REPORT ON THE STATUS OF WEATHER STATIONS IN UGANDA

Prepared by:

Maximus B. Byamukama, PhD candidate WIMEA-ICT project

Mary Nsabagwa, PhD candidate WIMEA-ICT Project

Richard Okou, Component Lead, RC3, WIMEA-ICT Project

Julianne Sansa Otim, Principal Investigator,WIMEA-ICT Project

James B. Magezi-Akiiki, Assistant Commissioner, Training and Research, UNMA

ACKNOWLEDGEMENTS

We would like to acknowledge the contributions of the UNMA team including Mr. James B. Magezi-Akiiki for his assistance in retrieving the information that we requested for from UNMA seamlessly, Mr. Mark Muwanga, Mr. Khalid Muwembe, Mr. Stephen Tanywa and Mr. Caphers Martin Mangau for their useful insight and ideas provided during the stakeholders survey.

We also acknowledge Prof. C. P. K Basalirwa for providing his research findings of the climatic zones of Uganda and for the valuable comments that refined the data collection tools. To Felix Nanjubu, a student at the College of Engineering, Art and Design for the assistance offered in superimposing the maps.

To Dr Agnes Rwashana, Dr Josephine Nabukenya of the College of computing and Information sciences who gave valuable input into the refinement of the data collection tools.

Special acknowledgement goes to the weather station observers for availing time to answer our questions even on short notice.

PREFACE

The WIMEA-ICT project started in November 2013 and is funded by NORAD under the NORHED programme. It aims to improve the accuracy of and access to weather information by East African communities through suitable ICTs for increased productivity (in the agricultural, energy, water resources and construction sectors) and safety (in the aviation, disaster management, fishing, health, mining, and defense sectors). The project has four Research Components (RCs): i) RC1 - Numerical Weather Prediction; ii) RC2 - Weather Data Repository set up; iii) RC3 - Weather station network densification; and iv) RC4 - Weather information dissemination. All four RCs are being achieved through Research and Teaching capacity building.

This report presents results of an RC3 survey conducted to ascertain the status of weather stations and communications pathways. The survey was conducted between November 2014 and January 2015.The main aim of the survey was to derive mechanisms used in powering existing Automatic Weather Stations (AWS), identify the communication pathways, maintenance of the weather stations including methods used to protect them from vandalism and availability of human resources, network coverage, Uganda climatological zones and coming up with densification strategies among others.

The survey findings highlight some attributes that could be used in design, prototyping and deployment of new AWS and a number of challenges which have rendered currently installed AWSs unreliable. Some of the challenges include: inadequate technical support, funding and human resources to maintain and improve weather stations. Based on the identified gaps, the report presents recommendations to improve the status of the weather stations. We also present densification strategies based on current weather station distribution, network coverage, Uganda climatological zones and security. The report is organized as follows:-

Section 1 provides a general introduction about weather information management in Uganda and how NORHED and the WIMEA-ICT project, working with various academic institutions are involved in the survey that was the subject of this report. The geographical distribution of weather stations in Uganda is also highlighted in this section.

Section 2 contains tabulated information pertaining to the status of the manual and autonomous weather stations. A description of the various brands found, power supply and communication pathways are also given.

In Section 3, we present a detailed discussion on the densification strategies using various agreed upon criteria. The section highlights the contribution of network coverage and climatological zones among others in the selection of locations for new stations.

Finally, in section 4, we give various recommendations that we believe will improve the status of weather stations and information if adopted.

TABLE OF CONTENTS

Contents

ACKNOWLEDGEMENTS i

PREFACE ii

Section 1: Introduction 1

1.1 Weather Information management in Uganda 1

1.2 Distribution of weather stations in Uganda 2

Section 2: Survey Findings 3

2.1 Status of Weather Stations visited 3

2.2 Brands of Automatic Weather Stations in Use 4

2.3 Power Supply and Storage 5

2.4 Communication Pathways 5

2.5 Technical Challenges and Maintenance 6

2.6 Other general challenges 6

Section 3: Densification Strategies 8

3.1 Introduction 8

3.2 Densification Parameters 8

3.2.1 Climatological Zones 8

3.2.2 Location of existing operational stations 10

3.2.3 Network Coverage 10

3.2.4 Network Reliability Index 14

3.2.5 Security 15

3.2.6 Land policies 16

3.3 Proposed Locations 16

Section 4: Implications and Recommendations 17

4.1 Implications 17

4.2 Recommendations 17

References 19

APPENDIX 20

APPENDIX A: Weather stations managed by UNMA 20

APPENDIX B: Weather Stations managed by NARO 21

APPENDIX C: Survey questionnaire 23

APPENDIX D: Researchers 28

List of Figures

Figure 1.1 Some of the weather Stations in Uganda....2
Figure 2.1Movement of weather data from weather station to the observation Station....5
Figure 3.1 Climatological zones of Uganda (Basalirwa, 1994)....9
Figure 3. 2 2G coverage of UTL at -90dBm....11
Figure 3. 3 Comprehensive coverage of MTN....12
Figure 3. 4 Comprehensive coverage of Orange Uganda.....13
Figure 3. 5 Comprehensive coverage of Airtel Uganda....14
Figure 3. 6 Town Centres in Uganda....15
Figure 3. 7 Proposed sites for new stations....16

List of tables

Table 2.1 Status of weather stations in four regions of Uganda....4
Table 2.2 Automatic weather stations in use....5
Table 2.3 Technology specific skills at Entebbe met station....6
Table 3. 1 Proposed locations and their climatological zones....16

List of Acronyms

DWD	Department of Water Development
MoA	Ministry of Agriculture
NARO	National Agricultural Research Organization
UNMA	Uganda National Metrological Authority
UWA	Uganda Wildlife Authority
AWS	Automatic Weather Station(s)

Section 1: Introduction

1.1 Weather Information management in Uganda

In Uganda, about 71% of the citizens rely on subsistence farming, which is heavily dependent on rain seasons (Uganda Bureau of Statistics, 2014). Besides agriculture, many other activities rely on weather information and as such it is paramount that weather information delivery is done accurately and timely. The Uganda National Meteorological Authority (UNMA) is a government authority charged with the management of weather information in the Country. The authority performs duties including installing new weather stations, maintaining the old stations, collecting weather data, processing weather information and distributing it among others. The information is disseminated in various media channels and these include: local and national radios, telephone calls and television among others.

Due to insufficient coverage of the country by weather stations and other challenges, various institutions whose operations rely on weather information have resorted to installing their own stations. These include, among others, agricultural organizations, such as NARO, state authorities such as UWA and Academic institutions. WIMEA-ICT, a NORHED project, being implemented by four academic institutions namely Makerere University, Dar-es-Salaam Institute of Technology (DIT), University of Bergen and the University of Juba, in collaboration with their respective National Meteorological Authorities, is aiming to improve the weather information management through the use of Suitable ICTs. The project intends to set up a total of seventy (70) Automatic Weather Stations in three countries including Uganda, Tanzania and South Sudan. In a bid to kick start the project, weather station surveys were conducted in all partner institutions in Africa and for the case of Uganda, some weather stations in all the five regions namely South, North, West, Central and East were visited between December 2014 and January 2015.

While UNMA has the mandate to densify the network of AWS in the Uganda, one of the expected outcomes of the WIMEA-ICT project is the densification of the same as an addition on the stations that already exist. To this end, strategies of choosing the locations of new AWS with the aim of acquiring a representative network are given a rigorous treatment in this report.

1.2 Distribution of weather stations in Uganda

This report lists thirty nine (39) weather stations that are managed by UNMA together with their GPS coordinates. Some weather stations are managed by private institutions such as NARO and UWA and their existence may or may not be known to UNMA. The map in Figure 1.1 shows the distribution of the weather stations in Uganda. Wherever there is at least an automatic weather station, there is also a manual station to validate the data collected from the automatic weather stations. The manual weather stations are indicated only in stations where automatic weather stations are absent. The weather station numbers are extracted from Appendix A.

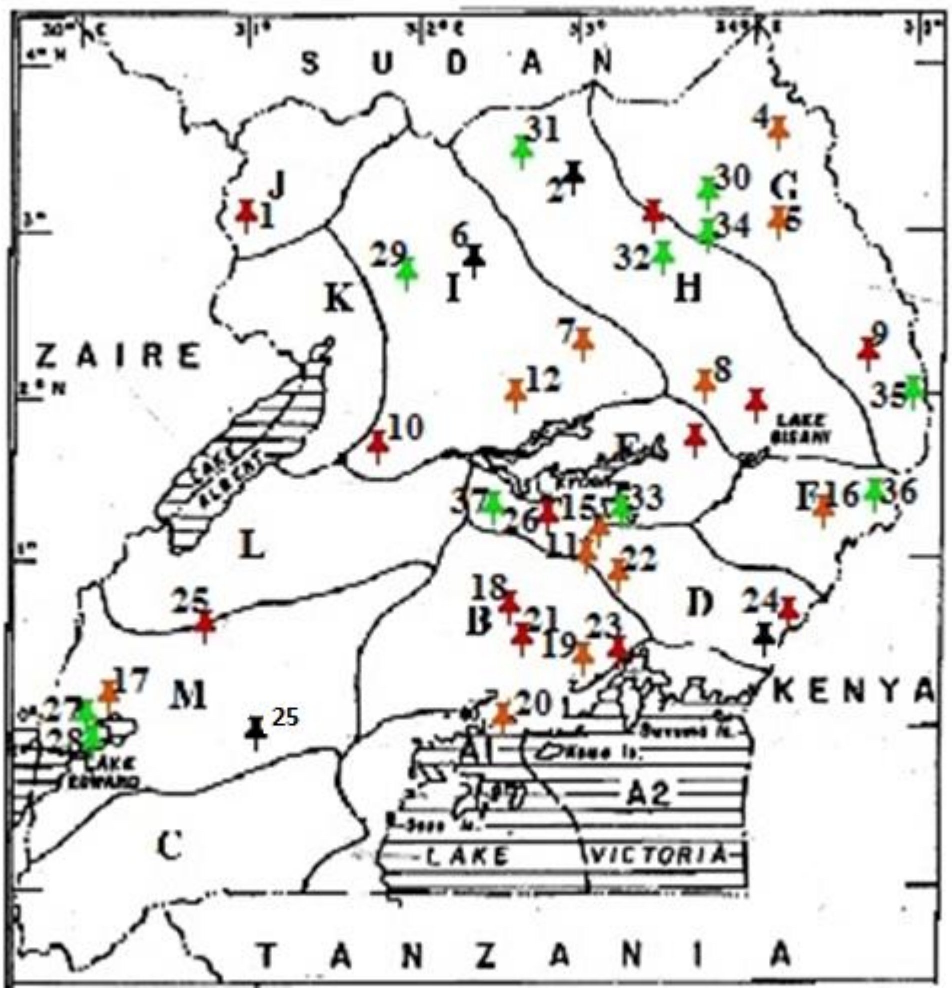

Figure 1.1 Some of the weather Stations in Uganda

Key

	Non-Operational AWS
	Automated weather station(coordinates provided)
	Automated weather station (no coordinates provided by UNMA)
	Manual weather station

Section 2: Survey Findings

2.1 Status of Weather Stations visited

Table 2.1 below shows the names, regions and condition of the stations that were visited.

Item	Station Name	Region	Manual	Automatic	Condition
1	Gulu Met Station	North	✓		• Poor office condition • Understaffed • Environment interferes with the readings • No Barometer- Code Atlas, Code table book, slide rule, thermometer stand, anemometer, Sunshine recorder, evaporation pan and Scientific Calculator to use for manual computations • No Internet
2	Gulu Airport	North		✓	• Data logger battery spoilt and so data captured cannot be received
3	Namotora	North		✓	• Poor environment • Unsure of location of the data logger
4	Kalongo Hospital				Non-existent
5	Kitgum VTC	North	✓		• Automatic station faulty • Faulty Rain gauge • No airtime or Internet
6	Bukalasa Agricultural College	Central		✓	Not working
7	Kawanda	Central	✓	✓	• Only authorized personnel view the data • Faulty MTU battery • Un harmonized data • No dedicated Internet connection • Broken Manual Rain gauge
8	Makerere University	Central	✓	✓	• WagTech station no longer working • Davis weather station logger has low power battery causing breakage of the digits • Evaporation pan not working • DAVIS tipping Bucket not functional
9	National Meteological Training school Entebbe	Central	✓	✓	• Equipments in bushy environment
10	Mbarara	West			Many vandalized parts • Un-operational
11	Kabale	West	✓	✓	• Golf course location causing the ball to hit the panel • Wag tech station sent reading out of range and was abandoned • No Internet

					• Rain gauge records on data cards which cannot be interpreted by observers • Another rain gauge never worked • Tipping bucket no longer tips
12	Kasese	West			• Functional AWS • No internet • No personnel available on daily basis
13	Kamuli District	East		✓	• New and functional station
14	Former Namasagali college/ Busitema University	East		✓	• New and Functional weather station

Table 2.1 Status of weather stations in four regions of Uganda

From table 2.1, it is clear that the challenges faced at the weather stations are of multiple types, ranging from technical to administrative. A general review of the challenges is given in section 2.5 and 2.6.

The findings in table 2.1 are summarized below.

1. Of the weather stations visited, most of weather stations have insufficient human resource both in skill, number and commitment. Basing on a threshold of at least 3 observers per station, 11 AWS that were visited did not meet this baseline. The other 3 were installed at large observation stations that were well manned.
2. Most of the weather stations cannot send their data because of an inability to pay for their communication infrastructure.
3. Vandalism of the weather stations' equipment (especially solar panels) is rampant.
4. Many weather station parts get damaged easily.
5. There is an insufficient number of weather stations in the country. Many regions, such as North East Uganda, were poorly covered by the weather station network.
6. Different weather station models will at times give enormously different parameter readings even in the same area.

2.2 Brands of Automatic Weather Stations in Use

Table 2.2 lists the brands or types of Automatic weather Stations used in Uganda. All weather stations were imported and assembled by teams of experts

Brand Name	Parameters	Communication
ADCON	Air Temperature, Rainfall, solar Irradiance, Relative Humidity, Wind direction,Wind Speed	RF (WSN support), GPRS
DAVIS	Air Temperature, Rainfall, solar Irradiance, Relative Humidity, Wind direction,Wind Speed, pressure	Various Proprietary RF options

WAGTECH	Air Temperature, Rainfall, solar Irradiance, Relative Humidity, Wind direction,Wind Speed	RS232, GSM
METOS	Air Temperature, Rainfall, solar Irradiance, Relative Humidity, Wind direction, Wind Speed	GSM, GPRS

Table 2.2 Automatic weather stations in use

2.3 Power Supply and Storage

Automatic weather stations in use are powered by rechargeable battery packs. The battery packs are recharged by solar cells. Some stations have components which are powered solely by batteries that replaced when they run out. Examples of the latter are the transmission Units from ADCON and the data loggers from DAVIS.

The ADCON OEM battery is not available on the local markets. Many of the weather station observers are not able to perform battery replacements or maintenance of any kind. Section 4.4.3 gives a discussion on power supply recommendations.

2.4 Communication Pathways

Figure 2.1 shows the most common pathway for the stations that were visited and had remote logging capabilities. The AWS distributed all over the country periodically collect weather data and store it in the data logger. The data logger is usually located at or near the weather station. After a period between one to three hours, the data may be read off from the data logger and sent to an observation station manually or sent to the station using GSM/GPRS. Here, the data is aggregated from all the weather stations in the country to be fed into prediction models.

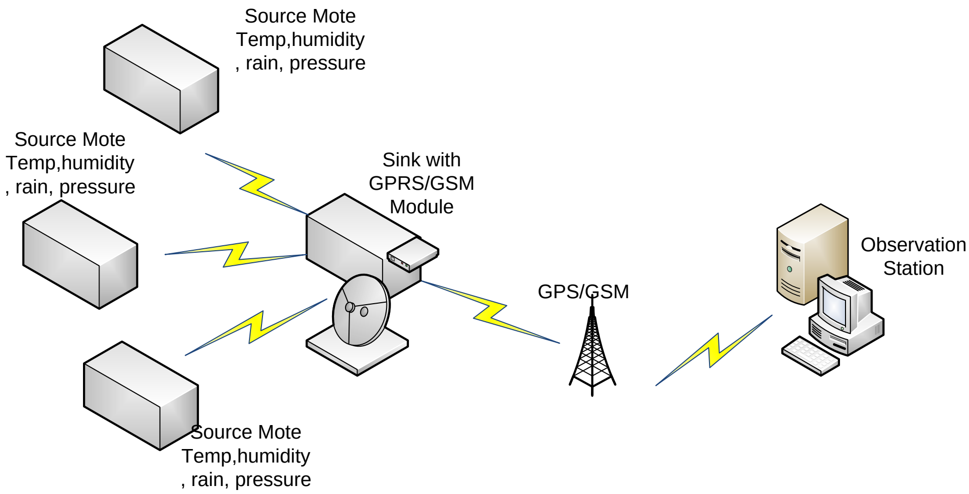

Figure 2.1Movement of weather data from weather station to the observation Station

In the past, the transmission of weather data has been done by other techniques such as using short wave radios and mailing of data cards to the observation station using the postal services. Currently, emails are also used for stations that do not have any GPRS or GSM uplink but have active internet connections.

2.5 Technical Challenges and Maintenance

Some of the problems highlighted in some of the stations include:

i. Sensors especially for the rain gauges easily get damaged
ii. Sensors are not well calibrated
iii. Some stations don't collect accurate data
iv. High cost of replacing damaged components
v. Batteries are neither readily available nor easily replaceable. This is attributed to the component selection which doesn't take the local market into consideration.

There is barely any funding given to UNMA stations for maintenance and the human resource available is not skilled enough to carry out station maintenance.

Table 2.3 below shows the human resource statistics at Entebbe meteorological station. The station employs the most and best human resource in the country.

This gives an idea as to the poor human resource status of other stations in Uganda.

No	Technology	People with related training		Rating of the experience with the technology
		Male	Female	
1	Numerical Weather Prediction Models	2	-	Fair
2	Computer Grid Infrastructures	2	-	Fair
3	Wireless Sensors	1	-	Good
4	Earth Observation Satellite Data	10	1	Very Good
5	Information Dissemination Technologies such as mobile Phones	10	2	Good
6	Programming	No experience at all		
7	Databases	Few		Good
8	Hardware maintenance And Systems Administration	Few		Good
9	Sensor configuration And Network Management	Few		Good

Table 2.3 Technology specific skills at Entebbe met station

2.6 Other general challenges

i. We were told that some of the station attendants guess the data, which is then shared with the dispatch center in Entebbe. This is because some of the personnel are not always on site to read off the data from the manual weather stations and yet the automated weather stations are yet to be fully utilized.

ii. The entire geographical distribution of the weather stations is far from reaching the level that is representative of the country. Many stations are either partially or completely non-operational.

iii. Many stations are not known by UNMA and as such, the data they collect is only accessed by only those particular organizations.

Section 3: Densification Strategies

3.1 Introduction

The data gathered and reported on in the section 2 of this report provides some insight into how the densification exercise can proceed in such a way as to cover the whole country uniformly.

As we observed in the main surveys in which we interviewed some of the major stake holders namely: UNMA, NARO, DWD, MoA and others, one of the main challenges faced in the deployment of Automatic Weather Stations by projects governed by foreign institutions (such as Non-Governmental Organizations) is that they dictate the locations of these station. This is because the weather data they collect is used locally—in the geographical boundaries where their projects are based. As such, a huge contribution and outcome of this report is to provide suitable locations for new stations. We now move our discussion onto the parameters that will affect our decisions. These site selection parameters are listed below and will be discussed in some detail.

i. Climatological zones of Uganda
ii. Locations of existing operational stations
iii. Network Coverage
iv. Network Reliability Index
v. Security
vi. Land ownership

Using GIS software, the maps of the climatological zones of Uganda and locations of existing stations were geo-referenced (GIS Dictionary, 2015) with a map of Uganda from Google Maps and the resulting maps were used to determine the locations of the proposed stations.

3.2 Densification Parameters

3.2.1 Climatological Zones

Uganda, being landlocked and filled with various geographical features such as mountains, lakes and vegetation demonstrates significant changes in climate per unit distance. For example, the areas that immediately surround Rwenzori Mountains in the South West of Uganda are more prone to rainfall even in the dry season. In the tropics, the climatic patterns of a region are adequately determined by the rainfall characteristics because rainfall is the climatic element which exhibits the highest variability both in time and space (Basalirwa, 1994).

To this end, it appears that the large amounts of data to be collected from these stations provides for more accurate weather prediction results if analyzed basing on the climatological zones from which the stations are installed.

The map below shows the various zones of Uganda as established by space (Basalirwa, 1994), using principal component analysis of rainfall patterns over the whole region or country.

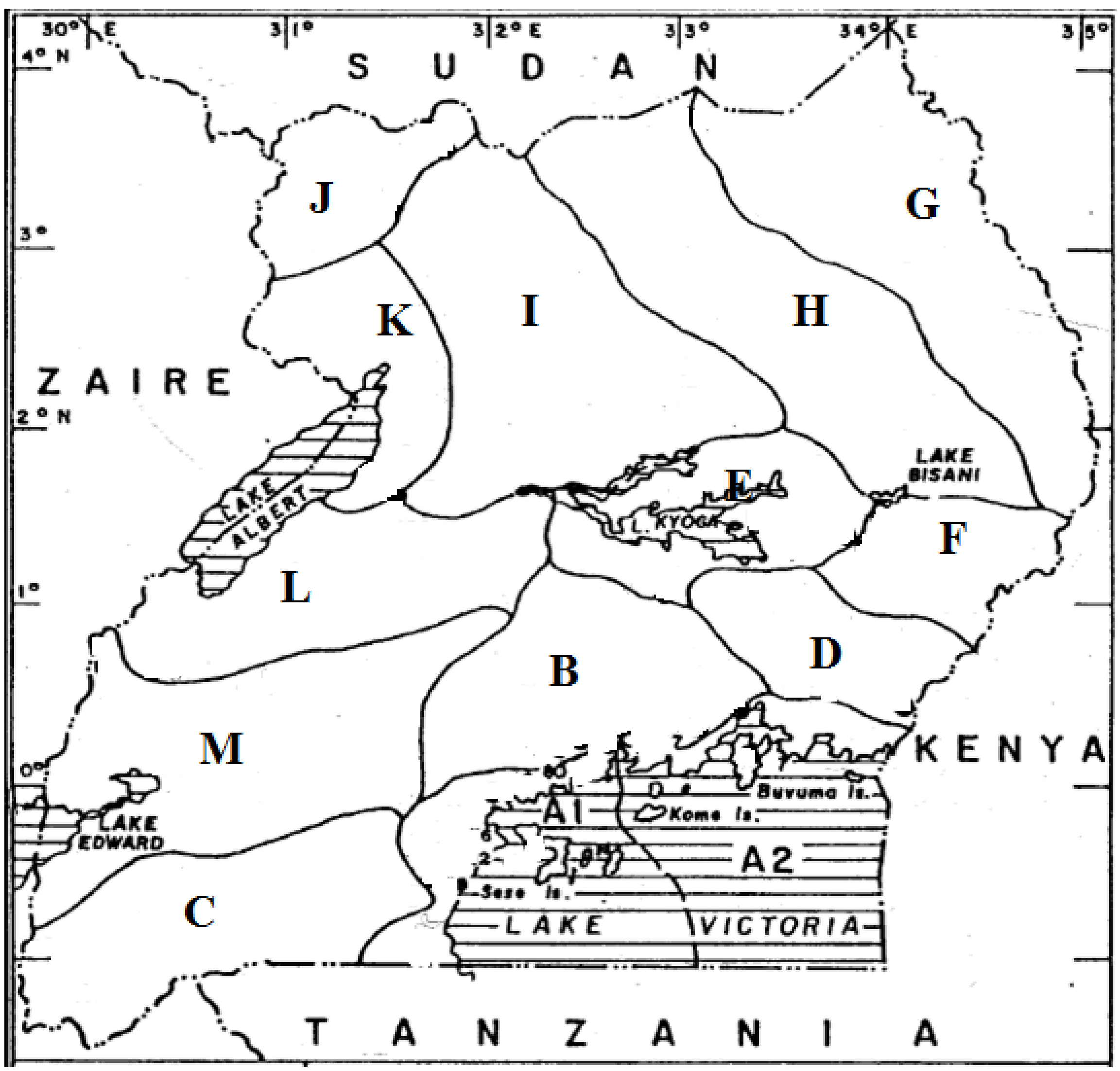

Figure 3.1 Climatological zones of Uganda(Basalirwa, 1994)

The various individual features of the zones shown in Figure 3.1 are not of concern in our objective of densifying the weather station observation network —we shall consider their geographical boundaries only.

3.2.2 Location of existing operational stations

One of the survey findings was that a few Automatic Weather Stations managed by UNMA are operational. This means that, with proper administrative protocols, the data collected by these stations could be stored in the same repository as the data collected by the stations to be installed. To that end, any operational station in a climatic zone will be considered during the densification process. The stations to be installed, therefore, should be at an optimal distance of separation from existing ones to avoid duplication, while, at the same time, promoting redundancy when either is down.

3.2.3 Network Coverage

Section 2.4 has presented the findings of the survey in regards to the communication pathways. While many pathways may be investigated during the course of the project, GSM/GPRS/3G/4G pathways are currently the only realistic options largely because of the extent of their coverage over the whole of Uganda. The relative cost of using these will also be quite low as compared to having dedicated radio links.

Our major guideline to the best communication criteria is that the AWSs shall be installed in areas where there is at least 2G network coverage by at least one service provider. Such a requirement will ensure that network coverage doesn't put major restrictions on the locations of the stations to be installed.

The maps in Figures 3.3, 3.4 and 3.5 indicate the coverage of some of the major telecom service providers including UTL, MTN, Orange Uganda and Airtel Uganda.

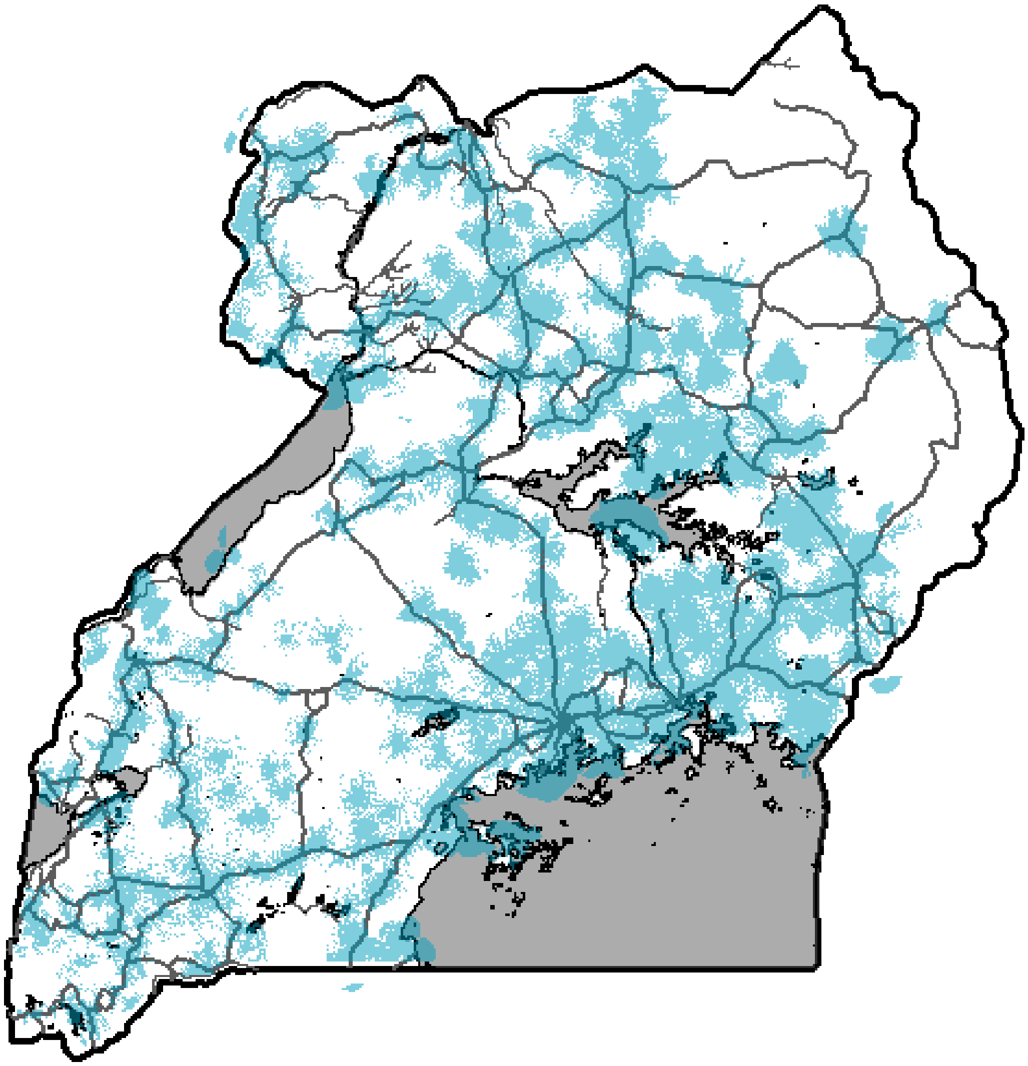

Figure 3. 2 2G coverage of UTL at -90dBm

UTL provided several maps including 3G and CDMA coverage. Another service provider, MTN, had more readily available data on coverage of all speeds. Figure 3.3 shows extensive MTN's coverage of both 2G and 3G over the whole of Uganda.

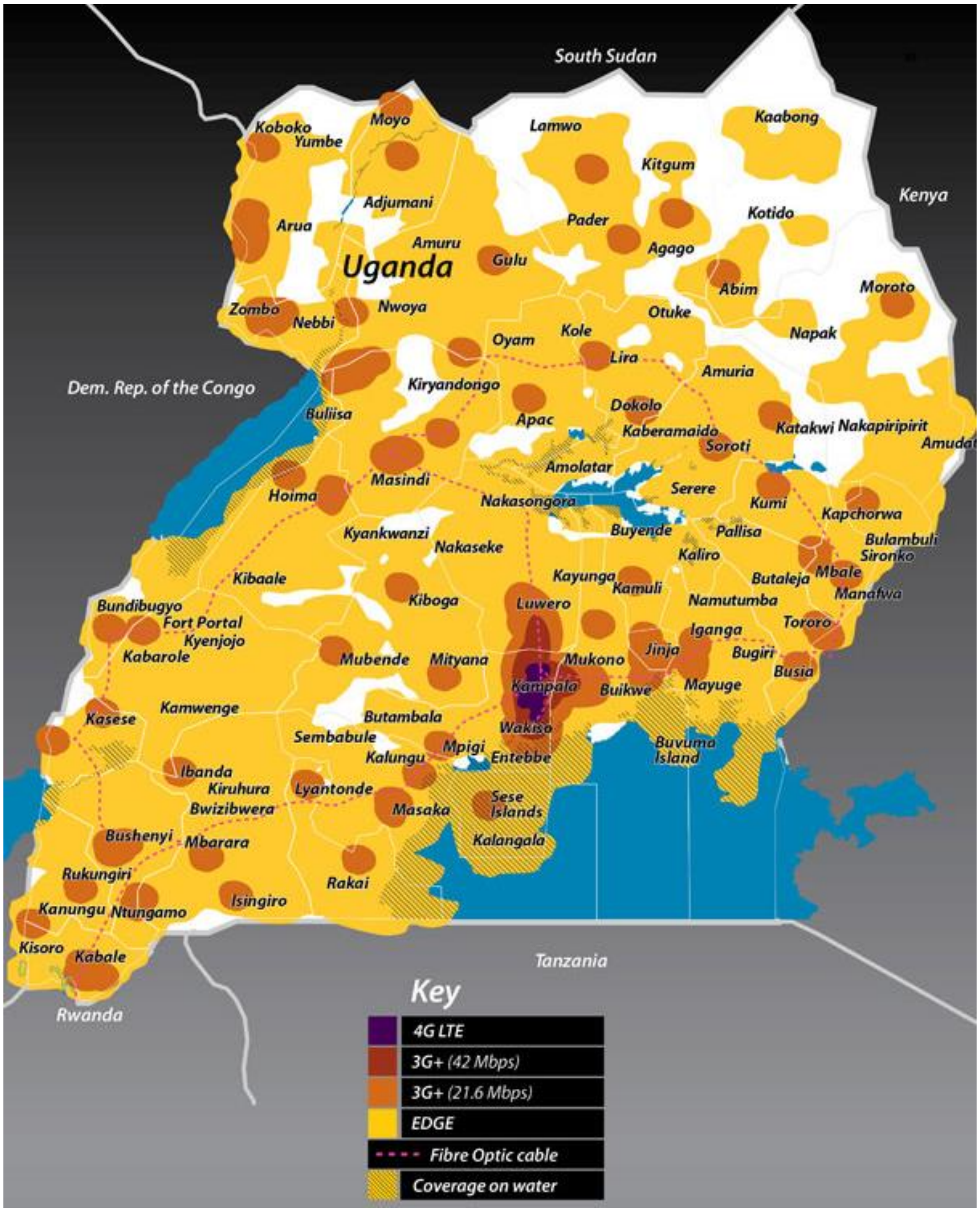

Figure 3. 3 Comprehensive coverage of MTN

Another service provider, Africell Uganda (previously Orange Uganda at the time the maps were received), has almost as extensive coverage as MTN. The coverage map is shown in Figure 3.4.

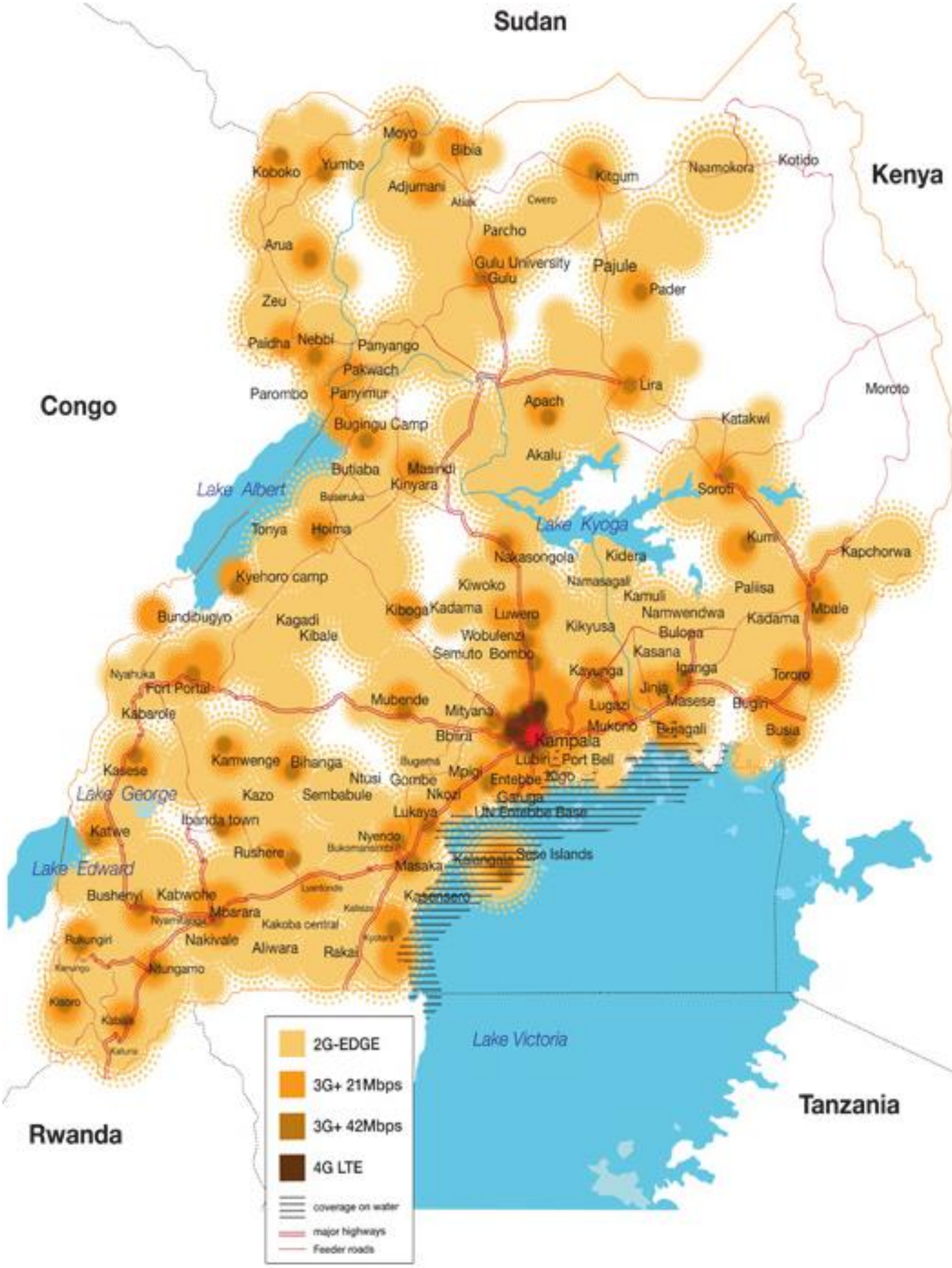

Figure 3. 4 Comprehensive coverage of Africell Uganda.

Finally, we looked at the coverage of Airtel Uganda whose map is shown in Figure 3.5. A point to note is that this map is a little outdated regarding 3G coverage indication. Most of the planned 3G sites have since been implemented.

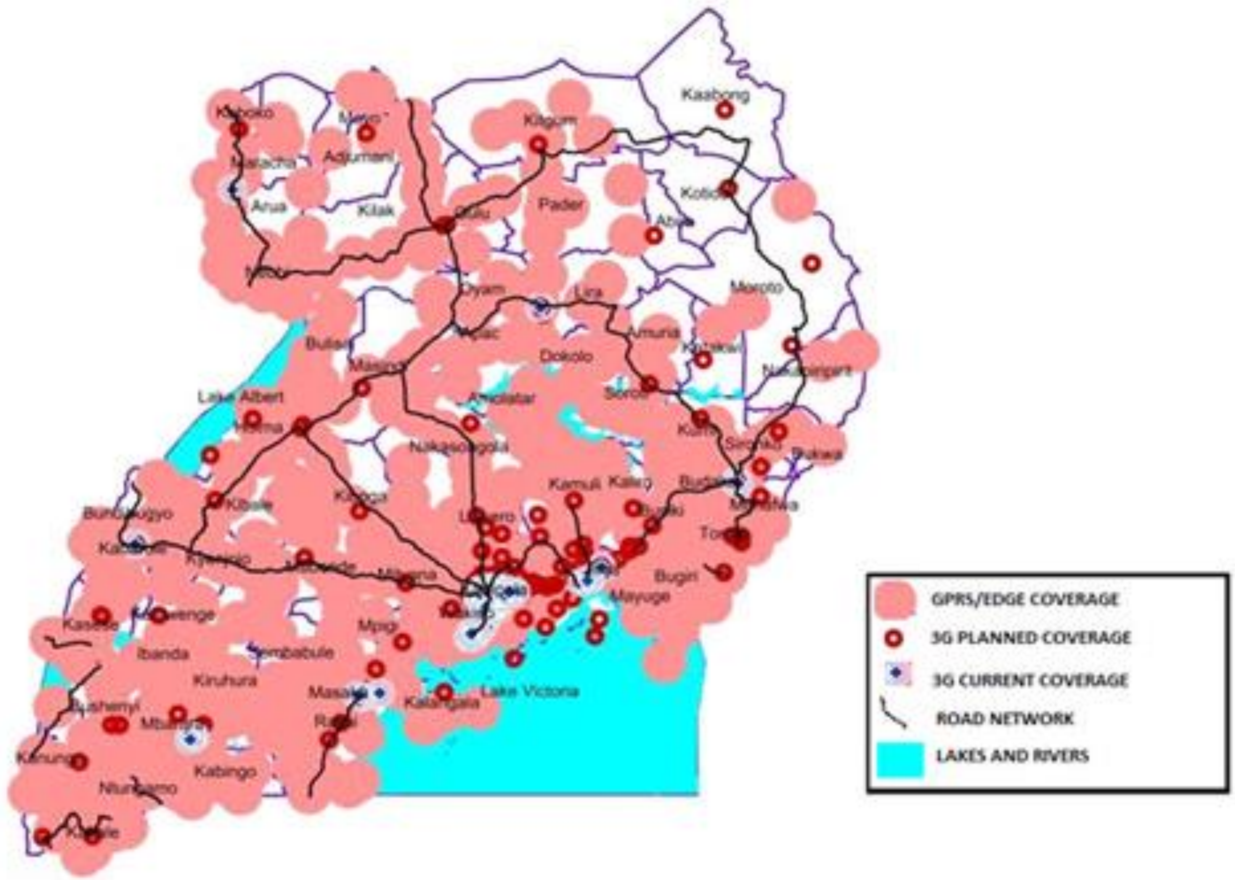

Figure 3. 5 Comprehensive coverage of Airtel Uganda

However, upon a quick visual inspection, it is easily noticeable that 3 of the providers (MTN, Orange and Airtel) have almost similar coverage in all climatic zones apart from a large part in zone 1. This means that network coverage alone will be the major criteria to follow when choosing potential sites in zone 1.

It is the intention of the researchers to perform actual signal strength tests in the proposed sites before deployment.

3.2.4 Network Reliability Index

We defined this, for every service provider's base station, as $\frac{p}{p+q}$, where p is the total uptime and q is the total down time. This is very detailed information making the computation of amalgamated values and incorporating all service providers involved impossible. Moreover, the information was not readily available, except from the data of Orange Uganda, and we would have had to mine it.

Furthermore, we plan to incorporate into the new automatic weather stations the ability to store data locally when there is weak or no network signal. It was therefore decided that this particular parameter was not very central to the deployment exercise.

3.2.5 Security

While all the parameters discussed here are fundamental to the deployment process of any AWS, we noted from our survey that security was probably the most important parameter. Most stations were installed near the district or police headquarters. An example is Gulu Met station which was being managed by the Police Officer-in-Charge.

The general hypothesis regarding security is that there is more security near the town centers and municipalities rather than farther. One of the criteria to be used therefore is the location of the nearest town centre.

UNMA is currently setting up partnerships with organizations such as schools to take over the maintenance of the weather stations. In that way security of the weather stations will be guaranteed and vandalism lessened. Plans are also underway of setting up sensitization workshops for the people around the weather stations. It is important that the people are sensitized about the use of the weather stations and also consider taking up their maintenance where possible.

The map in figure 3.6 below shows the town centers in Uganda.

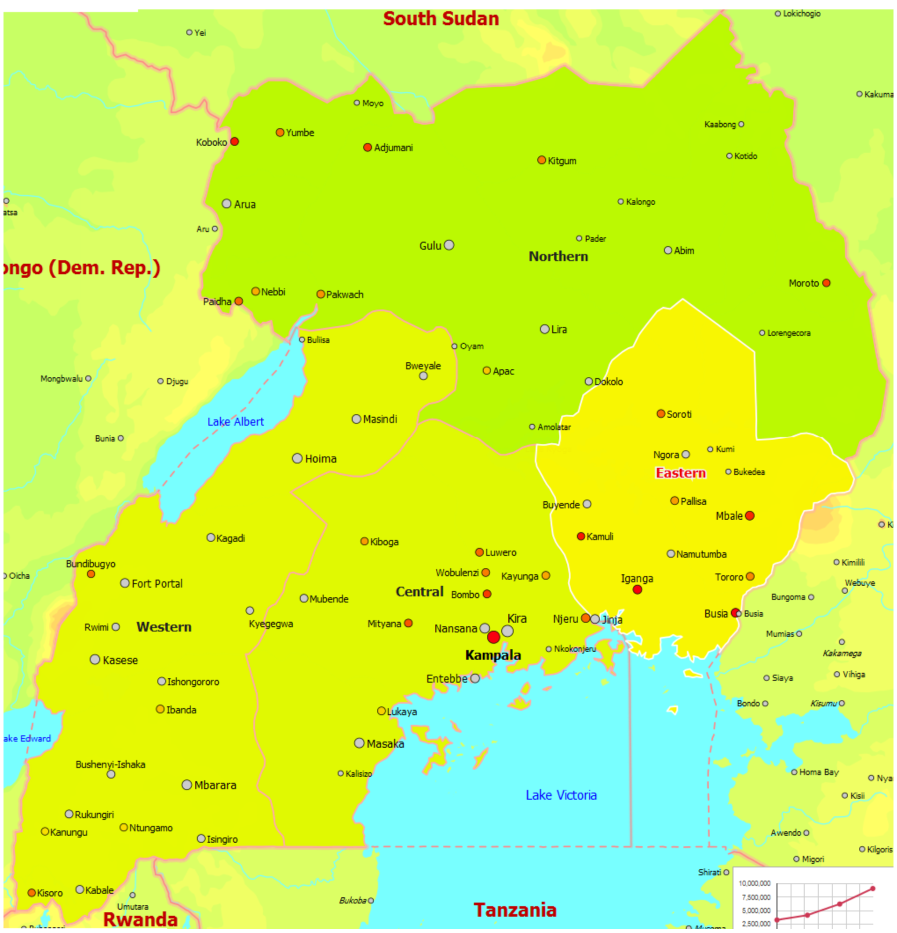

Figure 3. 6 Town Centres in Uganda

3.2.6 Land policies

When placing weather stations, land policies must be put into consideration. Most of the land is owned by individuals who have the rights to do anything on it including selling, demolishing and constructing among others. When buildings are constructed, they interfere with some of the parameters to be measured such as wind speed. Also, land owners may relocate the weather stations. A case in point is Bulindi weather station which was temporarily relocated because of a presidential visit to the area. Given this background, it is important that the selection of sites for placement of new weather stations be done based on ownership of the land by UNMA. UNMA is in the process of identifying all the weather stations in the country and taking over ownership. This report currently considers only weather stations known by UNMA.

3.3 Proposed Locations

The above maps were visually superposed on each other to determine the locations where the intersection did not have any stations and yet there was network coverage of at least one provider and security.

In the map in Figure 3.8, we indicate the proposed locations of new stations basing on the parameters we have explained in section 3.The station numbers and letters are extracted from Table 3.1 below, which also shows the proposed station names based on the district or town council location and the zones in which they lie.

	STATION	**ZONE**
A	Kanungu	M
B	Mbarara	C
C	Rakai	A1
D	Sembabule	M
E	Ntoroko	L
F	Kyenjojo	L
G	Buhaguzi	L
H	Nakaseke	L/B/M (border)
S	Madi-Okollo (Nebbi)	K
J	Terego (Arua)	J
K	Yumbe	J
L	Lamwo (Kitgum)	H
M	Nwoya	I
N	Matheniko (Moroto)	G
T	Buhweju	M
P	Gomba	B/M (border)
Q	Buwekula	M
R	Bugiri	D
I	Tororo	D
T	Soroti	E
U	Katakwi	U
V	Nakapiripirit	G

Table 3.1 Proposed locations and their climatological zones

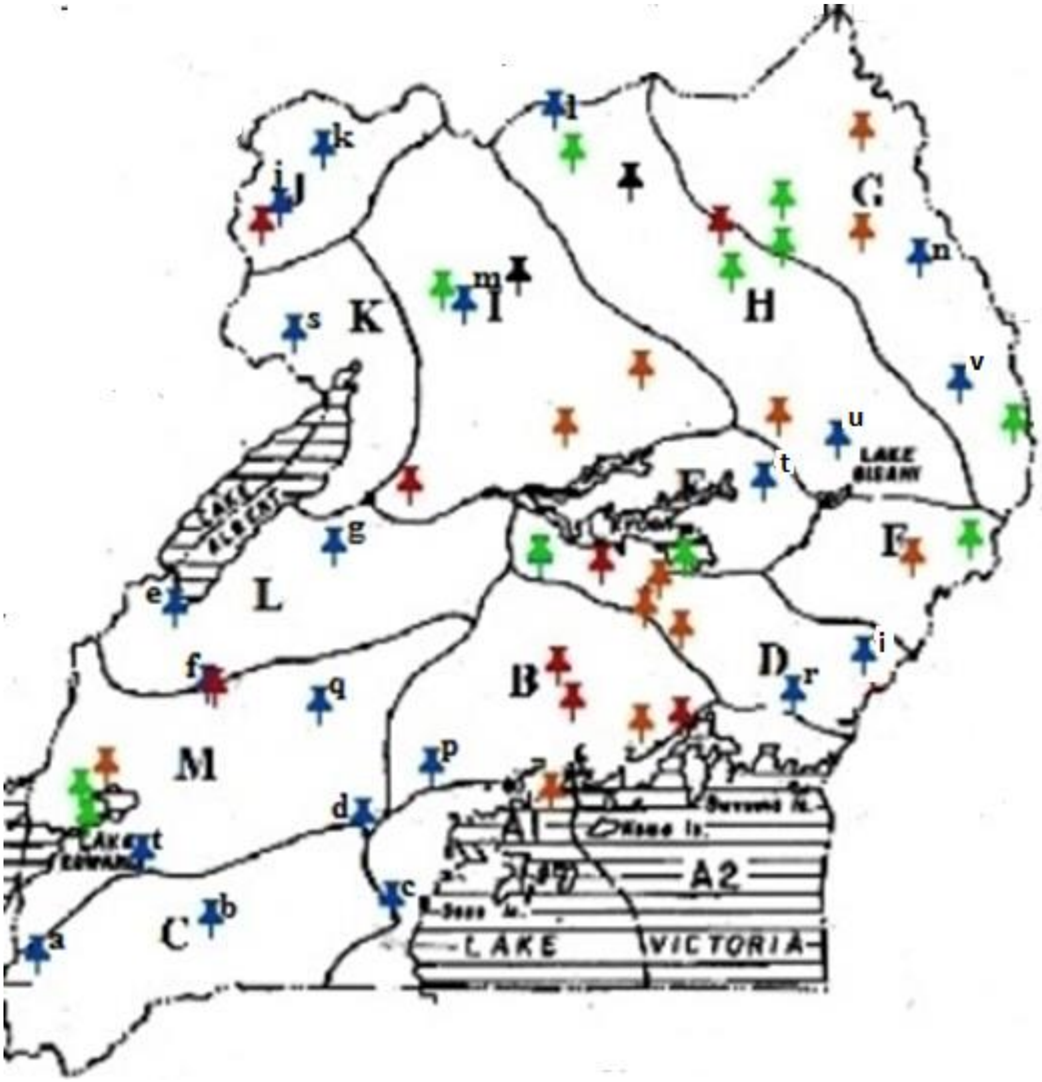

Figure 3. 7 Proposed sites for new stations

	Non-operational Weather stations
	Automated weather station
	Automated Weather Station (no coordinates provided by UNMA)
	Proposed stations

Section 4: Implications and Recommendations

4.1 Implications

The findings listed in section 2.1 imply the following underlying issues.

1. Ensuring that the weather stations have sufficient human resource (skill, number and commitment) will lead to sustainable operations of the weather stations
2. Expensive communications infrastructure leads to intermittent transmission of weather data.
3. Vandalism of weather station equipment disrupts operations and increases the cost of maintenance
4. The installation of non-robust weather stations causes constant breakdown of automatic weather stations due to failing components.
5. The insufficient number of weather stations in the country leads to poor representation of some regions in the weather forecasts.
6. Non-standardized weather station components lead to inaccurate weather parameter readings.

4.2 Recommendations

We recommend the following.

1. UNMA and academic institutions should train more weather station personnel in various disciplines including, but not limited to, computing, meteorology and engineering by December 2016. The salary structures of the staff should also be revised to increase motivation and commitment.
2. UNMA should proactively engage academia, NITA-U, UCC, etc. in exploring affordable communications options immediately.
3. UNMA and weather station designers should address vandalism of weather station equipment using methods such as motion detection sensors to detect vandals, careful selection of the installation location, alternative power sources etc.
4. UNMA and other station owners should develop strict calibration protocols. As soon as new stations are procured, their sensors should be standardized against the already well tested sensors. This shall ensure that the readings of the different station models are a match within a specific region. The existing manual stations can be used as a basis of calibrating the automatic weather stations and as such, manual weather stations can be left to work alongside the new automatic weather stations.

5. UNMA, in partnership with academic and researchers should immediately develop technical criteria against which the robustness and power consumption of AWS can be evaluated.
6. By December 2016, UNMA should have installed at least 30 new AWS in various climatological zones of Uganda following, at least in part, the densification criteria stipulated in section 3. This will not only increase the number of weather stations in the country but also increase redundancy in climatological zones such that reliable data is still available even when one station is down.
7. The use of AWS that rely on Wireless Sensor Networks is proposed. These could consist of individual sensors connected to Radio Frequency nodes in one Automatic Weather Station setup. The setup shall have full duplex communication with a central node that has an uplink to the remote server. The nodes could themselves store data locally when the Radio Frequency links to the central node are down and flush it if links are restored. This will ensure that downtime does not lead to loss of data.

References

Basalirwa, C. (1994). Delineation of Uganda into Climatological Rainfall Zones using the Method of Principal Component Analysis. *International Journal of Climatology*, 1161-1177.

GIS Dictionary. (2015, 04 02). Retrieved from www.esri.com: http://support.esri.com/en/knowledgebase/GISDictionary/term/georeferencing

Uganda Bureau of Statistics. (2014). 2014 Statistical Abstract. Uganda Bureau of Statistics.

APPENDIX

APPENDIX A: Weather stations managed by UNMA

	Station	Name	District	Lat	Lon	Type	Remarks
1	86300100	ARUA MET. STATION	Arua	03 03 N	030 55 E	Wag Tech	power problem
2	86320000	Kitgum Centre V.T.	Kitgum	03 17 N	032 53 E	Davis	Working
3	86330010	Kalongo Hospital	Kitgum	03 03 N	033 22 E	Davis	Vandalised
4	86340010	Kaabong	Kaabong	03 33 N	034 06 E	Davis	Working
5	86340020	Kotido	Kotido	03 01 N	034 06 E	Davis	Working
6	87320000	GULU MET. STATION	Gulu	02 47 N	032 17 E	Wag Tech	Working
7	87320390	Lira Ngetta Agro. Met.	Lira	02 17 N	032 56 E	Davis	Working
8	87330002	Amuria Water Dept	Amuria	02 02 N	033 40 E	Davis	Working
9	87340110	Nakapiripirit	Nakapiripirit	02 14 N	034 39 E	Davis	
10	88310030	MASINDI MET STATION	Masindi	01 41 N	031 43 E	Wag Tech	Vandalized
11	88320001	NamasagaliBusitema Univ.	Kamuli	01 01 N	032 57 E	Davis	Working
12	88320301	Apac District	Apac	01 59 N	032 32 E	Davis	Working
13	88330010	Katakwi Dispensary	Katakwi	01 55 N	033 58 E	Davis	Vandalized
14	88330060	SOROTI METEOROLOGICAL	Soroti	01 43 N	033 37 E	Wag Tech	Vandalized
15	88330470	Kiige Water Dev Depart.	Kamuli	01 11 N	033 02 E	Wag Tech	Working
16	88340590	Buginyanya Coffee Reseac	Bulambuli	01 17 N	034 22 E	Wag Tech	Working
17	89300630	KASESE MET. STATION	Kasese	00 11 N	030 06 E	Wag Tech	Working
18	89320010	Bukalasa Agric. Station	Luwero	00 43 N	032 30 E	Davis	Working
19	89320110	Lugazi Estate	Mukono	00 25 N	032 56 E	Davis	Working
20	89320660	ENTEBBE INT. AIRPORT	Wakiso	00 03 N	032 27 E	Wag Tech	power problem
21	89320670	NamulongeRes.Station	Mpigi	00 32 N	032 35 E	Davis	power problem

22	89330181	Kamuli District	Kamuli	00 54 N	033 09 E	Davis	Working
23	89330430	JINJA MET. STATION	Jinja	00 27 N	033 11 E	Wag Tech	power problem
24	89340190	TORORO MET.STATION	Tororo	00 41 N	034 10 E	Wag Tech	power problem
25	90300030	MBARARA MET.STATION	Mbarara	00 36 S	030 41 E	Wag Tech	Vandalized
26	91290000	KABALE MET. STATION	Kabale	01 15 S	029 59 E	Wag Tech	Working
27		Kitswamba	Kasese			Davis	Working
28		Rwankunyu	Kasese			Davis	Working
29		Amuru	Amuru			Davis	Working
30		Otuke	Otuke			Davis	Working
31		Namukora	Kitgum			Davis	Working
32		Agago	Agago			Davis	Working
33		Kidera	Buyende			Davis	Working
34		Abim Hosp.	Abim			Davis	Working
35		Amudat Hosp.	Amudat			Davis	Working
36		Kapchorwa	Gamatui Girls			Davis	Working
37		Nabiwera	Nakasongola			Davis	Working

APPENDIX B: Weather Stations managed by NARO

Weather Station Name	District	Status
NaCRRI	Wakiso	Working
Bulindi	Hoima	Working
Kachwekano	Kabale	Working
NaSARRI	Soroti	Working
Ngetta	Lira	Faulty (Not transmitting data, technician still trying to figure out)
Abi	Arua	Faulty (Not transmitting data, technician still trying to figure out)
NaLIRRI	Tororo	Working
NaFIRRI	Jinja	Working
MbaZardi	Mbarara	Working
Rwebitaba	Fort Portal	Faulty RTU
NaFORRI	Mukono	Faulty (Not transmitting data, technician still trying to figure out)

MuZardi	Mukono	Faulty (Not transmitting data, technician still trying to figure out)
Buginyanya	Mbale	Faulty (Not transmitting data, technician still trying to figure out)
NARL Kawanda	Wakiso	Faulty RTU

APPENDIX C: Survey questionnaire

WIMEA-ICT Research Component 3 Regional Weather Station Survey for Uganda

Introduction

We are conducting research on status of weather stations in Uganda. This survey is part of project name WIMEA-ICT that brings together Researchers from Makerere University, University of Bergen and Uganda National Meteorology Authority with aim of improving weather information management using ICT. Please answer the following questions. Responses you give are restricted for this purpose and will be confidential.

The purpose of the survey is to

1. To investigate the quantity and performance of the available weather stations in Uganda installed by your organization
2. To investigate the existing power sources in use at the different weather stations in the country.
3. To investigate the communication techniques used by the weather stations to transmit data to the operational center and their reliability
4. To find out the staffing structure and requirements of your organization
5. To solicit suggestions on how weather station management can be improved in terms of automation and densification

SECTION 1: GENERAL INFORMATION

1. Title/Position/Occupation of Respondent: Senior Meteorological Officer
2. For how long have you worked at in this section?.19yrs...
3. Did you receive any weather station management skills? Yes
4. If yes in 5 above, what Kind of skills were you trained in? Installation, management of Automatic Weather Stations.
   ....
   ....
5. **Please indicate the current staffing structure and requirements**

Experts	**Available**	**Required**	**Responsibility**
Meteorology	Available		
Engineering	Available		
Computer Scientists	Available		
IT Officers	Available		
Other	Technicians		

SECTION 2: SENSORS AND AUTONOMOUS WEATHER STATIONS (AWS)

6. **Please indicate the location, number and status the AWSsthat have been installed by this organization.**

Location	Station Number	Type/Model	Operational? (please Tick)	Reliability	Remarks

7. **Please indicate information about the AWS' sensors performance and selection**

Item	Yes	No	Not sure
Selection of the sensors was done withtheir performance in mind			
Sensors were selected because they were the cheapest			
The station was assembled by experts and we were not informed about the choices			

8. **Indicate the technology being usedto store weather information.**

Type of method	Please tick	Remarks
Database Management System		
Spreadsheet (such as Microsoft Excel etc)		
Data Cards (Hand written, punched etc)		
Other		Self RecordingRaingauges, Weather Summary Forms, Registers

9. **Please indicate thecurrent and the preferred format types used for storing various data**

Data Type (e.g temperature, rainfall)	Current format (e.g. text, binary, mm)	Preferred format (e.g text, cm)

SECTION 3: POWER SUPPLY AND STORAGE

10. Please indicate your assessment of the following considerations regarding power system cost, reliability and suitability

	Power factor	**Yes**	**No**	**Not sure**
1	The stations have a reliable and dependable power supply			
2	Power consumption considerations were made during equipment selection			
3	The power storage equipment are able to store sufficient power for a very long period of time			
4	The authority has enough funds to maintain the power requirements of the stations			
5	Power sources and storage devices need constant replacements			
6	Power stations are safe from tampering			
7	The stations incur high power bills every month			
8	Power system maintenance consumes the biggest part of maintaining the station			
9	The power sources are very specific and not available locally			
10	The Solar powered AWSs were installed in areas of known solar irradiance			
11	A large part of AWSs faults occur in the power system			
12	Power sources have to be installed by trained expatriates			

SECTION 3: COMMUNICATION

11. Please indicate the kind of communication framework in use

	Type	**Tick**	**Remarks**
1	GSM/GPRS (including 3G and LTE)		
2	Satellite		
3	Dedicated RF or Microwave link		

4	Voice call to data center		
5	Data is transported in hard copy (by road, rail etc)		

12. Please indicate your preferred communications service provider and explain why

13. Please indicate the reliability performance and support offered by the service provider

	Yes	**No**	**Remarks**
The service provider has dependablenetwork infrastructure			
The service provider's network infrastructure covers the whole country			
The service provider's communication equipment is easily acquired locally			
The service provider's charges are affordable			
Information sent over the network arrives in time			
The communication infrastructure is greatly affected by harsh weather			
The service provider's customer care is timely and accurate			
The service provider provides space for data storage			
The service provider provides technical assistance when a fault occurs			

SECTION 5: WEATHER STATION MAINTENANCE

14. Please provide information about the AWSs maintainability

	Yes	**No**
A manual was provided for the operation and maintenance of the AWS		
Components of the weather station can easily be acquired locally		
The stations components fail often		
The operation of the AWS requires minimal human intervention		
Replacing faulty weather station components affordable		

The station has some redundant components to increase reliability		
The station is well protected from physical trauma and theft		
Maintenance funding is available on a regular basis		

SECTION 6: CHALLENGES AND RECOMMENDATIONS

15. Please indicate any other challenges faced in weather data acquisition/transmission or management of this station

Challenge	**Yes**	**No**	**Not sure**
Continuous monitoring of the status of the station is impossible			
The number of stations deployed is insufficient to make valid conclusions			
It is not certain if the sensors collect the right data			
Sensors used are not well calibrated			
Sensors get damaged easily			
The station lacks trained personnel to perform specific tasks			
The format in which data is stored/captured makes it hard to analyze			

16. Please suggest if you would like any new AWS to be located in a different location than existing ones and state your reasons why.

17. Suggest any other recommendations to improve on the performance of the weather stations.

18. Give a few remarks about data integration and the challenges you are facing in this area. Would it help if you had one interface to access all weather data from the different weather stations in a preferred format?

APPENDIX D: Researchers

1. Dr. Julianne Sansa-Otim (COCIS, Makerere University)
2. Assoc. Prof. Richard Okou (CEDAT, Makerere University)
3. Prof. Charles P. K. Basalirwa (Met Unit, CAES, Makerere University)
4. Mr Maximus Byamukama (CEDAT, Makerere University)
5. Ms Mary Nsabagwa (COCIS, Makerere University)