Scaling-up Early Warning Systems and Use of Climate Information in Malawi – Feasibility Assessment

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A report prepared by the Government of Malawi, with technical support from United Nations Development Programme.

Foreword

Malawi, a landlocked, agrarian least developed country, is particularly vulnerable to climate change and variability. Projected changes in the climate of Malawi indicate an increase in mean temperature of between 2 and 3 ^{o}C by 2050, a decrease in total annual rainfall and water availability and increase in erratic rainfall events (CEPA 2012). The combination of increased temperatures and reduced rainfall is likely to result in considerable loss of agricultural output and a reduction in the extent of land suitable for rain-fed production of the staple maize crop. Increases in temperature and erratic rainfall cause impacts leading to more frequent and intense droughts, floods and severe weather, which in turn disrupt lives and livelihoods among Malawi's most vulnerable communities.

The IPCC notes that "strengthening communication systems for anticipating and responding to climate risks" is an important tool to improve adaptive capacity for climate change. Yet current early warning systems in Malawi are insufficient to provide the population with timely, relevant information that can help them make decisions that improve their livelihoods – from seasonal forecasts that can help farmers plan their harvests, to information on coming storms, to warnings from upstream communities about downstream flooding.

These types of early warning systems are within reach to create transformational change in Malawi. From the availability of technology that lowers the cost of localized forecasts, to school and faith-based programs to disseminate warnings in communities, to innovative uses of mobile communications to provide information to farmers, several pilot programs in the country have been implemented successfully by the government, private sector, and civil society, demonstrating significant potential for application at scale across the country.

We are pleased to present the findings of the 'Scaling-up Early Warning systems and Use of Climate Information in Malawi – Feasibility Assessment', prepared jointly by the Department of Climate Change and Meteorological Services (DCCMS), Department of Disaster Management Affairs (DoDMA), and the Department of Water Resources (DWR) in collaboration with the Ministry of Agriculture, Irrigation, and Water Development and with technical support from United Nations Development Programme. The study examines in detail the current state of early warning systems and climate information in Malawi; identifies gaps in technology and information dissemination; surveys existing pilot programs for scalability; and recommends measures for implementation across the country, targeting disaster-prone communities and agricultural livelihoods. These recommendations will be used to identify concrete activities for implementation to strengthen the adaptive capacity and reduce exposure to climate risks of the country's most vulnerable communities.

The feasibility study is informed by extensive consultations with stakeholders in Malawi, including civil society, private sector, representatives across the Government of Malawi, and international development partners. We look forward to working together to increase the resilience of Malawi's most vulnerable communities, improving their livelihoods and saving lives.

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Executive Summary

This feasibility study provides the basis for the GCF proposed project "Saving Lives and Protecting Agriculture based Livelihoods in Malawi: Scaling up the use of Modernized Climate information and Early Warning Systems" (henceforth referred to as "the project"). The project builds on key early experiences with climate information and EWS pilots around Malawi to propose a comprehensive approach that scales the most effective solutions to commonly encountered barriers to the uptake of climate information, advisories and warnings. This study examines the latest science on climate impacts in Malawi; reviews the current state of early warning systems in Malawi; identifies gaps in current information provision; and reviews existing projects under implementation in Malawi. Recommendations are provided to increase the resilience of the most vulnerable people and communities of Malawi. In summary the study makes the following conclusions:

Malawi is particularly vulnerable to climate change and variability. A landlocked, least developed country in Africa, Malawi is expected to suffer an increase in mean temperature beyond 2^{o}C by 2050, a decrease in total annual rainfall and water availability, and more erratic rainfall events as a result of climate change. These impacts will have a negative effect on Malawi's agricultural production, responsible for 85 percent of the country's employment, the ability to respond to floods, and on the safety of fishermen reliant on distant fisheries in Lake Malawi.

Existing early warning systems and sources of climate information in Malawi are under-resourced and under-utilized. EWS and climate information can help communities learn of pending weather events, plan harvests, and respond to the threat of flash floods. Yet these data are not widely available or accessible to communities. Malawi's weather/climate and hydrological observation infrastructure, whilst declining over recent years, is in the process of being improved and rebuilt but is still in a state which limits the ability to accurately monitor current conditions and produce tailored information and forecasts. While data are transmitted daily from staffed stations, these data are only incorporated into the central database once per month, limiting their real-time utility. Seasonal forecasts, which help farmers plan their crops, are available but only used to a limited degree, partly due to understanding and confusion regarding the application of probabilistic information for assessing risks. Hydrological monitoring and forecasts have recently been improved for the Shire river basin but remain unavailable for much of the country.

Stakeholder consultations identified that investments in EWS and climate information that focus on crops & livestock, fisheries, and water resources will be beneficial to the public, already have pilot activities being undertaken in the field, and have the potential for scale. Government of Malawi (GoM), supported by UNDP, conducted several rounds of extensive stakeholder consultations over the past year. Further consultations, the concept validation workshop, and pre-appraisal were conducted during the periods 8-12th June and 6-11th July, 2015. Representatives from civil society (Red Cross, Christian Aid and CISANET), private sector, and various government agencies were consulted in developing this feasibility study and the GCF project proposal.

These stakeholders identified a number of gaps in EWS and climate information that, if resolved, would improve the livelihoods of vulnerable communities. In agriculture, gaps were related to the timing, content, availability, and accessibility of information provided to farmers. For fishers, information is currently not sufficiently localized or timely, given that it takes fishers in traditional craft a significant amount of time to return to shore from ever more distant fisheries. Improved EWS for flash floods will also help reduce the vulnerability of Malawi's communities by improving the timeliness of warnings and use of decision support tools.

Pilots to create and/or improve early warning systems have been carried out successfully, but remain geographically limited. Community-based EWS (CBEWS) projects, largely implemented by non-governmental organizations (NGOs), are on-going in several communities across Malawi. CBEWS have been successful by disseminating information from upstream to downstream communities, through school and faith communities, and using locally relevant communication methods. Other international organizations, including the World Bank, World Meteorological Organization (WMO), and UNDP through its Least Developed Country Fund (LDCF)-funded EWS project in Malawi,[1] have focused on building forecasting infrastructure and piloting technology, such as the use of Information and Communications Technology (ICT) in information dissemination. All of these projects demonstrate potential for scaling.

[1] "Strengthening climate information and early warning systems in Eastern and Southern Africa for climate resilient development and adaptation to climate change – Malawi."

This study recommends a comprehensive approach to increasing resilience in Malawi through scaling up current efforts. The approach should include the following components:

- Tailored products and services, including ICT, to disseminate early warnings and climate information to vulnerable communities, including farmers and fishers. These products should be demand-based and focus on stimulating a private market for information services.
- Improving the information available for monitoring and forecasting floods and water resources.
- Scaling up of community-based early warning systems to provide “last-mile” access to information and improve disaster preparedness.
- Additional weather and climate infrastructure to underpin information dissemination. The project should prioritise the use of low-cost technologies like automated weather stations and making better use of existing data sources.
- Training for first responders at the district and community level in technology and information dissemination to improve disaster preparedness and response.

List of Acronyms

Acronym	Acronym Definition
ACPC	Area Civil Protection Committees
AWS	Automatic Weather Stations
CBEWS	Community Based Flood Early Warning System
COU	Community Outreach Unit
CPC	Climate Prediction Centre
CPCs	Civil Protection Committees
CPT	Climate Prediction Tool
DCCMS	Department of Climate Change and Meteorological Services
DCPC	District Civil Protection Committees
DEMs	Digital elevation models
DFID	Department for International Development
DHI	Danish Hydrological Institute
DIPECHO	Disaster Preparedness European Community Humanitarian Office
DoDMA	Department of Disaster Management Affairs
DWR	Department of Water Resources
ECHO	European Community Humanitarian Office
ECMWF	European Centre for Medium range Weather Forecasts
ECRP	Enhancing Community Resilience Project
EOC	Emergency Operational Centers
EWS	Early Warning Systems
FFEWS	Flood Forecasting Early Warning System
FFGS	Flash Flood Guidance System
GFCS	Global Framework for Climate Services
GFDRR	Global Facility for Disaster Reduction and Recovery
GFS	Global Forecasting System
GoM	Government of Malawi
HYCOS	Hydrological Cycle Observing System
ICT	Information and Communications Technology
IFRMP	Integrated Flood Risk Management Plan
IFRMS	Integrated Flood Risk Management Strategy
IPC	Innovation Productivity Centre
MDRRF	Malawi Disaster Risk Reduction Framework
MECCM	Ministry of Environment and Climate Change Management
MVAC	Malawi Vulnerability Assessment Committee
MWD	Ministry of Water Development
NCEP	National Centres for Environmental Prediction
NDCC	National Disaster Coordination Committee
NDPRC	National Disaster Preparedness and Relief Committee
NDVI	Normalized Difference Vegetation Index
NEOC	National Emergency Operations Centre
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
ODSS	Operational Decision Support System
PSDs	Programme Support Documents
SRBMP	Shire River Basin Management Project
SWFDP	Severe Weather Forecasting Demonstration Project
VCPC	Village Civil Protection Committee
WFP	World Food Programme
WRA	Water Resource Authorities

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1 Climate risk profile of Malawi

1.1 Vulnerability to climate change impacts

Malawi is particularly vulnerable to climate change and variability. Observed changes in climate include a shift in the rainfall season, with later onset and cessation, as well as increases in the length of the dry season and statistically non-significant reductions in the length of the growing season[2,3]. Temperature has increased by 0.9°C between 1960 and 2006, at an average rate of 0.21°C per decade, with the highest increases during December-February (mid-summer) and lowest during September-November (early summer)[4]. The number of hot days per year increased by 30.5 days between 1960-2003, particularly in summer, whilst the average number of hot nights increased by an additional 41 days per year over the same period[5]. The projected climate change scenario in Malawi shows an increase in mean temperature of between 2 and 3 °C by 2050, a decrease in total annual rainfall and water availability and increase in erratic rainfall events (CEPA 2012)[6]. The combination of increased temperatures and reduced rainfall is likely to result in considerable loss of agricultural output and a reduction in the extent of land suitable for rain-fed agriculture production of the staple maize crop. Increases in temperature and erratic rainfall will result in more frequent and intense droughts, floods and severe weather – including strong winds and associated storm surges over Lake Malawi.

Malawi is classified as a low-income economy and least developed country. Malawi's economy is heavily agriculture-dependent, accounting for 85 percent of employment. Smallholders, primarily subsistence farmers, account for 80 percent of production.[7] The IMF in its 2014 update of Malawi's debt sustainability noted that the country's external public debt was at "moderate risk" of debt distress with recent deterioration in public finances.[8]

The vulnerability of Malawi's economy and local communities to climate change is as a result of a number of compounding factors, namely: i) unique and highly degraded ecosystems; ii) socio-economic and demographic situation, including high population growth rates in combination with high poverty levels, which reduces capacities to cope with climate change; iii) limited financial capacity to finance adaptation measures; iv) over dependence on rain-fed agriculture; v) heavy reliance on natural resources, particularly within the agricultural and fisheries sector; vi) limited knowledge on climate change and variability at community level to inform adaptation practices; vii) sub-optimal agricultural productivity and practices, and limited diversification within the household economy both on and off-farm; viii) limited access to affordable and sustainable clean energy sources; and ix) limited organization at local levels for policy dialogue around climate change.

The impacts of climate-related hazards in Malawi have already severely disrupted food production, led to the displacement of communities, loss of life and assets, and caused an overall reduction of community resilience. For example, during the 1992/93 rainy season, landslides killed over 500 people and caused extensive damage to infrastructure in parts of Mulanje and Phalombe districts[9]. From 1979 to 2010, natural disasters in Malawi affected nearly 21.7 million people and killed about 2,596 people[10]. Sectors already experiencing negative impacts include agriculture, fisheries, infrastructure, health, education and hydroelectric power production. The 2011-12 droughts had severe effects on food security in 15 districts[11] (see Figure 1), with approximately 2 million people affected particularly in the southern districts. The number of flood and drought events and the number of people affected by these events has clearly increased since the 1980s (see Figure 2).

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2 COSMO NGONGONDO, LENA M. TALLAKSEN & CHONG-YU XU (2014) Growing season length and rainfall extremes analysis in Malawi. Hydrology in a Changing World: Environmental and Human Dimensions Proceedings of FRIEND-Water 2014, Montpellier, France, October 2014 (IAHS Publ. 363, 2014). Available online at: http://folk.uio.no/chongyux/papers_SCI/IAHS_363_Cosmo.pdf

3 Tadross M., Suarez P., Lotsch A., Hachigonta S., Mdoka M., Unganai L., Lucio F., Kamdonyo D., Muchinda M. (2009) Growing-season rainfall and scenarios of future change in southeast Africa: implications for cultivating maize. Climate Research. Vol. 40. 147-161. DOI: 10.3354/cr00821

4 Vincent, K., Dougill, A. J., Mkwambisi, D. D., Cull, T., Stringer, L. C. & Chanika, D. (2013) Deliverable 1: Analysis of Existing Weather and Climate Information for Malawi. Leeds: University of Leeds.

5 McSweeney, C., M. New and G. Lizcano (2012). UNDP Climate Change Country Profiles. New York: UNDP

6 CEPA May, 2012: Draft Position Paper: Towards Development of Climate Change Policy in Malawi. ECRP and DISCOVER Consortia.

7 World Bank (2012). Country Assistance Strategy for the Republic of Malawi for the period of FY13-FY16. Report No: 74159-MW

8 IMF (2015). Malawi. http://www.imf.org/external/pubs/ft/dsa/pdf/2015/dsacr1583.pdf

9 IIED (2004). Adverse Impacts of Climate Change and Development Challenges: Integrating Adaptation in Policy and Development in Malawi. Capacity strengthening in the least developed countries (LDCs) for adaptation to climate change (CLACC). Available at http://pubs.iied.org/pdfs/10013IIED.pdf

10 Government of Malawi (2015). National disaster risk management policy. Available at https://www.ifrc.org/docs/IDRL/43755_malawidrmpolicy2015.pdf

11 Chikhwawa, Nsanje, Phalombe, Zomba, Balaka, Mangochi, Ntcheu, Dedza, Kasungu, Lilongwe, Salima, Nkhotakota, Karonga, Nkhata bay and Machinga.

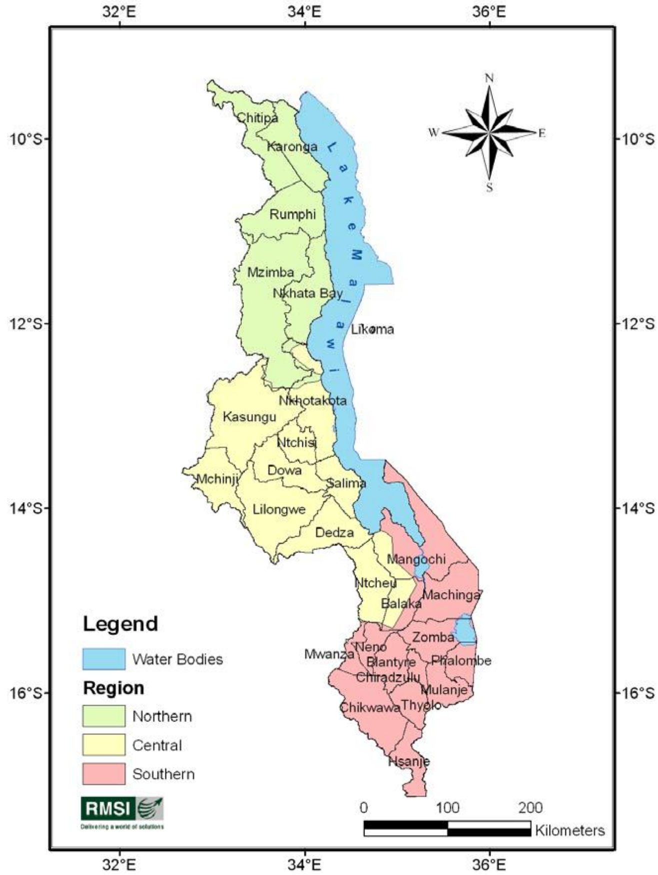

Figure 1: Regions and districts of Malawi.
Source: RMSI 2009.[12]

Any increase in temperatures and/or the frequency and intensity of droughts could potentially negatively affect crop growth as projected for southern Africa as a whole, whereas floods and severe storms may impact the agricultural value chain - including drying, storage and transport to market[13,14]. Likewise any increases in the frequency and severity of floods and storms would increase the hazards faced by fishermen. Furthermore, water levels of some large shallow lakes fluctuate with rainfall anomalies, resulting in the aforementioned knock-on effects. For example, Lake Chilwa nearly dried-up in November 2012, and – even after the rainy season – water levels were still considerably low in May 2013. An Economic Vulnerability and Disaster Risk Assessment in 2009/2010 showed that drought impacts on agriculture pose a greater threat than floods in terms of geographical range and likely economic effects (IFPRI/RMSI 2010)[15], mostly affecting maize crop production rather than area planted. Annualised average losses depended on the type of maize (6-8% for long season varieties and 1-2% for more drought resistant varieties). A national average of 10% reduction in total maize yield was modelled for the end of the 21st century under an A2 emissions scenario.

[12] RMSI (2009). Malawi: Economic Vulnerability and Disaster Risk Assessment Draft Final Report (Volume 1: Main Report). pp 147.
[13] Lobell, D.B., M.Bänziger, C.Magorokosho, and B.Vivek 2011. "Nonlinear heat effects on African maize as evidenced by historical yield trials." Nature Climate Change 1(1):42-5
[14] Zinyengere, N., O. Crespo, S. Hachigonta, 2013. Crop response to climate change in Southern Africa: A comprehensive review. Global and Planetary Change
[15]IFPRI/RMSI (2010) Malawi: Economic Vulnerability and Disaster Risk Assessment. Economy-Wide Impacts of Droughts and Floods.

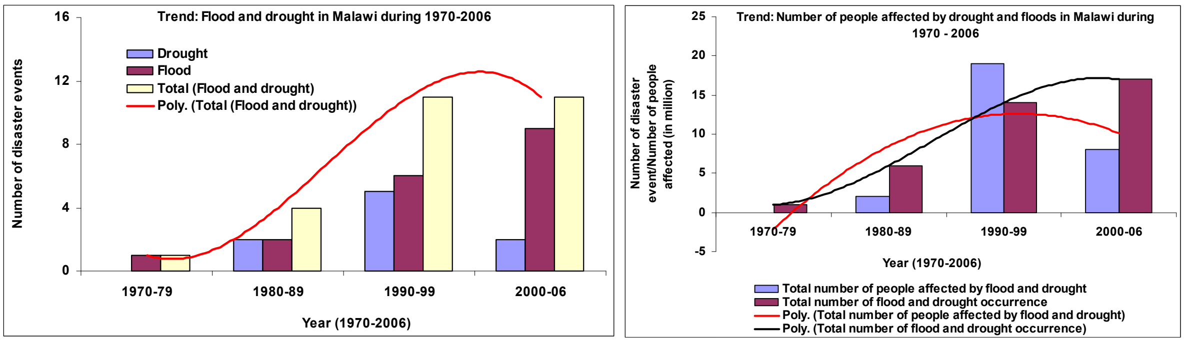

Figure 2: Number of drought and flood events (left) and the number of people affected (right) in Malawi.

Source: Action Aid 2006[16].

There is limited detailed data for Malawi on the projected economic costs of climate change and the additional costs and benefits of adaptation. Assessments of other African countries facing similar challenges, however, indicate that the economic costs of climate change in Africa could equal an annual loss in GDP of approximately 1.5 to 3% by 2030 under a business-as-usual scenario[17]. In the long-term, these costs could increase rapidly to a loss of approximately 10% of GDP by 2100. Assessments undertaken indicate high benefits incurred by adaptation compared to costs. For example, appropriate adaptation measures could reduce the economic costs of climate change in Africa from approximately 2 to 1% of GDP by 2040 and from 10 to 7% of GDP by 2100. One way to support effective adaptation planning – in particular for an increase in intensity and frequency of droughts and floods – is to improve climate information and early warning systems. Accurate weather and climate information and forecasting are essential for planning and managing economic production and for the provision of social services, particularly under a changing climate.

The GoM recognizes the fact that no meaningful reduction in poverty can be achieved in the country without addressing the impacts of disasters and climate change. Thus, it is indicated in the Malawi Growth and Development Strategy II Theme 3 (2012-2016) that in responding to these challenges, the GoM will implement a number of strategies including: i) strengthening disaster risk management coordination mechanisms; ii) developing an integrated national EWS; and iii) implementing mitigation measures in disaster prone areas.

1.2 Drought risk and household vulnerability

An analysis of drought risk[12] demonstrates that the return period for drought is low (i.e. the risk is high) particularly in the districts of Chitipa, Karonga, Rumphi, Mzimba and Nkhata bay in the north, and Salima, Mangochi, Balaka, Neno and Mwanza in the south and central regions (Figure 3).

Drought, however is not the only determinant of food security: prices, access to markets, socio-economic constraints, farming systems and poverty levels all play a role. Additionally the drought index used to construct Figure 3, is a relative index and shows how frequent drought is relative to its own local climatology, ignoring absolute levels that are necessary when growing crops etc. With this in mind an analysis of food insecure households was conducted using data collected by the Malawi Vulnerability Assessment Committee (MVAC) over a period of 10 years (see Table 1).

[16] Action Aid (2006). Climate change and smallholder farmers in Malawi. Understanding poor people's experiences in climate change adaptation

[17] UNEP/SEI. Estimates of the costs of adaptation in Africa. Synthesis Briefing Note. Available at http://www.unep.org/climatechange/Portals/5/documents/Adaptation/1-AdaptCostPolicySynthesis.pdf

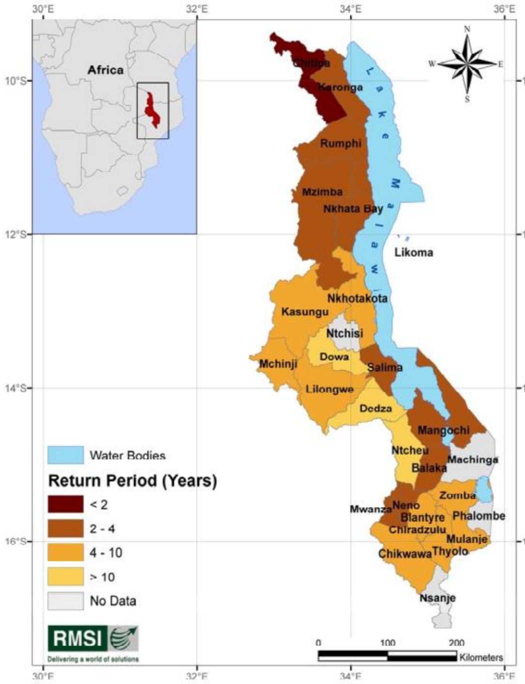

Figure 3: Drought return period – drought is defined as below 75% of long term (1969-2008) seasonal average standard precipitation index[12].

	TIMELINE OF FOOD INSECURE HOUSEHOLDS OVER A PERIOD OF TEN YEARS										Analysis
	Years										
Districts	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total # Years**
Balaka	247,500	25,900	0	27,091	55,332	64,553	8,698	3,031	69,645	29,186	9
Blantyre	236,300	106,500	0	74,159	0	79,058	24,111	8,439	37,111	30,271	8
Chikwawa	348,200	59,900	177,400	26,240	57,596	161,205	45,042	15,764	82,547	15,947	10
Chiradzulu	225,100	0	0	125,339	0	80,235	24,217	8,475	49,352	0	6
Chitipa	12,300	0	0	0	0	0	0	0	0	0	1
Dedza	103,800	0	0	82,745	0	0	0	0	56,262	13,675	4
Dowa	48,400	48,800	0	0	0	0	0	0	31,753	40,005	4
Karonga	20,900	0	62,600	13,805	0	8,844	0	0	56,005	33,891	6
Kasungu	98,500	238,200	0	0	0	0	0	0	112,251	0	3
Lilongwe	170,400	12,300	0	0	0	21,649	0	0	0	81,079	4
Machinga	263,500	0	0	57,661	0	54,280	0	0	110,834	36,625	5
Mangochi	221,300	39,500	0	136,269	0	0	0	0	96,648	0	4
Mchinji	55,500	0	0	0	0	0	0	0	14,979	30,700	3
Mulanje	398,500	0	0	246,882	0	74,198	0	0	0	55,453	4
Mwanza	76,000	11,200	0	23,523	0	12,861	4,027	1,409	71,358	22,528	8
Mzimba	0	57,300	0	100,716	0	0	0	0	191,652	45,287	4
Neno	74,500	11,200	0	0	0	20,044	7,348	2,573	77,218	7,136	7
Nkhotakota	142,100	0	0	0	0	0	0	0	38,676	0	2
Nsanje	185,500	51,900	83,900	46,225	34,564	100,711	23,850	8,348	67,367	11,843	10
Ntcheu	292,600	0	0	0	0	47,202	29,251	10,238	0	61,376	5
Ntchisi	47,200	98,500	0	13,009	0	0	0	0	23,360	0	4
Phalombe	170,500	27,000	0	121,789	0	54,201	11,665	4,083	71,020	45,851	8
Rumphi	21,600	25,300	0	0	0	0	0	0	29,415	34,818	4
Salima	226,100	13,800	0	31,697	0	0	0	0	83,228	25,524	5
Thyolo	390,300	0	0	94,787	0	202,426	0	0	0	0	3
Zomba	511,600	0	0	268,268	0	94,893	23,685	8,290	91,264	18,814	7
Total	**4,588,200**	**827,300**	**323,900**	**1,490,205**	**147,492**	**1,076,360**	**201,894**	**70,650**	**1,461,945**	**640,009**	

Table 1: Food insecure households per district collected between 2005 and 2014.

LEVEL OF FOOD SECURITY RISK		
Low	**Medium**	**High**
Chitipa	Chiradzulu	Balaka
Kasungu	Dedza	Blantyre
Mchinji	Dowa	Chikwawa
Nkhotakota	Karonga	Mwanza
	Lilongwe	Neno
	Machinga	Nsanje
	Mangochi	Phalombe
	Mulanje	Zomba
	Mzimba	
	Ntcheu	
	Ntchisi	
	Rumphi	
	Salima	

FAST FACTS
* Data sourced from Malawi Vulnerability Assessment Committee annual vulnerability forecast. MVAC is a multistakeholder committee mandated to conduct food security assessments in the country
* While the assessments may factor in other hazards such as floods, the major hazard that is considered is drought/dryspells
* The high drought risk districts are also the most food insecure districts in the country as evidenced by the number of years they registered food insecure population

Key	
Low risk	1-3 years out of 10 years analysed
Medium Risk	4-6 years out of 10 years analysed
High risk	7-10 years out of 10 years analysed

Table 1 continued: Food insecure households per district collected between 2005 and 2014.

APPROXIMATE COST OF ADDRESSING DROUGHT/DRYSPELL THROUGH HUMANITARIAN RESPONSE PROGRAMME (FOOD OR CASH)										
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cost (million $)	97	22.6	No data	27	2.4	15.1	0.54	30.1	20.5	3.9
Operational Cost	48.5	11.3	No data	13.5	1.2	7.55	0.27	15.05	10.25	1.95
Total (Million $)	145.5	33.9	No data	40.5	3.6	22.65	0.81	45.15	30.75	5.85

Table 2: Cost of addressing droughts through humanitarian assistance.[18]

Districts were ranked either low risk (food insecure households in 1-3 years), medium risk (food insecure households in 4-6 years) or high risk (food insecure households in 7-10 years). This resulted in the following districts being classified as high risk: Balaka, Blantyre, Chikwawa, Mwanza, Neno, Nsanje, Phalombe, and Zomba, with the following classified as medium risk: Chiradzulu, Dedza, Dowa, Karonga, Lilongwe, Machinga, Mangochi, Mulanje, Mzimba, Ntcheu, Ntchisi, Rumphi and Salima. Other districts were classified as low risk.

It can be seen that whilst drought is a most severe risk in Chitipa, household food insecurity is a relatively low risk. Likewise whilst Dowa, Dedza and Ntcheu have a low drought risk, they are medium risk for household food insecurity. For the reasons given above (why drought does not necessarily equate to food insecurity) and because one focus of this project is tailored agricultural products for farmers (to enhance food production and food security), the risk classification using the MVAC data is used in preference to drought-based risk classification in this feasibility study. The total population (2008 and 2015 projected), as well as the area of each of these districts is presented in Table 3 and used later to estimate the coverage required by automatic weather stations and the number of beneficiaries from deploying the equipment in each district.

[18] The costs include the cost of procuring the food itself or the actual cash to be disbursed as estimated by MVAC and operational costs for distribution or disbursement.

District	Reg	HASC	ISO	FIPS	Population	Area(km.²)	Projected population (2015)[19]	Area(mi.²)
Balaka	S	MW.BA	BA	MI26	316,748	2,193	420,159	847
Blantyre	S	MW.BL	BL	MI24	999,491	2,012	1,543,218	777
Chikwawa	S	MW.CK	CK	MI02	438,895	4,755	583,735	1,836
Chiradzulu	S	MW.CR	CR	MI03	290,946	767	382,131	296
Chitipa	N	MW.CT	CT	MI04	179,072	4,288	220,550	1,656
Dedza	C	MW.DE	DE	MI06	623,789	3,624	860,341	1,399
Dowa	C	MW.DO	DO	MI07	556,678	3,041	651,778	1,174
Karonga	N	MW.KR	KR	MI08	272,789	3,355	314,039	1,295
Kasungu	C	MW.KS	KS	MI09	616,085	7,878	833,446	3,042
Likoma	N	MW.LK	LK	MI27	10,445	18	15,020	7
Lilongwe	C	MW.LI	LI	MI11	1,897,167	6,159	2,636,277	2,378
Machinga	S	MW.MA	MH	MI28	488,996	3,771	491,726	1,456
Mangochi	S	MW.MG	MG	MI12	803,602	6,273	1,000,144	2,422
Mchinji	C	MW.MC	MC	MI13	456,558	3,356	586,253	1,296
Mulanje	S	MW.MJ	MU	MI29	525,429	2,056	713,500	794
Mwanza	S	MW.MN	MW	MI25	94,476	826	231,838	319
Mzimba	N	MW.MZ	MZ	MI15	853,305	10,430	753,392	4,027
Neno	S	MW.NN	NE	MI31	108,897	1,469		567
Nkhata Bay	N	MW.NA	NB	MI17	213,779	4,071	223,260	1,572
Nkhotakota	C	MW.NK	NK	MI18	301,868	4,259	383,630	1,644
Nsanje	S	MW.NS	NS	MI19	238,089	1,942	292,821	750
Ntcheu	C	MW.NU	NU	MI16	474,464	3,424	656,328	1,322
Ntchisi	C	MW.NI	NI	MI20	224,098	1,655	302,132	639
Phalombe	S	MW.PH	PH	MI30	313,227	1,394	409,179	538
Rumphi	N	MW.RU	RU	MI21	169,112	4,769	187,374	1,841
Salima	C	MW.SA	SA	MI22	340,327	2,196	449,338	848
Thyolo	S	MW.TH	TH	MI05	587,455	1,715	758,451	662
Zomba	S	MW.ZO	ZO	MI23	670,533	2,580	941,443	996
28 districts					13,066,320	94,276		36,400

Table 3: 2008 Population Census by National Statistical Office and 2015 projected population

1.3 Flood risks

An analysis of flood risks,[12] using the HEC-RAS hydraulic model, observed flows and flood extents, as well as populations and exposed assets, determined the number of affected households (and exposed roads) in the southern region of Malawi for different flood intensity return periods (Figure 5). The districts with the most affected households are Mangochi, Chikwawa and Nsanje (see Figure 4 for exposure map for 1 in 100 year flood events).

[19] Estimated population source DoDMA

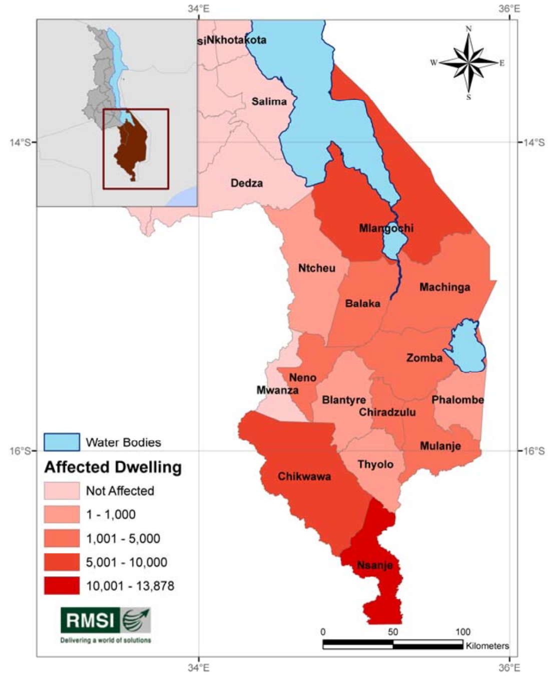

Figure 4: Number of households affected by 1 in 100 year floods in the southern regions of Malawi.

District Name	Affected Main Roads (Km)							
	RP 2	RP 5	RP 10	RP 20	RP 50	RP 100	RP 200	RP 500
Balaka	0.2	0.4	0.5	0.6	0.8	1.1	1.4	1.6
Blantyre	0.2	0.5	0.7	0.9	1.1	1.3	1.5	1.5
Chikwawa	0.3	0.8	1.1	1.6	2.1	2.5	2.9	3.3
Chiradzulu								
Machinga	0.0	0.1	0.1	0.2	0.3	0.3	0.3	0.3
Mangochi	0.4	1.8	3.2	5.2	7.4	9.2	11.0	11.9
Mulanje	0.3	0.6	0.7	1.0	1.2	1.5	1.7	1.8
Mwanza								
Neno	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
Nsanje	0.3	0.6	0.9	1.2	1.7	1.9	2.4	2.9
Ntcheu	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5
Phalombe								
Thyolo	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.4
Zomba								

District Name	Affected Population							
	RP 2	RP 5	RP 10	RP 20	RP 50	RP 100	RP 200	RP 500
Balaka	945	1891	2386	3241	3929	5099	6548	6548
Blantyre	339	677	854	1064	1290	1435	1612	2418
Chikwawa	4749	13599	18522	23065	28780	32018	37517	38031
Chiradzulu	998	1996	3091	3849	4666	5190	5832	5832
Machinga	1286	2573	3246	4043	4900	5451	6125	6125
Mangochi	2857	8669	11189	14552	19515	25469	29085	29555
Mulanje	848	2375	3639	4531	5493	6110	6866	7270
Mwanza								
Neno	1019	2038	2571	3202	3881	4318	4852	4852
Nsanje	10749	23126	29183	37109	48393	55908	62818	62818
Ntcheu	631	1261	1592	1982	2402	2673	3003	3003
Phalombe	828	1656	2090	2602	3154	3509	3943	3943
Thyolo	252	755	952	1186	1437	1599	1796	2994
Zomba	2727	6343	11046	13755	16673	18548	20841	20841

Figure 5: No. affected people (left) and affected roads (right) for different flood return periods in the south Malawi.

A national analysis conducted by DoDMA for the whole of Malawi and based on the number of households affected by floods between 2000 and 2010 is presented in

LEVEL OF FLOOD RISK		
Low	**Medium**	**High**
Balaka	Blantyre	Chikwawa
Chiradzulu	Dedza	Karonga
Chitipa	Machinga	Mangochi
Dowa	Mangochi	Phalombe
Lilongwe	Nkhotakota	Salima
Kasungu	Nkhatabay	Zomba
Mchinji	Rumphi	
Mulanje		
Mzimba		
Mwanza		
Neno		
Ntcheu		
Ntchisi		
Thyolo		

KEY	
>30,000	High
5000-30000	Medium
>5000	Low

FAST FACTS
*Data sourced form the National Disaster Profile * The analysed period was randomly selected due to availability of data * However, 2009 data was not availble in the database * Affected households includes those whose houses were damaged and those whose farmlands and crops were damaged

Table **4**. Highest risk districts are Karonga, Salima, Phalombe, Chikwawa, Nsanje and Zomba, with Nkhotakota, Nkhatabay, Rumphi, Machinga, Blantyre, Mangochi and Dedza classified as medium risk districts. These priorities are reflected in Figure 6 where most of the medium and high risk districts are shown to be located in the south and close to the lakeshore.

	TIMELINE OF HOUSEHOLDS AFFECTED BY FLOODS OVER A PERIOD OF ELEVEN YEARS (2000-2010)											
	Years											Total per District
Districts	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	
Balaka	0	0	1,488	303	0	0	14	31	778	0	0	**2,614**
Blantyre	0	2,000	150	0	0	0	4,894	0	0	0	0	**7,044**
Chikwawa	19,280	1,997	0	0	5,065	0	20,497	917	6,460	0	0	**54,216**
Chiradzulu	0	0	0	0	0	0	0	0	0	0	0	**0**
Chitipa	0	0	164	0	0	0	0	0	0	0	0	**164**
Dedza	0	975	0	578	0	308	0	0	4,306	0	0	**6,167**
Dowa	0	0	0	190	0	0	0	0	0	0	0	**190**
Karonga	13,224	6,873	45,396	0	0	0	5,533	74	145	0	946	**72,191**
Kasungu	0	0	0	0	0	0	0	0	0	0	0	**0**
Lilongwe	0	0	0	0	0	0	0	0	0	0	0	**0**
Machinga	0	12,000	155	39	0	0	0	382	30	0	0	**12,606**
Mangochi	0	8,447	65	826	0	0	4,866	483	23	0	0	**14,710**
Mchinji	0	2,000	0	0	0	0	0	0	0	0	0	**2,000**
Mulanje	0	0	0	0	0	0	0	0	0	0	0	**0**
Mwanza	0	0	0	3,935	0	0	0	0	0	0	0	**3,935**
Mzimba	0	0	0	29	0	0	0	0	0	0	0	**29**
Neno	0	0	0	0	137	0	0	0	0	0	0	**137**
Nkhotakota	1,912	15,540	7,258	289	0	0	0	470	55	0	100	**25,624**
Nsanje	2,259	25,000	700	31	1,516	0	8,512	1,351	11,582	0	0	**50,951**
Ntcheu	0	737	0	176	0	29	0	643	0	0	0	**1,585**
Ntchisi	0	0	0	0	0	0	0	0	259	0	0	**259**
Phalombe	6,196	17,000	129	15	2,338	0	0	0	6,654	0	0	**32,332**
Rumphi	0	28	369	11,665	112	0	0	0	0	0	0	**12,174**
Salima	0	9,000	185	27,568	0	0	250	41	0	0	6	**37,050**
Thyolo	0	1,051		0	0	0	0	0	0	0	0	**1,051**
Zomba	13,000	0	5,443	3,252	69	2,240	0	94	7,276	0	0	**31,374**
TOTAL (all districts)	**55,871**	**102,648**	**61,502**	**48,896**	**9,237**	**2,577**	**44,566**	**4,486**	**37,568**	**0**	**1052**	**368,403**

LEVEL OF FLOOD RISK		
Low	**Medium**	**High**
Balaka	Blantyre	Chikwawa
Chiradzulu	Dedza	Karonga
Chitipa	Machinga	Mangochi
Dowa	Mangochi	Phalombe
Lilongwe	Nkhotakota	Salima
Kasungu	Nkhatabay	Zomba
Mchinji	Rumphi	
Mulanje		
Mzimba		
Mwanza		
Neno		
Ntcheu		
Ntchisi		
Thyolo		

KEY	
>30,000	High
5000-30000	Medium
>5000	Low

FAST FACTS
*Data sourced form the National Disaster Profile
* The analysed period was randomly selected due to availability of data
* However, 2009 data was not availble in the database
* Affected households includes those whose houses were damaged and those whose farmlands and crops were damaged

Table 4: Districts categorized according to flooding risk level based on number of households affected by floods 2000-2010

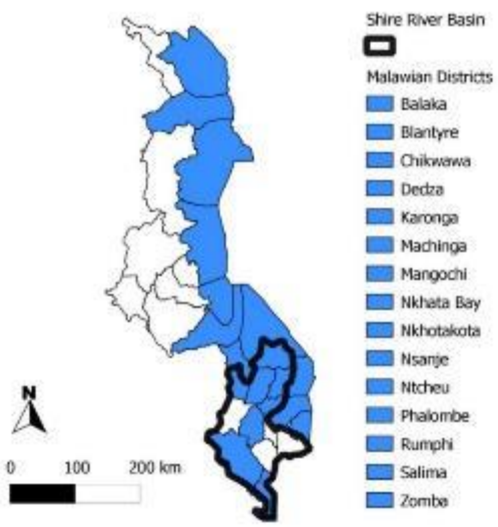

Figure 6: 15 priority flood prone and drought prone districts in Malawi.

2 National status of climate data and forecasts

2.1 Current status of the meteorological observing and forecasting system operated by DCCMS

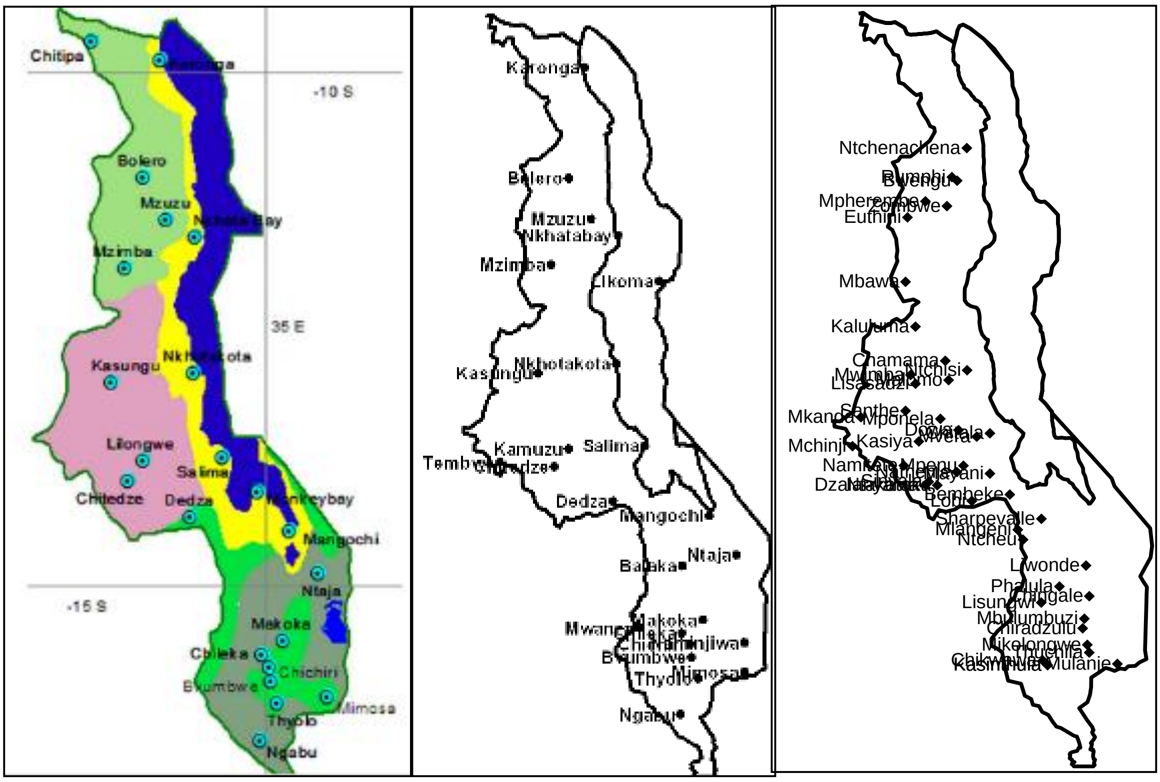

Figure 7: Location of existing 22 synoptic weather stations, 28 automatic weather stations and 53 rainfall logging stations (these maps do not include stations to be installed through the UNDP LDCF-funded CI/EWS project).

The following provides a brief summary of the current systems and processes which DCCMS currently uses and follows. It draws on previous assessments of DCCMS capabilities and needs (CSAG 2013, UKMO 2013)[20,21] and on discussions with DCCMS.

2.1.1 Available weather station data

Currently, daily observations are received mostly by phone and used by forecasters (in combination with observations from other countries – SYNOP reports sent via the GTS) when drawing up synoptic weather charts. UKMO (2013) states that only 3 stations in Malawi transmit over the GTS using the Netsys system, limiting the influence of local observations on internationally made weather forecasts. There are currently no upper air measurements or radar, which could be used to initialise Numerical Weather Prediction (NWP) models.

Estimates of number of available stations differ depending on the source but Figure 7 identifies the number of stations prior to investments being made through the SRBMP and UNDP-managed LDCF project. UKMO (2013) estimate that 25 to 43 stations are reporting, though it is not clear how this number is split between synoptic, AWS and rainfall stations. However, DCCMS reports 21 functioning principal stations (and 15 subsidiary and 40 rainfall only stations) across Malawi with 8 principal stations in the Shire Basin

[20] Climate Systems Analysis Group (CSAG) (2013) Capacity Support to Malawi Department of Climate Change and Meteorological Services, World Bank contract 7163861
[21] UKMO (2013) Support to the Department of Climate Change and Meteorological Services Malawi, Rapid Needs Assessment for Engagement with the Shire River Basin Management Programme, World Bank

(Government of Malawi 2013)[22]. Discussions with DCCMS suggest the total number of synoptic stations is 28 but 21 have data prior to 1980.

Observations are recorded each morning at 8am and are received by the head office either by phone or email, with some pulled from AWS by HQ. All received data are used for forecast production (drawing up synoptic charts) but not assimilated into a database (e.g., CLIMSOFT, to which they are migrating with UKMO support). Only later when data is sent at the end of the month are they entered into the database. This limits real-time interpretation or use of the data for bulletins and other information dissemination, and their assimilation into local weather and flood models.

Additionally there are records of undigitised data going back many years and for stations that have stopped reporting. Much data are reported to be on tapes, which cannot be read anymore. Some are still in paper records, but these are not kept in suitable storage conditions. Whilst some may still be at the stations, many have been moved to HQ. It is unclear how many of these records cover the Shire basin (and for how long), though the DCCMS agro-meteorological team estimates that data from as many as 60 stations may be available.

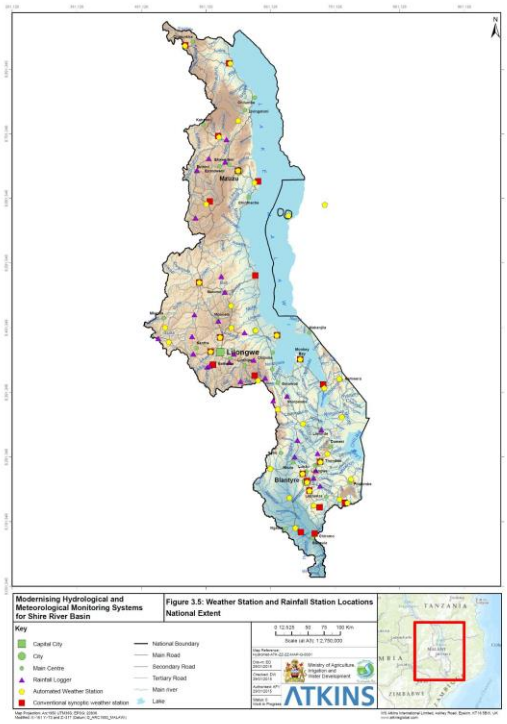

Figure 8: Locations of current weather stations: AWS, synoptic and rainfall only.

Figure 8 shows the locations of the current network of weather stations in Malawi, including synoptic, AWS and rainfall stations. Atkins (2015)[23] notes that of the currently installed AWS stations the Casella manufactured stations are only partly serviced with new parts through an agreement with Fairmount weather systems in the US. Those installed with ADCON equipment are currently working well.

2.1.2 Use of satellite observations

DCCMS operates a PUMA/SYNERGIE system that through EUMETSAT delivers MSG (Meteosat Second Generation) images (12 channels) every 15 minutes and other products (see following sections). This helps understand the synoptic situation beyond Malawi's borders. Estimates of rainfall (mm/hr) are provided and images can be used to monitor tropical cyclones. However, the MSG rainfall product currently underestimates rainfall from warm stratiform clouds (e.g., when Congo air mass is active). Local calibration would improve this situation. Additionally EUMETSAT provides annotated MSG products (based on time lapse imagery), which indicate where clouds are developing, waning and the direction they are moving. There is currently no capacity to utilise these images through integrated viewing systems.

[22] Government of Malawi (2013) Report for the Meteorological station assessment in the Shire river Basin. Department of Climate change and meteorological services.
[23]**Atkins** Malawi SRBMP Hydromet Inception Report | Version 3.0 | 21 April 2015 | 5135807

2.1.3 Agro-meteorological products

The agro-meteorological team produces bulletins every 10 days with updates on the current state of the maize crop – as measured by a calculated water requirement satisfaction index (WRSI). Further information is provided on the start of the rains, as well as the cumulative rainfall for some stations. To derive the WRSI datasets for the bulletins, the agro-meteorological team typically uses the GeoWRSI and agrometshell tools developed by FEWS and distributed through SADC and SARCOF processes.

WRSI is calculated using satellite-based rainfall product generated by FEWS. This rainfall estimate product (RFE2.0) is derived from a combination of satellite observations and rainfall measurements from GTS-reporting stations, and is known to contain significant biases in areas remote from the stations used in the process.

Additionally the agromet bulletins use Normalized Difference Vegetation Index (NDVI) data (derived from NOAA AVHRR and MODIS satellite platforms) to monitor the state of vegetation and hence imply the current status of the maize crop, as well as to monitor on-going droughts etc. The team also monitors and reports weather indices (temperature + radiation) for tobacco and maize. The insurance company (Microinsure) relies on DCCMS to provide these data under an agreement whereby they provide equipment but do not pay for the data/service. It is worth noting that the WRSI-based crop models (agrometshell and GeoWRSI) do not include the effects of flooding damage on crops.

2.1.4 Weather forecasts

Weather forecasts are currently issued for the next 5 days for all regions in Malawi and are based mostly on forecaster interpretations of the available information (SYNOPS reports, satellite imagery, synoptic charts available through the internet etc.) and international forecasts detailed above (mostly GFS and ECMWF). These DCCMS forecasts are a word summary and are used for television broadcasts and distribution (see Appendix B: Examples of current 1 & 5 day weather forecasts issued by DCCMS). There is no documented standard procedure or standard operating procedures, which would allow new recruits to quickly get up to speed. Most importantly, the currently available numerical weather forecasts are not downscaled (though the UM 12km data is available through the SWFDP website) and there has been no systematic assessment of skill of the different forecasts that are used.

Available weather forecasts to DCCMS include:

→ **Severe Weather Forecasting Demonstration Project.** Through the Severe Weather Forecasting Demonstration Project (SWFDP) DCCMS has access to a range of products including the Flash Flood Guidance System (FFGS), European Centre for Medium Range Weather Forecasts (ECMWF) and output from a 12km run of the UK unified model, run at SAWS for the whole of southern Africa. Data and information are distributed by SAWS, which acts as the Regional Meteorological Service Centre (RSMC) via a password-protected website. There are also data from a nowcasting system using the MSG 10.8 µm infrared band, and cold cloud duration is used to identify growing/mature/decaying thunderstorms. The UM model output through the SWFDP was noted by DCCMS as being useful for synoptic evaluations but only as a guide – this may be due to images for the whole southern domain being distributed and/or viewed. The FFGS is currently a very useful tool for issuing warnings about floods. It provides exceedance thresholds required for flash floods in different catchments. Currently DCCMS does not geolocate the data and overlay with other environmental or risk data, but .shp files and .csv data exist which will allow this to be developed. The information is produced via a streamflow model run in the US using satellite rainfall estimates. The model calculates the soil moisture and saturation levels and the amount of daily rainfall required to produce a flood. Spatial maps of the required amount of rainfall are distributed and it is left to the forecasters to decide on the risk of exceeding that threshold, and hence whether to issue a warning. Station data delivered over the GTS are used to correct the rainfall estimates from satellite, but this could be improved using more local data.

→ **ECMWF short-range forecasts**. Whilst these forecasts can be accessed via the SWFDP website and PUMA system, there is also a direct login option to the ECMWF website. Here it is possible to download meteograms giving the ensemble forecast for individual stations. The following NWP (Numerical Weather Prediction) model forecasts are also provided: ECMWF 2.5/1.0, ECMWF East/West 1.0, UKMO (UK Met office) 2.5/3.0.

→ The **Global Forecasting System (GFS)** is a weather model run by the National Centres for Environmental Prediction (NCEP) and produces global forecasts at 28km for the first 7 days. Forecasts are also produced at a lower resolution out to 14 days. These data are freely available and widely distributed. DCCMS currently accesses these data on a regular basis as part of their daily forecast discussions, through the University of Wyoming website (http://weather.uwyo.edu/models/fcst/gfs003.html). The WXMAPS website (http://wxmaps.org/pix/af.fcst.html) provides useful visualisations of the GFS data and allows the forecasters to see easily the forecasted dynamical and diagnostic attributes of the forecast.

→ **UKMO** are operationalizing a website (funded through their VCP programme) to distribute a number of products which will be useful for forecasting: a 4.4.km UM forecast for East Africa, the southern boundary of which will be just south of southern Malawi. DCCMS are currently not getting ATDnet data (measures of lightning strikes which indicate severe weather and convective cloud development) due to a technical problem, but this will be made available through the new VCP website. The accuracy of the lightning data (which is used for nowcasting and identifying developing weather systems) through ATDnet may be limited, but DCCMS are also going to test installation of a local lightning detection system (funded through the UNDP-managed LDCF project).

→ DCCMS do not run their own **NWP model**, though they have experimented with WRF and COSMO. Currently through the UNDP-managed LDCF project they are installing the computational facilities to run these models. However it is to be seen how high a skill these models will demonstrate; this assessment needs to be undertaken once the model(s) are set up and running. Additional constraints to getting this system running include the limited bandwidth DCCMS currently has – running these models requires downloading potentially gigabytes of initial and boundary condition data each day.

→ An additional model that can be considered for NWP purposes (but is not currently used) is the **CCAM** model run by the Council for Scientific and Industrial research (CSIR) in South Africa. This is a stretched grid model (low resolution at far field, high resolution close to area of interest), and also runs in seasonal mode – thereby able to produce seamless forecasts between the weather and seasonal forecasts.

2.1.5 Seasonal forecasts

Currently DCCMS engages with the Southern Africa Regional Climate Outlook Forum (SARCOF) initiative, through which it produces a seasonal forecast. The seasonal forecast is based on statistical models (COF tool below) that it develops through this process, and does not use the available dynamical seasonal forecasts available through ECMWF, CFS, UKMO and CCAM. Additionally it does not currently use the statistical CPT tool (developed by the IRI at Columbia University), which is available to support the SARCOF process. All of these forecasts are detailed below, recognising that most are not currently used.

→ **The Geo Climate Outlook Forum (GeoCOF) tool**. Observed SSTs are used to make forecasts, which are converted (through a subjective process) into categorical forecasts used for dissemination by SARCOF and nationally. This tool works through the following procedure:
- Use a K-means clustering to identify homogeneous rainfall zones, or define manually (these can be based on any rainfall index but usually seasonal mean rainfall is used). Based on 30 years of data;
- Correlate each zone time series with global SSTs and identify statistically significant correlations.
- Develop regression model with statistically significant SST areas as predictors for rainfall (or other) index as the predictand. Models are tested for a validation period (not used for training).

→ **Climate Prediction Tool (CPT)**. Not currently utilised, though the tool is endorsed by WMO and SADC. Indications from DCCMS was that it was perceived as either too complicated to understand, or perhaps the steps are not as intuitive or visualised in comparison to the COF tool. This tool does however allow for a downscaling of GCM (dynamical)- based forecasts through a MOS approach, and has the advantage that it is based on PCs of SST, therefore minimising the potential for developing forecast models based on small areas of significant SST correlation which might be random (one possible problem with the GeoCOF tool).

→ **ECMWF seasonal forecasts**. The ECMWF (and all dynamical seasonal forecasts) are not currently utilised by DCCMS. However there are indications that there might be accessible skill in these forecasts as demonstrated by the studies for nearby African regions, and these forecasts can be accessed through the ECMWF website.

→ Seasonal forecasts from the National Oceanic and Atmospheric Administration (NOAA) **Climate Prediction Centre (CPC)** are also not currently utilised though are also available through NOAA websites.

→ **UK Meteorological Office GloSEA** seasonal forecasts. The GloSEA seasonal forecasts run by UKMO are also available for southern Africa and several authors have assessed their skill over the region. Landman and co-authors compared the skill of the raw GCM rainfall with a MOS downscaled output from the same model and found improvements in skill for some regions. Over Mozambique Arlindo Meque (through a fellowship with UKMO) demonstrated that a MOS type approach significantly improved the skill of rainfall predictions during the early summer season (September to November), a critical time for agriculture. Additionally he found that the GloSEA4 system accurately predicted the onset of the rainfall season, a very important piece of information which farmers can use to decide when to plant.

→ **CCAM model run by CSIR in Pretoria**. The stretched grid CCAM model run by CSIR can be run both as a weather forecast and seasonal forecast model. These data can be downloaded with permission of the CSIR.

2.1.6 Human resources and current capabilities to derive tailored products

General information on DCCMS management and personnel organisation is found in UKMO (2013). Especially important is to note the gap is high between senior and junior staff in terms of skills, resulting in many senior staff taking on several roles. Additionally, most junior technical staff do not hold relevant postgraduate qualifications. However, enthusiasm to learn new skills is high, especially around programming and producing tailored information products.

DCCMS have the mandate to issue flash flood warnings (i.e., warnings with little lead time), whereas DWR are mandated to issue general flood warnings. This may reflect the types of data and information each has access to – DWR have access to limited automatic hydrological gauge data that is not always automatically relayed to HQ, which makes the real time monitoring of water levels very difficult. On the other hand DCCMS can see convective storm development via MSG imagery and they have access to the FFGS, which provides a reasonably well-defined mechanism and approach for issuing flash flood warnings.

Currently DWR are given expected values of rainfall for station locations from DCCMS. These data are not interpolated to other areas, though this would be possible if a joint satellite - rain gauge product is developed that can be implemented in real time. Usually DWR are only sent rainfall estimates when they exceed a certain value (e.g., 30mm). This is risky as it is a subjective choice and responses may not be triggered as in the recent floods. This situation is currently being reviewed.

It is clear that DoDMA, MinAg, DWR and DCCMS need to work together more to share data and information. The DCCMS website allows access to the latest forecasts and agrometeorological bulletins. These forecasts are disseminated through email to radio stations, NGOs and communities. Severe weather warnings are also issued, including for tropical cyclones. DCCMS indicated that mobile phones (SMS alerts etc.) are not used much for communicating forecasts, but the Red Cross do disseminate to communities after receiving the forecast from DCCMS.

2.2 Current status of the hydrological observing and forecasting systems operated by DWR

2.2.1 Hydrological observing systems

A surface water monitoring system already exists, divided into thirteen hydrometric districts, and a 2011 survey by Aurecon (2011)[24] (see Figure 9) concluded that of the 303 hydrometric monitoring stations in this network, 164 were closed, and only 31 were still of good operational quality. Further important operational aspects include:

- Five stations exist to monitor the height of Lake Malawi.
- Surface water monitoring is done manually, and data is mailed in to the DWRM.
    - At key points, observers phone in readings where the water exceeds certain threshold values. However, this lack of real-time information hinders rapid-response flood EWS.
- Groundwater monitoring is extremely low, with monitoring boreholes failing to keep up with the proliferation of extraction boreholes.
- Long term data from flow 144 gauging stations is stored in the HYDSTRA database.
    - Records extend from 1948 to present
    - There is a high incidence of missing data, ranging up to 94%

24 Aurecon (2011). Consultancy services for establishment of water resources monitoring system – Situation and Needs Assessment Report. Report No 03/106334.

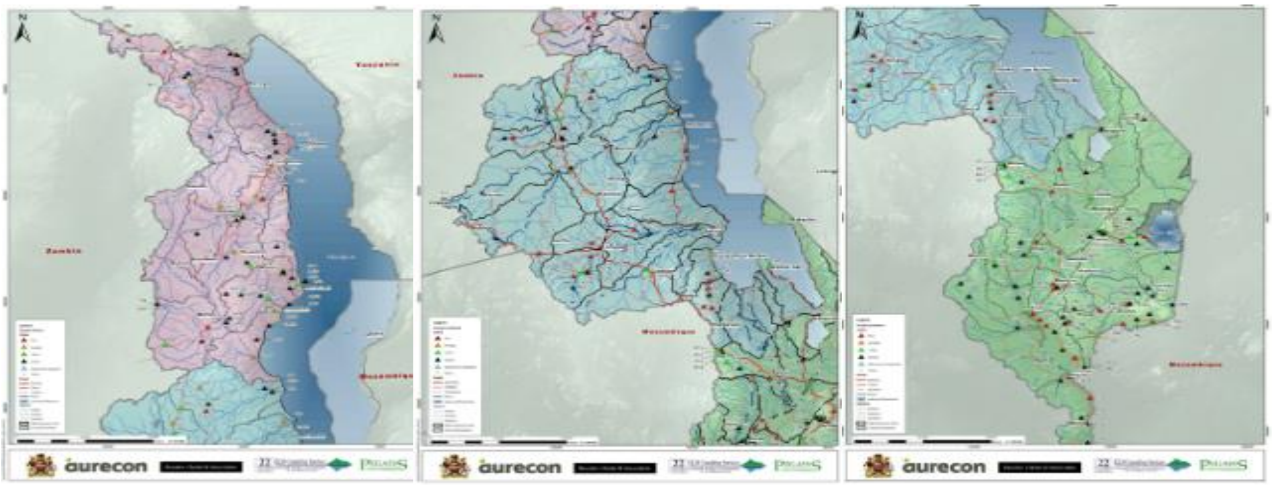

Figure 9: Status of hydrological gauging stations in the north, central and southern regions. *Source*: *Aurecon 2011.*

2.2.2 Hydrological modelling and data assimilation

Whilst the current hydrological monitoring and predictive capacity of the country is relatively low, significant investment is being made available through the SRBMP for the Shire river basin. The UNDP-managed LDCF project will provide flow and river height measurement infrastructure for key rivers in districts not covered by the SRBMP. Whilst the majority of central data management and hydrological modelling capacity building and infrastructure will be provided by the SRBMP, the integration of observations, development of modelling capabilities and forecasts, and flood hazard mapping for other basins, remain to be undertaken. An example of the type of flood risk assessment needed for other rivers and lakeshore areas is provided in Figure 10 (Atkins 2012[25]). Note, that producing these maps requires well-calibrated hydraulic models (good quality flow observations and rating curves for each river), as well as accurate digital elevation models (DEMs) derived from satellite (e.g. SRTM) or aircraft LIDAR measurements.

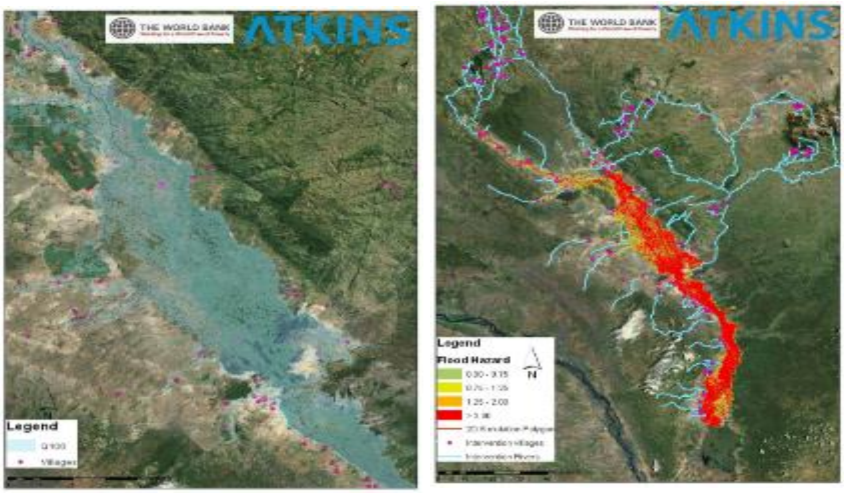

Figure 10: **Example of 1 in 100 year flood inundation (left) and hazard (right) maps with vulnerable villages in the Shire river. *Source:*** *Atkins 2012.*

2.2.3 Operational priority funding for the establishment of a functioning network

Aurecon (2011) clearly identify operational priorities for funding, which are needed to provide the basic system functions on which can be built increased capacity and further equipment/systems. These priorities include the following (note that many of these funding priorities also apply to the operations and maintenance of meteorological stations):

- Many gauge readers have stopped work and consequently no data are being collected at many stations because they are not paid honoraria;
- A minimum number of staff are required per district to undertake the work, but this minimum is not

25 Atkins (2012) Shire Integrated Flood Risk Management Project Volume I - Final Report. pp 106.

currently met;

- Equipment for transportation, survey, safety, flow gauging, district offices and general maintenance at stations is recommended in order for the teams to operate effectively;
- Transport is a priority, so it is recommended to acquire new vehicles or undertake maintenance on existing vehicles first. One 4x4 and one motorcycle are needed per district. Sufficient budget should also be set aside for fuel and maintenance to operate these vehicles;
- The tools and consumable goods required for everyday maintenance of stations such as gauge plates, angle irons, bolts and nuts, paint, cement, slashers, hammers, pangas, shovels, picks, wheel barrows, shifting spanners, spirit levels are needed for each district;
- A program of station maintenance should then be started using the transport, survey equipment, station maintenance consumables and tools procured above;
- Re-rate all the stations for low-flows;
- Once all the above issues have been addressed, it is recommended to begin refurbishing the high flow gauging equipment and network. This includes refurbishing all the cableways and installing new cableways where necessary. A program of re-rating all the stations for high flows should then be undertaken so that the measurement of high flows can be at a high level of confidence.

Whilst NGOs/CSOs are involved in localised EWS activities (particularly working with local communities), the primary governmental institutions involved in generating, communicating and using EWS messages and warnings are: Department of Climate Change and Meteorological Services (**DCCMS),** The Department of Water Resources (**DWR),** Department of Disaster Management Affairs **(DoDMA),** and the Malawi Vulnerability Assessment Committee **(MVAC).**

2.3 Description of Government of Malawi Departments and Capacities

2.3.1 Department of Climate Change and Meteorological Services (DCCMS)

The Department of Climate Change and Meteorological Services (**DCCMS)** in the Ministry of Environment and Climate Change Management (MECCM) is the national agency charged with monitoring weather and changing climatic conditions, and providing forecasts, seasonal outlooks and long-term climate change planning instruments for all national partners. The department has a low vacancy rate, and a number of qualified staff, but lacks the infrastructure and technology to fully realise its mandate. In terms of the Malawi Disaster Risk Reduction Framework (MDRRF), DCCMS is responsible for forecasts and intense storm warnings, as well as for the collection and management of weather data.

The DCCMS has grown in the coverage of its network as well as the number of its mandates since establishment. The mission of the department is to provide reliable, responsive and high quality weather and climate services to meet national, regional and international obligations through timely dissemination of accurate and up-to-date data and information for socio-economic development. Thus, its mandate is to monitor, predict and provide information on weather, climate and climate change that would contribute towards the socio-economic development of the country. The objectives of the department as derived from its mandates are as follows:

→ To monitor, analyse and predict weather and climate. The thrust of this objective is to ensure that weather forecasts are produced for early warning purposes. This information is vital for advisory on natural disaster early warnings for the development of climate change adaptation strategies;

→ To provide weather and climate data and information for various socio-economic sectors such as Aviation, Agriculture, Water, Marine, Construction, Insurance, Tourism, Health, and Sports and Recreation;

→ To carry out research and development that would improve quality of weather and climate data and information for the general public. The main focus is to carry out research for all aspects of meteorology that can be disseminated to *inter alia* the general public through mass media;

→ To establish and maintain a well-equipped network of meteorological stations. This objective intends to ensure that meteorological data and information is reliable, timely and up to date;

→ To strengthen the policy and regulatory framework on climate change, climate and weather.

Accordingly DCCMS have been involved in the production of a National Meteorological Policy (2014)[26], which will help the country in the following ways:

- Improving planning, programming and financing of climate change activities in Malawi;
- Provision of meteorological information that would support various institutions to access resources from a variety of global funding agencies;
- Ensuring that the relevant sectors are targeted and there is early preparedness by the key departments concerned;
- Assisting in monitoring, evaluation, and reporting on progress made with regard to climate change interventions and meteorological services in Malawi;
- Assisting on how cross cutting issues can be addressed in a systematic manner in relation to climate change;
- Facilitating stakeholder coordination in climate change interventions;
- Creating enabling environments for public participation in the generation and utilisation of meteorological data;
- Enabling provision of reliable, responsive, high quality, timely and up-to date climate services;
- Improving relevance of meteorological information to various sectors; and
- Improving access to meteorological information.

The DCCMS includes four divisions which oversee and guide a number of offices, namely: i) Management and Support Division which is responsible for policy guidance on both technical and administrative matters, and oversees the Human Resource Management, Finance, and Administration offices; ii) Monitoring and Prediction System Division, which is responsible for planning and co-coordinating weather and climate monitoring and forecasting, and oversees the National Forecasting Observatory; iii) Meteorological Engineering and Communications Division, which is responsible for Station Networks maintenance, meteorological engineering and information, and communication services; and iv) Weather, Climate and Climate Change and Research Services Division, which is responsible for planning general public and commercial weather and climate services, and oversees the Aeronautical Meteorological, Agro-meteorological, Climate services, Public Weather Services, climate change issues and research services.

The weather and climate observation network – managed by the DCCMS Headquarters (HQ) through three regional centers (North, Central and South) – comprises: i) 18 full synoptic meteorological stations, where data is collected four times daily between 5am and 5pm and provided to regional centres over the phone; ii) 4 main aviation synoptic stations which report on an hourly basis; iii) 28 AWSs, which send daily updates using the Airtel GSM network directly to DCCMS HQ; iv) 43 rainfall logging gauges, where data is collected on daily basis; v) 53 volunteer observing stations, where data is observed daily but collected on a 10 day basis as well as on a monthly basis; vi) one satellite receiving station (METEOSAT Second Generation) at DCCMS in Blantyre, which receives images every 15 minutes; and vii) two obsolete and non-functional radars at Lilongwe and Chileka Airport stations. Stations at Chileka and Lilongwe International Airports are open 24 hours daily.

Each regional center (North, Central and South) relays the observed data to DCCMS headquarters in Blantyre mainly via telephone and in some cases via email. DCCMS then archives the data in Excel spreadsheets[27] and relays some of the data through the WMO GMTS centre in Pretoria, South Africa. Observations at 22 main synoptic stations are done by fully trained Meteorological Assistants, who initially undergo a six-month weather observations training course as well as on-the-job training and refresher courses from time to time. DCCMS has 5 technicians and engineers that maintain the various pieces of equipment in the observation network.

2.3.2 Department of Water Resources (DWR)

The Department of Water Resources (DWR) in the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) is mandated with the management of ground- and surface water in the country. The capacity of the department is currently low, but it is receiving considerable support through two investment programmes funded by the AfDB and the World Bank respectively. These programmes are expected to address some of the capacity and infrastructural constraints facing DWR. Under the MDRRF, DWR is responsible for the issuing of flood warnings.

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26 National Meteorological Policy. Draft White Paper. Ministry of Natural Resources Mining and Environment. August 2014.
27DCCMS HQ prints this out and keeps printouts for 3 months.

DWR is responsible for the development and management of water resources in the country for use by all sectors. This includes management of surface water resources, groundwater, water quality, administration of the Water Resources Act, and implementing regional and international agreements and obligations on trans-boundary water courses. The Department is organized into four Divisions: Surface Water, Ground Water, Water Quality Services and the Water Resources Board Secretariat.

The Surface Water Division is responsible for the monitoring, assessment, conservation, management and development of the surface water resources. This includes responsibility over the monitoring network and storage and dissemination of data to users. The Surface Water Division is structured into three regions and thirteen districts. The three regions coincide with the three main governmental regions in Malawi: North, Central and South. The districts are divided along hydrological and logistical boundaries, and generally can include more than one governmental district. Two central district offices are in charge of two districts each: Blantyre district office manages both Blantyre and Zomba districts, while Mzuzu district office manages Mzimba and Nkhata Bay districts. Each district office has a team who is responsible for the stations in their area.

The Surface Water Division of DWR under is responsible for collecting hydrological data (principally river gauge and lake level data) and developing and issuing flood warnings. The Hydrology section of the Surface Water Division is responsible for water resources assessments, maintaining the hydrometric network, and offering hydrological advisory services. In addition, MoAIWD has responsibilities to support any necessary emergency provision of water supplies for the public affected by floods, to support the rehabilitation of design inputs to structures damaged by floods, and indirectly to make necessary technical inputs to catchment management and long-term flood mitigation efforts. The DWR collects river flow data on a daily to monthly basis through a network of 158 manual hydrometric stations (see Section 3 for the location and operational status of existing stations)(Atkins 2012).[28] This includes five stations to monitor the levels of Lake Malawi. There are an additional six hydrological monitoring stations, which were installed in the late 1990s under the SADC Hydrological Cycle Observing System (HYCOS) Phase 1 Project and are equipped with automatic data collection platforms. Long-term data from 144 of these gauging stations are stored in the MoAIWD's HYDSTRA database. Approximately 94% requires re-coding as it was encoded in obsolete formats.

Surface water monitoring is done manually from these stations and the data is sent to the DWR. At key stations, observers use mobile phones, telephone and radio to transmit readings to the Chief Hydrological Officer in Lilongwe, when water exceeds threshold values. Gauge readers (personnel) must therefore be "at station" close to full time before and during flood events. The observers must have a charged phone, credit and adequate phone signal for this to work. Gauge reading is hazardous, particularly when it is dark and raining, and gauge readers presently receive very little remuneration for their efforts. These factors in themselves represent a significant risk to effective flood warning (Atkins 2012)[29]. Furthermore, the lack of real-time information hinders the functioning of a rapid-response flood EWS.

Whilst the current hydrological monitoring and predictive capacity of the country is relatively low, significant investment is being made available by the World Bank through the Shire River Basin Management Project (SRBMP) and Integrated Flood Risk Management Strategy (IFRMS), namely through i) providing flood risk assessment tools, including the development of a hydrodynamic modelling framework; ii) enhancing flood preparedness and response through development of a flood forecasting and early warning system for the Shire Basin (including 8 of Malawi's identified 15 disaster prone districts, namely Nsjane, Chikwawa, Blantyre, Zomba, Machinga, Mangochi, Balaka and Ntcheu as well as other Shire Basin districts, Thyolo, Mwanza and Chiradzulu; iii) building capacity for flood risk management in Malawi, including institutional development and capacity building; and iv) reducing flood risk and building resilience in Malawi through structural interventions such as check dams, gabions, sand bags, catchment improvement and food and grain stores. Therefore, SRBMP and IFRMS will include central data management and hydrological capacity building at a national level as well as the installation of automated hydrological stations along key rivers in the Shire River Basin. This will include the procurement and installation of 15 new/refurbished river level gauges equipped with telemetry via Meteosat (and manual observation), 15 automatic rainfall gauges equipped with telemetry via Meteosat, and one new Meteosat ground station receiver at the DWR in Lilongwe. Furthermore, the project will upgrade the existing Meteosat ground station at the DCCMS in Blantyre, and build capacity to use and maintain the new equipment (See section 3 for the proposed project sites for automated river and rainfall gauge installation under the SRBMP and IFRMS).

During flooding and severe weather events, river levels are continuously monitored and the observed data are sent – by DWR gauge readers – to the flood officer at the headquarters of the DWR in Lilongwe (see

28Atkins 2012. Appendix E. Institutional Capacity Development Building
29Atkins 2012. Appendix E. Institutional Capacity Development Building

Figure 11). Depending on the water levels and the outlook of a weather forecast of a catchment area provided by DCCMS, a flood warning will be issued by DWR. As soon as precipitation values of more than 50 mm are observed at one of the meteorological stations, a warning message is sent to the DWR by DCCMS. This procedure has proved to be ineffective, particularly over public holidays, weekends and during the night as a result of different working times between DCCMS and DWR. For example, in certain cases during heavy rains there are no individuals to issue flood warnings. There is a need for the roles and the responsibilities of DWR and DCCMS to be reviewed with regards to issuing flood warnings. There is also a need for DCCMS and DWR to collaborate and work together for the management and operation of automatic and manual stations, data collection, data exchange, data processing, data analysis, water resource assessment and warnings, and communication mechanisms – in particular for flood, drought and severe weather risks – as well as the WMO flash flood guidance procedures.

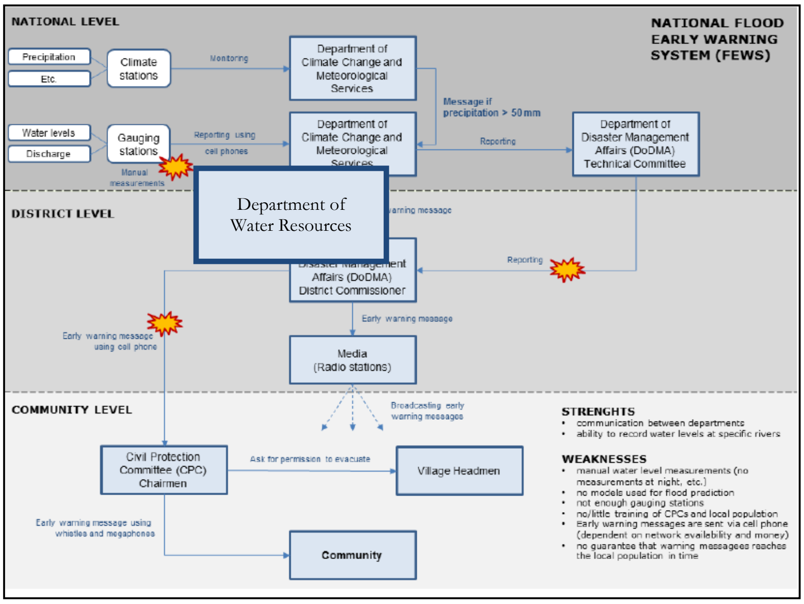

Figure 11.The Malawi national Flood Early Warning System (FEWS) which is maintained and operated jointly by the DCCMS, DWR and DoDMA. Red and yellow flash points represent potential faults in the system according to the interviewees.[30]

2.3.3 Department of Disaster Management Affairs (DoDMA)

Department of Disaster Management Affairs **(DoDMA)**, a department of the Office of the President and Cabinet, is mandated with co-ordinating disaster risk reduction, relief and early warning systems in the country. The organisation presently lacks capacity to fill this mandate, and requires considerable training and infrastructural investment. DoDMA is the key agency for coordinating responses to disasters, and for dissemination of warnings once they have been generated from the national centre.

DoDMA is a Government agency, which is mandated to coordinate and oversee disaster risk management programs and projects being implemented by various stakeholders in the country with the aim to build and improve resilience of households, communities and the nation to disaster risks. The Department was established in 1994 by the DPR Act (1991), which was enacted after the Phalombe floods catastrophe to coordinate and implement measures to alleviate effects of disasters. The Act emphasized establishing the institutional functions required for the coordination of disaster risk management programmes and activities in the country, comprising: i) the Secretary and Commissioner for Disaster Management Affairs in the Department of Disaster Management Affairs (DoDMA); and ii) the National Disaster Preparedness and Relief Committee (NDPRC), Civil Protection Committees (CPCs).

DoDMA acts as the mouthpiece through which weather related early warning messages are announced by the DWR and DCCMS. The NDPRC provides policy level guidance to DoDMA and is responsible for coordinating the implementation of measures to alleviate disasters, while the Civil Protection Committees constitute the

30Cooperazioneinternazionale COOPI. 2012. Consultancy to assess the current hazard mapping capacity and effectiveness of scenario based tools for long term planning mechanism.

frontline decentralized institutions at the Area and Village levels (ACPC and VCPC), providing community level coordination of preliminary disaster impact assessments in the affected communities before any relief operations are initiated. These institutions also serve as entry points for any dissemination of disaster early warning information at the community level.

The Malawi Vulnerability Assessment Committee (MVAC) is a coalition of government and non-government organisations that provide regular drought vulnerability updates in order to coordinate relief efforts in the country. The vulnerability warnings are obtained through a collaborative method, integrating information from FEWSNet, DCCMS, and a variety of community indicators gathered through NGO structures.

2.3.4 Department of Agricultural Extension Services (DAES)

The Department of Agricultural Extension Services (DAES) within the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) is focused on providing extension services to farmers in all districts of Malawi. In this regard providing relevant and timely information for extension workers is a key requirement. One of their key decisions where weather/climate information plays a role is to know when to promote irrigation farming. Presently farmers tend to use indigenous knowledge for making farm management decisions though there is currently a limited use/awareness of seasonal forecasts. The monitoring information provided by AWS can be very useful, but currently these data are not shared with DAES, which restricts their ability to identify areas facing high risks.

DAES are involved in the GFCS pilot in Balaka and stress the need to choose traditional authorities in areas with high weather risk. In their experience there needs to be a balance between using ICT technologies and traditional means of communicating with farmers; successfully using mobile phones means that farmers need to value the information, otherwise they will not want to buy the airtime. Radio is an important communication medium and packaging information and designing programmes is a core function for DAES. Ideally they use community radio and part of their budget is used to buy time for programmes. Print media and publications are another important means of dissemination. Both radio and TV stations need sellable material and hence packaging of information and content needs careful consideration and planning. DAES have personnel who develop jingles and other communications in order to build interest before information programs are aired (e.g., before ‘Good Morning Malawi,’ which is a prime slot).

Mobile vans are also used in districts to show educational videos; where shows have expert content, an expert is made available to explain it. Agricultural Resource Centres are another form of outreach that provide a permanent environment for education and could be linked to district Climate Centres. Such facilities help to engage with commonly held ideas: e.g., that the weather and climate are determined by deforestation. Such collaborations could ensure that materials are co-developed by extension workers and weather/climate experts. Other options for dissemination include boards at local offices which carry weather information, as well as using Climate Centres to answer questions, such as what does an increase in temperature and/or rainfall mean for planting and soil conditions? Currently DAES is also working with Plantwise to provide plant health services; a farmer brings a sick plant to the local extension officer who uploads the information to a database. This information is used to develop materials and monitoring of potential outbreaks of pests and diseases.

The ESOKO platform is used to send messages to farmers at a current cost of 3m MKw per year, part of a subscription paid by MoAIWD to reach 120,000 farmers. Within this system there are options to have farmers request information (e.g. should I plant, irrigate etc.), but the farmer needs to pay for SMS and hence needs to value the quality of the information. Working through a consortium known as the National Agricultural Content Development Committee for ICT extension, which includes ESOKO and the National Association of Small holder Farmers (NASFAM), information is sent to farmers through a 3-2-1 service funded by Human Network International and the Catholic Relief Services, who pay the provider Airtel. This enables every Airtel subscriber to be able to download 2 messages free per month. On the other hand, the ESOKO platform, much like the FrontlineSMS system being developed by NASFAM, is also a pull/targeted service, which can respond to questions and targeted requests from farmers (based on a database of numbers and activities such as which crops are being planted, which livestock kept, etc).

DAES has had limited success approaching private sponsors for programs, and these tended to work where the private entity has a self interest – e.g., Bank of Malawi wanting to help farmers who have taken out loans.

2.3.5 Department of Fisheries (DoF)

The DoF is based within MoAIWD and is focused on providing support to two main sectors: aquaculture and capture fisheries, with a total of approximately 60,000 people involved in capture fishing nationwide and over 500,000 people indirectly involved in fish processing, fish marketing, boat building and engine repair. The sub-sector is largely artisanal in nature, except that in Lake Malawi there are also semi-commercial and commercial fisheries, made up of pair trawlers and larger stern trawlers respectively. The small-scale sector produces 90% of the annual fish production while the rest is landed by the industrial sector. The total production from capture farming varies from year to year with an average of 70,000 tonnes, though the catch of Tilapia over southern Lake Malawi has been declining (from 12,000 to 3,000 tonnes), with a dominance of smaller fish than previously caught.

DoF work includes supporting fishers and helping them to reduce their vulnerability through programs focused on safety at sea (adapted for lake conditions), as well as for diversifying livelihoods (including for fish processors, many of which are women). The department closely collaborates with the Marine Police to ensure that fishing quotas are adhered to. Mangochi, Salima and Nkhotakota districts have both small- and large-scale operators, although the majority are in Mangochi. These districts have large areas that are shallow, hence fishers go further to reach deeper areas since the shallower areas are generally overfished. The long distance to the deeper areas puts lives of the fishers at risk, and without prior knowledge about the weather, they experience accidents while on the lake.

Currently the safety at sea program runs courses in fishing communities on use of lifejackets and procedures if caught at sea in severe weather. There is some use of the forecasts distributed by DCCMS, but these contain little information of use to fishing activities (see Appendix B), and fishers tend to rely on indigenous ways and local knowledge of the weather. Forecasts are broadcast on local radio and through community outreach units based in Mangochi, Nkhotakota and Salima, with forecasts of Mwera winds and severe weather of most interest to fishers, whereas rain and temperature forecasts are important for those involved in fish processing and outdoor drying activities.

3 Current gaps and needs: infrastructure, processes and institutional capacity needed to deliver priority requirements

A survey of government officials from Agriculture, Energy, Environment, Civil Aviation, Water Management and Disaster Risk Management sectors suggested that the level of services provided by DCCMS for disaster risk management and early warning, agriculture and aviation was better than for sectors such as water resources, lakes and rivers, road and rail, energy production, construction and tourism (Venäläinen et al 2015).[31] This clearly suggests room for improvement in many sectors that could be served by climate information and warnings. Twenty four hour warnings of rainfall intensity have also been identified as a clear need.

In discussions with the government of Malawi (GoM) and stakeholders (both during the consultation workshop in Malawi and in separate meetings), three primary sectors were identified where improvements in climate information and Early Warning Systems were agreed to be beneficial to the public, already have pilot or small-scale activities being undertaken in the field and have the potential for scaling up to wider regions and districts. Two sectors are agriculturally based – crops/livestock and lake-based fishery activities, whilst the third is expansion of the flood and water-resource early warning activities undertaken as part of the SRBMP. All three sectors are important to the economy of Malawi and for the sustainability of low-income livelihoods.

3.1 Agriculture – land based crops and livestock

The use of weather and seasonal climate information by farmers and those undertaking crop and livestock management activities is currently minimal for a variety of reasons, including the timing when information/advisories are received; the content of the information/advisories (i.e., average rainfall change for a seasonal forecast, as opposed to information on onset, cessation and seasonal duration); whether the

31 Ari Venäläinen, Karoliina Pilli-Sihvola, Heikki Tuomenvirta, Reija Ruuhela, Elina Kululanga, Lucy Mtilatila, Joseph Kanyanga & Jacob Nkomoki (2015): Analysis of the meteorological capacity for early warnings in Malawi and Zambia, Climate and Development, DOI: 10.1080/17565529.2015.1034229

information is applicable for the local environment; and the ability to interpret information (i.e., translation to local languages, scientific concepts and tying in with local knowledge).

Additional complications arise due to the scientific limitations of forecasting and being able to convey these concepts in ways that are easy to understand (e.g., a probabilistic seasonal forecast). In Malawi the use of weather and seasonal forecasts is limited for many of the above reasons, which is why NASFAM (see section 4.8), an association for small scale farmers and agri-businesses, as well as the Department of Agricultural Extension Services (DAES), does not include this type of information in its advisories.

Nevertheless, with careful application and use, including training and interpretation of forecasts for different contexts, it has been demonstrated that seasonal forecasts can be useful for planning cropping activities.[32] The pilot intervention being undertaken by the Norwegian-funded GFCS project (see section 4.11) in the drought-prone district of Balaka (with expansion to Nsanje) is developing tailored products for agriculture (including weather and climate information) and trialing their use to support small-scale farmers in the district. Discussions with the World Food Programme (WFP) and DAES, who are implementing the GFCS pilot actions on the ground, emphasized the need to first identify those communities most at risk and in need of weather/climate information. Within a district there may be a wide difference in risk depending on local circumstances (including social safety nets and community leaders) and the environment/climate. The approach undertaken by GFCS is therefore to have a detailed screening (using existing risk and vulnerability assessments when available as well as community consultations) before identifying where to situate weather stations, and engaging in co-developing the tailored products. The co-development process further engages communities to understand local customs and combine indigenous and scientific knowledge, as well as building local capacity (through identified leaders and/or observers) to undertake basic analyses of local climate data (trained by University of Reading, UK). This helps to build local capacity to interpret and understand the scientifically based forecasts.

Discussions with DCCMS (the government lead in the GFCS project) and DoDMA highlighted the priority districts that are known to be food insecure (based on MVAC figures - see section 1 of this report) and where an expansion of the GFCS approach would be beneficial. Fourteen of these districts were identified for placement of AWS to provide additional drought and tailored agricultural weather/climate monitoring capabilities and include: Karonga, Lilongwe, Salima, Dedza, Mzimba, Phalombe, Zomba. The farmer extension services will be used to raise awareness and promote adoption and use of the products among the farmers in the targeted communities.

3.1.1 Needs for promoting the uptake and adoption of weather/climate information by agricultural communities

An approach on how to promote the uptake and adoption of weather/climate information by targeted communities, was discussed and agreed with DAES and involves:

- Conducting sensitization meetings for DAES staff in the implementing districts
- Conducting village level sensitization meetings
- Making public announcements using mobile vans
- Conducting road shows in implementing districts
- Production and airing of radio and TV programs, comedies and jingles where feasible
- Production and dissemination of print materials such as leaflets, posters, flyers and brochures
- Sending text and audio messages to farmers and staff using mobile platforms such as ESOKO and 3-2-1
- Using Agricultural Resource Centres as information hubs with access to information from weather stations and provision of print materials covering weather and climate related issues, in collaboration with Climate Centres where possible

Training DAES extension workers and farmers on interpretation of weather and climate data would enable the DAES to continue providing weather and climate related information to the farmers even after phasing out of the project. DAES would also incorporate weather and climate related information during production and airing of radio and TV programs. In addition, since DAES will develop print materials it is expected that DAES will continue printing distributing weather and climate change related information to the farmers, even after the project is phased out, through the Agricultural Resource Centres as well as during farmer meetings.

32 In a study of smallholder farmers in four villages in Zimbabwe (2002/03 and 2003/04 growing seasons, n = 500), of the 75% of farmers who reported receiving seasonal forecast information, 57% reported changing time of planting and cultivation as a response (Patt et al., 2005). This was also observed for farmers that participated in training on the uncertainty that surrounds climate forecasting. Based on elicited crop yields, normalized relative to elicited historic ranges, farmers who reported changing management based on forecast information experienced a 19% yield benefit in 2003/04

The number of extension workers and farmers, which can be reached in each of the fourteen proposed target districts, are given in Table 5, and include more than half the national population of each.

DISTRICT (RDP)	NO OF EPAs	NUMBER OF FARM FAMILIES	Number of sections	Number of extension workers in positions
Karonga	6	71813	51	37
Rumphi	7	47701	48	37
Mzimba central	13	177787	152	63
Mzimba North	9	106023		54
Nkhata- Bay	9	52389	64	44
Ntchisi	9	67617	48	33
Dowa	9	175425	99	74
Salima	7	102336	54	52
Ntcheu	7	159349	69	59
Dedza	10	197492	128	100
Lilongwe	19	430673	200	273
Zomba	9	238072	105	90
Chiradzulu	3	106157	44	42
Phalombe	6	102793	60	40
Chikwawa	6	107021	124	55
Total		**2,142,648**		**1,053**

Table 5: Number of Extension Planning Areas (EPAs), farm families, sections and extension workers in each district. National number of farm families: 4, 018, 087, extension staff: 1720. Extension farmer ratio: 1 extension worker to 2336 farm families

3.2 Fisheries

Fishing remains a dangerous occupation in Malawi. One of the basic constraints to improved safety is the fact that regulations covering construction and equipment exempt dugout canoes that contribute more than 90% of the catch. The number of fishing crafts on Lake Malawi has increased by 11% from 11,962 in 1999 to 13,282 in 2005. Currently, fishers are at a high risk of maritime accidents because the inshore stocks are depleted and are under increasing pressure to venture into offshore fishing to improve their returns at the expense of their safety. Small fishing units have traditionally been used in inshore waters until recently, when fishers have began to seek better returns by venturing further offshore because of the low fish catch rates experienced in inshore waters. These small-scale fishers have expanded their fishing zone to deep offshore waters (> 50m) to improve their returns but at the margins of their safety. This exposes fishermen to offshore extreme weather, with a greater reliance on being able to return to shore before inclement weather strikes (thus increasing the time requirements for advance warnings)[33]. Cases of accidents are on the increase especially during strong *mwera* and *mpoto* winds and are occasionally reported on local radio stations and print media every year. Such incidents are common among the small-scale fishers with small fishing crafts, which cannot withstand the strong winds. The use of inappropriate crafts and bad weather conditions seem to be the major contributing factors to the increased rate of inland water accidents. Currently DCCMS sends weather messages through national radio stations but these messages are not location specific and tailored to the needs of fishermen. Consequently, small-scale fishers rely on the traditional way of interpreting weather, which is usually not accurate. The development of accurate forecasts for fishers will require localised weather/wave information for lake Malawi (e.g. lake wind/wave buoys), accurate weather forecasts (produced by DCCMS e.g. through NWP models or MOS-based forecasts), and better nowcasting (e.g., through combining lightning detection systems as a proxy for radar with satellite data and other nowcasting tools).

33 Small-Scale Offshore Fisheries Technology Development Project. Policy Brief on Safety in Inland Waters. Small-scale Offshore Fisheries Technology Development Project P.O. Box 47. Monkey Bay

3.2.1 Current outreach to fishing communities

Extension services are currently based on training and scenarios whereby extension agents visit various beaches with fisheries extension messages mainly on fishing regulations like closed seasons, mesh size regulations, minimum table sizes of fish, gear restrictions and in some cases safety at sea. Among other duties, each extension worker is expected to do the following:

- Conduct meetings with Beach Village Committees and fishers within the minor strata – the proposed project area has 15 minor strata with 5 in each the districts of Mangochi, Salima and Nkhotakota;
- Display technologies during open or field days;
- Collect and process fish catch data;
- Prepare and submit monthly, quarterly and annual work plans;
- Prepare and submit monthly, quarterly and annual reports;
- Liaise with other development agencies to address needs of the fishing communities;
- Facilitate formation of beach village committees;
- Train beach village committees.

However there are gaps/problems with this kind of extension approach as follows:

- Some migrant fishers miss some of the messages. It is also difficult to reach out to some women fish processors and traders who do not attend such meetings as they are usually away to markets;
- Limited manpower (extension agents) to reach out to several fishing communities as some fishing areas do not have fish scouts whose role is to collect data. In such areas the extension agent does both the work of data collection and providing extension services;
- Limited resources such as fuel and motorbikes hamper effective and efficient delivery of extension services within the fishing communities; and
- Lack of refresher training opportunities for the newly recruited extension staff is affecting their work as they lack new extension methodologies and approaches that could be imparted to them.

3.2.2 Current methods of reaching out to fishers

- Community awareness campaigns through use of the Community Outreach Unit (COU) based at the Malawi College of Fisheries. The unit has two vans, though one needs repair and servicing, and can disseminate technical messages packaged by the Unit. The vans have audio visual aids and can show videos as training materials;
- Meetings with Beach Village Committees and traditional leaders organised by extension workers;
- Use of print media through brochures, leaflets, calendars, policy briefs, and quarterly newsletters (Usodzi wa Lero);
- Use of electronic media like Dzimwe and Nkhotakota community radios at a fee. The messages are developed and recorded at the COU; and
- Efforts are underway to develop a Fisheries department website.

3.2.3 Priority areas

Mangochi, Salima, Nkhata Bay and Nkhotakota districts have both small- and large-scale operators, although the majority are in Mangochi. Not including Nkhotakota, there are 6,787 fish processors/traders, out of which 3,888 are women, representing 57% of traders in the three districts. The districts have large areas that are shallow hence fishers move longer to reach deeper areas where they are currently preferred for good stocks of fish since the shallower areas are generally overfished. The long distance to the deeper areas puts lives of the fishers at risk, and, without proper knowledge about weather, they can experience accidents while on the lake.

3.3 Water Resource Authorities and those at risk of flooding

3.3.1 Integrated Flood Risk Management Plan

One of the key projects on which the GCF-funded project will build is the SRBMP, part of which is focused on the Integrated Flood Risk Management Plan (IFRMP). The IFRMP involves building capacity at DWR and DCCMS to use monitoring data (from AWS, satellites and hydrological gauges), as well as short-term weather forecasts, to forecast floods and water resources in the Shire Basin. This will be accomplished through the Operational Decision Support System (ODSS) being developed by the Danish Hydrological Institute (DHI) and partners. The ODSS project will create an integrated, short-term meteorological, hydrological and hydraulic flood forecasting and warning system, based on MIKE CUSTOMISED REALTIME and MIKE by DHI software suite. This water management system will help decision-makers issue early warnings (increasing lead times) and mitigate the adverse impacts of flooding, through better operational water management. It will also support sound decision-making related to optimal water use through dedicated scenario analyses.

Currently this system is being implemented only for the Shire river basin but has the potential to be extended to cover other basins in Malawi. The work in the Shire will be achieved through establishing the following (DHI 2014)[34]:

- A comprehensive multi-faceted, open, expandable and fully operational IT DSS platform;
- Comprehensive hydro-meteorological database and knowledge base system supporting multi-source data capture, temporal and spatial data processing and analysis, and visualisation capabilities;
- Fast and proven multi-disciplinary mathematical modelling tools, which accommodate production of best possible predictions for short-term and seasonal forecasting;
- Information and dissemination web-based platform supporting basin wide and community-oriented early warnings;
- Sustainable operational framework, including institutional workflow process guidelines, comprehensive education of staff to ensure competent operation and maintenance of all components of the ODSS System;
- Support to DWR in the procurement processes, including preparation of specifications and tender documents for all equipment, for establishing the ODSS;

3.3.2 Framework for developing an ODSS outside Shire river basin

This work undertaken for the Shire basin presents a unique opportunity to implement a similar integrated flood modelling system in additional river systems within Malawi and improve on the existing Flood early warning system in the central and northern areas, which only covers the high risk areas towards the lakeshore (as categorised by DoDMA – see sections 1 & 2 of this report), yet is largely dependent on catchment rainfall that falls in the upper reaches of each catchment. Expanding the ODSS to provide comprehensive modelling and decision support coverage for the whole of the river basins (including the upper catchments) will improve the accuracy of flood warnings, as well as allowing the water resources within a catchment to be modelled in greater detail, thereby providing more useful disaggregated information for water resource management.

The upper reaches of the main river systems in the north and central regions are found in neighbouring districts which themselves are categorised as low flood risk and have traditionally been neglected in terms of observing/monitoring equipment. The ODSS applied to the whole basin will allow a more holistic approach to flood forecasting, incorporating rainfall and flows from other districts in these areas. This is expected to improve significantly the forecasting of floods, as well as the modelling and monitoring of water resources in these areas, thereby improving information available for drought management, irrigation scheduling and related activities.

3.3.3 Needs for delivering ODSS for catchments in the north and central regions

The work required to extend the ODSS to other WRA in Malawi can be split into seven tasks:

- **Task 1**: Analyse the decisions to be supported using the ODSS System. This will ensure that relevant and adequate information and knowledge is gathered for a high quality development of the System including appropriate recognition of:
    - Client/stakeholder views, decision making requirements, and warning needs;
    - Proper account and utilisation of previous and on-going project information;
    - Review of available data provided by the client and suggestions for additional sources of information, which could help to enhance these. This will include review status of data collection network, data flow, management and access; and
    - Review and provide recommendations on other relevant potential data sources at various levels from other global experiences that can be adapted to Malawian context to improve the information content of services provided.

- **Task 2**: Develop an Integrated Visualization and Analysis Platform. This will ensure that a powerful Visualization and Analysis Platform (V&AP) is developed as an integral component of the ODSS System, to store, analyse, process and display of temporal and spatial data from ground-based monitoring networks, earth observation data and produced forecast and early warning information.

- **Task 3**: Improve Hydro-Meteorological Forecasting. This will ensure that the System will be able to produce reliable and timely weather- hydrological-, flood- and seasonal forecasts based on the improved hydro- meteorological data (established by a parallel consultancy service), including skills

34 DHI (2014) Operational Decision Support System through Enhanced Hydro- Meteorological Services, Inception Report.

to evaluate the performance of the forecasts including uncertainty estimates.

- **Task 4**: Design and Deploy System for Decision Support. This will ensure that a multi-functional system is able to provide real-time and planning oriented forecasts and early warnings for a range of purposes, including short-term flood, agricultural support (short-term and seasonal forecasting); water related infrastructure operations; drought seasonal warnings for agricultural management; and lake/wetland management. The System will avail innovative knowledge products and support appropriate dissemination of information through various means, including web-portals, cell broadcasting and other media.
- **Task 5**: Dissemination Systems. This will ensure that user groups are established to promote systematic development, use, and refinement of each of the systems components developed. It will determine appropriate messaging, content, formats and timing for each client group and create relevant and appropriate information for bulletins/updates to key agencies. It will also establish an Alert System and establish and operationalize operational control rooms at targeted locations in close collaboration with DWR and DCCMS; and be able to avail relevant briefings to key stakeholders on a regular basis.
- **Task 6**: Performance Assessment. This will ensure that the performance of the ODSS System is evaluated once implemented to ensure that it fulfils expectations for warning and alerting various stakeholders including preparing performance assessment reports for major hydro- meteorological events. Operational Decision Support System through Enhanced Hydro-Meteorological Services
- **Task 7:** Capacity Building and Facilitation. This will ensure that System has been delivered, understood and is operational; proven by active use of the system by trained operations staff and forecasters at DWR and DCCMS, who also must be able to gradually transfer the responsibility and operation ODSS to Shire River Basin Authority staff.

3.4 DCCMS observations, forecasting, processes and capacity

3.4.1 Gaps in observation network

In terms of national coverage of the observation network, blind spots exist in: i) eastern Chikwawa; ii) north eastern Nsanje; iii) Makanjila, Malindi and Namwera areas as well as central parts of Mangochi; iv) western parts of Zomba; v) eastern Balaka; vi) eastern Dedza; vii) southern Salima; viii) eastern Dowa; ix) southern and northern Nkhota-kota; x) the whole of Ntchisi; xi) eastern and northern Kasungu; xii) western Mchinji; xiii) south western Lilongwe; xiv) southern and western Mzimba; xv) Livingstonia area in Rumphi; xvi) Nyika Plateau; xvii) southern Karonga; and xviii) southern and central Chitipa. In general, coverage is biased towards the west of the country, with the lakeshore and eastern parts of Malawi less well covered. There is only one AWS for Lake Malawi, situated on Likoma Island, and most of the river and large water bodies catchment areas are not adequately covered. Floods that occur in flood-prone districts, such as Karonga and Salima, originate upstream in catchment areas. Most of the catchment areas above flood prone regions are not adequately covered with automated observation stations. As a result flooding cannot be accurately forecasted in a timely manner. There is a need to increase observations in catchment areas for all major rivers in the country and on Lake Malawi – including smaller rivers that are at present not included in the observation network.

In addition to the poor spatial coverage, existing stations only partially function as a result of: i) vandalism; ii) limited spare parts; iii) inefficient maintenance; and iv) incorrect calibration. Furthermore, reporting of information from manual stations is frequently inaccurate or absent. This is as a result of inadequate diligence or technical capacity of personnel to collect and transmit readings via mobile phone, telephone and/or radio. Regarding AWSs and rainfall logging stations, data collection and transmission is hindered by limited airtime availability for GSM transmission and expired licenses for visualisation software.

Most of the existing stations under the DCCMS are in need of rehabilitation. Manual and automatic stations do not have the full complement of equipment and sensors required for efficient functioning. This includes – for manual weather stations – missing or non-functional thermometers, barometers, wind speed and direction masts, solar sensors, radiotelephones for communication, and weather fences, and – for automatic stations – missing or non-functional sensors, data loggers, GPRS modems, dry cells, computer servers and software, power supply, weather fences, solar panels, armoured cable, batteries, wind speed and direction masts. The DCCMS's radar stations at Lilongwe and Chileka are obsolete and in need of upgrades. Furthermore, there are no facilities for lightning detection, and the upper air and pilot balloon stations are non-functional.

3.4.2 Current and future weather station expansion plans

The following are the presently known expansion plans for weather and climate observing stations:

- 22 full meteorological stations. Data is gathered four times daily, between 5am and 5pm. No data is gathered at night. Of these, 4 were fully functional. 17 of 26 districts will be covered after the rehabilitation of 18 manual Synoptic Weather stations through the UNDP-managed LDCF project.
- 28 automatic weather stations (AWS). These send daily updates using the Airtel GSM network, but paying for the data bundles has proved expensive, and when the bill has gone unpaid, there has been no data gathered. Through the UNDP-managed LDCF project up to 20 new Automatic Weather Stations will be installed to cover blind spots in the existing observation network in the eastern parts of Malawi, Lake Malawi and lakeshore areas.

3.4.3 Operational constraints

A recent survey finds several problems with the current network of weather stations operated by DCCMS (Atkins 2015)[35]. In particular the following key issues are identified:

- The funding and the implementation of an operational maintenance plan for the meteorological monitoring network, the conventional stations and the automatic stations;
- The integration of redundancy in the monitoring network and the data communication network to enhance sustainability and promote business continuity;
- The establishment and funding of a reliable, secure data communication system (private APN);
- The use of weather observers at the conventional stations at the highest possible level to provide a manual back-up for data from the automatic stations when needed;
- The redesign of AWS with the aim of redundancy of meteorological sensors in particular with regard to the power supplies, batteries, loggers and communication links;
- Change in the job description requirements of the weather observers indicating their responsibility for the real time provision of the data from the weather stations assigned to them to the DCCMS headquarters and for first line maintenance on the stations when needed.

3.4.4 Forecasting processes and dissemination

DCCMS currently provides the following weather and climate information to user agencies, including DWR, DoF and DAES as well as the public:

- Daily and five day weather forecasts;
- Flood information and related forecasts such as: i) seasonal, seven day and daily rainfall forecasts; ii) severe weather warnings for strong winds/storms and cyclones; iii) 50 mm rainfall threshold warnings; and iv) Mwera[36] warnings over Lake Malawi; and
- Drought information and relevant forecasts such as: i) seasonal rainfall forecasts; and ii) 10-day agro-meteorological bulletins.

Daily weather forecasts are produced every morning at the DCCMS in Blantyre as well as at the airports in Chileka and Lilongwe. Five-day forecasts are also produced twice a week. A seasonal forecast is produced once a year in September before the rainy season starts. Generally, forecast models are statistical and produced using Excel spreadsheets by the DCCMS. These are then presented at the Southern African Regional Climate Outlook Forum (SARCOF) meeting where a consensus forecast is produced by SARCOF. The consensus forecast, once approved by the Office of the President and Cabinet, is released to the media and public. The consensus forecast has course resolution and only presents total seasonal rainfall. This is not useful for stakeholders as there is high spatial climate variability across Malawi. Other information that could be of more relevance to user-agencies and end-users includes parameters such as seasonal onset, seasonal length, risk of flood events or strong winds. At present DCCMS does not supply any climate change specific products, such as > 6 month forecasts and climate change projections. Climate change models are not used routinely to produce information for long-term development planning.

Medium-range weather forecasting and climate prediction tools can be applied to extend warning times and produce pre-warning information. However, the DCCMS does not have the technical capacity for conducting accurate and fine-scale short-, medium- and long-term forecasting, in particular for droughts. Furthermore, DCCMS does not undertake numerical modelling as a result of limited availability of forecasting equipment including modern meteorological facilities and human resources. At present, DCCMS's computers also have

35 Atkins Malawi SRBMP Hydromet Inception Report | Version 3.0 | 21 April 2015 | 5135807

36Mwera winds are a major risk to fishing communities particularly on Lake Malawi and Lake Malombe. Therefore, there is a need to strengthen hydro-meteological services and networks to monitor and predict the occurrence of these winds. This will require a stronger link with Mozambique NMHS as well as improved coordination among DWR, DCCMS and DoDMA and effective communication strategy with the communities.

insufficient speed and memory for basic modern meteorological tasks, including satellite image and model data analysis display and presentation. Furthermore, meteorologists at the DCCMS do not have the capacity to utilise fully satellite products and images through dynamic models.

Venäläinen et al (2015) identify several constraints within DCCMS, which prevent effective early warnings being issued, including shortage of trained personnel and meteorological infrastructure. Key focus areas include: modernization of the observation network including remote sensing equipment, improvement of telecommunications, forecasting, post-processing and service production system, a basic instrument calibration facility, climate database facility and training of Class I meteorologists.

Basic operations and maintenance must be improved and are a prerequisite for purchasing equipment with likely high running costs such as upper air measuring stations and weather radar. A lightning detection system combined with satellite imagery can provide similar information at a fraction of the cost of radar. Through the UNDP-managed LDCF project a small lightning network will be tested; should this be successful there will be a need for its expansion to cover the whole country, and in particular the Lake Malawi region.

Whilst manual stations have proved difficult to use to get timely information (see earlier comments on incentives for observers), AWS are also not a perfect answer. Problems are often encountered ensuring power and security to the AWS (e.g. stealing solar panels and batteries), as well as communications (telemetry) costs and reliability for the equipment.

Improvements in forecasting can be achieved utilising satellite information in conjunction with the full suite of products provided through the SYNERGIE information system from Meteo France International (e.g., utilising satellite image updates every 15 minutes combined with the thunderstorm tracking data/imagery.

3.4.5 Human resource constraints

Given the need for tailored products in agriculture and fishing sectors, this will require building the human capacity to generate appropriate products, part of which will be undertaken by each sector in order to ensure weather/climate information is packaged correctly with other information sources. However, part of the work will also need to be undertaken by DCCMS and DWR (the data/information providers), to ensure that the weather/climate information is of the required scale and provided in a timely manner in useable formats for use by the different sectors: fisheries, agriculture and water. This will require developing human capacity at DCCMS to utilize available hardware and software to i) visualize meteorological, environmental and oceanographic data; ii) analyze and properly use satellite-based data and information; iii) produce and issue < 1 day severe weather nowcasts, 1-10 day weather forecasts and 1-6 months seasonal forecasts; and iv) edit and package weather and climate data and information into a suitable format for user-agencies – including DWR and DoDMA – and local community end-users such as farmers and fishers. This will include building capacity for generating accurate and timely forecast products including seasonal drought forecasts and drought alerts focused on assisting local community preparedness for agricultural stresses. Severe weather alerts (advisories, watches and warnings) for Mwera winds need to be developed for assisting fishers on Lake Malawi.

3.5 Existing gaps and needs in current DWR operations

Figure 12 below shows the distribution of the Water Resource Authorities (WRA) in Malawi and the Water Resource Units (WRU) that make up each WRA[37]. Discussions with DWR and DoDMA clearly identified the districts and rivers given in Table 6 as being important for flood risk and monitoring water resources, information for which could be provided through expansion of the ODSS system being developed through the SRBMP:

No.	Name	WRU	Catchment Area (km^2)	Rivers
4	Linthipe	4A	463	Lifisi
		4B	3190	Diampwe, Lifidzi, Lilongwe, Linthipe, Msunduzi, Tete

[37] Project for National Water Resources Master Plan in the Republic of Malawi. Undertaken by CTI Engineering International Co., Ltd., Oriental Consultants Co., Ltd and NEWJEC Inc. for the Ministry of Agriculture, Irrigation and Water Development (MoAIWD), Funded by the Japan International Cooperation Agency (JICA).

		4C	1572	Lilongwe, Nanjiri
		4D	1854	Chaulongwe, Katete, Likuni, Lilongwe
		4E	937	Lingadzi, Mteza
		4F	625	Lumbadzi
9	Songwe/Lufira	9A	1790	Chambo, Kalenje, Lufira, Mbalizi, Sekwa
		9B	1890	Hanga, Ipenza, Kaseye, Kyungu, Makeye, Songwe, Yamba
5	Bua	5C	1388	Bua
		5D	2770	Bua, Kasangadzi, Mphelele, Mtiti
		5E	3916	Bua, Ludzi, Namitete, Tete
		5F	2580	Liwilezi, Rusa
7	South Rukuru/North Rumphi	7A	2897	Mzimba, South Rukuru
		7B	1302	Kapembere, Luwewya, Luweya, South Rukuru
		7C	1648	Luwewe, South Rukuru
		7D	2258	Kasitu, Lunyangwa, Lusangazi
		7E	1456	South Rukuru
		7F	1482	South Rukuru, Luviri, Runyina, South Rumphi
		7G	950	Luviri, Muhuju, South Rukuru
		7H	712	Kaziwiziwi, North Rumphi
15	Nkhota-kota Lakeshore	15A	2293	Chirua, Lingadzi, Namanda
		15B	2458	Kaombe, Likoa, Lufulizi, Mbambara, Nkula
		15C	198	Liwaladzi

Table 6: WRA, WRUs and associated rivers identified by DWR and DoDMA as requiring investments in hydrological stations (particularly for upstream catchments not covered by existing investments) with the potential to include coverage by the Shire river basin ODSS.

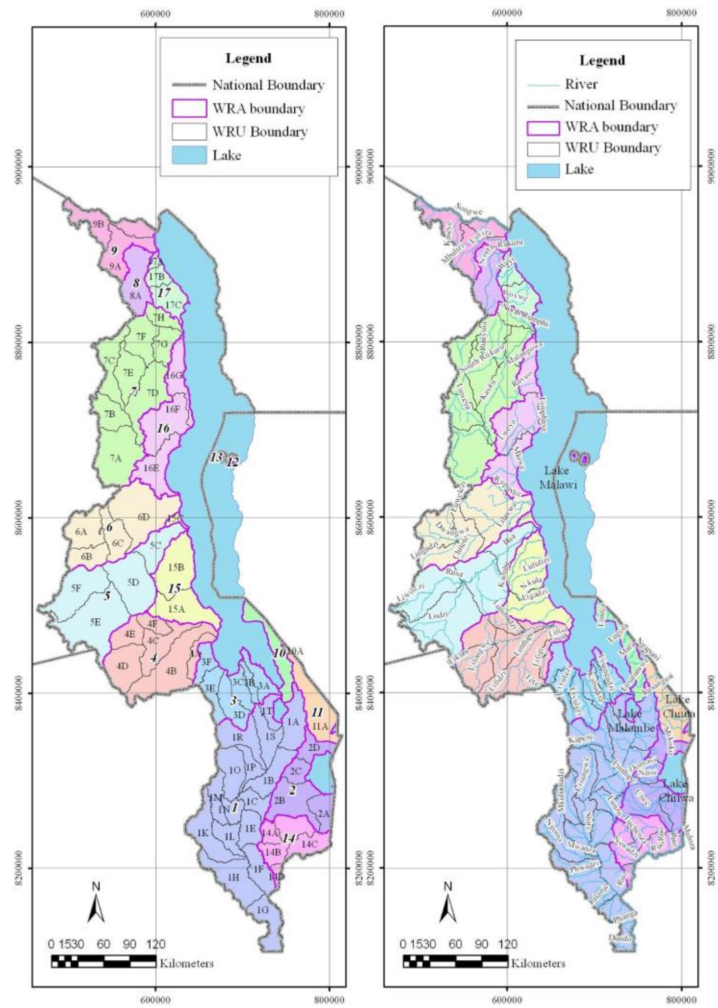

Figure 12: Water Resource Authorities and Units of Malawi. *Source: CTI Engineering International Co.* [37]

These rivers include areas which are flood prone but not fully covered by the UNDP-managed LDCF project or the SRBMP:

1. Chitipa & Karonga : Songwe and Lufira river systems (WRA9),
2. Lilongwe & Salima: Linthipe, Lumbadzi, Lilongwe river system (WRA4)
3. Nkhotokota & Mchinji, Kasungu & Ntchisi: Kaombe, Lifidzi, Lifuliza river systems (WRA15) and Dwangwa, Bua river systems (WRA5)
4. Mzimba & Nkata Bay: Rumphi, South Rukuru river systems (WRA7)

The UNDP-managed LDCF project (see Section 4) is covering some of the lakeshore regions – but only partly as it is only installing 10 hydrological stations spread across the districts of Karonga, Salima, Nkhota-kota, Rumphi, Nkhata-bay, Dedza and Phalombe.

DWR confirm (*pers comm. Piasi Kaunda, 3/7/15*) that at present there are no functioning automatic water sensors in Malawi and the only planned installations are those through the LDCF and SRBMP projects. Currently the number of functioning (F) and non-functioning (NF) manual hydrological stations are: Chitipa - 3 F and 8 NF; Karonga - 3 F and 6 NF; Rumphi - 1 F and 7 NF; Mzimba - 2F and 4NF; Nkhatabay - 3F and 5 NF; Kasungu - all NF; Nkhotakota - 4F and 2NF; Mchinji all - NF; Lilongwe - 4F and 4NF; Salima - 2F and 3NF; Phalombe - all NF; Dedza - all NF; Ntcheu - all NF

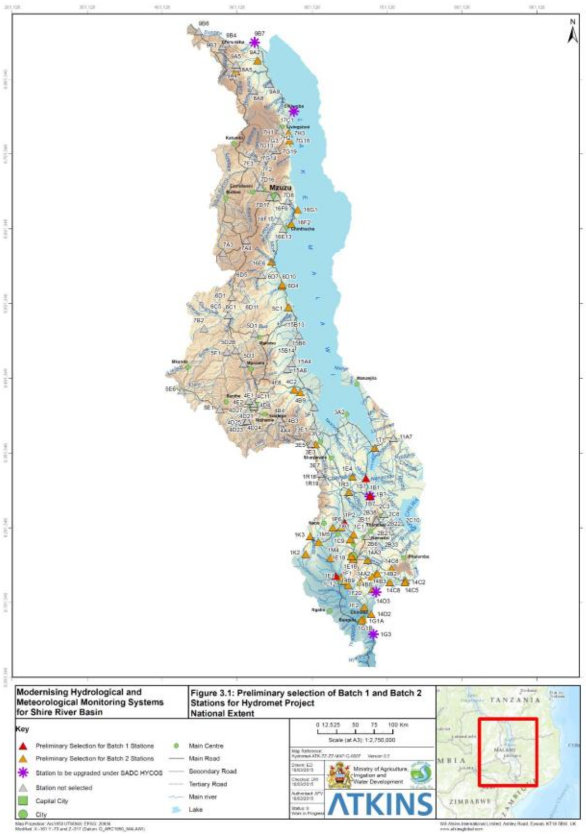

Figure 13: Station locations identified for rehabilitation and where infrastructure and/or observers first need to be strengthened. *Source:* *Atkins (2015)*[23]**.**

3.5.1 Planned expansion of existing network

The Atkins (2015) report[23] identifies a set of hydrological stations and locations which will be targeted through the SRBMP. Through a weighted prioritization scheme the report identifies those stations that are ready for rehabilitation in a first round (batch 1) and those where infrastructure needs to be first strengthened, and/or observers needs should be met, before proceeding with rehabilitating existing infrastructure. Many of the stations in the central and northern region (besides near the lakeshore) are not selected. The report additionally recommends the following key issues:

- Rehabilitation of the core network of gauging stations is urgently required including the installation of GPRS/GSM telemetry logging systems and appropriate water level sensors;
- The purchase of further supporting equipment is required such as leveling equipment, ADCPs, conventional rotating element current meters;
- Payment of gauge readers needs to be resolved;
- Appropriate training at the field and data processing level is required;
- Steps need to be taken to secure reliable vehicles for hydrometric activities and these should remain with the area hydrometric teams and not be commandeered for other purposes;
- Information is required on projected budgets over the next 5 – 10 years. The final design of network can only be sustainable if the recurrent costs of Operation and Maintenance do not exceed the available budget; and
- The stage-discharge relationships for all key gauging stations need to be checked, improved, further developed, revised and/or confirmed.

3.5.2 Gaps in infrastructure, products, capacity and communications

Assessments undertaken by DWR and others[24,28,37] have clearly identified gaps in both infrastructure, products, capacity and communications with communities:

i. *<u>Hydrological monitoring stations</u>:*

New hydrological monitoring stations are required in the upper part of catchments of rivers (the sources of rivers) that flood every year but that are not covered by LDCF-funded or SRBMP investments. Priority areas/districts include Chitipa, Mzimba, Lilongwe, Mchinji, Ntchisi, Mulanje and Thyolo. The Shire River Basin Management Project is conducting some interventions in the basin but not in the areas where Shire River tributaries come from: for instance Thyolo and Mulanje. In addition, the DWR needs to develop a decentralized system, whereby automated hydrological sensors are installed and disseminate water level information and messages to Village Civil Protection Committee chair people. This will allow warnings of rising flood levels to reach communities in a more timely manner and provide communities with more time to engage in evacuation and flood mitigation procedures.

ii. *Water products and services:*
There is a need to produce a hydrological yearbook, hydrological bulletins and updated hydrological databases. This information (water levels, measured discharges, water quality, ground water levels, sediment load and weather/climate information) is essential and can be used by planners, policy makers, private sector and the public at large.

iii. *Capacity building at National, District and Community level:*
DWR has six professional officers and two assistant hydrologists who need training to at least Masters level in hydrology/flood forecasting and bachelors level in hydrology respectively. This is very important to support the expansion of the SRBMP ODSS system and flood analyses in the future, as well as for establishing a flood-forecasting unit. Additionally, a core of well-trained officers will be needed to man the forecasting hub and disseminate the warnings/alerts both nationally and regionally. Three officers will need to be trained for this purpose.

iv. *Community sensitisation*
Awareness meetings with the communities will be needed in order to instill a sense of ownership of any installed equipment. This activity will need to involve the officers from the headquarters, District, Village Civil Protection Committee (VCPC) and the local communities.

v. *Automated Rain gauges*
According to WMO standards each hydrological station requires a rain gauge in order to collect meteorological data that is used to understand runoff for flood forecasting and input to hydrological models. These rain gauges will need to be installed in districts across the river basins (particularly the proposed Scaling up districts, but also possibly to supplement LDCF-funded weather stations where coverage is limited).

vi. *Lake Malawi Monitoring Equipment/Lake buoy*
Lake Malawi has been adversely affected by climate change and other environmental factors e.g. siltation due to land use change on its periphery. Currently DWR has no scientific data to monitor environmental trends on Lake Malawi itself. The installation of lake buoys on Lake Malawi will enable the collection of a wide range of weather, climate and hydrological data, which will allow climate-related trends to be monitored and eventually disaggregated from other environmental processes and effects on Malawi’s largest water reservoir, which is one of its major resources (for fisheries, hydropower and utilities).

3.6 Current status of district climate information centres

Government of Malawi, with support from the Japanese Government and technical support from UNDP, initiated climate information centres in 7 districts[38] with the aim of sharing climate information using different media for planning. This was against the background of lack of access to climate information by different stakeholders: farmers, fishermen in the lakeshore, business people whose enterprises rely on weather and lack of authenticated information source in cases of disasters like flooding. Through the Africa Adaptation programme and the Africa Climate Adaptation and Food Security Project, different information materials have been generated targeting the print media, and ICT infrastructure has been procured for downloading real-time climate information from the Department of Climate Change and Meteorological Services to the climate centres. Equipment for outreach activities has also been procured for use by the climate information centres. Systems for disseminating information have been set up in districts, where information is sent to members of

[38] Nsanje, Chikwawa, Mulanje, Zomba, Kasungu, Salima, Karonga. Of these, Nsanje, Mulanje, salima and Karonga have had special attention in terms of resources, but Kasungu, Zomba and Chikwawa are in need of support to function.

civil protection committees who further disseminate weather information to the public. Climate centres have also been linked to rural radios where listeners would get real-time climate information in their local language, and early warning messages in cases of a pending disaster would be disseminated to them.

3.6.1 Gaps/Needs for climate information dissemination

Current gaps include the translation of climate information into the language of the target audience – in most areas the majority of users of climate information understand the information better in their local language. Another gap is in linking climate centres to rural radios, which costs $21,200 per rural radio. The other gap is capacity building for those managing the climate centres and the entire chain that transmits the information, because the image that is currently downloadable is the global weather image, which demands knowledge of climate science and Meteorology to interpret. Targeted capacity building is therefore necessary. Linked to this, advisories linked to the weather forecast is an area that needs huge investment because users require a trusted source of information that advises them on what to do with that information. Should there be need for upscaling this initiative, space is not always easy to find. Some rooms in district councils have had to be renovated for the centre to find space.

3.7 Developing a community based early warning system

Early warning without early action is of limited use. The installation of any early warnings should be preceded by community sensitization on the prevailing hazards and their vulnerability, followed by training of the communities on the use of the system. The communities should be oriented on the nature of the hazard, how to monitor and communicate change in hazard, how to disseminate information about the hazard and how to respond to warning messages. Community based approaches for establishment of early warning systems recognize the fact that the first response to a disaster always comes from the community itself. Thus, a community-based flood early warning system empowers communities to be able to protect themselves, thereby developing their resilience to flood disasters.

3.7.1 Technological gaps in community based flood early warning systems (CBEWS)

Over half of disasters experienced in Malawi are weather-related, mostly floods and prolonged dry spells, with floods claiming more lives and destroying more property. With climate change these extreme weather conditions are likely to increase in frequency and intensity. To mitigate the impact of flooding in Malawi, a CBEWS can be developed, in particular to ensure “last mile” access to information. The CBEWS that was piloted by Christian Aid in partnership with Evangelical Association of Malawi on Mwanza River in Chikwawa district in the Lower Shire in 2009 proved to be effective in saving lives and reduce economic losses. Establishing this information and communications technology (ICT) enabled a flood early warning system that uses a flood sensor attached to a transmitter to detect rising water levels. When the water reaches a critical level, a signal is wirelessly transmitted to a receiver and the flood warning is disseminated via mobile phones to appropriate agencies and vulnerable communities downstream. During the 2009 floods in Chikwawa, 6,660 people from 1,332 households and their assets were protected by the warning system; however the pilot project has not yet been rolled out to other rivers due to lack of funding (Christian Aid 2009).[39]

3.8 National emergency response efforts

Emergency operations centres (EOCs) are critical to planning for disaster preparedness (evacuation plans, contingency plans, media information, etc.), monitoring disasters, mobilizing resources to manage them, and coordinating with relevant stakeholders on disaster risk management activities. While recently several projects have set up EOCs (UNDP PS DRM and LDCF EWS), the 2015 flood emergency response exposed a gap in the management of the EOCs and in the use of the Cluster System. The cluster system was introduced in the districts that were seriously affected by the 2015 floods without proper orientation/training of the district council officials, including in the use of climate risk information/early warning information both from local and international sources. The latter, in combination with poor communications, meant that although the chances of flooding were predicted to increase dramatically, the mobilization of resources to respond did not occur rapidly. Similarly, emergency operations centres were opened in these districts without any orientation/training of the district council officials on the running and management of the EOCs. This posed a big challenge in the

[39] Christian Aid, ‘Community answers to climate chaos: Getting climate justice from the UNFCCC’ (2009)

utilization of the cluster system and management of the EOCs at district level. In addition, a lack of operational guidelines was noted.

4 On-going efforts on early warning systems, use of climate information and community disaster preparedness

There are several projects that are already providing early warnings in Malawi, in a number of different areas. These projects are being implemented by a number of agencies. However, the role of national agencies in community-based EWSs is fairly limited at present, with the majority of community-based EWSs being implemented through the actions of NGOs and CSOs. Government agencies are building national systems to provide early warnings (particularly under the UNDP LDCF-funded project and the World Bank Shire River Basin Management Programme), with further investment potentially through the the Climate for development (ClimDev) programme, which is a joint initiative of the African Union Commission (AUC), the United Nations Economic Commission for Africa (UNECA) and the African Development Bank (AfDB)[40]. It is critical that these national scale systems are linked to efforts within communities to ensure that warnings reach the 'last mile'. There are no national guidelines for the development and implementation of EWS, which has led to several different approaches to EWS. This diversity represents a good baseline situation for evaluation of successful approaches within the national context. In addition, a number of new EWS projects are starting. Current EWS activities include:

4.1 UNDP Malawi

UNDP Malawi has put in place a system in the new UNDAF (2012-2016) to streamline the development of new projects and programmes for the country. This entails that all donor projects are merged into more substantive programmes: 1) Climate Change; 2) Environment and Natural Resources; 3) Sustainable Energy; and 4) Disaster Risk Management. Programme Support Documents (PSDs) have been developed for each of these areas and the objective is that all new projects are fully merged within these PSDs.

*Under the PSD ENR***,** the following outputs are being delivered: i) environment and natural resources management mainstreamed in policies, development plans and programmes at national level and implemented in 15 disaster prone districts; ii) data and knowledge on the impact of environment and natural resource degradation collected and made accessible to decision makers in government, private sector and civil society; and iii) coordination mechanisms and implementation arrangements for ENR established and used at national level and in disaster prone districts.

*Under the PSD DRM***,** the following outputs are being delivered: i) disaster risk management is mainstreamed in national development plans, policies and programmes; ii) data and knowledge on the impact of natural disasters collected and made accessible to decision makers in government, private sector, civil society, development partners and communities; and iii) coordination mechanisms and implementation arrangements for DRR established and used at national level and in the 15 disaster-prone districts Chikhwawa, Nsanje, Phalombe, Zomba, Balaka, Mangochi, Ntcheu, Dedza, Kasungu, Lilongwe, Salima, Nkhotakota, Karonga, Nkhata bay and Machinga.

The LDCF-funded **UNDP EWS** project on strengthening climate information and early warning systems is contributing to these aims by supporting the purchase of hydrometeorological observing infrastructure for 7 disaster-prone districts. It is also supporting the training and capacity building within DCCMS and DWR to undertake operations & maintenance of the equipment, as well as supporting the development of warnings/advisories by DoDMA and communication of these products to users. This project will provide co-financing for support developed under the GCF. However, it has limited funding to develop tailored products and engage communities in the co-production and dissemination of these products. In particular, the LDCF funding does not allow for extensive consultations with communities and the testing of information content and delivery mechanisms. Additionally, the focus on 7 disaster-prone districts ignores the importance of upstream catchments on downstream flooding and it does not include any provision for the successful use of community-based EWS for flood risk management. Additional valuable lessons have been learned through this project – including the need to engage early in the procurement of equipment, as procurement procedures can be slow; that tailored products need to be developed jointly with the users of products; that not all information is scientifically feasible to generate; and that sensitising users to the limits of predictability is important. This project has not yet undertaken a mid-term evaluation, but annual reports are available through UNDP.

[40] http://allafrica.com/stories/201411271597.html

4.2 Disaster Preparedness ECHO (DIPECHO)

The European Community Humanitarian Office (ECHO) launched the **Disaster Preparedness ECHO (DIPECHO)** internationally in 1998 to improve the capacity of communities to prepare for and protect themselves from the effects of natural hazards. In Malawi, this project launched in 2008, and has implemented community-based EWS in Chikhwawa, Salima and Nsanje districts. It operates through international NGOs operating in the target areas, and focuses exclusively on floods. These EWS make use of simple river level gauges in upstream villages, which are read by community members regularly. Warnings are disseminated to downstream village civil protection committees (CPCs) using mobile phones, megaphones, whistles and community flags. This low-technology warning system has proved to be fairly effective, and the methodology has been adopted by the ECRP (see below). Funding for this project is awarded annually by ECHO.

In Malawi, DIPECHO operates through the following implementing partners:

- Christian Aid, Evangelical Association of Malawi in Chikhwawa district;
- COOPI in Salima district;
- GOAL – Malawi, Action Aid in Nsanje district; and
- Food and Agriculture Organization in Chikhwawa district.

Among the various activities that these NGOs have been implementing, community based early warning has been one of their main project components. Thus one of the important lessons from DIPECHO projects from these partners is that community-centered EWS, whereby community gauge readers monitor water levels, analyse data, interpret it and disseminate it to VCPCs using phones and the VCPCs disseminate information using megaphones, whistles and community flags, are effective in providing timely early warning messages. These are community-based and people-centred systems, as opposed to government early warning systems, which are "top-down" and which sometimes fail to provide important information in time.

Lessons learnt through the DIPECHO programme:

NGO	Good Practice
EAM, Christian Aid, Malawi Red Cross	Community based flood early warning system piloted along the Mwanza River in the Southern Region and in Salima for Malawi Red Cross; it has been very effective in minimizing impacts of flooding downstream. The premise of these programs is that much money which is spent on relief could be reduced if the communities are warned in time and damage is minimized. The systems are managed by the people who become affected by the floods. Proper linking of up-stream and down-stream communities (through CPCs) is key to the success of a community based flood early system.
Mainly Christian Aid and Action Aid	School children are an effective mechanism for disseminating disaster related information to communities. Under DIPECHO Christian Aid has used school children to carry early warning messages to their communities. School children and faith leaders have also been used to raise awareness about various means of communicating and sensitizing communities on the risks. With regards to faith based leaders, this is quite effective in raising awareness as the information dissemination is integrated into church (religious) sessions and events.
Malawi Red Cross, GOAL Malawi, EAM, Action Aid	Local means of communication: Disasters are known to be very fast and untimely, therefore appropriate communication channels can be efficient if they are based on local knowledge. Drums, whistles, bicycles and local radios have proved to be very effective in community communication as they are easily understood.

4.3 Enhancing Community Resilience Project (ECRP)

The **Enhancing Community Resilience Project (ECRP)** is funded largely by the British Department for International Development (DFID, which is responsible for 82% of the funding), Irish Aid and the Norwegian government. It has £21.5 million in funding, the majority of which is directed at building community resilience. However, project activities include community-based EWS along the same lines as those developed through the DIPECHO project. This project operates through two consortia of NGOs and CSOs operating in the districts: The DISCOVER network and the Christian Aid network. This project is also developing community drought EWS. This EWS will interact with the Malawi Vulnerability Assessment Committee (MVAC).

4.4 Malawi Red Cross Climate Change Project

The **Malawi Red Cross Climate Change Project** in Salima (funded by the Finnish Red Cross) started in 2012. This project is designed to capitalise on a previous climate change project that focussed exclusively on food security by providing irrigation to this sensitive area. This climate change project is providing mobile weather stations to the DCCMS to enhance its ability to provide technical reports for the area, with a specific focus on area-specific farming information. Whilst it has now finished it provided useful lessons on disaster response and the required information to respond[41].

4.5 FEWSNet

FEWSNet is an international programme (funded by USAID) that provides vital information for the reduction of famine and drought impacts in Malawi. FEWSNet does not directly disseminate information, but rather makes use of national agencies and structures. It conducts regular field assessments of key indicators (crop growth, market prices and trade). This information, combined with regional drought likelihood analyses, is fed into the Ministry of Agriculture and Food Security, and is used in the preparation of monthly reports of food availability and trends. In addition, this information is used in the MVAC reports (see below).

4.6 Malawi Vulnerability Assessment

The **Malawi Vulnerability Assessment** Committee is a multilateral committee with members from government, UN, NGOs and civil society. It is mandated with the provision of early warning information with respect to the food security situation in the country. This information is used in i) the assignment of national budget to food security issues, ii) the identification of priority areas for disaster reduction and food aid dissemination, and iii) development of national policy. DoDMA is a key national agency for coordinating these responses, although it is currently lacking in capacity to fully realise this mandate. It makes use of indicators from within the coalition of partner organisations, as well as from the DCCMS to determine vulnerable areas in a timely manner. The MVAC has indicated that it would welcome an improvement in the quality and timing of information provided by the DCCMS, which will enable it to function more efficiently, as well as move from response to preparedness activities.

4.7 Integrated Flood Risk Management Plan (IFRMP)

The **Integrated Flood Risk Management Plan (IFRMP)** for the Shire Basin is a component of the $100 million World Bank Shire River Basin Management Programme (SRBMP). The IFRMP is designed to complement the large-scale irrigation and river management infrastructural investments undertaken through the SRBMP by providing accurate and timely hydrological measurements and forecasts. This project will be installing ground- and surface-water measuring equipment to provide real-time information to a control centre within the DWR. A flood early warning system has been developed for the Shire Basin in 2005/6, with a set of rules to guide the issuance of warnings. It is run by the MoIWD, and makes use of rainfall observations and forecasts from the DCCMS for initial alerts, as well as manual river observations at key points. Alerts are issued and relayed by telephone from manual observers, and warnings are issued on a four-stage alert system as conditions reach pre-determined thresholds. In order to upgrade this system and utilise timely data collected by the automatic observing equipment, a decision support system is being developed which will include the use of hydrological and flood forecast models, as well as forecasts provided by DCCMS.

The overall concept of the new and improved Flood Forecasting Early Warning System (FFEWS) proposed in the Integrated Flood Risk Management Strategy includes the following key components: i) real-time, telemetry-based observation systems for the Lower Shire River Basin and Ruo River flood areas; ii) community-based flood warnings for a selection of river tributaries; iii) a strengthened institutional framework and a strong focus on capacity building and community engagement; iv) improved data flow – horizontally as well as vertically – using appropriate technology; v) a strengthened role for the observer network/volunteers; vi) the use of pilot studies to test new ideas and approaches; and vii) the development of procedures for expanding the system more widely in the Shire River Basin, as well as nationally for flood warning. This will include the procurement and installation of 15 new/refurbished river level gauges equipped with telemetry via Meteosat (and manual observation), 15 automatic rainfall gauges equipped with telemetry via Meteosat, and one new Meteosat ground station receiver at the DWR in Lilongwe. Furthermore, the project will upgrade the existing Meteosat

[41] See, e.g., https://vimeo.com/111796443

ground station at the DCCMS in Blantyre, and build capacity to use and maintain the new equipment. See Figure 14 for the proposed project sites for automated river and rainfall gauge installation.

Whilst the IFRMP is building and installing important new flood forecasting infrastructure and systems for the Shire river basin, there remain areas to the east of the basin, which are not covered under this project. Also there are currently no plans to extend the data telemetry (and associated AWS and hydrological stations) and flood/water resource monitoring and forecast systems to the rest of the country. This presents a unique opportunity to build on the foundational work undertaken by the IFRMP.

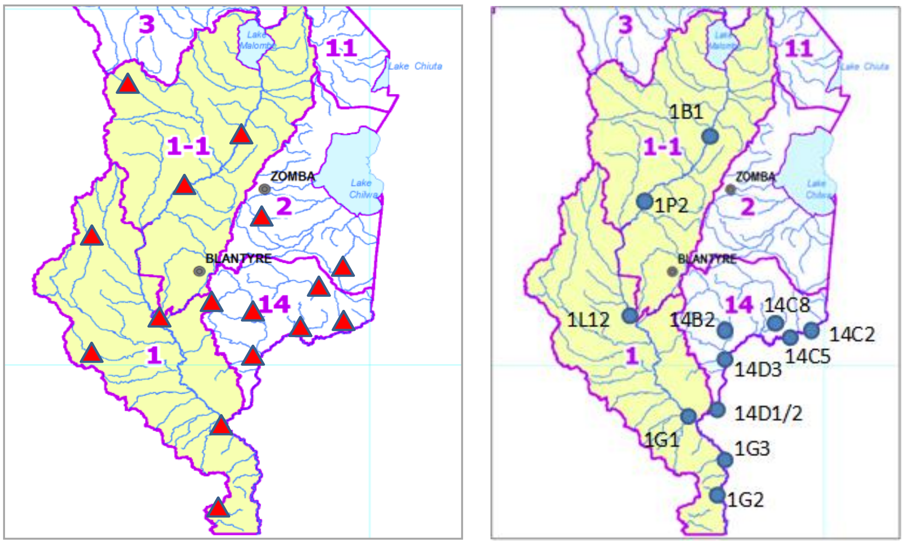

Figure 14: Proposed sites for river and rain gauges to be installed under the WB SRBM and IFRMS in the Shire River Basin.

4.8 Information dissemination mechanisms operated by NASFAM

NASFAM's unique position and ability to address the multi-faceted problems that smallholders face is widely acknowledged. It acts as a catalyst to smallholder farmers' agricultural development. NASFAM Associations provide members an opportunity to overcome the barriers to market access and to higher productivity which, combined with their own determination, has led to NASFAM's long-term success. In terms of incomes from crop production, the 2011 NASFAM impact assessment study indicated that NASFAM members' incomes increased by 51% over the previous five years, from USD840 in 2006 to USD1,272 in 2011. This latter figure is significantly higher that the USD867 that was earned by non-NASFAM members in the same areas. This is achieved through organised farmers and enhancing production.

Organised Farmers:
By grouping farmers together in clubs and thence Associations, NASFAM is able to bring the power of collective bargaining to crop marketing, input procurement and service supply. These same structures are also used to provide up to date training and extension services at a local level. District-level Associations are supported by NASFAM at a national level through a wholly owned trading company, NASCOMEX Limited, which trades, processes and markets many of the crops that members produce, whilst NASFAM itself delivers a wide range of developmental services. At farmer-level, these include interventions in food and nutrition security, HIV/AIDS awareness and mitigation, gender integration, adult numeracy and literacy, training through radio and publications, farming business training, and a wide range of support for agricultural production extension services. Organisational development services are also provided for Associations, including work with both leaders and staff. Through an aggressive policy agenda, NASFAM works with its Associations to empower smallholder members by addressing issues of relevance to smallholders and rural development – from conducive environments for technology release and adoption, improvement of rural infrastructure, promotion of irrigation, pricing systems and marketing mechanisms for farmers' produce, to taxation policy and the protection of the legal rights of women and children.

4.8.1.1 Enhancing Production

Whilst it is possible to increase the immediate returns to a smallholder farmer by providing improved access to more reliable markets, the additional amount that can be earned "per kilogram sold" is limited. Once access to appropriate markets is in place, the real gain to farmer income is secured through increasing production and productivity. In regard to almost all crops, smallholder productivity is low, not just when compared to yields available under ideal conditions, but in comparison to smallholder performance in neighbouring countries, and even compared to what has been achieved in Malawi in past decades. Some of the factors driving this include: increased pressure on arable land, declining soil fertility, increasing land degradation, low technology adoption, limited use of necessary inputs (due to high input prices and availability), and lack of crop production extension services. The inadequate extension services have implications on the extent to which research and technology developed can be disseminated, adopted and efficiently used by smallholder farmers. NASFAM extension systems provide many of the services that might otherwise have been provided by Government. NASFAM's services are delivered through a pyramidal structure, as demonstrated in the accompanying graphic. Particular services are delivered to the farmer from the most appropriate and effective layer. For most services, this is the farmer-trainer (lead farmer). Farmer-trainers are selected by the local community and typically serve not more than 70 members in their vicinity. At club level, there are Club Model Farmers who serve a maximum of 9 farmers in their club to provide advisory services. They mount demonstration plots where they conduct regular field days and training sessions. They also systematically visit members' fields, providing regular technical crop and animal production guidance. The farmer trainers are supervised, supported and trained by Association Field Officers who attend field days and for more specialised matters, deliver assistance directly to members. This direct contact is supplemented by radio programmes (30 minutes three times weekly) and technical bulletins, and through services delivered through linkages and partnerships with other, specialised service providers.

Currently, NASFAM is providing a service to its members (small holder farmers and micro/small agricultural enterprises) to access crop advisories through mobile phones. This is supported by GoalMalawi, an NGO which funds the paid-service to subsidize the costs to the end-user. Members use the 3-2-1 service on the mobile phone to receive agricultural advisories. Weather and climate information (seasonal forecast information, weather conditions) can be incorporated into these advisories to improve decision-making and planning among the farmers. Furthermore, NASFAM is in consultations with Airtel to enhance and extend the use of a web platform that disseminates crop advice through SMS services.

NASFAM has also established a two way mobile communications system in Mchinji and South Mzimba Innovation Productivity Centres (IPCs). The aim is to enhance communication between Head Office, the IPC offices, and members by using text messages to disseminate information and get quick feedback on service delivery. A flexible SMS platform enables dissemination of information and advice from headquarters to the IPCs through group or targeted (farmer profiles) messaging. This enables quick and timely outreach even to remote areas. Lessons are emerging from this project including best practices and challenges (such as keeping data up to-date). The system is not cost-effective at the scale deployed (costs have to borne by end users or organizations delivering the service). The organisation is taking advantage of Airtel text bundles to bring down the cost of SMS and using an open source free software for bulk communication. The farmers pay when they reply to texts.

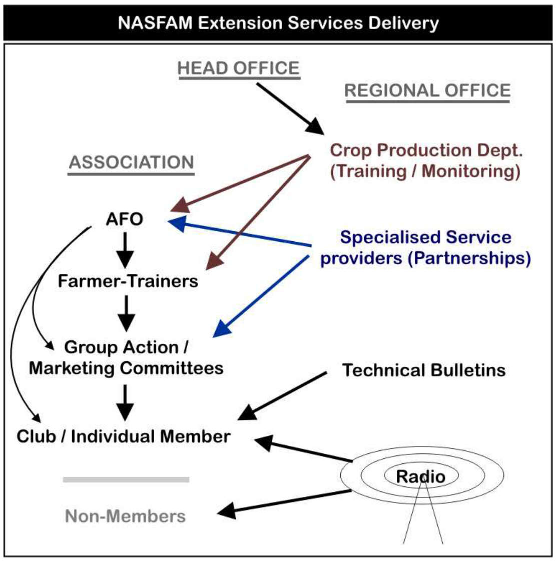

Figure 15: NASFAM extension services.

How the system operates:
The first four calls made every month are free, after which each call costs about K20. By dialing *321# farmers are able to access a menu and read the same information – this feature is free for farmers. However, the system does not enable two-way communication as of today and the information has to be generic for smallholder farmers – for example, it may not be suitable to inform selected farmers of a certain technology.

Currently a pilot uses open source software called FrontlineSMS to send text messages to members. The Software is free for download on the Internet and it is a flexible SMS platform allowing wide range of uses and two way communication. The software is installed on a computer and uses an android phone with FrontlineSync, which enables it to connect to the computer. The message is typed on the computer, and it is sent out through the phone as a modem. Content for the messages comes from units at Head Office and the Mchinji and South Mzimba IPC offices.

Advantages:	Disadvantages:
Bulk/group messaging is possible i.e. sending a message to many farmers at once	Mobile networks tend to have weak intermittent signals or no coverage in some areas
The message is referable; farmers can look back	Some farmers don't know how to read.
Relevant farmers are profiled so that they receive specific information	Some farmers own phones but don't know how to write, view, and respond to messages.
Timely information and quick feedback	Unless the line used is toll free, farmers have to bear the cost of sending messages
Two way communication	If the line is toll free, organisations have to pay for outgoing and incoming messages
Reach out to remote areas	The content in the message may be inaccurate or outdated, and once it is sent out there is no way of removing it from farmer's phones
Reminder of good agricultural practices	

Table 7: Advantages and disadvantages of mobile approaches

4.8.1.2 Technical challenges
Resource requirements for mobile communications technologies include system programmers, server computers, GSM modems, internet access, and airtime. These tend to be quite expensive investments not suitable for a pilot project. Developing a system requires at least four million kwacha. Other technical challenges include:

- Farmer/end user problems: unable to write, view, and respond to text messages; don't delete texts when their phone's capacity is full; sell their phones with their SIM card in it
- Electricity constraints: charging is done every other day, farmers switch off phones to save battery life
- Some areas have no/intermittent coverage, congestion of bulk SMS
- Human element: withholding information, not giving feedback

4.8.1.3 The cost structure of the mechanism
There are no figures for the cost of developing the 3-2-1 platform as it was coordinated by the Human Network International. Farmers are able to make four free calls to 3-2-1 every month. After the fourth call, each call costs K20 for that month. The USSD and SMS features are currently free for the farmer throughout the month. On the farmer's end, the costs are very low –free if they make less than four calls. However, the costs Airtel and the implementing partners incur are not known. Unless an organisation decides to customise FrontlineSMS, there are no costs involved in developing the platform apart from downloading it off the internet. Since FrontlineSMS is being used without any formal arrangements with Airtel or TNM, the cost of sending text messages is the normal rate.

The most expensive aspect of using mobile communication technologies, especially SMS, is the cost of sending text messages. In Malawi, the cost of SMS is about K10 for same network exchanges and K22 for cross network. Making the following assumptions in Table 8 below, the range of costs for SMS would range from MK12,000,000 to MK26,400,000 per year (which is the equivalent of USD 60,000 for the more expensive option).

Members	50,000
Texts/month	2
Months in year	12
Same network cost (MK)	10
Cross network cost (MK)	22
Lowest SMS cost (MK)	12,000,000.00
Hightest SMS cost (MK)	26,400,000.00

Table 8: Costs and assumptions for NASFAM 3-2-1 service (1 year).

For the pilot project, the organisation is taking advantage of Airtel text bundles to bring down the cost of SMS and using an open source free software for bulk communication: i.e., FrontlineSMS. However, this means the number is not toll free i.e. the farmers pay when they reply to texts. One way to reduce the cost of SMS is to use mobile data and mobile applications. However, many farmers do not currently have smart phones and this will restrict the use of any system based on data and mobile applications. Discussions with Airtel and other mobile service providers, to reduce the costs of SMS as part of scaling up nationwide will need to be undertaken. Another cost saving that will be undertaken will be to only send/receive SMS from lead farmers – these are the farmers who typically work with and are the intermediary between regular farmers and NASFAM. Each of these lead farmers typically works with 10 regular farmers and can be relied on to pass on information given out by NASFAM, as well as providing feedback on the service. This intermediary mechanism will significantly reduce costs though the project should be careful to evaluate that it does not prove a bottleneck for receiving feedback.

Which one? 3-2-1 or Frontline SMS

If the objective is to simply disseminate information to farmers, then 3-2-1 is more effective as it is a platform able to cater for farmers nationwide. In addition, the audio messages enhance access to information for the illiterate. However, the exact cost mechanism is not known.

If the objective is to disseminate information and get feedback from farmers, then FrontlineSMS is more effective because unlike other two-way platforms, the feedback does not have to be coded. Coded feedback involves training each and every farmer on which codes to use when replying to text messages. In this case, NASFAM will be more inclined to use the piloted Frontline SMS**.**

3-2-1 is essentially already working at the national scale: it is able to handle large volumes of calls, USSD, and SMS. What is required is to:

1. Find out what will be involved to use the platform to send targeted information to 16,000 farmers i.e. will there be substantial costs involved or will it simply be the cost of developing content. There might be need to sign a contract.
2. Promote 3-2-1 among the targeted 16,000 members through awareness campaigns and training on using the facility.

Scaling up FrontlineSMS: what needs to be done

1. Invest in a server computer and other necessary technical requirements to make FrontlineSMS robust –may even consider a programmer customising the platform slightly. Alternatively, migrate to FrontlineSMS Cloud, which is an online version of FrontlineSMS and should be able to handle 16,000 farmers.
2. Engage in formal agreements with Airtel and TNM in order to negotiate lower SMS costs, a short code for a toll free line. This may result in developing a different platform as FrontlineSMS may not be compatible with the Airtel and TNM system.

4.9 Weather Index-based Crop Insurance in Malawi

The GFDRR **Weather Index-based Crop Insurance in Malawi** aims to supply agricultural early warning information to farmers that sign up for weather-based insurance for their crops. This project was piloted using the Chitedze weather station, and has not yet received widespread subscription. There is still scope for improvement of the coverage of such stations to further improve the resolution of climate data gathered by the DCCMS and help develop index insurance in other regions. This project is coordinated and managed by the World Bank.

4.10 Southern Africa Flash Flood Guidance (SARFFG)

DCCMS is a member of the **Southern Africa Flash Flood Guidance (SARFFG)** system, which promotes exchange of information on flash floods between regional meteorological networks. Specifically, the South African Weather Service (SAWS) is providing information that can be downloaded from its website regularly to help to guide flash flood warnings within the country. In addition, it assists in the notification process for extreme weather. This information is integrated into DCCMS's current early warning systems.

4.11 Global Framework for Climate Services (GFCS)

The Climate Services Adaptation Programme in Africa implemented by WMO and CCAFS under the **Global Framework for Climate Services (GFCS)** is helping develop user-driven climate services for food security, health, as well as disaster risk reduction. Project partners are collaborating to identify exact user needs, build capacity, provide training and awareness activities to ensure that climate information is used effectively and evaluate the contribution of climate services to sustainable development. In order to improve the data available for developing seasonal forecast products, observed station data for Balaka, Nsanje, Lilongwe and Chikwawa will be checked and analysed. DCCMS will also be working on improving the data management system. However, discussions with the GFCS project manager indicate they will not be able to accommodate all of this work within this project and there is a need to continue work on data recovery and improving the data management system.
The project is working in Lilongwe, Nsanje and Balaka districts with DCCMS to develop improved seasonal forecast products, co-production of agricultural advisories with households, developing a methodology for farmers to access and utilize agroclimatic information, as well as investigate the use of ICT technologies to disseminate information and advisories. The project is partnering with World Food Programme (WFP) and using their Community-based Participatory Planning approach to identify the types of climate services farmers require. Discussions with DCCMS and GFCS indicate that there is a high potential to extend similar activities to other areas in Malawi.

4.12 Establishing a well-equipped functional national emergency operations centre (NEOC)

Under the current DRM and LDCF-funded programmes, there is a component of supporting the establishment of Emergency Operational Centers (EOC). The NEOC is to be equipped with satellite phones, GPS, computers, emergency lights, GIS information system, high speed internet, etc. The NEOC will be responsible for ordering measures to protect the population in cases of emergency. The duties of the NEOC will include constantly observing and assessing the disaster risk situation. If there is an event that results in an increase in emergency risk, NEOC will inform government and its partner organizations and the likely communities to be affected in a bid to protect the population.

The mandate of the NEOC will be to:

- Monitor all disasters on a 24/7 basis.
- Mobilise national resources to manage rapid onset disasters.
- Co-ordinate disaster management activities.
- Collaborate and network with other stakeholders.

Specifically the NEOC will be responsible, among others, for:

- Ensuring agencies are informed of the activation of disaster contingency plans.
- Translating the decisions of the National Disaster Coordination Committee (NDCC) into action.
- Prepare inventories for resources/assets countrywide.
- Develop a prioritized list of needs for donors & partners.
- Prepare evacuation plans, shelter and refugee areas.

- Clearance for aircrafts, ships, overseas disaster relief personnel, agencies supplies
- Prepare disaster information media programmes.
- Carry out annual review, evaluation and validation disaster preparedness and response in the country.
- Prepare and issue daily situation report (SITREP) on disasters/Incidences in the country.

5 Recommendations for technical interventions and costs given gaps, current efforts, and scalability

Given the previously identified gaps and needs, and the ongoing initiatives that have the potential to be applied more widely, a dialogue was initiated with government and non-government stakeholders to identify the priority requirements for equipment, capacity building and tailored products/services that can utilise climate information. Based on these discussions, as well as discussions at the stakeholder consultation workshop (see appendix A) and the preceding needs/gap analysis, the districts within which equipment will need to be deployed and the areas that can be covered by the products/services were identified. It is important to recognise that the starting point for these discussions was the potential tailored services/products which showed promise for scaling up and which allow the expanded EWS activities to reach the users of EWS messages and warnings. These activities form part of component 2 in the project design. Once the tailored services/products were identified, gaps in the current observation network and the ability to forecast (weather, seasonal and hydrology), which will limit the ability to deliver the required services, were identified. This resulted in the design of a set of activities related to installing observing equipment and capacity building for the two main information providers: DCCMS and DWR. These activities form part of component 1 in the project design.

5.1 Tailored Services/Products to Improve Community-based "Last-Mile" Disaster Management and Response

Tailored demand-based services/products, which demonstrate a high potential for scaling up, include the following identified interventions:

5.1.1 Tailored agricultural products for managing risks

Tailored climate related products for managing agricultural risks, particularly for smallholder farmers suffering food insecurity, are needed. These products should build on the work undertaken by the GFCS project in Balaka, in collaboration with DCCMS, WMO, WFP and CCAFS, as well as the UNDP EWS project which is developing tailored forecasts for agriculture. The GCFS project is working with communities to co-develop appropriate products (utilising both weather and seasonal forecast information), which can be understood and used by farmers for decision-making. **Therefore, this study recommends extending the initial design work and testing its application in a wider set of districts, where farming systems may change and other social and environmental concerns may come into play.** Partnering with both DAES and NASFAM to utilize their well established and trusted networks will provide the essential support to undertake this. The robustness of the products, their usefulness and delivery mechanisms can be extended and tested, through which a set of generalised products will be identified for different farming concerns, locations and crops/livestock. Given Malawi's dependence on agriculture and especially smallholder farmers, there is a clear need for these products. The development of products will be dependent on the availability of weather station data for monitoring local conditions.

Given NASFAM's position as an intermediary/boundary organisation and its work directly with farmers, already providing advice on cropping and livestock strategies, this presents an opportunity to build weather/climate information services from the ground up. NASFAM already has successfully piloted SMS and UTMS based advisory services used by its members (not including weather/climate information as yet). This presents the opportunity to develop weather/climate information specifically tailored to the existing NASFAM advisories, to see if they add value. It also presents the opportunity to utilise and test the GFCS-project products in a different environment, one potentially more geared to farmers' activities and decision processes. Furthermore the mobile communications system used by NASFAM can be utilised to enable two-way communications, including feedback from farmers. **This study recommends forming a partnership with both DAES and NASFAM to test addition of weather and climate information to their services and to implement the two-way communication system.**

5.1.2 Advisories and warnings for fishers on Lake Malawi

Existing warnings and information products for fishers on Lake Malawi are currently limited (besides tailored products developed through the UNDP EWS project), though extension services and communication centres exist and mostly provide information on safety at sea. These communication channels, which have direct contact with fishers, offer the potential for expansion and inclusion of warnings of extreme weather important to fishers and their safety – thunderstorms, squalls, extreme waves and winds. This has the potential to reduce loss of life and help direct fishers to safer areas. Weather information can also be used by fish processors and traders to estimate likely catches, current supplies and prices. In addition, tailored forecasts will be useful to fish processors to plan when they can smoke and dry their fish. Likewise fish traders will be able to plan when they can go to beaches to buy and process fish. Current estimates are that around 30,289 small-scale fishers that are extremely vulnerable to bad weather and 28 commercial fishers using engines of over 45 hp can be targeted, as their boats also capsize during strong winds. Collaborating partners will need to include Departments responsible for Meteorology and Climate Change, Disaster Risk and Management, Marine Police, and Safety of vessels (Marine Department).

The following are examples of the types of technical messages which have been identified and should be developed through this project:

- → **Early warning messages** for the fishers, fish processors and traders so that they are aware of the kind of weather expected for the next few days. This should help them to plan and do other business or income generating activities for their households. In the case of fishermen the likelihood of extreme weather that may cause boats to capsize or sink will be key – warning fishers before they leave port. The processors can be informed about what type of weather lies ahead and how it will affect catches, areas which may be fished (types of fish), and for traders they will be prepared to expect changes in fish prices like higher fish prices on the beach and hence be able to revise their plans as to which markets they can target with fish products to be selling at such high prices. In this case we will have better packaged information flow of weather changes to the targeted stakeholders who may be informed and adjust their daily programmes to reduce lake accidents and fish spoilage;
- → **Use of safety equipment like life jackets** – this message is important to be promoted among the fishers so that life saving facilities are available within their areas and fishers are properly trained for use;
- → **Survival messages** for the fishers who go out fishing. The messages will help those in distress. These messages will also be important to fisheries staff who go out for research or extension work. In this case, distress signals will also be considered;
- → **First aid messages** for use by fishers when one is involved in any accident while fishing;
- → **Unseaworthiness of vessels** to minimise accidents that are caused by using vessels that are not fit to withstand certain weather conditions. This could apply to both small- and large-scale operators;
- → **Other messages** including loading of fishing vessels, fire and failure of fire fighting equipment for large scale fishers, lack of, or poorly maintained, vessels, mechanical defects, collision avoidance etc could also be produced and disseminated to the fishing communities.

5.1.3 District climate information centres

This study recommends that proposed interventions related to the climate information centres include climate information advisories, site specific weather information, and capacity building of the entire information sharing chain. Linking to rural radio stations also needs supporting, as in other districts this effort has been limited by budgets. Department of Climate Change and Meterological Services would also be linked to Malawi Broadcasting Station, which is the major national media house, and linking to other media houses could be considered because some media houses enjoy wider coverage as well. In spite of Nsanje, Mulanje, Salima and Karonga having been linked to rural radios, the work is still incomplete because the funds were not enough to connect all radios to the districts. Also, issues of engaging local media experts need to be considered.

List of Existing centers	New building estimated cost	Estimated costs on equipment, transmission and delivery facilities	Estimate cost to link centre to rural radios and DCCMS headquarters	List of new centres to be created	Estimated costs on equipment, transmission and delivery facilities	Estimate costs of building	Estimate cost of link to radios and DCCMS headquarters

Karonga	None	5 million	8 million	Nkhata Bay	20 million	30 million	16 million
Salima	25 million	5 million	8 million	Bolero/Rumphi	20 million	30 million	16 million
Mulanje	None	5 million	8 million	Nkhotakota	20 million	30 million	16 million
Nsanje	None	5 million	8 million	Phalombe	20 million	30 million	16 million
Kasungu	30 million	20 million	16 million	Dedza	20 million	30 million	16 million
Zomba	30 million	20 million	16 million	Lilongwe	20 million	30 million	16 million
Chikwawa	None	20 million	16 million	MBC link with DCCMS studio	3 million		8 million

Table 9: Estimated costs per climate centre (Malawi Kwacha).

5.1.4 District and Community level capacity development on disaster management.

To address the gaps in management of the Cluster System and the district emergency operations centres, **this study recommends that district civil protection committees (DCPC) in the 15 district councils that were declared disaster areas during the 2015 floods be trained in the use of the cluster system in emergency response and setting, running and management of district EOCs.** Each DCPC has an average of 50 members. In addition, this study recommends building upon the work of the UNDP EWS and other projects in establishing a national emergency operations centre**. Development of operational guidelines for the NEOC should be supported. Strengthening EOCs will also involve:**

- Procurement of equipment for the EOCs and any other gaps.
- Necessary training to the officers manning EOCs.
- Undertaking a best practices tour to neighbouring countries in order to learn how such centres are run. Some countries are well advanced in areas of running EoCs. One such country is Mozambique.

5.1.5 Regular training of area civil protection committees

The first responders of any emergency are the community members led by the Area Civil Protection Committees (ACPC) and District Civil Protection Committees (DCPC). These are committees established in all traditional authorities by the district councils. Most of the ACPC and DCPC members in the district councils have not been trained in disaster management, climate change and how to use climate risk information/early warning information, rendering them inefficient. Each district council has an average of 10 ACPCs with an average membership of 20 members, whereas there are on average 50 DCPC members. **The study recommends regularly training (repeated at least once a year) all DCPC members in the 15 districts, as well as community members involved in responses and using EWS information (at least 150 community members)**. This would include short courses in the areas of disaster risk management, climate change and climate risk information/early warning information, sourced both locally and internationally, and the trainings should be given by DoDMA in collaboration with DCCMS and DWR.

5.1.6 Improving Community-based Early Warning Systems (CBEWS)

At times of disaster, impacts and losses can be substantially reduced if authorities, individuals and communities in hazard-prone areas are well prepared and ready to act, and are equipped with the knowledge and capacities for effective disaster management. The National Climate Change Investment plan (NCCIP) identifies priority activities under Disaster Risk Management Programme including improving the disaster risk management systems for the sectors and enhancing dissemination and use. Strengthening preparedness capacity and people-centered early warning systems are also key policy priorities under the recently developed National Disaster Risk Management Policy (NDRM, 2015). EWS must provide warnings that are timely and understandable to those at risk, take into account the demographic, gender, cultural and livelihood characteristics of the target audiences, including guidance on how to act upon warnings, and support effective operations by disaster managers and other decision makers. An EWS can be based in a community without being owned or driven by that community. The most lasting impact, however, occurs when a community has a strong understanding of the EWS; EWS are only as good as the actions they catalyze as triggered action is an essential part of any warning system.

DoDMA intends to learn from and more widely apply best practices (see table below) in community-based flood early warning systems in the country (CBEWS). The CBEWS that was piloted by Christian Aid in partnership with Evangelical Association of Malawi on Mwanza River in Chikwawa district in the Lower Shire in 2009 proved to be effective in saving lives and reduce economic losses. During the 2009 floods in Chikwawa, 6,660 people from 1,332 households and their assets were protected by the warning system; however the pilot project has not yet been rolled out to other rivers due to lack of funding.

In designing a CBEWS, solutions must aid communities in both receiving urgent information and in acting upon it. **Therefore, this study recommends scaling up the successful DIPECHO pilot projects through 1) awareness raising 2) improved communication methods and 3) installation of sensors to provide early warnings** (see Infrastructure section below). For example, the project should work with communities, particularly through schools and churches, to build awareness of potential vulnerabilities and conduct emergency response drills and early warning testing to prepare the community for potential natural disasters. Various communication methods – i.e., radio, drums, mobile phones, whistles, etc – should be implemented to act as warnings for community members. Besides these requirements there is a clear need to provide outreach and training for communities (focusing on community leaders and first responders) to enable to understand how warnings and information is produced, as well as some of the intricacies when using forecast products. Community leaders and responders should know the differences between a seasonal forecast, and even weather forecasts on 1-7 day timescales, including how the accuracy and uncertainty may change depending on the timescale. Efforts need to include local knowledge within any decision process and a starting point should be how currently the communities are warned and when they decide to react to any warnings. Working through schools and church groups will offer a way for the community as a whole to learn and benefit. DCCMS and DWR will need to be involved in the trainings and discussions as they may need to adapt and change the information content and way in which warnings are designed.

5.2 Infrastructure needed to service identified products

5.2.1 Observational equipment needed to service identified products

In order for these products and services to have access to the required information streams it will be necessary to upgrade some of the current observing equipment and monitoring/forecast processes in strategic locations where there are existing gaps. **The study recommends focusing on installing the following equipment:**

- Automatic weather stations in key locations to service both the hydrological modelling (i.e. providing information on catchment rainfall for the ODSS) and the need for localised weather data for developing the agricultural advisories. A further use for collected weather data is that in the long term if can be used to de-bias satellite estimates which will help reduce dependence on weather stations and extend the ability to monitor to further regions. The exact locations for AWS (and target farming communities) within each district will need to be determined through an analysis of existing risk assessments (on weather/shock prevalence, household insecurity, and nutrition including from WFP/FAO), as well as consultations with local communities and agricultural extension services. These AWS will be in addition to the 10 stations installed through the UNDP EWS project.
- Hydrological monitoring stations will be needed in the northern and central catchments to provide information to the ODSS, which is used to tie the hydrological models to represent current conditions. This helps ensure that the hydrological models do not drift too far when estimating current and near-future conditions. Installed stations will be in addition to those being installed in the 7 priority flood prone districts through the UNDP EWS project.
- Lightning detection as a proxy for rainfall and for detecting severe weather. Extending the current system (providing an additional two sensors to cover areas of lake Malawi and the north, beyond the 5 provided by the UNDP EWS project) and developing products which can be combined with existing satellite-based nowcasting systems will enable more accurate and timely warnings for fishers over lake Malawi as well as helping forecasters at DCCMS to identify where high intensity rainfall may fall, improving their ability to use the flash flood guidance system and provide more accurate rainfall predictions for use in the ODSS.
- Lake buoys, which measure the weather and wave conditions on Lake Malawi, will provide data and information not currently available. This will enable DCCMS to better predict inclement weather, which poses a danger to fishers, as well as improve their forecasts of the lake Malawi region, including the ability to predict Mwera winds. It will further be able to provide weather/wave information, which will be used as the basis for developing the warnings and services for fishers in component 2. Initially it is proposed to install 2 of these buoys (one in the north and one in the south), with a view to installing

more once it is demonstrated that the systems and arrangements for operations and maintenance (jointly undertaken with the Malawi Defence Force) work well.

- Sensors for CBEWS: In addition to this equipment and as part of the proposed community-based EWS work undertaken through component 3, **this study recommends installing a set of community-based AWS and hydrological sensors.** The hydrological sensors should be placed in low-lying areas in the 7 districts identified for community-based EWS activities: Karonga, Salima, Nkhotakota, Nkata Bay, Phalombe, Ntcheu and Zomba. Community-based AWS should be installed in surrounding highland areas and districts to observe high intensity rainfall that may lead to flooding. All these systems will send warnings/alerts to both the central data centres at DWR and DCCMS, as well as directly to village/community leaders and designated contact points. This is to avoid delays in information that can prove critical for timely evacuation and undertaking emergency response procedures.

The list of the proposed services and amount of monitoring equipment, together with the target districts, are presented in Table 11. The geographical spread and concentration of the equipment are further illustrated in the maps found in Figure 16 and Figure 17. Note that the exact locations will need to be determined in consultation with local communities and the operating departments, to ensure that there is sufficient access, security, data communications and support from local residents. Additionally it is recommended that where regular observers exist or are available, additional manual observing equipment (low cost rain gauges and hydrological staff gauges) are installed, to provide checks for data transmitted automatically and as a fail safe in situations where automatic telemetry fails and takes time to repair.

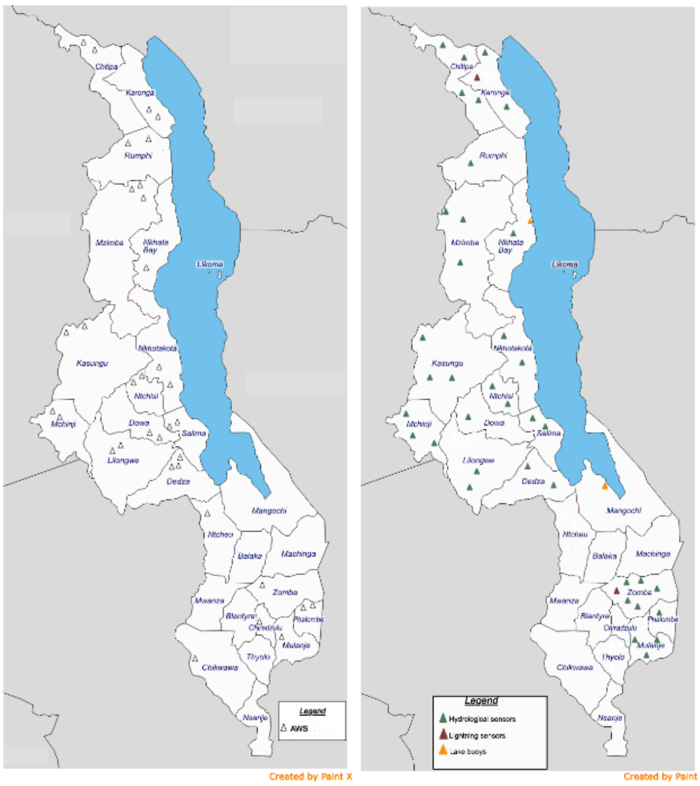

Figure 16: Maps of proposed districts for installation of AWS (left) and hydrological water level stations, lightning sensors and Lake buoys (right).

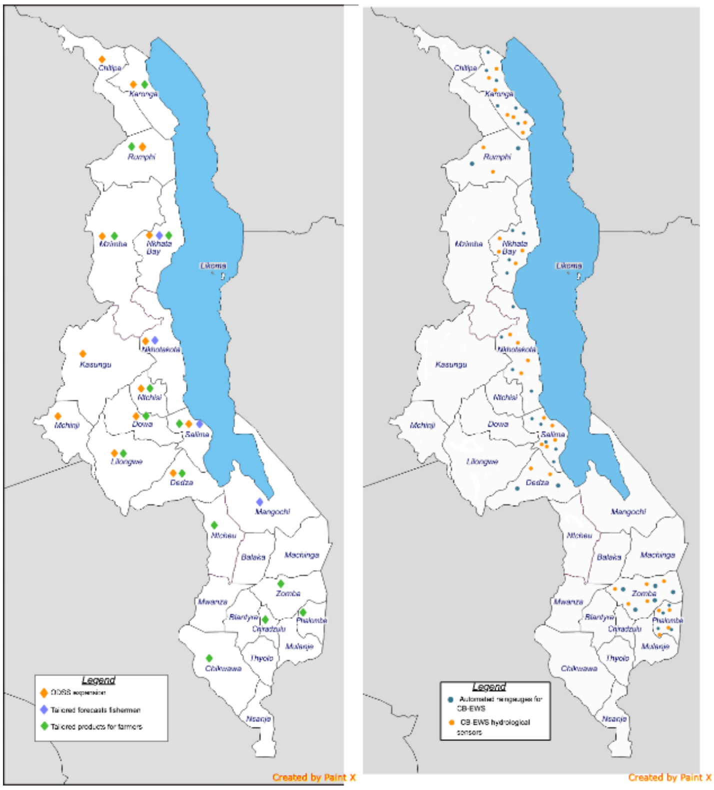

Figure 17: Maps of proposed districts for ODSS expansion, tailored forecasts for fishers and farmers (left), and automated raingauges and hydrological sensors for community-based EWS for floods (right).

5.2.2 Approach and budget for operations and maintenance of additional equipment

Operations & Maintenance (O&M) of the installed hydrometeorological infrastructure will need to be pursued through a wide range of approaches, recognizing that no single approach is likely to be able to provide all the required resources. Approaches can include the leveraging of domestic resources, human and financial (planning) capacity building for sustained O&M, and exploring private sector partnerships to operationalise and provide financial returns from the generation of early warnings and climate information. Domestic resource allocations and provision of training for O&M can enable country ownership and strengthen the mandates of DCCMS, DoDMA and DWR, which will help when negotiating future increases in allocated domestic finances and commitments, which in turn strengthen the long-term viability of established infrastructure. Maintenance and service contracts (for 3 years) should be bundled in the procurement notices, beyond which O&M will be provided by DCCMS, DWR and DoDMA through their budget allocations, including the following domestic resources which have been discussed and agreed upon:

- Co-financing from DCCMS (USD535,000) includes O&M of equipment including AWS, lake buoys and lightning sensors among others as well as staff training
- Co-financing from DWR (USD400,000) includes O&M of hydrological sensors, as well as staff support for flood forecasting and operating the ODSS
- Co-financing from DoDMA (USD576,000) includes O&M for community-based EWS.

Additional support is being provided through the LDCF EWS project (for the first two years), and embedded within the proposal cost estimates are allowances for spare parts (bought during the final two years of the GCF project) which will be used after the GCF project and service/maintenance contracts end, and the cost of O&M for each year. It is critical that DCCMS and DWR invest in enhancing both staff capacity and numbers, which will allow these agencies to provide O&M services beyond the project time frame and for expanded networks of observing infrastructure. These agencies have also committed to undertake replacement of equipment through budget investments. In addition to the hydromet agencies, DoDMA as the implementing partner has also allocated domestic resources for O&M of community-based EWS equipment, mostly focused on training and establishing community-based monitors and those responsible for regular (day to day) O&M (replacement of spare parts and more technical interventions will be undertaken by the respective hydromet institutions).

The project can support capacity building of the relevant agencies as well as communities to ensure that the technical capabilities and human resources are sustained for O&M beyond the project lifetime. Specifically, the project includes:

- Training for staff from DCCMS, DWR and the Malawi Defence Force on O&M of the lake-based weather and wave buoys and to assimilate/combine these data with forecasts
- Training for technicians at DCCMS and DWR to operate & maintain the installed AWS and hydrological water level stations and associated telemetry systems and calibration of sensors.
- The procurement agreement with suppliers for supply of equipment for DCCMS and DWR will include factory trainings by the supplier at their manufacturing sites, as well as on-site training at one or two selected sites in Malawi. This will enhance technicians understanding on the operation and maintenance of the equipment being installed.
- Where possible, after sales service contracts for the lifetime of the project will be negotiated, ensuring spare parts are available beyond the project lifetime.
- Training of trainers for both DoDMA district officers and community members on O&M of community-based EWS equipment (including establishing community based responsible technicians) to provide basic maintenance and safety care of the AWS/hydro met stations.

The following table (Table 10) indicates the resources that can be made available for O&M activities for the initial 6 years of the project and for the 4 following years, based on committed domestic co-financing, UNDP TRAC and GCF funding. This would cover the expected lifetime of the equipment assuming it was installed in year 1. Where equipment is installed in years 2 and 3 the timeframe will shift accordingly (including bundled service and maintenance contracts), but still incorporate provision for purchasing spare parts before the project ends. Funds for years 1 & 2 will still be required to allow for site visits and planning of infrastructure rollout (including vehicle maintenance), as well as to purchase tools and equipment for maintenance etc.

Table 10: Estimated costs of O&M and funding sources for the 6 years of the GCF project and for 4 years post project (the expected lifetime of the equipment).

Equipment	Year 1 (USD)	Year 2 (USD)	Year 3 (USD)	Year 4 (USD)	Year 5 (USD)	Year 6 (USD)	Year 7 (USD)	Year 8 (USD)	Year 9 (USD)	Year 10 (USD)
Lake-based buoys										
Domestic financing from DCCMS + DoF budget: Spare parts							5000	5000	5000	5000
Domestic financing from DCCMS + DoF budget: Human resources & travel (fuel and vehicle/boat maintenance)	0	4000	9000	14000	19000	24000	34000	34000	34000	34000
GCF: Spare parts				15000	15000	15000				
GCF: Human resources & travel (fuel and vehicle/boat maintenance)	20000	30000	25000	20000	15000	10000				
GCF: Training for O&M of lake based buoys		30000	30000		30000					
Lightning sensors and services										
Domestic financing from DCCMS budget: spare parts							5000	5000	5000	5000
Domestic financing from DCCMS budget: Human resources & travel, and costs of private sector services (warnings and alerts) associated with detection network	0	10000	20000	30000	40000	50000	50000	50000	50000	50000
GCF: Spare parts				15000	15000	15000				
GCF: Human resources & travel, and costs of private sector services (warnings and alerts) associated with detection network	30000	40000	30000	20000	10000	0				
GCF: Training for O&M and system use	58333	58333	58333	58333	58333	58333				
Automatic weather stations and hydrological stations *#										
Domestic financing from DCCMS + DWR budget: Spare parts							10000	10000	10000	10000
Domestic financing from DCCMS + DWR budget: Human	0	21000	41000	51000	61000	71000	91000	91000	91000	91000

resources & travel (fuel and vehicle maintenance)										
GCF: Spare parts				40000	40000	40000				
GCF: Human resources & travel (fuel and vehicle maintenance)	50000	71000	51000	41000	31000	21000				
GCF: Training for DCCMS and DWR for O&M of AWS and hydrological equipment	60000	60000	35000		35000					
Operation of commmunity based EWS										
Domestic financing from DoDMA budget: Spare parts							10000	10000	10000	10000
Domestic financing from DoDMA budget: Human resources & travel (fuel and vehicle maintenance)	0	0	11000	11000	22000	22000	33000	33000	33000	33000
GCF: Spare parts				20000	20000	20000				
GCF: Human resources & travel (fuel and vehicle maintenance)	20000	33000	22000	22000	11000	11000				
GCF: Training of DoDMA district officers and community members on O&M of community-based equipment	98000	98000	98000	98000	98000	98000				
Development of strategy + contingency										
Development of long term O&M strategy	100000 TRAC/GCF	100000 TRAC/GCF			50000 TRAC/GCF	50000 TRAC/GCF				
Contingency	40000 TRAC/GCF	40000 TRAC/GCF	40000 TRAC/GCF	40000 TRAC/GCF	40000 TRAC/GCF	40000 TRAC/GCF				

Note:
* DCCMS: Currently has 7 Meteorological Engineers + 4 IT personnel. Require extra 3 people trained from current staff for period of 2 years to cover extra equipment (no extra human resource costs) – GCF funds used for training;
# DWR: Currently 4 technicians per district and 3 per region + 3 specialised data/hydrologists for countrywide data management. Require 3 additional hydrologists/technicians at headquarters (20k per year)

Table 10 is a draft O&M budget which will need to refined during project implementation, based on a more detailed examination of current human and financial resources, as well as an accurate estimate of the required increases needed to service the equipment. The costs of developing a long term strategy for O&M, is provided for during the first two years, and the strategy will be reassessed towards the project completion (final two years). The budget assumes that GCF resources will need to finance the human resources, tools, equipment and travel for O&M initially, with a decreasing contribution towards the end of the project lifetime, after which domestic financing (from the budgets of designated authorities) will take over. For this purpose it is assumed that both DCCMS and DoF will finance O&M costs associated with lake-based buoys, DCCMS will finance the lightning detection system, DCCMS will finance AWS costs, DWR will finance O&M associated with hydrological stations, and DoDMA will finance O&M associated with the community based raingauges and water level sensors. Assuming that, for the first three years after equipment installation, spare parts are covered through bundled maintenance contracts with suppliers, it is suggested that the final two years of GCF funding are used to buy spare parts to last beyond the lifetime of the project – assuming no service/maintenance contract is in place for this period. There may yet be requirements for spares and so this has been included under domestic financing at a lower rate (to take up any extra requirements). Training for O&M will be funded through GCF resources for the lifetime of the project and will not be needed after it finishes. Contingency funding (for unforeseen events e.g. floods washing away equipment, lightning strikes, vandalism etc) is provided for each of the 6 years of the project.

In order to address any shortfalls in domestic financing beyond the first 6 years, the project can also tackle barriers around legal and institutional arrangements related to public private partnerships to support the participation of private sector actors in the generation of EWs and CI while contributing to the operational and financial viability of the national hydromet services. It is expected that the services delivered through the information provided by the lake buoys (for fisheries – including potential commercial clients) and the lightning detection system (for severe weather and thunderstorms) will contribute to any shortfall in O&M costs beyond the project financing. Currently, a handful of AWS in Malawi are owned by the private sector and maintained by DCCMS and such opportunities can be further explored for potential co-benefits, including O&M being undertaken by private sector (through Activity 2.4). In particular, the project should explore viable policy and institutional arrangements for potential investments in O&M of infrastructure and dissemination of EWs and CI.

Finally, the impact assured through capacity building, knowledge sharing and learning, private sector engagement and operationalization and contribution to relevant policies, will strengthen the mandates for these agencies for securing further financing through national budgets. The agencies indicated that annually the additional O&M costs will be included in the estimated budgets submitted to the Ministry of Finance and will be embedded in department activities beyond the project time frame. These commitments and mandates promote financial viability for sustained O&M of the project in the long-term.

5.3 Forecasting and analytical capacity needed to provide information for tailored products

5.3.1 Expanding ODSS for the Shire basin to other catchments

This study recommends applying the ODSS to other catchments that have the potential to help better understand flooding risk and develop knowledge products. Expansion of the ODSS for the Shire river basin should be to river basins in the north and central regions. The investments made through the SRBMP to enable the development of this system are significant (>$2m) and much of the work has been to develop the software, data processes and visualisations. Once these aspects have been developed, applying the system to other regions will require less development and testing, though it will still need to be calibrated for different river systems and catchments, which will depend on the available hydrological, weather, satellite and other environmental data (e.g. soils and vegetation). It was noted that this system applied to catchments in the north will help better understand flooding risk (increasing the lead times for flood warnings) and water resource availability, and how they depend on upstream catchments which may themselves not be prone to flooding. It therefore offers an opportunity to develop catchment wide knowledge products and not only focus on the highest flood risk areas. To do this will require installing hydrological and weather stations in related catchments, some of which may not demonstrate high flood risk.

5.3.2 Enhancing capacity of DCCMS and DWR staff

Staff at DCCMS and DWR will require training both to operate and maintain the weather and climate-forecasting infrastructure and to effectively utilize the produced data. **This study therefore recommends the following capacity building activities** (which build on activities undertaken through the UNDP EWS project)**:**

1) training staff on O&M for equipment, including AWS, hydrological water level stations, lake buoys, and calibration of sensors. Taking a training the trainer approach will reduce reliance on external consultants in the long term, though initially it is recommended that new equipment is purchased with a minimum of 3 year service warranties to ensure that staff have the time to become familiar with equipment and the subtleties of O&M under field conditions;

2) training trainers to teach community members basic maintenance of equipment and providing support when communities are unable to fix or maintain equipment; and

3) training staff in data analysis and visualization; forecast production (both for weather and seasonal prediction, downscaling e.g. MOS and for running numerical weather prediction models); development of other tailored products, such as drought alerts; and formatting to facilitate use of data by end-users, including communities and other agencies.

A key consideration highlighted in this assessment is that DCCMS and DWR staff participates in co-production and co-analysis of data with communities and users of the information and products. This is essential if there is to be uptake of monitoring and forecast products. Some of these activities should be conducted through the Climate Centres and other decentralized resources such as the Agricultural Resource Centres, Beach Outreach Committees, as well as the training of ACPC/DCPCs. It is recommended that these interactions are not only conducted by staff from HQ, but also by local observers who understand the local context. These staff are a valuable resource and should be trained to undertake basic analyses on the data they collect, as well as providing an interface with local users of data/information, with whom they can interact and explore the available weather/climate/water data on a day to day basis (not only in a workshop environment). It is also critical that DCCMS/DWR staff are involved in developing the products that will be distributed via mobile phone and other media, and that interactions with communities/users are approached from a learning perspective, where both the scientific and local knowledge/perspective are given equal consideration.

District	AWS	Automated raingauges - for community-based EWS	Hydrological sensors [L,M,H flood risk according to doDMA]	No. hydrological sensors	Community-based EWS hydrological sensors	Lightning sensors	Lake buoys	ODSS expansion for flood forecast and water catchment from SRBMP	Tailored products for farmers [yellow - chosen districts][L,M,H food security risk according to DoDMA]	NASFAM (national)	Tailored forecasts fishermen	Climate information dissemination centres
Chitipa (WRA 9)	2		L	4				x	L	x		
Karonga (WRA 9)	2	7	H	2	7	X	X	x	M	x		x
Lilongwe (WRA 4)	2		L	2				x	M	x		x
Salima (WRA 4 & 15)	2	5	H	2	5			x	M	x	x	x
Dedza (WRA 4)	3	2	M	2	2			x	M	x		x
Nkhotokota (WRA 5 & 15)	2	4	M	2	4			x	L	x	x	x
Kasungu (WRA 5)	2		L	3				x	L	x		x
Mchinji (WRA 5)	2		L	3				x	L	x		
Ntchisi (WRA 5 & 15)	2		L	2				x	M	x		
Dowa (WRA 5 & 15)	2		L	1				x	M	x		
Mzimba (WRA 7)	3		L	3				x	M	x		x
Nkhata Bay (WRA 7)	1	4	M	1	4			x	M	x	x	x
Rumphi (WRA 7)	2	2	M	1	2			x	M	x		x
Phalombe	2	4	H	1	4				H	x		x
Chiradzulu	1		M - Partly covered by SRBMP						M	x		
Ntcheu	1		M - Partly under SRBMP						M	x		
Mangochi			H - Covered under SRBMP				X		M	x	x	x
Zomba	1	5	H	5	5	X			H	x		x
Mulange	1		L - Partly covered by SRBMP	3					M	x		x
Chikwawa	1		H - Covered under SRBMP						H	x		x
Nsanje			H - Covered under SRBMP						H – covered under GFCS	x		x

Table 11: Target districts for services/tailored products and the numbers of equipment proposed for each district.

6 Summary and conclusions

This feasibility assessment has been undertaken on behalf of the Government of Malawi in order to identify priority interventions and opportunities for funding development actions related to the use of climate information and Early Warning Systems in Malawi. Through the examination of recent reports and studies on climate impacts in Malawi, as well as reviewing the current state of early warning systems and associated projects, this assessment has identified clear gaps in current information availability and dissemination.

The approach adopted throughout this study was directed by the need to develop climate services, which serve a particular sector and/or community, and which have been piloted and tested to some degree within the cultural and capacity context of Malawi. A focus on services which are practically feasible to implement and can be expanded with appropriate investments in both human and technical capacities is expected to be beneficial in the long term. Not only can vulnerable and at risk communities benefit through the improved use of warnings and advisories, but by focussing on the service we ensure that appropriate dissemination channels are considered; there is an end product that can better service the private sector (and hence build potential income streams in the future); and equipment choices are directed by the required service. Where further equipment is required to provide new weather and climate observations, the study recommends low-cost solutions where feasible, though it is important that any solution is within the capacity of the technical departments to operate and maintain (based on previous experience), and fits with planned expansions being undertaken by each department.

This study recommends a comprehensive approach to increasing resilience in Malawi through scaling up current efforts, focussing in particular on the following services, which through stakeholder consultations and this assessment are deemed the most promising opportunities:

- Tailored products and services, including ICT, to disseminate early warnings and climate information to vulnerable communities, including farmers and fishers. The products and services for farmers will build on efforts underway through the GFCS pilot in Balaka and Nsanje province, and will require further investment in AWS for sites where tailored agricultural products will be disseminated and used, as well as capacities within DCCMS, DAES and NASFAM to produce, understand and disseminate these products. For fishers there are currently very limited forecasts of winds, waves and severe weather and these services will be developed through capacity building at DCCMS and DoF to produce, disseminate and understand these forecasts. Their production will be supported through investments in lake buoys to measure wind and wave conditions, DCCMS capacity to run NWP models and the expansion of a lightning detection network for identifying severe weather. These products should be demand-based and include development aimed at stimulating a private market for information services.
- Improving the information available for monitoring and forecasting floods and water resources, through an expansion of the decision support tools currently being developed for the Shire river basin and run by DWR, for the northern and central regions. This will result in an improvement in data assimilation from observations (of weather and hydrology) and weather/climate forecasts which will increase the lead time for flood warnings, providing DoDMA more time to plan for flood evacuation and response. This will be supported through the installation of AWS and hydrological sensors covering currently unreported catchment areas.
- Improving and extending community-based early warning systems to provide “last-mile” access to information and improve disaster preparedness. Training for first responders at the district and community level in technology and information dissemination to improve disaster preparedness and response, including how to use and interpret weather/climate/flood warnings and advisories, as well as translation into local languages and customs.
- Improved dissemination and community outreach services through expansion of the Climate Centres, support to Agricultural Resource Centres, ACPC/DCPCs, Beach Village Committees, and dissemination mechanisms including radio, print media and mobile phone technologies. The latter will build on existing services being developed and supported by NASFAM and DAES, and will include development of products which incorporate weather/climate information into existing services.

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Appendix A: Agenda, participants and notes from group discussions at stakeholder consultation workshop

The following summarises the agenda, attendees and discussions held at a stakeholder consultation workshop at the Golden Peacock Hotel, Lilongwe, 10th June 2015.

Agenda:

Empowered lives.
Resilient nations.

DRAFT PROGRAMME FOR A
STAKEHOLDER'S VALIDATION WORKSHOP FOR A REPORT ON ASSESSMENT OF EXISTING CENTRALISED AND DECENTRALISED EARLY WARNING SYSTEMS

Time	Activity	Responsible person
08:30 -08:45	Registration of participants	DoDMA
08:45-09:00	Opening Remarks	DoDMA
09:00-10:00	Presentation of the assessment of centralized and decentralized early warning systems in Malawi Report	Dr Chavula
10:00-10:30	Early Warning Systems Project Proposal	Srilata Kammila
10:30-10:50	**Tea Break**	**All**
10:50 -12:50	Group work discussing: • Assessing the effectiveness and efficiency of early warning data collection methods • Assessing the effectiveness and efficiency of early warning communication/dissemination methods • Assessing the effectiveness and efficiency of EWS coordination mechanisms and governance structures • Proposal for Up-scaling of EWS project	All
12:50-13:50	Group Presentations	All
13:50-14:00	Closing remarks	DoDMA
	Lunch and Departure	**All**

Attendees:

Name	Institution/Position	District	Phone No.	Email
Geoffrey Mkandawire	Nkhotakota DC-HRMO	Nkhotakota	0888500322	geochizo@yahoo.com

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Discussions:

GROUP 1

1. Scientific and indigenous EW collection methods are both effective and efficient, however their effectiveness and efficiency is debatable, for example:
   - River gauges providing scientific data, unless they relay data which is used in real time, may not be as effective as people in the upper catchments who can tell that there will be a flood downstream. However, the magnitude of the flood cannot be quantified as reliably as when using hydrological measurements.
   - Indigenous systems are efficient because they are area specific, for instance, abundant mangoes can indicate that there will be drought. However people take this information lightly, hence there is a need for this information to be documented in a formal way if people are to take it seriously.
2. Need to consider that some districts that are not recognised as disaster districts, affect other areas in terms of hazards e.g. Lilongwe and Ntcheu affect Salima in terms of flooding, even if Salima didn't experience high rainfall.

3. Need automated weather stations and rain gauges at local level such as villages, and need for more weather information centres.

GROUP 2

1. There are centralized and decentralized communication dissemination methods.
   - Hydrometers (water level monitoring) - when critical levels arise, phone calls are made to warn people to move to upper lands (safer places). However the challenge is when there are network coverage problems; megaphones, whistles, and shouting should also be used to warn others.
   - Centralised methods use radios, news papers and television broadcasting
2. Climate information products:
   - Too general and not area specific
   - Need for increasing monitoring stations
   - Validate indigenous knowledge
3. Dissemination channels need to include:
   - Extension workers
   - Radios
4. The project should consider strengthening the capacity of the decentralised structures and government systems.
5. A two-way system of disseminating information should be used rather than just a top down system of disseminating information.
6. Last-mile partnerships should be enhanced and coordinated.

GROUP 3

1. There is a lack of coordination between key players (MH, DoDMA and CCMI)
2. Need to be able to timely analyse and disseminate information received by DCCMS
   - DWR takes time to act on the information received from DCCMS
   - Weak linkages between DCCMS and DWR
   - Shorten the channels and data for message dissemination
3. No acting mechanisms to enable communities to get information
   - No/weak coordination between community structures and government structures to timely disseminate information
4. Need to re-establish (hydrometric structures)
5. DoDMA should make sure the task force on EWS should meet regularly.
6. Establishment of community climate information centres at ADC level (literature inclusive). Weather forecast messages should be area specific.
7. Need to engage corporate social responsibility for service providers like Airtel MW, TNM (for free coverage in times of disasters). Insurance companies should sell their products (climate related products) and be involved to help raise awareness to communities.

Appendix B: Examples of current 1 & 5 day weather forecasts issued by DCCMS

EXAMPLE DAILY FORECAST

WEATHER FORECAST FOR 7th JULY, 2015

WEATHER SYSTEM AND EXPECTED RESULTS:
The high pressure area located off South Coast of South Africa is inducing cool and moist South Easterly air flow into Malawi. It will be cloudy and windy with a chance rain drizzle over highlands. **Strong Mwera winds will be blowing** over Lake Malawi, Lake Chilwa and Lake Malombe.

SHIRE VALLEY
Cool in the morning. Expect locally cloudy conditions later in the day. Strong Mwera winds will be blowing.
Forecast Temperatures Ngabu Min. 15°C and **Max.26°C**

SOUTHERN HIGHLANDS
It will be cold in the morning. It will be windy and locally cloudy with a chance of rain drizzle during the day.
Forecast Temperatures: Blantyre Min 12°C and **Max. 22°C**

CENTRAL AREAS
It will be cold in the morning. Expect windy and partly cloudy conditions later in the day.
Forecast Temperatures: Lilongwe Min. 10°C and **Max. 23°C**

LAKESHORE AREAS
Cool in the morning. Expect partly cloudy conditions later in the day. Strong Mwera winds will blow over the Lake.
Forecast Temperatures: Mangochi Min. 16°C and **Max.27°C**

NORTHERN AREAS
It will be cold in the morning. Expect windy and locally cloudy conditions in the afternoon.
Forecast Temperatures: **Mzuzu Min. 10°C** and **Max. 20°C**

WINDS: South easterly.

OUTLOOK FOR WEDNESDAY: Expect windy conditions with chances of rain drizzle over highlands.

TIMES FOR SUNRISE AND SUNSET FOR 7th JULY, 2015

CITY	SUNRISE	SUNSET
MZUZU	06:06	17:32
LILONGWE	06:10	17:29
BLANTYRE	06:09	17:21

For further information, contact:
The Director
Department of Climate Change and Meteorological Services
P.O. Box 1808, BLANTYRE
Tel :(265) - 1- 822014/577 Fax: (265) -1- 822 215
Email: metdept@metmalawi.com Web: www.metmalawi.com

EXAMPLE 5 DAY FORECAST

ISSUED ON 6th July, 2015: VALID 7TH JULY TO 11TH JULY, 2015

HIGHLIGHTS

- Locally cloudy with patches of rain drizzle and rain showers…
- Windy conditions and Mwera over the lake likely…
- A drop in day time temperatures…

MALAWI'S WEATHER FOR THE PAST TWO DAYS

''

'

SOUTHERN AFRICA REGIONAL WEATHER ANALYSIS

Cool and moist south easterly air mass will be dominant over Malawi from Tuesday into Thursday, thereafter warm easterly airflow will affect Malawi.

WEATHER FORECAST FOR MALAWI

Expect a drop in day time temperatures and windy conditions plus locally cloudy conditions with rain drizzle and rain showers. Strong Mwera will be blowing over the lake.

VALID 7TH MAY, 2015 TO 11TH JULY, 2015

Shire Valley (areas along Shire River and around Lake Chiuta and Chilwa)	Windy conditions and patchy rains from Tuesday into Thursday. **Forecast Temperatures: Ngabu Min. 14°C and Max. 28°C**
Southern Highlands (Shire highlands, Kirk Range up to Dedza)	Cloudy conditions plus rain drizzle and rain showers up to Thursday. It will be very cold at night. **Forecast Temperatures: Blantyre Min.08°C and Max. 23°C**
Central Areas (Lilongwe, Mchinji, Dowa, Kasungu and part of Mzimba District)	Locally cloudy with few rain showers on Tuesday and Wednesday. **Forecast Temperatures: Lilongwe Min.07°C and Max. 24°C**
Lake Shore areas (Salima, Nkhotakota, Nkhatabay, Karonga, Mangochi)	Cloudy conditions with rain showers from Tuesday into Thursday. Strong Mwera will be lowing over the lake. This is a warning to the fishermen and other lake users. **Forecast Temperatures: Mangochi Min. 16°C and Max. 28°C**
Northern areas (all areas in the north except lakeshore)	Cloudy with rain drizzle in the first three days. It will remain very cold at night. **Forecast Temperatures: Mzuzu Min.08°C and Max. 21°C**

Next bulletin will be issued on Thursday 9th July, 2015.

Appendix C: Letters of commitment for post project operations and maintenance of installed equipment

Ref. No. **MET/TCP/12**

Telephone: +265 (0) 1 822 577/824 712
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Fascimile +265(0) 1 822 215
E-mail :metdept@metmalawi.com
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The Director,
Department of Climate Change & Meteorological Services,
Ministry of Natural Resources, Energy and Mining
P.O. Box 1808,
BLANTYRE,
Malawi.

27th August 2015

Ms. Adriana Dinu,
Officer-in-Charge and Deputy Executive Coordinator,
UNDP-GEF

Dear Madam,

RE: Operational and Maintenance (O&M) Support to the Saving Lives and Protecting Agriculture based Livelihoods in Malawi: Scaling up Early Warning Systems and Climate Information in Malawi Project

As per the requirement communicated by the Green Climate Fund Secretariat, I hereby provide the letter of commitment for post-implementation O&M support for the project *"Saving Lives and Protecting Agriculture based Livelihoods in Malawi: Scaling up Early Warning Systems and Climate Information in Malawi Project"*, to be implemented from 2016 to 2022.

As indicated in the co-financing commitment letters provided earlier, the Department of climate Change and Meteorological Services will contribute as part of its core mandate to the operation and maintenance of observational equipment during the project lifetime and thereafter. I would also like to express our endorsement of the O&M plan (as detailed in the project Feasibility Assessment) which the Department of climate Change and Meteorological Services drafted together with support from UNDP.

I commit the Department of climate Change and Meteorological Services efforts to supporting the post-implementation O&M of the observational equipment as envisioned in the O&M plan which is in line with the department's core mandate of maintaining meteorological station network in the country

Yours sincerely

Jolamu L. Nkhokwe
DIRECTOR OF CLIMATE CHANGE AND METEOROLOGICAL SERVICES

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Telephone: (265) 01 770 344/ 221
Telegrams:
Fax No. (265) 01 773 737
Email: secretary@irriwater.org

All communications should be addressed to: The Secretary for Irrigation and Water Development

MINISTRY OF AGRICULTURE, IRRIGATION AND WATER DEVELOPMENT
TIKWERE HOUSE
CITY CENTRE
PRIVATE BAG 390
LILONGWE 3
MALAWI

28th August 2015

Ms. Adriana Dinu,
Officer-in-Charge and Deputy Executive Coordinator,
UNDP-GEF

Dear Madam,

RE: Operational and Maintenance (O&M) Support to the Saving Lives and Protecting Agriculture based Livelihoods in Malawi: Scaling up Early Warning Systems and Climate Information in Malawi Project

As per the requirement communicated by the Green Climate Fund Secretariat, we hereby provide the letter of commitment for post-implementation O&M support for the project *"Saving Lives and Protecting Agriculture based Livelihoods in Malawi: Scaling up Early Warning Systems and Climate Information in Malawi Project"*, to be implemented from 2016 to 2022.

As indicated in the co-financing commitment letters provided earlier, Department of Water Resources will contribute to the operation and maintenance of observational equipment during the project lifetime. We would also like to express our endorsement of the O&M plan (as detailed in the project Feasibility Assessment) drafted together by the afore-mentioned agencies with support from UNDP. We commit to supporting the post-implementation O&M of the observational equipment as envisioned in the O&M plan.

Yours sincerely

Pepani Kaluwa
DEPUTY DIRECTOR OF WATER RESOURCES (SURFACE WATER)

Our Ref. No.
Your Ref.________

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Department of Fisheries
Ministry of Agriculture,
Irrigation and Water
Development
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Lilongwe
MALAWI

Date: 27 August 2015

Ms. Adriana Dinu,
Officer-in-Charge and Deputy Executive Coordinator,
UNDP-GEF

Dear Madam,

RE: Operational and Maintenance (O&M) Support to the Saving Lives and Protecting Agriculture based Livelihoods in Malawi: Scaling up Early Warning Systems and Climate Information in Malawi Project

As per the requirement communicated by the Green Climate Fund Secretariat, I hereby provide the letter of commitment for post-implementation O&M support for the project *"Saving Lives and Protecting Agriculture based Livelihoods in Malawi: Scaling up Early Warning Systems and Climate Information in Malawi Project",* to be implemented from 2016 to 2022.

As indicated in the co-financing commitment letters provided earlier, the Department of Fisheries will contribute to the operation and maintenance of observational equipment during the project lifetime. I would also like to express my endorsement of the O&M plan (as detailed in the project Feasibility Assessment) drafted with active participation of the Department of Fisheries with support from UNDP. I commit to supporting the post-implementation O&M of the observational equipment as envisioned in the O&M plan which is in line with the core function of the Department of Fisheries on sustainable fish resource utilisation and safety of the fishing communities for enhanced livelihoods.

Yours sincerely

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Alexander Bulirani
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