McMaster University School of Engineering Practice

Master of Engineering and Public Policy Final Inquiry

Using mobile phones for environmental protection in Africa: The Equatorial Africa Deposition Network case study

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CONTENTS

ABSTRACT

By providing communications channels that were previously nonexistent because of the lack of basic landline communication infrastructure, mobile phones have revolutionized all kind of sectors in Africa. This report explores mobile phones' potential for environmental protection in the continent.

The African Great Lakes are a unique natural and human environment. Headwaters to the three great African rivers, lakes Victoria, Tanganyika and Malawi are also the habitat of a significant number of species, some of them endemic. As a critical component of the riparian countries' development plans to end poverty and enable economic growth, the management of the African Great Lakes represent a big challenge.

The Equatorial Africa Deposition Network (EADN) is a project proposed by 12 African countries aimed at investigating the sources and deposition of nutrients into the African Great Lakes, problems that affect the environmental integrity and productivity potential of the water bodies.

Based on the African reality, a mobile framework presents a solution that facilitate the operation of the EADN. More importantly, taking into account the fact that mobile phones represent something more than a communication channel in Africa, the framework proposes tools focused at understanding the behavior of the communities that interact with the African Great Lakes, an analysis needed by any management plan. Anticipated findings include:

- Modifications to the current EADN organization structure in order to implement and analyze the data generated by the Mobile Environmental Framework.
- The need for establishing collaboration channels with the regional Mobile Network Operators.

INTRODUCTION

Because of their ubiquity potential, mobiles phones represent the most used form of telecommunication worldwide (Bhavnani et al. 2008). In the case of Africa, by providing communications channels that were previously nonexistent, mobile phones have revolutionized all kind of sectors (Ekine 2010). Under the context of a telemetry project aimed at investigating the atmospheric deposition of nutrients into the African Great Lakes, this paper explores how mobile phones can be used for environmental protection.

In the first section, a description of the African Great Lakes and their environmental and economic importance is presented. The challenges faced by their management is analyzed. The second section provides an overview of the Equatorial Africa Deposition Network (EADN), an ambitious transboundary project that tries to identify sources of eutrophication[1], a major threat to the African Great Lakes integrity. In the third section, a mobile environmental framework around the EADN project is presented. The first part of the section explores the impact mobile phones have worldwide and regionally as a consequence of its current penetration. Then, the key role mobile phones can play as development boosters is presented. The mobile framework proposes services that can optimize the EADN daily operations and ultimately, presents mobile based solutions that can help to understand the behavior the communities that directly interact with the African Great Lakes have. Finally, the fourth section present recommendations towards the implementation and use of the mobile framework and general conclusions.

[1] Eutrophication is defined as "the over enrichment of receiving waters with mineral nutrients. The results are excessive production of autotrophs, especially algae and cyanobacteria". (Correll 1998)

THE AFRICAN GREAT LAKES

Delimited in the north by the Lake Turkana Basin and in the south by the Lake Malawi Basin, the East Africa Rift Valley Region (EARVR) is a transboundary natural and human habitat that involves the following countries: Ethiopia, Kenya, Sudan, Uganda, Tanzania, Rwanda, Burundi, Democratic Republic of Congo, Zambia, Malawi and Mozambique. As shown in Figure 1, the EARVR includes lakes Victoria, Tanganyika, Malawi, Turkana, Albert, Edward, George and Kivu. These tropical lakes form the African Great Lakes (AGL) and act as sources of the Nile, Congo and Zambezi African rivers.

Figure 1 EARVR region (Odada 2006)

Because they have surface areas and volumes comparables to those of the Laurentian Great Lakes of North America, it is common to find references in the literature of Lakes Victoria, Tanganyika and Malawi as the only members of the AGL . Table 1 summarizes some of the physical characteristics of these 3 major AGL in comparison with those of the Laurentian Great Lakes.

	Victoria	Tanganyika	Malawi	Superior	Michigan	Huron	Erie	Ontario
Surface Area (km2)	68,800	32,600	29,500	82,100	57,750	59,800	25,800	19,000
Max Depth (m)	79	1470	700	407	282	229	64	245
Volume (km3)	2,760	18,900	7,775	12,230	4,920	3,537	483	1,637
Residence Time (years)	23	440	114	107	59	16.4	2.2	6.7

Table 1:African and Laurentian Great Lakes physical characteristics (Bootsma,2003)

Table 1 shows that the residence time, or the amount of time water or dissolved substances stay on the lake, of the AGL is bigger on average than that of the Laurentian Great

Lakes. A characteristic of concern when dealing with eutrophication that must be taken into account while planning any type of environmental protection program.

One distinction between these two Great Lakes systems is their age. Lakes Tanganyika and Malawi have an age estimate of 10 to 20 million years, which makes them very much older than any of the Laurentian Great Lakes. Because of their age, these two African Lakes are ideal for paleoecology studies, like those related to the evolution of climate change (Johnson, 1996).

Another important difference between the AGL and the Laurentian or North American Great Lakes is their surrounding economic environment. The regional poverty in all the AGL riparian countries and their need for economic growth represent a challenge for their management (UNU-INWEH 2011). As will be described, both the fishery and the agricultural industries around the AGL are critical components of the economy and development of the riparian countries.

Because they are the major water bodies of the AGL system, a more detailed description of Lakes Victoria, Tanganyika and Malawi, their surroundings environments and their principal management organizations is presented.

LAKE VICTORIA

Representing the second largest lake in the world and the largest in the African Continent, Lake Victoria is bordered by Tanzania (51%), Uganda (43%), and Kenya (6%) (Odada 2006). However, Burundi and Rwanda are members of the lake Basin. Located at 1134 meters above sea level, the lake has a catchment area of 184000 square kilometers. Rainfall, evaporation and the outflow that comes from the Nile River are the major components of the Lake's water balance (Spigel and Coulter 1996).

With a population density that goes up to 1200 persons per square kilometer (Hoekstra and Corbett 1995), Lake Victoria basin support one of the densest, multi-ethnic and rural populations in the world.

80% of the lake catch is related to some kind of agricultural practice (Majaliwa et al. 2000). As a result, 21 million of people in the Basin have agriculture as their main source of money, with an average income of 90-270 USD per year (World Bank 1996).

Besides agriculture, fishery and manufacturing represent the two other major economic sectors related to Lake Victoria. As expected, fish is the most affordable and common source of animal protein within the riparian countries (Bwathondi et al. 2001). It is estimated that the exports made by Lake's Victoria fishery industry represent earning of about 600 millions USD (Duda 2002).

Regarding manufacturing, Ntilba and others (2001) identified breweries, sugar refineries, food processing factories, textiles and mining companies as examples of the industries related to Lake Victoria.

Excessive nutrients loading can be identified as the major cause of environmental problems of Lake Victoria. However, unsustainable fishing practices and the presence of invasive species like the water hyacinth are also causes of environmental concern. (UNU-INWEH 2011).

Even though Lake Victoria is the major source of water and animal protein for the surrounding communities, the most common health issues are related to waterborne diseases. This can be explained by the fact that the lake is a repository for human, agricultural and industrial waste and taking water for domestic consumption directly from the lake without previous treatment is common practice in the lakeshore communities (Bwathondi et al. 2001).

As a heritage of their common colonial past, collaboration between the riparian countries is something common on Lake Victoria (Bootsma and Hecky,2003), starting with the East African Freshwater Fisheries Research Organization (EAFFRO) establish in 1947 by the British government. More recent transboundary management efforts are the Lake Victoria Fisheries Organization (1994) and the Lake Victoria Development Programme (LVDP), presented by the East African Community in 2001.

Lake Tanganyika

With a length of 673 kms, Lake Tanganyika is the longest lake in the world (Odada 2006). Its shoreline perimeter is shared between Burundi (9%), Democratic Republic of Congo (43%), Tanzania (36%) and Zambia (12%). (Hanek et al. 1993). Fed by a catchment area of 220,000 square kilometers, the Rusizi and Malagarasi are the major water inputs into Lake Tanganyika, along with numerous small rivers. Evaporation is Lake Tanganyika's main cause of water loss (Coulter 1991).

A fact that must be taken into account about Lake Tanganyika is that all of the surrounding riparian countries are amongst the poorer in the world. The Human Development Index (HDI) is a compound index developed by the United Nations Development Programme that includes measurements of health, education and income levels. In comparison with a total of 187 countries, in the UNDP 2013 Human Development Report Tanzania was ranked 152th, Zambia 163th, Burundi 178th and DR Congo 186th (UNDP, 2013). It is clear that extreme poverty is a constant challenge for Lake Tanganyika's riparian countries. With rates as high as 50% in some lake basin areas, illiteracy and the historical war conflicts suffered throughout the region represent another issues of concern. (Odada 2006).

Fertile land is limited on the Tanganyika basin with the majority of the agricultural activity happening on narrow strips of land between the EARVR escarpment and the lake. Still, land clearing for both agriculture and fuel-wood demand is a common practice in the Lake Basin (Meadows and Zwick 2000).

Even though Lake Tanganyika is a strategic resource for its riparian countries because of the freshwater and animal protein it provides, the Lake Basin is not as rich in minerals and agricultural lands as other areas of these four countries (Odada 2006). This could be the reason behind the fact of Lake Tanganyika being the one with less human impact in the East African Region. However, regional insecurities and refugee movements could increase the industrialization, urbanization and population density of the basin area. (UNU-INWEH 2011).

A major environmental concern is the Lake's residence time capability (400 years). Any type of contamination will stay in the Lake for a long time.

In terms of management, the Lake Tanganyika Authority was launched by the four riparian countries in December 2008 in collaboration with international organizations such as the United Nations Development Program (UNDP) or the Global Environment Facility (GEF) .

LAKE MALAWI

Known as Lake Niassa in Mozambique and Lake Nyasa in Tanzania, Lake Malawi is a great resource for the riparian countries when taking into account the drought-prone and semi-arid characteristics of Southern Africa. Even though it has an area of 126,500 km2, it only has a catchment area of 97,750 km2, something not that common considering its magnitude (Drayton 1984).

Approximately 260 rivers flows into Lake Malawi from the near mountains and escarpments. However, the majority of them are short making the hydrology balance of the

Lake delicate because of its dependence on seasonal rainfall. As a result, the Lake's level fluctuates as a reaction to changes in seasonal rainfall. (Spigel and Coulter 1996), This characteristic is crucial to Malawi's electricity, which heavily relies on the hydroelectric plant on the Shine river, the only out flowing river of Lake Malawi. (Odada 2006).

With a fish fauna comprising 800 species, some of the endemic like the cichlids, Lake Malawi is the lake with more species of fishes in the world and, as a consequence, the most vulnerable to fishing pressure (Ribbink 2001). Such amount of biodiversity has led to international efforts to protect the lake's fauna such as the Lake Malawi Biodiversity Conservation Project.

According the World Bank (2003) 80% of the lakeshore population lives in Malawi. In addition, 70% of Malawi's land area is constituted by the Lake Malawi Basin. These statistics shows that any kind of human impact assessment on Lake Malawi must prioritize Malawi as the initial country subject of study.

Besides a source of water and animal protein, Lake Malawi is also used as an easy transport for commerce and crops irrigation. Based on its unique biodiversity, the Lake represents an opportunity for tourism. Some of the undesirable human effects on the Basin and the Lake are deforestation, loss of fertility due to biomass burning and excessive nutrient transport via the watershed (Ribbink 2001).

Water-borne diseases like schistosomiasis are common in coastal settlements around Lake Malawi as a result of the lack of secure water sources. By 2010, the WHO/UNICEF Joint Monitoring Program reported that 21%, 56% and 67% of rural Malawi, Tanzania and Mozambique, respectively, live without access to safe drinking water (JMP 2013).

Regional management plans around Lake Malawi were initially based on the Lake's unique Biodiversity, like the Lake Malawi Biodiversity Conservation Plan developed between 1996 and 2000. Even though all the riparian countries have passed policies related to issues around the Lake, they have been made without consultation and independently. Launched in 2003 and funded by the World Bank, the Lake Malawi Ecosystem Management Plan was the first multinational effort intended to maximize the benefits of the riparian communities while sustaining the Lake ecosystem (World Bank 2002).

EQUATORIAL AFRICA DEPOSITION NETWORK (EADN)

BIOMASS BURNING IN AGRICULTURE AND ENERGY PRODUCTION

As has been stated, the agriculture industry developed around the AGLs basins and catchment areas represent a significant percentage of the riparian countries' Gross Development Product (GDP) and labor force occupation as shown in Table 2.

Country	**GDP**	**Labor force Occupation**
Tanzania	27.7 %	80%
Uganda	24.2 %	82%
Kenya	24.2 %	75%
Burundi	30%	93.6%
Rwanda	33.3%	90%
Democratic Republic of Congo	44.2%	Not available
Zambia	85%	85%
Malawi	29%	90%
Mozambique	29.5%	81%

Table 2: AGL riparian countries agriculture GDP and labor force occupation percentages

Source: https://www.cia.gov/library/publications/the-world-factbook/

Electricity access represent a constant challenge African population faces. By 2009, 585 millions of people in Sub-Saharan Africa have no electricity access. (IEA 2012). In terms or electrification 30.5%, 59.9% and 14.2% represent the total, urban and rural rates in Sub-Saharan Africa, respectively (IEA 2012). Table 3 provides the electrification rate and amount of population without electricity access of the AGLs riparian countries.

Country	Electrification	Population without electricity in millions
Tanzania	13.9%	37.7
Uganda	9%	28.1
Kenya	16.1%	33.4
Burundi	Not available	Not available
Rwanda	Not available	Not available
Democratic Republic of Congo	11.1%	58.7
Zambia	18.8%	10.5
Malawi	9.0%	12.7
Mozambique	11.7%	20.2

Table 3: AGLs riparian countries electricity access. (IEA 2012)

In hands of farmers or housewives, biomass burning is a common practice in developing countries. Andreae (1991) recognize several purposes biomass burning serves:

-Land clearing for agricultural use, either for shifting agriculture or for permanent removal of forests. Usually, at least two burns of dry out vegetation are associated with land clearing (Fearnside 1985).

-Grazing and crops lands nutrients regeneration.

-Charcoal production for industrial and domestic use.

-Energy production for domestic use such as cooking or heating.

-Weeds and bush control in Savannas, common ecosystems in Africa. In this case, biomass burning is executed to avoid the overgrown of grassy vegetation, a needed condition for grazing, the most common agricultural use of the grassy savannas. (Andreae 1991).

Even though the majority of emission to the atmosphere from biomass burning are dominated by oxides of carbon, relatively low levels of nutrient emissions will be present because of the presence of such elements in dry plant biomass (Bowen 1979).

In terms of the amount and type of biomass burned in Africa annually Delmas and others (1991) found that 2.9 Gig tons of dry matter are burned every year and that savanna fires are the most common type of human related biomass burning emissions.

Studies like the one mentioned above have spotted savannas' biomass burns as one of the major sources of nutrient emissions in Africa. However, little information related to nutrients atmospheric deposition have been gathered. Funded by the GEF, International Water Projects on the AGL have enabled empirical measurements at lakeside locations that have thrown estimates about wet[2] and dry[3] deposition of nutrients. Due to the fact that management efforts such as the Phase 2 of the Lake Victoria Management Plan will propose more extensive monitoring of nutrients deposition, better understanding of transport macronutrients around the African continent is needed (UNEP 2011).

EADN General Description

Research done by the International Water Project on the AGL has provided evidence of the relationship between atmospheric deposition of nutrients and eutrophication. The majority of these projects have been deployed around the lakes' shorelines or catchment areas (UNEP 2011). Projects aimed at investigating how much nutrients are transported from outside the basin areas into the lakes are needed in order to identify the largest sources of

[2] Wet deposition is defined as "the is the transfer of atmospheric compounds to the earth's surface via precipitation" (Airzone One and Bootsma 2011)
[3] Dry deposition is defined as " the transfer of compounds to the earth's surface by uptake of gaseous compounds or the deposition of aerosols or particles" (Airzone One and Bootsma 2011)

nutrients over enrichment that are already causing environmental damages to the AGL, being Lake Victoria the most affected.

In the context of a workshop organized by the African Collaborative Center for Earth System Science (ACCESS) held in Kenya in 2005, the need to design and implement a long range atmospheric deposition network that includes measurements out of the lakes' shorelines and basins areas was identified. As a result, the Equatorial Africa Deposition Network (EADN) project was proposed with the support of the following 12 countries: Burundi, Cote d'Ivoire, Democratic Republic of Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Senegal, Tanzania and Uganda. Co-founded by the GEF, the United Nations University Institute for Water, Environment and Health (UNU-INWEH), the United Kingdom Department for International Development (UK-DFID), the Alliance for Green Revolution in Africa (AGRA) and the operating agencies of the 12 involved countries, the EADN project was designed in a way that will extent from areas where biomass burning is intensively practice in central and southern Africa, to the west of the continent in which Sahelian dust is expected to be a major source of Phosphorus. The declared objectives of the EADN are to identify the sources of atmospheric nutrients in Africa, trigger the mechanisms that introduce such nutrients to the atmosphere, determine the pathways by which nutrients are transport and finally, understand how much atmospheric deposition contributes to the AGLs eutrophication (UNEP 2011).

Consisting of 12 points, Figure 2 shows the general locations of EADN's monitoring stations. Even though a detailed technical description of the network is out of the interest of this paper, its main characteristics

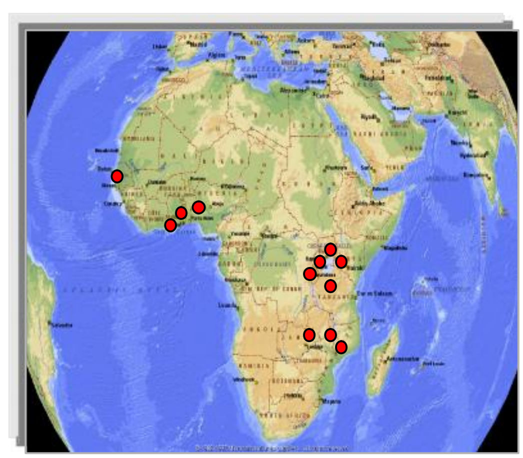

Figure 2 EADN's monitoring stations (Airzone One and Bootsma 2011)

are presented as described in the EADN operational manual (Airzone One and Bootsma 2011):

- Two types of sites exist, regional representatives that provide estimates for deposition of nutrients (Nitrogen and Phosphorus) in regions inside and outside the AGLs catchment areas. Lake-side sites provide direct estimates of nutrients deposition within the AGL[4].
- To determine the airborne nitrogen and phosphorus compounds, the network includes active and passive measurements of airborne particles and of reactive gasses.
- The network has the capability to collect event-based precipitation.
- In order to support results modelling and interpretation, meteorological measurements will be provided.

INSTITUTIONAL FRAMEWORK

Due to the fact that the mobile framework that the next section proposes was conceived as a complement to EADN's monitoring sites, it is important to identify the different stakeholders involved in the project, as they could be the one responsible of the operation of the mobile framework. Figure 3 shows EADN organization structure.

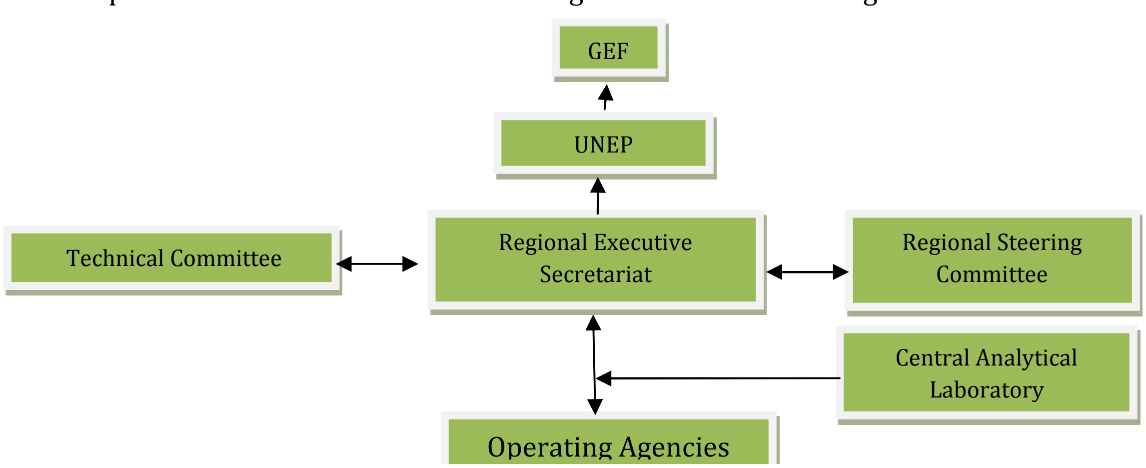

Figure 3: EADN Organization structure (UNEP 2011)

[4] The EADN operational manual provides the exact coordinates of 11 of the 12 monitoring stations. By March 2013, with 4 out of 12 monitoring sites installed, the network was not 100% operational. It is unknown by the author of this paper when will the totality of the sites will be installed.

Table 4 summarizes the main responsibilities each one of the stakeholders has.

Stakeholder	**Responsibility**
UNEP	As the GEF Implementing Agency, UNEP provides coordination and regional cooperation
Technical Committee	With representative from each of the Operating Agencies, it is the supreme authority over all the EADN technical operation. Their decisions are binding on national Operation Agencies. In charge of constantly review the EADN operation and issue recommendations if needed.
Regional Executive Secretariat	Provides overall management of the EADN by coordinating Operating Agencies network and quality assurance activities.
Regional Steering Committee	Overall policy setting body. In charge of assessing progress and monitoring inputs of the different partners.
Central Analytical Laboratory	In charge of analyzing all the samples using a common set of Quality Assurance of Control methods. Having only one central lab will guarantee having the saving quality control no matter where the samples came from.
Operating Agencies	With a mix of local universities or government environmental departments, the agencies will support one of more sites of the EADN. Each operating agency must have one site operator and one site supervisor that will manage the site according to the EADN established protocols.

Table 4: EADN Stakeholders (UNEP 2011)

Mobile Environmental Framework (mEF)

Mobile Phones Penetration

For the last 10 years, different kind of Information and Communications Technologies (ICTs) have spread throughout the world. A common indicator to measure the impact any given ICT has is measuring its penetration, or number of subscribers per 100 inhabitants. Based on the International Telecommunications Union (ITU) ICT indicator database, Figure 4 shows the penetration different ICTs had during the 2001-2011 period.

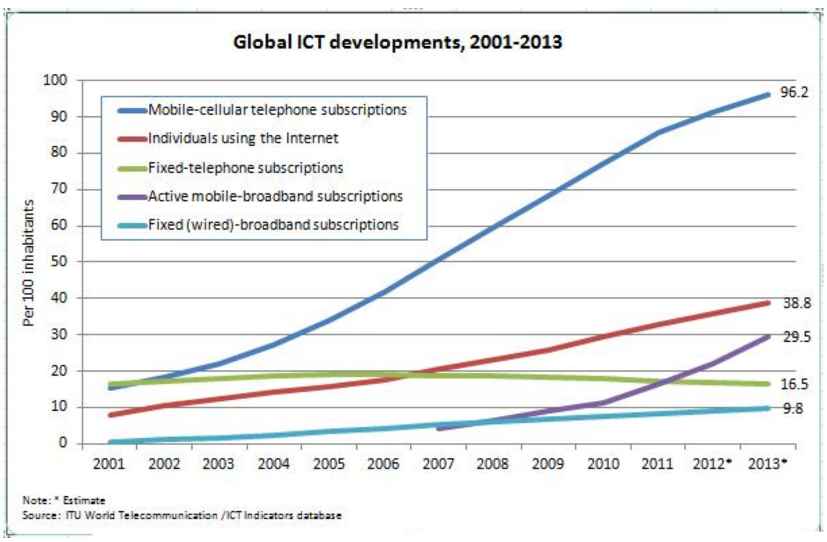

Figure 4: ICTs Penetration 2001-2013. Source: http://www.itu.int/ict/statistics

From Figure 4, it is clear that mobile phones represent the predominant ICT worldwide. In a short period of time, the mobile industry has experienced an enormous growth. While 20 years were needed to sell the first billion of mobile phones, four and two years were needed to sell the second and third billion, respectively (Bhavnani et al. 2008).

In order to better understand the status of the mobile industry worldwide, is it useful to analyze mobile technology penetration from two different perspectives, as shown in Figures 5 and 6.

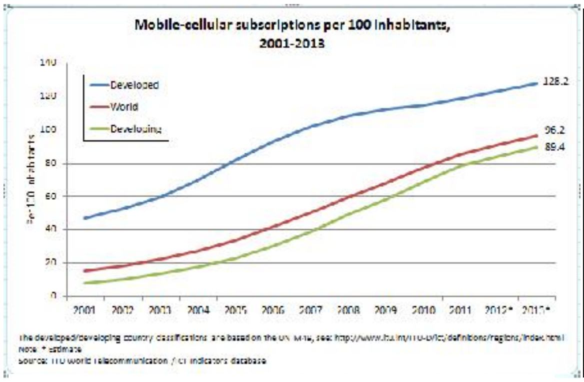

Figure 5: Developed vs Developing countries mobile penetration 2001-2013. Source: http://www.itu.int/ict/statistics

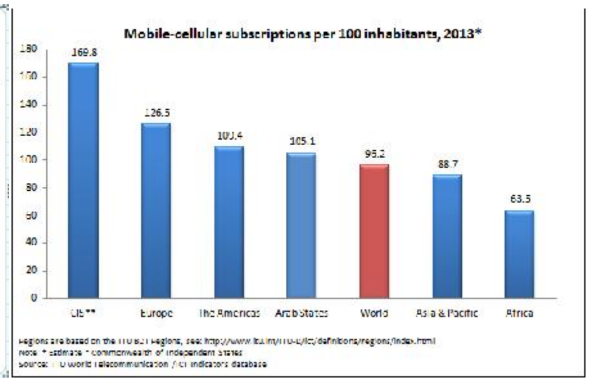

Figure 6: Regional mobile penetration 2013. Source: http://www.itu.int/ict/statistics

Figure 5 shows the evolution mobile penetration has had in both developed and developing countries in the 2001-2013 period. Even though the penetration rates vary significantly, it is fair to say that no matter the economic, social or technological surrounding environment, mobile penetration has kept growing worldwide. From a regional perspective, Figure 6 suggests that even Africa, the region with the lowest mobile penetration, offers an environment in which more than half of its population has access to mobile phones. This fact must be taken into account when developing policies intended to reach as much population as possible.

Mobile For Development

Introduced in the mid nineties, the term digital divide is defined as "the gap between those with regular, effective access and ability to use digital technologies and those without" (Boyera 2004). Since that time, the access to digital and information technologies has been identified as an enabler of prosperity and development. ICTs have been seen as tools to reduce the digital divide and also as a way to help achieving and measuring international development targets, such as the Millennium Development Goals proposed by the United Nations 2000 Millennium Declaration. A generalized interest appeared to research strategies aimed at introducing ICTs in developing countries as effective as possible.

The Information and Communications Technologies for Development (ICT4D) movement is based on three major domains: Computer Science, Information Systems and Development Studies. As explained by Heeks (2008), this multidisciplinary approach tries to propose solutions that, while still being techno-centric, incorporate other concepts like understanding the human, political and economic contexts around a specific development problem.

One of the problems faced by the earlier solutions proposed by the ICT4D movement was that they introduced in developing countries projects that were previously implemented in North America or Europe without taking into account the surrounding context. An example of this is the rural telecenter, a room with one or more computers with Internet access intended to provide information and services to poor communities. Many of these telecenters failed to achieve their purpose because of issues like sustainability or scalability. As stated by Brand and Schwittay (2006), when introducing a certain technology, sometimes it is also needed to import the economy that supports it. Local communities might experience difficulties to sustain technologies that do not match their economic and social environments. More importantly, the kind of information poor communities accessed through them offered limited value (Jagun and Heeks 2007). To really reduce the digital divide, enabling internet access is only part of the solution. In order to make a real impact in poor communities, policies should be implemented to guarantee that the information accessed through those data channels is the one needed to improve their everyday life.

From this perspective, mobile technology as a new option for ICT4D solutions offers an interesting opportunity. While projects like the telecenters required the introduction and acceptance of previously inexistent technology, as it was previously mentioned, mobile phones are already part of the everyday reality all around the world. Just like the Web 2.0 is based in the idea that people should be the one generating the information available online instead of just reading it, ICT4D 2.0 can avoid sustainability or scalability problems by focusing on delivering innovative solutions using communication channels that have reached and are already being used by, for example, rural communities (Heeks 2008).

Establishing a clear distinction from conventional telephony, even the most simple and cheap mobile phones represent something more than a communications channel between individuals. Text messaging (SMS) or simple data exchange applications are examples of the different services mobile technology offer. Jagun and Heeks (2007) stated that the benefits mobile phones can be classified in:

-Incremental: improvements to activities people already do, like enabling a faster exchange of ideas.

-Transformational: New services like mobile banking solutions to poor people.

-Production: New sources of income related to mobile technology, like the sale of pre-paid phone calls.

When thinking on the role mobile phones can have as part of the ICT4D movement, we have to consider the challenges such technology faces in developing countries. In terms of infrastructure, lack of stable power sources and mobile coverage are common issues, especially in rural areas because of the urban-first approach followed when deploying mobile services (Wicander 2010). With around 800 million people worldwide that are not capable to read and write, illiteracy represent a challenge when using mobile phones and also when trying to use mobile services like text messaging (Knoche 2012).

EADN Mobile Status

Figure 7 show the penetration mobile phones had in the EADN region by 2011.

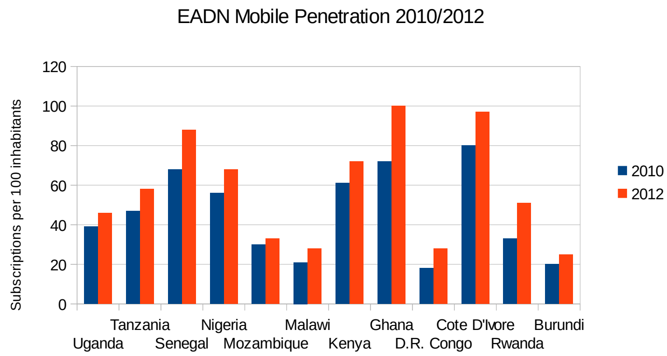

Figure 7: EADN Penetration. (ITU,2013)

Figure 7 shows confirms the growth trend mobile phones penetration have had in Africa in the last years. Actually, mobile penetration in Africa have doubled since 2008 (ITU,2013). Figure 7 also shows the different realities the mobile industry has all around the EADN region, In countries like Ghana, Senegal and Cote D'Ivoire, mobile penetration is close to 100. In contrast Malawi, Burundi, and D.R. Congo have penetrations below 40.

This penetration rate difference among the EADN may suggest that in some countries the mEF could not be as an effective channel as expected. However, this statistics hide a common practice in Africa: mobile phone sharing.

Mobile phone sharing in Africa represents a completely different understanding of a mobile phone. In western, or developed countries, mobile phones are seeing as personal accessories. Using a western mentality , a mobile phone represents something more than a way to keep in touch with others. A mobile phone represents an accessory that clearly reflects the owner personality. Things like size, color or external design are always considered when buying a mobile phone. In rural Africa a mobile phone is not always seen as a personal accessory. Simply stated, a mobile phone is a way, and many times the only one, to connect outside the villages. Under this understanding, mobile phones are conceived more a community asset.

Because acquiring a SIM card is cheaper than acquiring a mobile phone, it is common practice that individuals have more than one SIM card, even from different cellular carriers, and make use of them by means of the community mobile phone. . In low income/rural areas, it is expected that communities will have a limited number of mobile phones, usually one or two, which people share (Zuckerman 2009). For example, by 2006, a survey between households in rural Botswana revealed that 62.1%,43.8% and 20% of the phone owners share their phones with their families, friends and neighbors, respectively. From these mobile phone owners, only 2.2% of them charge for the use other people make of their mobile phones (Gillwald 2005), fact that reinforces the idea that a mobile phone is more a community utility rather than a personal object.

Regional illiteracy is something that must be taken into account. According to the UNESCO, 38% of African adults are illiterate[5]. Research like the one done by Knoche and Huang (2012) states that they are strategies to allow illiterate people to access services through mobile phones. Some of those strategies rely on the use of smart phones that would enable the development of apps with visual components aimed at reaching the illiterate population. As expected, mobile environments like the ones in Africa are not suited for these kind of visual mobile applications because the majority of the existing phones are cheap phones with text only capabilities.

Two factors might help to break the illiteracy barrier when using mobile phones as part of the EADN. First, as stated above mobile phones are more a social than a personal asset in Africa. When using them, social interaction and cooperation are expected. Such community effort might be a crucial factor to help illiterate people access mobile phones services. Second, national and international efforts have reduced the illiteracy rates in younger generations.

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[5] http://www.unesco.org/new/en/dakar/education/literacy/

Adults that are illiterate can rely on younger members of their families when accessing text based mobile applications.

Talking about the mobile industry environment, all of the EADN countries have more than one cellular carrier being MTN a case worth of mentioning. As Africa´s leading Telecommunications provider, MTN is the major carrier in 5 of the 12 EADN countries and it's also the carrier with the biggest number of subscribers in one single African country, Nigeria (Blycroft 2012). Actually, the existence of multiple cellular carriers has been a crucial factor in Africa's mobile penetration rates improvements. In terms of pricing, one interesting thing to highlight is the competitive pricing ratio between one minute of voice and one text message (SMS). For example, by 2006 Kenya, Uganda and Tanzania had a ratio around 1:6 (Mendes et al. 2007). Without a doubt, this pricing condition has been a key contribution for the development of the current SMS culture in Africa.

In terms of continental cooperation, the 12 EADN countries are member states of the Africa Telecommunications Union (ATU), the umbrella organization in charge of promoting development of info-communications in Africa.

mEF Definition

As stated during the EADN description, identifying the sources of atmospheric nutrients in Africa is one of the project main objectives. Even though past research projects have already tried to identify sources of nutrients emissions at the lakes' shorelines and catchment areas, one unique characteristic of the EADN is that it will try to indentify long-range sources that could come into the AGLs region from distant sources like, for example, the Sahara or the Sahel. Once the nutrient emissions sources are identified, hypothesis like the one proposing biomass burning as responsible of the AGL eutrophication could be evaluated.

Related to its social and economic environment, Africa is the continent where human related biomass burning is the greatest (Delmas et al. 1991). Because of that, any project intended to fully characterize nutrients emissions associated to biomass burning has to incorporate strategies aimed at understanding the human behavior around such activity.

Recognized as the ICT with the biggest penetration worldwide and with an impressive growth in Africa for the last 10 years, mobile phones represent a great opportunity to interact with communities all over the EADN region. Likewise, mobile phones can be used for something more than human oriented purposes. With data transfer capabilities, mobile phones can also be used as the "last mile" communication channel in a data network. Such characteristic must be taken into account when no other ICT is available, a reality that is common in developing countries like those of the African continent. One last characteristic worth of mentioning about mobile phones is, precisely, its mobility and how it can be related to their users mobility patterns, an approach that can be useful for understanding any kind of human impact.

As explained before, a major challenge faced by the mobile industry of EADN countries is the lack of proper electricity sources. However, many of the Mobile Network Operators faced this situation by using other sources of electricity, like solar, to energize their mobile infrastructure. Although requiring more investments from the MNO's, unstable or non-existent power grid infrastructures do not represent a barrier to access mobile services. For example, according to a survey made by Vodafone in 2005, 97% of the of people in rural areas that use biomass burning as their source of energy had no problems to use mobile phones in their everyday life (Wicander 2010).

In terms of environmental protection, as suggested by Mungai (2005), mobile phones represent an effective channel for creating awareness, promote sustainable practices, strengthen warning systems and enable communication channels between environmental agencies. The African Great Lakes represent a complex management case when taking into account the amount of countries involved. Agencies like the Lake Victoria Region Local Authorities Cooperation, the Lake Tanganyika Authority or the Lake Malawi Evaluation Group must see on mobile phones a regional channel that can be used to spread a common message.

Parallel to the telemetry network used by the EADN, a mobile framework could be implemented to analyze the human component of biomass burning and also to facilitate a more efficient exchange of data between the operating agencies and the central analytical laboratory. A mobile environmental framework (mEF) with operational, educational and monitoring components is presented in Figure 8.

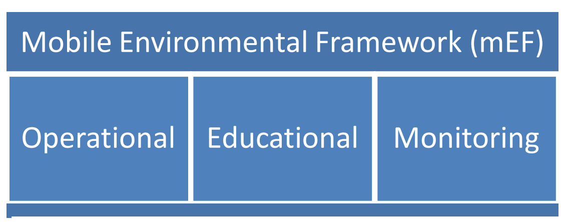

Figure 8: Mobile Environmental Framework Layers

A more detailed description of each one of the layers of the mEF is discussed.

Operational Layer

As mentioned during the project description, the countries' operating agencies will the ones responsible of the day by day activities. More specifically, the EADN field operations manual describes the protocol Sites Operators must follow. The procedure includes precipitation and air samples that must be collected daily and weekly, respectively. As part of the package that must be shipped to the Central Laboratory with the samples is the Sample History Form (SHF), document that must be filled by the Site Operator and contains information such as meteorological or field chemistry data related to the time in which the sample was collected. Once the Central Laboratory receives the samples, the staff must enter the SHF data into the database to develop further analysis. Every month, the Site Supervisor and Site Operator will receive a report from the Central Laboratory that details detected problems or recommendations for improving accuracy. Likewise, the manual suggests that a data communication channel must be establish between the Operating Agencies and the Central Laboratory to report equipment malfunctions, data problems or any other issue that require central assistance(Airzone One and Bootsma 2011).

As stated by Heeks (2008), one of the main reasons behind the failure of early ITC4D projects was the lack of understanding of the current environment. Taking into account the different locations of the EADN sites and their data transfer and ubiquity capabilities, mobile phones represent a good choice for establishing a data between the site operators and the laboratory . However, there is one fact that must be taken into account about mobile phones in Africa. Only 17% of the African mobile phones are smartphones (Blycroft 2012). It can be assumed that any data transfer solution involving mobile phones in Africa will have to deal with handset that only offer basic speech and text capabilities.

The Unstructured Service Supplementary Data, or USSD, is a messaging service used in a Global System for Mobile Communications (GSM) network. GSM is the dominating mobile technology in Africa (Blycroft 2012). Similar to SMS, USSD transmit data messages using the signaling channel, so no data plan is required to access it. More importantly, USSD works on any kind of GSM mobile phones, from old handsets to smartphones. Unlike SMS that uses a store-and-forward transaction model, USSD provides session-based connections, a characteristic that makes it faster. As defined by Sanganagouda (2011) "USSD is as similar to speaking to someone on the phone as SMS is to sending a letter".

USSD applications are made of menus that users can browse using their phone to upload requested information to a remote server. These applications are accessed by dialing a number that starts with an asterisk (*), then a combinations of numerals and asterisks and ends with a pound symbol (#). Common users of USSD worldwide are mobile pre-paid subscribers that use it to check their balance or top up their accounts. In Africa, USSD is broadly used for other kind of applications like mobile banking, or to access useful information in rural areas like agricultural and live stock prices (Ekine 2010).

Figure 9 shows a general diagram of a USSD application interacting directly with the EADN Central Laboratory.

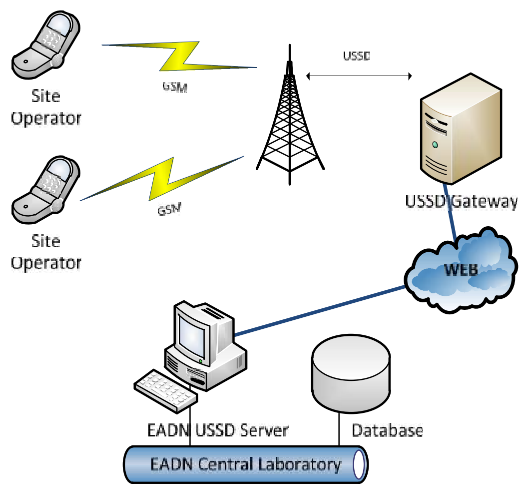

FIGURE 9 EADN USSD APPLICATION

Through the implementation of a simple menu base application sites operators could use their mobile phones to upload a sample SHF directly into the EADN Central Laboratory database without any intervention from the central lab staff. More importantly, because USSD offers network initiated messages, the central laboratory staff could use the USSD channel to send real time notifications to site operators, or even request them to upload more information as needed.

On the one hand, several are the benefits of incorporating USSD in the EADN; it's a commonly used technology in Africa so Site Operators might already be familiar to it, USSD prices are normally cheaper than SMS prices or, in some cases, free. Finally, as suggested by Ekine (2010), some Mobile Network Operators (MNO) keep USSD ports open for roaming traffic, so technically the USSD application could be accessed without problems from all the different EADN countries.

On the other hand, the development of any type of USSD application requires interaction and collaboration with the MNO, because they are the ones who manage or lease the USSD gateway from a third party owner. As a result, the development of the USSD application could be complex because of the different parties involved.

Educational Layer

The EADN represent a multinational effort aimed to understand the sources of nutrients deposition in the AGL. In the end, the information generated by the EADN will be input to policy makers while design and implementing environmental protections plans such as the Phase 2 of the Lake Victoria Management Plan.

As it has been mentioned, biomass burning related to human activities is expected to be one of the major reasons behind nutrients emissions. Consequently, reducing nutrients emissions, as any other kind of environmental concern, must heavily rely on education strategies.

Accessibility is one of the major challenges Africa faces. Lack of proper transportation is one the problems people in Africa have to deal with every day, a situation that gets worse in rural communities. According to the World Bank, by 2010, Kenya, Tanzania and Ghana had a percentage of paved roads of 14%,15% and 13%, respectively. Actually, the paved roads percentage all across Sub Saharan Africa was of 16.3% by that year. Other basic infrastructure like electricity or sewage also have low percentages or accessibility.

Through the Technology Task Fit Model (TTM), researchers have tried to explain technology acceptance by analyzing the fit that such technology represent in users everyday tasks. Even if they recognize a certain technology as advanced, users may decide not to use it if such technology does not fit their needs and make a significant improvement to their conditions (Junglas et al. 2008).

In the same way the TTM can explain why the telecenter approach used by many ICT4D projects in the early nineties were a failure (graffiti with the phrase "jobs not computers" appeared in India), it also explains the success mobile phone based applications have had in Africa. When taking into account the amount of time people spend moving around because of poor transportation systems, allowing them to have money transfers/payments, agricultural pricing information or health advices from their mobile phone,it is clear that such technology represents more than a communication channel in Africa, it represents a life changer.

Simple SMS-based applications have made a huge impact in all kind of sectors in Africa. In 2007 Safaricom launched M-Pesa in Kenya, a mobile applications intended to offer financial services to the unbanked[6] sector. Prior to the launch of M-Pesa, only 18.9% of Kenya's population had access to any kind of financial services. As a proof of M-Pesa's success, by 2011 70% of Kenyans used M-Pesa as a money transfer service (UNCTAD, 2012). In more socially oriented applications, SMS in Africa is being seen as major tool for activism. Fahamu, and African NGO with offices in Kenya, South Africa and Senegal used mobiles phones to promote the Protocol on the Rights of Women in Africa. A SMS alert service was set up so that users can sign up an receive updates of the progress of the campaign. This public awareness effort was key to the ratification of the Protocol by the Afican Union (Ekine 2010).

[6] In the literature, the term unbanked refers to the population, mainly low income, without access to a bank account and the associated services.

The implementation of an environmental SMS-based Government to Citizen application (G2C) as part of the EADN represents the following benefits:

-By means of using the MNOs' infrastructure as the communication channel instead of more traditional approaches to get in touch with the population, economic saving can be achieved.

-Based on mobile phones ubiquity, government agencies will be able to get in touch with communities in which normally it would be hard to access to.

-Launch awareness campaigns about increasing agricultural efficiency or education around non-wood fuel sources of energy, both activities related to biomass burning.

-Promotion of new economic activities that could reduce the overall regional dependency on agriculture.

MONITORING LAYER

Just like the Educational layer proposes a G2C application to implement a top to bottom strategy for creating awareness regarding biomass burning, the first part of the monitoring layer describes how mobile text messaging can be used to develop a bottom to top plan.

Advocacy has found an ally in mobile phones. Kubatana, an information and civic activism platform was founded in Zimbabwe in 2001 as a way to countercheck the repressive policies implemented by the government against free speech and independent press. Even though it uses different media like web pages, email or print publications, SMS offer Kubatana the best way to allow their subscribers to share their thoughts and feedbacks about the platform (Ekine 2010).

In the same way that the Kubatana platform did, the EADN can take advantage of the direct link mobile phones offer. As part of the policy making process, evaluating the impact of the mobile educational layer is something that must be addressed. Through a Citizen to Government (C2G) mobile app consisting of a SMS-based inputs server, the EADN staff can receive notifications from local civil servants, environmentalists or general public members regarding non sustainable practices detected in their communities. When compared the inputs received with the awareness campaigns launched by the education layer, an analysis of the effectiveness of such campaigns can be achieved and, if needed, recommendations towards improving their impact can be generated.

The second part of the monitoring layer incorporates the notion of Big Data for Development. Created by the computing world, the term Big Data refers to "an umbrella term for the explosion in the quantity and diversity of high frequency digital data" (GlobalPulse, 2012). Sources of this digital data could be social media like Twitter of Facebook, web browsers inquiries, mobiles phones call records or wireless sensor networks. The private sector has had an interest in Big Data analysis like, for example, identify customer trends or marketing strategies planning.

In 2009, the Global Pulse Initiative was launched by the United Nations to explore what Big Data can do for Development. More specifically, the Global Pulse Initiative does research around the idea of how the analysis of these huge quantities of real time data can help decision makers to track plans' implementation progress, improve social protection or understand adjustments policies need (Global Pulse 2012). As expected, one of the challenges Big Data represent is the intensive use of data mining and mathematical analysis techniques to create "data of our data", a step needed to correctly understand the huge amount of information a typical Big Data information set represents.

In the Developing world, lack of basic infrastructure and mobile phones ubiquity potential are reasons behind the innovative ways people is using this technology. Access to medical or pricing information are just examples of how mobiles phones are becoming more a more an important part of developing countries.

A Call Detail Record (CDR) is a record generated each time a mobile phone is used to make a phone call or send an SMS. CDRs are key features of a mobile network management. Things like generating phone bills could not be possible without the use of CDRs. The information contained in a CDR is refer to as metadata, a description of a mobile session. A CDR does not include information about the content of the session. Examples of the information a CDR contains are: Sending and receiving mobile phones, type of mobile exchange (voice call, SMS , etc), call duration, timestamp or antenna codes (Clayton 2001). As expected, access to CDRs requires interaction with MNOs and issues like privacy must be taken into account when dealing with this kind of information.

Recently, the Computer Social Science, an emerging multidisciplinary research field, became interested in using CDRs to understand human behavior. For example; Gonzalez and others (2008), used CDRs to trace people's movements.

CDRs analysis represents a valuable source of knowledge to the EADN. Just in the same way the proposed telemetry stations will try to understand the long range transport of nutrients before they are deposited in the AGL, mobile phones, and their associated CDRs, will trace human behavior all across the EADN region. Examples of the types of analysis the monitoring layer will perform are:

-Identifying human density around the lakeshore areas: Using CDRs' antenna codes and the geographical position of the associated cellular towers, patterns of how the people moves in and out the lakeshore areas can be established.

-Identifying work related activities: As it has been mentioned, agriculture represents the major labor force occupation in the EADN region. It could also be one of the main reasons behind biomass burning. Taking into account how much mobile phones are used in work related activities, the analysis of the CDRs on work hours will help to understand how much agricultural activity was done in a certain area in a specific period of time.

Of course, the huge potential of this type of Big Data analysis will occur when correlated with the data obtained from the EADN telemetry stations. Comparing the nutrients pathways generated by the stations measurements with the human traces obtained from the CDR analysis will provide a more holistic understanding to nutrients emissions and human behavior. Figure 10 gives a graphic example of how such correlated analysis might look like.

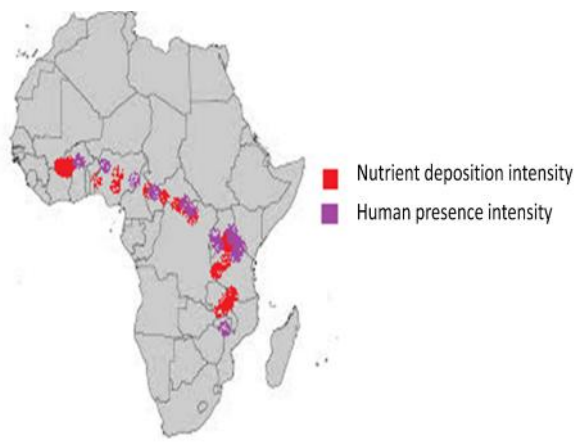

Figure 10: EADN correlated analysis

Recommendations and Conclusion

Mobile phones and their impact in Africa represent a huge opportunity for environmental protection. In the past, the lack of data has been one of the major challenge science faced when trying to propose solutions to the emerging problems of the African Great Lakes. The Equatorial Africa Deposition Network is the first project aimed at identifying long range sources of nutrients and their transport patterns. However, because of the huge dependence and interaction the Lakes have with their riparian countries, human behavior must be included to have a more holistic approach. Using mobile phones as a communication channel and also as a way to trace human activity will enrich the data generated by the EADN and, in the long run, will provide better evidence to policy makers while designing future management plans for the African Great Lakes.

For implementing the different layers of the mEF the following recommendations are provided:

- Following the policy of having one central facility to assure high quality analysis, a Mobile Data Laboratory should be incorporated to the EADN organization. The Mobile Lab should have a multidisciplinary team with experts with telecommunications, computer and social sciences background. The lab business model must follow the one used by the United Nations Global Pulse agency when implementing its Big Data labs located in New York City and Jakarta.
- The Mobile Lab should team up with the Central Laboratory to develop and support the USSD application Sites Operators will use to generate the real time Sample History Forms.
- Because it is the MNO with the biggest presence in the EADN region, MTN is recommended as the one hosting the USSD application.

- Through UNEP, the EADN should interact with the United Nations Global Pulse when developing the Big Data methodologies, with special emphasis in securing mobile phone users privacy.
- Supported by the African Telecommunications Union, a close relationship with the different Mobile Network Operators should be established. Projects like 2012 "Data for Development" Challenge realized by Cote d'Ivoire MNO, Orange, should be used as an example of how anonymous CDRs can be incorporated into the EADN while offering marketing benefits to the MNO's.

Once implemented, the following recommendations are provided towards using the mEF.

- The EADN Regional Steering Committee should consider the mEF results as inputs of the policy development process.
- Through the SMS-based channel, the EADN Regional Steering Committee must implement educational campaigns aimed at changing unsustainable practices detected by the mEF data inputs.
- When doing a final evaluation of the EADN results and proposing inputs to management plans regarding the AGL, the nutrients measurements obtained should be correlated with the information generated by the mEF.

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