

Using simple mobile technologies to scale up digital collection & processing of climate observation for adaptation actions in Malawi

UNEP CTCN Project: 2022000048

PILOT SITES: PRELIMINARY ASSESSMENT

July 2024



1. Scope

In the project “Using simple mobile technologies to scale up digital collection & processing of climate observation for adaptation actions in Malawi”, supported by UNEP CTCN, this document presents the preliminary assessment of possible piloting sites.

The assessment is the outcome of Activity 4.1, Select the pilot sites, of the project’s Output 4, Piloting the use of mobile phone technologies.

The deliverables in Output 4 are:

- **Deliverable 4.1 Pilot sites: preliminary assessment**
- Deliverable 4.2.a Minutes: 1-day workshop
- Deliverable 4.2.b Pilot sites: final selection
- Deliverable 4.3 Detailed pilot implementation plan (workplan)
- Deliverable 4.4.a Minutes: meeting
- Deliverable 4.4.b Final implementation plan
- Deliverable 4.5.a Minutes: local workshop
- Deliverable 4.5.b Official community endorsement (written)
- Deliverable 4.6 Report: reception & equipment installation
- Deliverable 4.7 Report: demonstrating start of testing
- Deliverable 4.8 Digital system development & operationalisation
- Deliverable 4.9 Minutes: demonstration workshop (8 people)(MUST)
- Deliverable 4.10 Report: updated equipment & digital system
- Deliverable 4.11 Minutes: technology validation workshop

Methodology

The consulting team produced a matrix, presenting the Working Group deliberations and ranking of ten potential testing sites against agreed mandatory and selection criteria, as per the ToR and input to date from the project Working Group.

The use of mobile and cloud computing technologies in the prototype will be at specific monitoring locations, i.e. the manual hydrological and meteorological observation stations.

For surface water management and weather monitoring, these observation sites have existed under government mandate, and for a long time and for strategic reasons - from understanding hydrology at the river and lake basin scale, through to weather forecasting for regions (three), districts (28), and agricultural Extension Planning Areas (EPA, 187).

Therefore, the definition and delineation of “piloting or testing sites” for the project was agreed to be geographic areas with overlaps of basins, districts and EPAs.

Criteria

Mandatory criteria	
Location benefit	The area can benefit from in-situ weather and water monitoring (one active weather and hydrological monitoring station).
Human resources	The area should also have informants (Gauge Readers and Observers): experts that are qualified to transfer the relevant information by SMS to the cloud.
Criticality	Importance of data for critical and prioritised water, weather, and climate change challenges facing Malawi.
Selection criteria	
Vulnerability	Vulnerability assessment of the site (a desk analysis of existing data will be done and if needed completed with satellites data, historical data). The most vulnerable sites to flood, drought and sedimentation changes will receive the higher score, while the less vulnerable will be ranked lower.
Strategic importance	Demographics of the zone: high densified zone, as well as strategic zones for key national infrastructure and agriculture for food security will be ranked the highest (e.g., reservoirs, irrigation schemes, areas of high food productivity etc.).
Network	Quality of internet / mobile phone connection could also be a key factor.
Equipment failure	Risk of vandalism of the material.
Costs	Cost consideration of necessary on-site training of Gauge Readers and Observers in terms of travel distance, fuel, car rental and staffing.
Demographics	Existence of indigenous people could also be considered
Other	Others to be defined between the implementer, the NDE and the project proponent.

2. Matrix

Piloting area/basin	Ruo & Mwanza, lower Shire	Bua & Dwangwa	Linthipe	South Rukuru & North Rumph	Lisungwi & Rivirivi	Wankuluma dzi	Lake Chirwa & South West Lakeshore	Nkhotakota Lakeshore & Nkhata Bay Lakeshore	North Rukuru, Rufira & Songwe	South East Lakeshore & Lake Chiuta
Ranking	<i>Top three piloting options</i>			<i>Cumulative criteria assessment not as high as top three options.</i>						
Location description	Southern Malawi, part of the Shire River system.	Central Malawi flowing into Lake Malawi.	Centra Malawi, flowing into Lake Malawi.	Northern Malawi, feeding into Lake Malawi.	Southern Malawi, part of Shire River system.	Southern Malawi, part of Shire River system.	Eastern Malawi, with surrounding wetlands.	Northern basins along Lake Malawi.	Northern basins flowing into Lake Malawi.	Eastern Malawi. .
Districts	Blantyre Chikwawa Mulanje Nsanje Thyolo Mwanza	Nkhotakota Kasungu Ntchisi Dowa	Dedza Lilongwe Salima	Rumphi Mzimba Karonga	Balaka Ntcheu Neno Mangochi	Chikwawa Thyolo Mwanza Nsanje	Zomba Phalombe Machinga Mulanje Chiradzulu	Nkhotakota Nkhata Bay	Karonga Chitipa Rumphi	Mangochi Machinga Balaka
Est. population ¹	3,650,000	2,320,000	3,930,000	1,530,000	2,450,000	1,720,000	3,120,000	695,000	820,000	2,380,000
Mandatory criteria										
Location benefit	Proximity to urban centres like Blantyre and agricultural zones such as Thyolo and Mulanje.	Monitoring impacts on the Lake Malawi ecosystem and local agriculture .	Important for managing water flow into Lake Malawi , high population and agricultural areas like Dedza and Salima.	Understandi ng northern catchment impacts on Lake Malawi.	Managing water flow into the Shire River and associated ecosystems.	Flood and sediment control in the Shire River basin, affecting areas like Chikwawa.	Managing Lake Chirwa water levels and ecosystem, affecting areas like Zomba and Phalombe.	Monitoring lake health and water quality, affecting towns like Nkhotakota and Nkhata Bay.	Understandi ng northern water flow into Lake Malawi, affecting areas like Karonga.	Managing water resources and ecosystems in the region, affecting areas like Machinga and Mangochi.
All ten areas of basins and districts have more than one manual, in-situ hydrological or meteorological observation station.										

¹ Estimates derived from [World Bank Data - Malawi](#).

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Human resources	DWR and DCCMS network of manual observation stations with human resources (i.e., manual river level Gauge Readers, manual rainfall Observers, and meteorological station Meteorologists) in all ten identified areas of basins and districts.									
Criticality	Frequent floods, especially in the lower Ruo River around Nsanje.	Managing Lake Malawi levels and sugarcane plantations around Dwangwa.	Impacts on Lake Malawi water quality and levels, including areas of high food production.	Addressing water security and agricultural productivity in the northern region.	Role in the larger Shire River Basin, impacting regions like Ntcheu and Balaka.	Contribution to Shire River hydrology.	Key water source and ecosystem.	Influence on Lake Malaw's ecosystem.	Water security and Lake Malawi management.	Face water and climate challenges.
Selection criteria										
Vulnerability	High flood risk in Nsanje and Chikwawa districts, moderate drought risk, sedimentation impacting downstream areas.	Moderate flood risk, particularly near Nkhotakota, moderate drought risk, sedimentation affecting Lake Malawi.	Moderate flood risk, particularly near Salima, moderate drought risk, sedimentation affecting Lake Malawi.	High flood risk in Karonga, moderate drought risk, significant sedimentation concerns impacting Lake Malawi.	High flood risk, especially in low-lying areas, moderate drought risk, sedimentation impacting downstream.	High flood risk in Chikwawa, moderate drought risk, sedimentation issues.	High flood risk, especially around Phalombe, significant drought concerns, sedimentation issues affecting Lake Malawi.	Moderate flood risk, particularly near Nkhata Bay, lower drought risk, sedimentation concerns.	High flood risk, particularly in Karonga, moderate drought risk, significant sedimentation concerns.	High flood risk, particularly around Machinga, significant drought concerns, sedimentation affecting lakes.

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Strategic importance	High population density , key agricultural zones for tea and sugarcane , significant infrastructure including roads and irrigation schemes.	Moderate population density , significant agricultural activities including sugarcane and tobacco farming.	High population density , key agricultural areas for maize and tobacco .	Lower population density but crucial for agriculture, particularly in areas like Mzuzu.	Significant for local agriculture, particularly maize and tobacco, and hydropower.	Moderate population density, significant agricultural activities including cotton and sugarcane.	High population density, critical for local agriculture (rice and maize) and fisheries.	Moderate population density, important for fishing and tourism.	Lower population density, strategic for regional agriculture, particularly rice and maize.	Moderate population density, crucial for agriculture (rice and maize) and fisheries.
Network	Generally good coverage near Blantyre and surrounding urban areas, moderate in rural regions.	Variable coverage , better near larger settlements like Nkhotakota and Dwangwa.	Generally good coverage , especially near urban areas like Dedza and Salima.	Limited in rural areas, better in towns like Mzuzu and Karonga.	Generally good, especially near urban areas like Ntcheu and Balaka.	Good coverage in most areas, particularly near Chikwawa.	Variable, with better coverage near larger settlements like Zomba.	Good in towns, variable in rural areas.	Limited in rural areas, better in towns like Karonga.	Variable coverage, better near larger settlements like Mangochi.
Equipment failure	The criteria assessment of the risk of vandalism to manual observation equipment indicates similar conditions across the ten areas of basins and districts. The equipment for river level monitoring involves gauge plates and angle irons which are not commonly considered high-value assets, particularly if the local community is informed of its importance. Equipment used for rainfall monitoring, rainfall bucket and glass measurement cylinder are equally not as high value assets as compared to an automatic weather station that contains solar panels and batteries. Therefore, the assessment of the ten areas against the criteria is similar across the ten piloting area options.									
Costs	The cost of deployment, on-site training, station rehabilitation, rating curves, no of Personal Protection Equipment will be adjusted to station numbers and needs. As the cost estimates are not known in Activity 4.1, scope will be adjusted based on prioritised areas. Therefore, the assessment of the ten areas against the criteria could not be assessed..									

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Demographics	Mostly Chewa and Lomwe populations with significant Yao and Sena communities	Diverse, including Chewa, Ngoni, and Tumbuka populations.	Mainly Chewa populations.	Primarily Tumbuka, with significant Ngonde and Tonga populations.	Mostly Lomwe and Yao populations.	Mainly Lomwe and Sena populations.	Mostly Yao and Lomwe populations.	Mostly Tonga and Tumbuka populations.	Tumbuka and Ngonde populations.	Mostly Yao populations with some Lomwe.
Other critical criteria considerations										
Observation Data scarcity	Addressing the data scarcity challenge is consistent nationally in Malawi, for both gaps in time-series for existing stations and low density of stations.									
Leveraging satellite observations	Confirmed overlay with NASA SWOT and ICESat-2 missions: enabling cross-check validation and data gap filling of larger river channels and lake bodies.			Overlay possible, but potentially more complex due to size of river channels.						

3. Assessment of important synergies of satellite data and of hydro-meteorological analysis considerations

In addition to the mandatory and selection criteria, the ten potential piloting areas were assessed in terms of two important factors. First, leveraging the synergies with remotely sensed satellite observation data on Malawi's river and lake system hydrology. And second, considerations of the monitoring in terms of hydro-meteorological analysis, and the analysis that shall derive from observation data - with river discharge estimates and flood modelling as two priorities. Below, these are elaborated to support the preliminary assessment of piloting sites and subsequent final selection of piloting areas/basins.

The robustness of any hydrological and hydraulic analyses relies on the availability of observation data of water and weather conditions. The availability of observation data is conditioned by both quantity and quality of the data.

To understand the hydrological behaviour of a watershed (i.e., river or lake basin/catchment), it is important to analyse the temporal evolution of the related environmental variables, such as rainfall, temperature, moisture, river discharge, among others, to understand the past conditions or predict future trends.

Very often the lack of data, due to the lack of manual observers or gauging stations, make the hydro-meteorological modeller/scientist, forecaster or water manager blind without having the possibility to perform analysis and studies.

However, there are several ways to collect and build on the synergies of observation data: in-situ observation data from manual measurements (the focus of the UNEP CTCN project), automated surface and groundwater sensors, automated weather stations, and short and long range remote sensing.

Remotely sensed observation data present big advantages of being consistent around the globe and having large spatial coverage. Altimeter missions, such as ICESat-2 or NASA SWOT (of which the consulting team lead, Water in Sight is an approved part of their early adopter programmes) are becoming effective solutions for measuring the water surface elevation of medium-large rivers. Remotely sensed observation data from satellites always require in-situ measurement for calibration and validation.

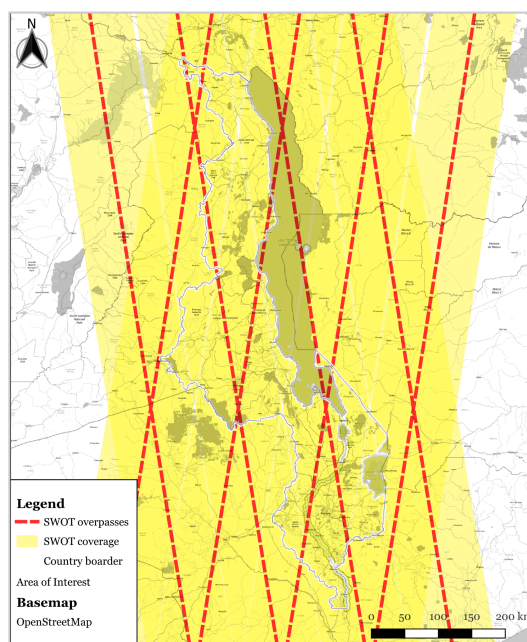
Leveraging the ICESat-2 and NASA SWOT mission hydrological is important for the UNEP CTCN project for two reasons:

- Collecting supporting observation data, especially in ungauged basins or basins with low density of monitoring stations. Combining gauging stations with in-situ observations allows the creation of a dataset with a higher temporal resolution with a continuous ground validation, in case of deviation of the instrument or change of the boundary condition.
- Enabling a cross-validating of data acquired by in-situ gauge readers and observers, detecting eventual outlier induced by a mistaken observation or recording. This brings in a quality 'sanity check' on the credibility of the manual observation measurement in the piloting, and thereby the ability and value of digitised manual observations for broader hydrological modelling and insights as part of the national water and weather observation system and mandate in Malawi.

The observation of changes in the boundary conditions is always important, e.g. in case of monitoring the water balance in a river system, especially the natural ones that are highly conditioned by the hydromorphological evolution and less constrained by human defence works. The change of the monitored cross section or the upstream/downstream profiles may lead to a total alteration of the relation between the observed water level and the related discharge flowing into the river (so called rating curves - RCs).

Thus, it is fundamental to plan a periodic update of the RCs in order to avoid a divergence in the transformation of water level to discharge, which will lead to the creation of a wrong time series (Tamagnone et al., 2019). An erroneous dataset will trigger a cascade effect of creating bias in all the downstream analyses and applications (“garbage in, garbage out”). In addition, RCs are important data for the calibration/validation of hydraulic models.

In terms of monitoring the water balance of a catchment, it is important to not focus only on the main stem, but also consider the hydrology of the major tributaries. This allows improving the understanding of the functioning of the system and the cause-effect relationships. Having a better discretisation of the river network implies a better classification of the flood hazard to which people and assets that might be potentially exposed. Moreover, selection of gauging stations strategically located in the waterhead may inform an observation-based early warning system for alerting the populations living downstream of the arrival of the flood (Tarchiani et al., 2020).



NASA SWOT overpasses and coverage over Malawi

4. Assessment considerations against criteria

Overview

The preliminary assessment of potential piloting areas was done to support the stakeholder workshop for discussing and ranking the options for piloting sites, held in Salima on June 7, 2024 (Activity 4.2). Ultimately, the sites/stations and final selection of piloting areas (basins and districts) need to bring value in terms of data application, forecasting, and general water resources and climatic information services.

The preliminary assessment of areas against criteria was done in relation to the prototype technology and design. Once piloted, it is expected that the technology solution of using mobile phones for hydro-meteorological data collection and processing, will have capabilities for receiving, processing as well as analytical and mathematical modelling, be GIS-based and integrate with associated ICT systems.

In identifying and assessing preliminary piloting areas, a systems thinking approach was applied within the frame of the geographical and hydro-meteorological unit of basins. It helped establish the linkages between data parameters and corresponding available application options of the basins and sub-basins and their conditions (e.g., characteristics such as hydrology, climate, geology, soils and vegetation). Basins also provide convenient boundaries for water and climate data collection as well as decision making with regards to improving the watersheds/catchments/sub-basins and restoration interventions in the context of water resources management and climate change adaptation.

Based on the team and the working group's comprehensive and in-depth understanding of Malawi's hydrometeorological regimes and areas, the following were the ten potential basins or sub-basins across Malawi:

- Ruo & Mwanza River Basins
- Bua & Dwangwa River Basins
- Linthipe River Basin
- South Rukuru & North Rumphu River Basins
- Lisungwi & Rivirivi River Basins
- Wankulumadzi River Basin
- Lake Chirwa & South West Lakeshore basins
- Nkhotakota Lakeshore & Nkhata Bay Lakeshore areas
- North Rukuru, Rufira & Songwe River Basins
- South East Lakeshore & Lake Chiuta Basins

At the stakeholder workshop on June 7, 2024, the consulting team presented the mandatory and selection criteria alongside the ten piloting options of geographic areas in Malawi to participants. The workshop was attended by the working group members and staff from the Salima District Council's water and sanitation section as well as the disaster risk management section. During the workshop, the ten options were discussed in detail where each participant supported a ranking discussion from the respective departmental perspectives.

5. Final selection of piloting areas/basin

The proposed piloting areas were assessed as per the above matrix, and discussed at the parallel workshop. From the ten proposed piloting sites, three were identified as meeting optimally meeting the mandatory criteria as well as important selection criteria. These areas are:

- Ruo & Mwanza River Basins (tributaries in the Lower Shire River basin) as part of the lower Shire River basin in southern Malawi.
- Bua & Dwangwa River Basins (tributaries into Lake Malawi) in northern Malawi.
- Linthipe River Basin in central Malawi.

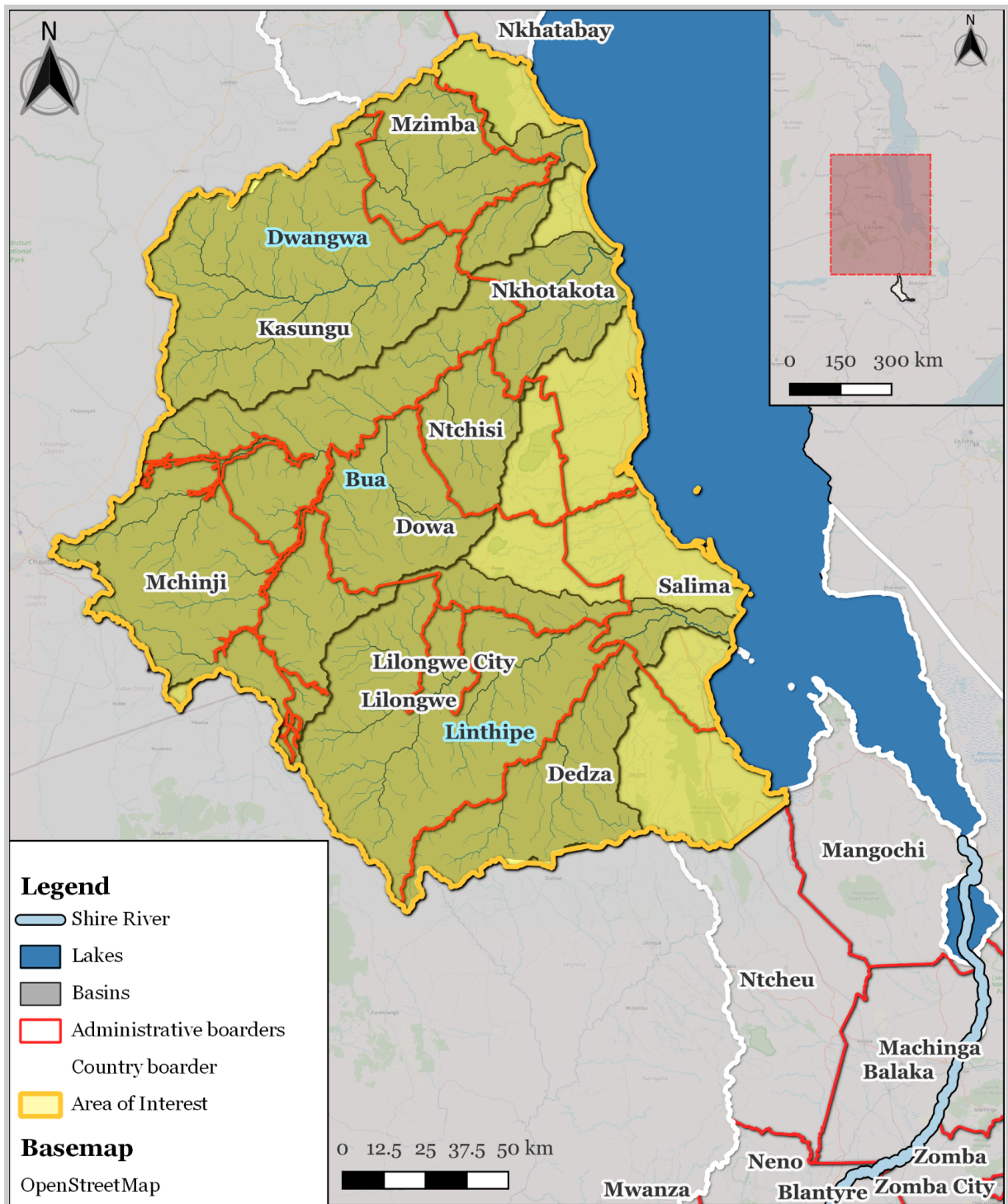
In Activity 4.4, the online meeting to discuss the draft pilot implementation plan, the Working Group will finalise area selection.

6. Maps of top three piloting area/basin options

Mwanza & Ruo River basins within southern Shire River basin



Dwangwa & Bua River basins, Linthipe River basin (combined map)



References

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