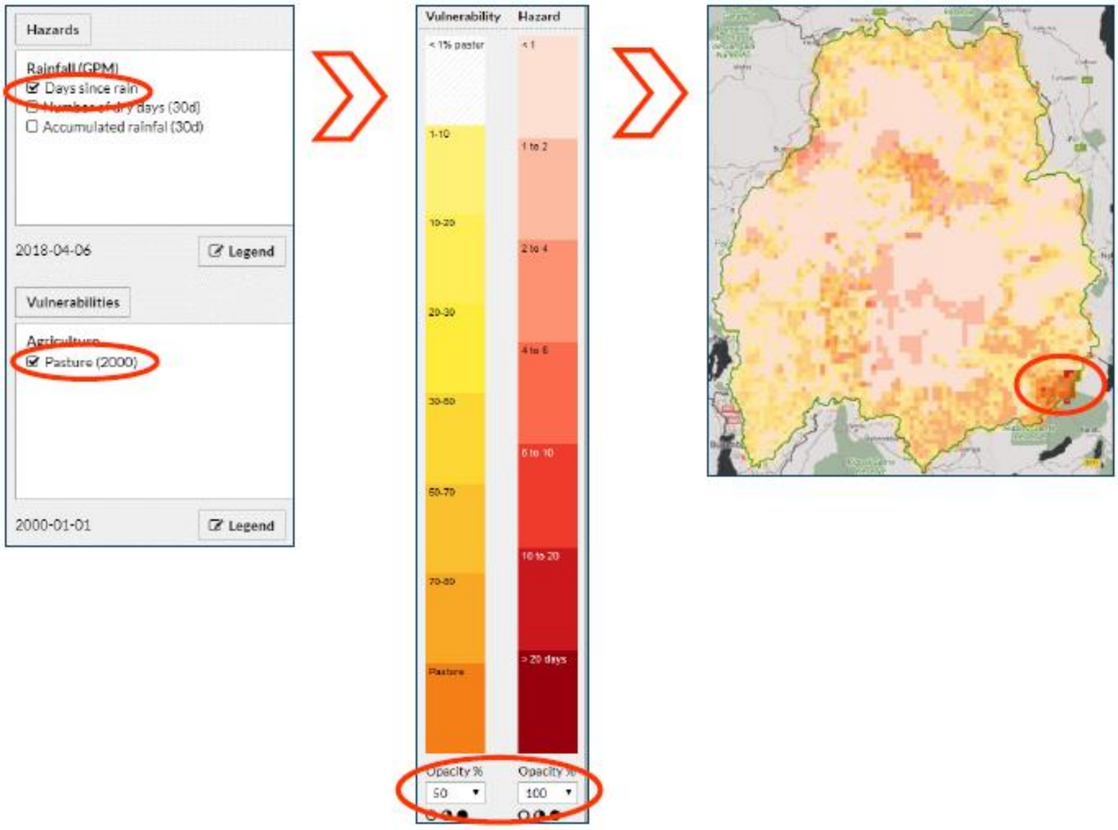


Figure 61 Identification of areas with risk of drought considering cropland and pasture with the highest number of days since last rainfall event.

4 Next steps

The next and last step of this technical assistance, Activity 3, aims at achieving increased national and regional capacity for planning with focus on climate change impact on Lake Victoria, and has the following key deliverables:

- Final national workshop will be held to inform relevant stakeholders and organisations in Uganda about the outputs of the CTCN assistance.
- Technical training to ensure the stakeholders are equipped with Capacity and knowledge for using the project outcomes on future climate adaptation projects
- Assistance provided to the LVBC in the regional dissemination to key organisations within the Lake Victoria basin through the council of ministers' meetings; this will include dissemination of reports, materials and tools to all relevant national and regional stakeholders.
- Finally, a roadmap describing recommendations for national and regional upscaling, and with an evaluation of funding options through regional partnerships and donors for post response interventions.

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APPENDIX A

Draft agendas for Activity 3 events

Table 19 Proposed agenda for the technical training

DAY 1		
Time	**WORK SESSION 1 LVBC MWE NBI**	**WORK SESSION 2 UNCST NAPE MUST RAN UNMA MWE**
09.00 – 09.30	Registration	
09.30 – 10.40	Welcome and presentation of the work sessions	
09.40 – 10.00	Presentation of participants	
10.00 – 10.45	Overview of key features and capabilities of the web portal. This includes what type of outputs is produced and how to be interpreted.	
10.45 – 11.00	Break & Away into sessions	
11.00 – 11.45	DATA & INFORMATION	DATA & INFORMATION
11:45 – 12:30	Exercises	Exercises
12:30 – 13:30	Lunch	
13:30 – 14:30	DATA & INFORMATION	REPORTING
14:30 – 14:45	Break	
14:45 – 15:30	Intro to PLANNING	Exercises
15.30 – 16.00	Discussion and wrap up	

DAY 2		
Time	**WORK SESSION 1 LVBC MWE NBI**	**WORK SESSION 2 UNCST NAPE MUST RAN UNMA MWE**
09.00 – 09.45	Re-cap Day 1	Re-cap Day 1
09.45 – 11.00	PLANNING	DATA & INFORMATION
11:00 – 11.15	Break	
11.15 – 11.45	Exercises	Exercises
11:45 – 12:30	Exercises	DROUGHT
12:30 – 13:30	Lunch	
13:30 – 14:30	DECISION	Exercises
14:30 – 14:45	Break	
14:45 – 15:30	Exercises	Exercises
15.30 – 16.00	Discussion and wrap up	

Table 20 Proposed agenda for the final workshop

Time	Title	Responsible
09.00 – 09.15	Welcome and presentation of the objective with the workshop	Host
09.15 – 09.45	Presentation of decision case by one of the local stakeholders. The decision case will be used throughout the day as an example • Type of decision to be made • Objectives, constrains and uncertainties • Current decision workflow • Types of data and output used in the decision case	Local stakeholder
09.45 – 10.00	Q&A	
10.00 – 10.45	Overview of key features and capabilities of the web portal. This includes what type of outputs are produced and how these need to be interpreted.	DHI
10.45 – 11.00	Q&A	
11:00 – 11.15	Break	
11.15 – 11.45	Exercise 1: use of web portal functionality in relation to the decision case	Local stakeholder / DHI
11:45 – 12:30	Exercise 2: use of web portal functionality in relation to the decision case	Local stakeholder / DHI
12:30 – 13:30	Lunch	
13:30 – 14:30	Assisted role-play focusing on use of tools for decision making. The exercise shall attempt to portray a real-life situation, based on the presented case, where participants will be able to identify a number of management and/or development options. Pre-made output from will be used in the exercise.	DHI
14:30 – 14:45	Q&A	
14:45 – 15:30	Discussion on how the web portal could be used in the decision process focusing on the operational use and sustainability of the portal.	All
15:30 – 15:45	Break	
15:45 – 16:30	Wrap up	Host

All workshop material and developed content will be compiled and disseminated to all participants.

In the following page, we present the proposed scheduling for the work plan above, currently under discussion with LVBC and UNCST.

APPENDIX B

Agenda and attendance register for Testing and Demonstration Workshop, March 2018

Adaptation to climate change through improved information and planning tools for Lake Victoria and Uganda - Validation Workshop

UNCST Meeting Room, Kampala, Uganda – 21st & 22nd March 2018

Validation Workshop – day 1		
Time	Title	Participants
09.00 – 09.30	Welcome and presentation of the objective of the workshop	DHI & UNCST[i]
09.30 – 09.45	Presentation of participants	
09.45 – 10.15	**Status of the ongoing technical assistance and outline of validation exercise** Outcome: Objective and current status of the project. Outline of exercise.	DHI
10.15 – 11.15	**Validation of data and information** *Validate the climate data with expert knowledge of the study area and observations* • Group work based on the Data and Information app. • Compare climate variable values with historic information in the form of records of precipitation, evaporation and temperature. • Verifying climate change projections • For a chosen area/district/catchment of interest, compare your knowledge of historical events with your data and the information from the portal. Outcome: User experience of the web portal; Understanding and applicability of climate data types; Adequacy of indicators; Climate change scenarios of interest reviewed;	LVBC[ii] & MWE CCD [iii]& UNMA[iv]
11.15 – 11.30	Break	
11.30 – 12.30	**Focus on guidelines for decision making - seasonal forecast** *Presentation of the decision making guidelines by the team*	DHI
12.30 – 13.00	Discussion and wrap up	LVBC & MWE CCD & UNMA
13.00 – 14.00	Lunch	
14.00 – 16.00	The LVBC WRIS *Loading of the climate change projections and seasonal forecasts into the WRIS; Reviewing water resources model.* • Agree on the outlined procedure for the WRIS operator to update the WRIS with seasonal forecasts and keeping these up to date • Reviewing the refined water resources model Outcome: Ensure extended functionality of the current WRIS by testing and acceptance of the procedure for updating seasonal forecasts. Refined model reviewed by LVBC.	LVBC & DHI
16.00 – 16.30	Preparation of the following day	LVBC & DHI

Validation Workshop – day 2		
Time	**Title**	**Participants**
09.00 – 09.30	Welcome and presentation of the objective of the workshop; Presentation of participants	DHI & UNCST
09.30 – 10.00	**Status of the ongoing technical assistance and feedback from testing and validation Day 1.** Outcome: Objective and current status of the assistance.	DHI
10.00 – 11.15	**Demonstration of planning application** *Presentation and demonstration of the planning application and underlying model setup.* • Group work based on the Planning application. • Outlining demo planning scenarios based on the LVEMPII and the WRM Strategy • Look at different scenarios within irrigation and hydropower development. • Using the refined water resources model available via the planning application, to add planned investments in the basin and carry out a demo evaluation. *Outcome:* Evaluate performance of the planning application with the refined model. Ensure that relevant scenarios are tested and verify applicability and ease of use of the planning application developed. Assess potential for further usage within organizations.	LVBC & MEMD[v] & UNMA & MWE CCD
11.15 – 11.30	Break	
11.30 – 12.30	**Focus on guidelines for decision making – climate change** *Presentation of the decision making guidelines by the team*	DHI
12.30 – 13.00	Discussion and wrap up Outcome: Applicability of guidelines produced. Ensure that decision making guidelines are useful for real-world applications.	LVBC & MEMD & UNMA & MWE CCD
13.00 – 14.00	Lunch	
14.00 – 16.00	The LVBC WRIS - continuation *Finalizing the work initiated on Day1.*	LVBC & DHI
16.00 – 16.30	Discussion and wrap up	LVBC & DHI

[i] UNCST: Uganda National Council for Science and Technology
[ii] LVBC: Lake Victoria Basin Commission
[iii] MWE CCD: Ministry of Water and Environment Climate Change Department
[iv] UNMA: Uganda National Meteorological Authority
[v] MEMD: Ministry of Energy and Mineral Development

Adaptation to climate change through improved information and planning tools for Lake Victoria and Uganda - Validation Workshop

UNCST Meeting Room, Kampala, Uganda – 21st & 22nd March 2018

Attendance List, 22nd March 2018

	Name	Affiliated Institution	Contact Number and email	Signature
1	Eng. OMARI R. MWINJAKA	EAC/LVBC	Box 1510, Kisumu Mwinjaka@lvbcom.org +254-718493311	[signature]
2	Calistus Quincy	EAC/LVBC	#1510-40100 KISUMU, KE quincy@lvbcom.org +254726986710	[signature]
3	Isaac OKIROR ORENX	CCD/MWE	0775583089 Ookiror@gmail.com	[signature]
4	MUGARURA MICHAEL	CCD/MWE	0783215882 mugarura.michael@gmail.com	

5	Bataze James	UNMA	0704472616 6 batazej@gmail.com	
6	Martin Kretschmer	MEMD	0788663949 m.kretschmer@gmail.com	
7	Prossy Alinaitwe	MEMA Ministry of Energy and Mineral Development Kampala.	natashaprossy@yahoo.co.uk 0776439837	
8.	ZION OKAMA	MEMD	zokama@energy.go.ug 0752546108	
9.	SÍLVIA LEIRIÃO	DHI	SLS@DHIGROUP.COM +4550333182 +256 7797 17685	
-	NIELS RIEGELS	DHI	ndr@dhigroup.com +45 4516 9361	