Climate Information Services
Market Assessment and Business Model Review

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Report Authors: Usher, Jeremy; Phiri, Catharine; Linacre, Nicholas; O'Sullivan, Robert; Qadir, Ujala.

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Prepared by: Winrock International
2121 Crystal Drive, Suite 500
Arlington, VA 22202
Tel: 703-302-6500
www.winrock.org

Principal Contact: Robert O'Sullivan
Robert.OSullivan@winrock.org

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 9

1. INTRODUCTION 12

1.1. Climate Change in Sub-Saharan Africa 12

1.2. Weather and Climate Information Services 13

1.3. Investment in WCIS 14

1.4. Sustainable Climate Information Services Project 15

1.5. Research Objectives 16

1.6. Methodology 16

1.6.1. Market Assessment 17

1.6.2. Private-Sector Business Model Case Studies 17

2. MARKETS FOR WEATHER AND CLIMATE INFORMATION SERVICES (WCIS) 19

2.1. Market Size 19

2.1.1. General Findings 19

2.1.2. Methodology 19

2.1.3. Market Expenditure Analysis 20

2.1.4. Total Available Market Analysis 24

2.1.5. Socio-Economic Benefit Analysis 24

2.1.6. Discussion 25

2.2. The Climate and Weather Enterprise 25

2.3. Role of Government in Climate and Weather Enterprise (CWE) in Sub-Saharan Africa 27

2.3.1. Sources of Funding for NMHS 28

2.3.2. NMHS Operating Models 29

2.3.3. Legal and Policy Environment 31

2.4. Capacity of National Meteorological and Hydrological Services (NMHS) in SSA 33

2.4.1. WCIS Infrastructure 34

2.4.2. NMHS Budgets 36

2.4.3. Case Study: South African Weather Service (SAWS) 38

3. PRIVATE-SECTOR BUSINESS MODELS FOR WCIS IN SUB-SAHARAN AFRICA 41

3.1. Types of WCIS Provided by the Private Sector 41

3.2. Geographic and End-User Reach 43

3.2.1. Willingness to pay 45

3.3. Business Models 45

3.4. Technological Innovations in WCIS Data Collection and Dissemination 47

3.5. Gender and the Private Sector 48
3.6. Opportunities and Barriers to Growth 49
3.6.1. Case Study: Impact of Donor Funding 51
3.7. Public-Private Partnerships 53
3.7.1. Case Study: Aircraft Meteorological Data Relay (AMDAR) Program 54
3.7.2. Discussion 55
4. CONCLUSIONS AND RECOMMENDATIONS 56
4.1. Recommendations for Donors 57
4.2. Areas for Further Study 57
5. APPENDIX I: PRIVATE-SECTOR BUSINESS MODELS: CASE STUDIES 1
5.1. Company Survey Instrument 1
5.2. Company Case Studies 3
5.3. List of Companies 3

FIGURES

Figure 1. Global spending on weather and climate information services....20
Figure 2. Global CIS and WIS information expenditures by sector, 2014/2015....22
Figure 3. Average per capita spending on commercial WCIS by region....23
Figure 4. Graphic comparing five NMHS operating models....30
Figure 5. Number of automatic and non-automatic weather stations by country....35
Figure 6. Density of weather stations in select countries of Sub-Saharan Africa....35
Figure 7. Revenue by source, South African Weather Service (2012-2016)....39
Figure 8. Government payments for operating and capital expenses, SAWS (2012-2016)....40
Figure 9. Government payments and aviation revenues, SAWS (2012-2016)....40
Figure 10. Private-sector engagement in climate and weather enterprise and data flow....42
Figure 11: Number of private-sector WCIS companies in select countries of Sub-Saharan Africa....44
Figure 12. Relationship between U.S. foreign aid to agriculture and number of WCIS companies....53

TABLES

Table 1. Sectors served by NMHSs in select SSA countries 37
Table 2. Private-sector involvement in WCIS, as reported by NMHS representatives.....37
Table 3. Number of end users served by select WCIS companies in Sub-Saharan Africa 44
Table 4: Business models used by WCIS companies in Sub-Saharan Africa.....46
Table 5. U.S. foreign aid to agriculture and number of WCIS companies in countries of SSA.....52

ACRONYMS

AMCOMET	African Ministerial Conference on Meteorology
AMS	American Meteorological Society
AWS	Automatic Weather Station
BOT	Build-Operate-Transfer contracts
CFA	*Communauté Financière d'Afrique* (Financial Community of Africa)
CIS	Climate Information Services
CIRDA	United Nations Programme on Climate Information for Resilient Development in Africa
GFCS	Global Framework for Climate Service World Meteorological Organization
GNI	Gross National Income
ICAO	International Civil Aviation Organization
IM	Industrial Meteorology
JMA	Japan Meteorological Agency
JMBC	Japan Meteorological Business Support Center
MNO	Mobile Network Operator
NGO	Non-Governmental Organization
NMHS	National Meteorological and Hydrological Service
NOAA	National Oceanic and Atmospheric Administration
NWRMC	Northwest Regional Modeling Consortium
NWS	US National Weather Service
ODA	Official Development Assistance
PPP	Public-Private Partnership
SSA	Sub-Saharan Africa
SEB	Socio-economic benefit
SMS	Simple Messaging Service
SOE	State-Owned Enterprise
UNDP	United Nations Development Program
UNMA	Uganda National Meteorological Authority
VAS	Value-added services
WAFS	World Area Forecast Service
WCIS	Weather and Climate Information Services
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

Climate change poses a serious threat to the people of Sub-Saharan Africa (SSA). The Intergovernmental Panel on Climate Change (IPCC) predicts that heat and drought stress will decrease crop productivity in Africa, with strong adverse effects on regional, national and household livelihoods and food security. In order to cope and adapt, companies and individuals will need accurate and timely weather and climate information services (WCIS).

The global market for WCIS is growing rapidly. WCIS expenditures increased by more than 35 percent from 2011-15, to an estimated total of $56 billion. Data for SSA is limited, but research indicates that the market for WCIS in SSA, including both public and private expenditures, is approximately $1.4 billion.[1] This is a small market compared to other regions, but it shows signs of growth.

Developed economies invest heavily in WCIS and investments in WCIS generate strong, positive returns on investment[2] in two ways. First, investing in WCIS yields benefits that greatly outweigh the costs. In the United States, Europe, and Australia, the cost-to-benefit ratio of national meteorological services ranges from 1:3 to 1:10,[3] with higher returns in lower-income countries associated with disaster risk management. For example, improvements in National Meteorological and Hydrological Services (NMHSs) to reduce loss from disasters have cost-to-benefit ratios between 1:4 and 1:36, and an El Nino early-warning system in Mexico had cost-to-benefit ratios ranging from 1:2 to 1:9.[4] In other words, every dollar invested in WCIS yields between $2 and $36 in benefits. Second, freely available weather and climate information can stimulate a larger private market for WCIS, where investments in WCIS generate a return. As of 2018, the U.S. government spends about $1 billion per year to sustain the National Weather Service. This investment, combined with an open data policy, has helped create a $7 billion market for private-sector weather and climate information products. A second example is the New Zealand NMHS, called MetServices, that operates as a commercial company under the Companies Act with a Board responsible for its business and affairs. MetServices' cornerstone contract with the Ministry of Transport generates financing from within the public domain for public good forecasting services. It has proven that a State-Owned Enterprise with appropriate mandate can operate as a commercial company, provide public services, discharge the nation's international WCIS obligations, and provide a return on investment to its shareholders.[5]

Despite the clear benefits of public investment, however, most governments in SSA do not yet have the resources to invest in operating and maintaining (much less upgrading) their meteorological and hydrological services. The region's network of weather observation and communication infrastructure has steadily degraded over time. In 2013, the World Bank estimated that SSA would

[1] Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. S*cience Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

[2] Qadir, U. (2017). Toward Sustainable Climate Information Services in Sub-Saharan Africa: A literature review. Developed as part of the USAID project Assessing Sustainability and Effectiveness of Climate Information Services in Africa (Sustainable CIS Project).

[3] Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research, 10*, 65–70. doi:10.5194/asr-10-65-2013

[4] WMO. (2015). Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. http://www.wmo.int/pages/prog/amp/pwsp/documents/wmo_1153_en.pdf

[5] Rogers, D. P., & Tsirkunov, V. V. (2013). *Weather and Climate Resilience: Effective Preparedness Through National Meteorological Services.* Washington, DC: World Bank.

need $1.5 – $2 billion in funding to make high-priority modernizations to WCIS systems. Operations and maintenance would require an additional $400-$500 million per year. Donor funding is helping the WCIS market develop in SSA, but it can distort the market at the same time.

NMHSs are the primary source of WCIS in SSA, but they lack sufficient funding to build and maintain modern observation networks. Private-sector companies can help fill gaps in services, but they rely on high-quality data gathered by governments to build value-added products and services. To engage the private sector, NMHS must generate robust and timely data at the national, regional, and local levels.

Sustainable CIS Project. This research is part of the USAID-funded Assessing Sustainability and Effectiveness of Climate Information Services (CIS) in Africa (Sustainable CIS project). The project supports research to design and implement sustainable WCIS models within and alongside SSA NMHS. The project focuses on a subset of SSA countries, including, but not limited to, Senegal, Ethiopia, Rwanda, Malawi, and Mali. The project is carried out by a Winrock International led consortia that consists of the International Research Institute for Climate and Society (IRI), the Climate System Analysis Group (CSAG), the AGRHYMET Regional Center, and the Global Framework for Climate Services (GFCS)[6].

Research team and objectives. Winrock International led this research study project that aimed to:

(1) Assess the current market for WCIS in SSA; and

(2) Identify existing private-sector engagement in WCIS and promising business models for private-sector involvement.

Approach. The Winrock team reviewed, gathered, and analyzed both quantitative and qualitative data. Researchers conducted desk research and analyzed data from multiple sources. The primary research consisted of two sets of interviews. Winrock interviewed a NMHS director or representative from Cote d'Ivoire, Malawi, Mali, Niger, Nigeria, Rwanda, and Senegal. In addition, the team interviewed 14 representatives of private-sector WCIS companies in SSA.

Key Findings. The research and analysis resulted in the following key findings:

The market for WCIS is large globally, but still nascent in SSA. Globally, nearly every industry invests in WCIS. So far, however, commercial aviation is the only sector in Sub-Saharan Africa to purchase WCIS on a large scale. WCIS could add value in many economic sectors, including agriculture, mining, and shipping/transportation.

Predictable financial support for a country's NMHS is critical. NMHSs in SSA need reliable funding to build and modernize observation infrastructure, operate and maintain systems, build staff capacity, and purchase the information technology and communications services required for data transmission and analysis.

The operating model used by the Government to manage the NMHS does not appear to influence the number of market participants or size of the market for WCIS. NMHSs in SSA

[6] GFCS is a global partnership of the World Meteorological Organization (WMO) with the UN International Strategy for Disaster Reduction, the World Health Organization, the World Food Programme, the Food and Agriculture Organization of the UN, and others.

and other regions vary in organization and structure, from governmental departments to autonomous organizations. These differences do not appear to affect private-sector involvement. The government policy and legal environment is more important, and are discussed further below.

Donor and government support often funds equipment without adequate funding for operations and maintenance. Much of the WCIS infrastructure in SSA is in disrepair, partly because NMHSs lack sufficient funds to maintain systems. To maintain sustainable services over time, NMHSs need ongoing funds for operations and maintenance, including information and communications technologies and services. Donors and governments should include this funding alongside infrastructure investments.

Revenue generation from WCIS is a rare—but promising—strategy for NMHSs and governments in SSA. Very few NMHSs in SSA have the information, expertise, and capacity to generate revenue by working with the private sector. As a result, NMHS budgets rely on government and donor support. Even when commercial clients purchase WCIS from the government, the NMHS may not receive the revenue.

Constrained or permissive legal and policy environments are more likely to promote private-sector involvement. Strong WCIS markets are more likely to develop where governments share WCIS data and allow private companies to sell services to end users. Policy that defines a process to develop partnerships rather than rigid roles of actors can promote partnerships, as can a neutral host to help mediate conflict and facilitate discussion between public and private actors.

Public-private partnerships can help the WCIS sector develop. Partnerships can grow the WCIS market, increase the range of services available to end users, and generate revenue for NMHSs. SSA has only a small number of public-private partnerships. All 14 private-sector companies Winrock interviewed work with NMHSs, but the limited capacity of NMHSs poses challenges. Winrock found some correlation between total amount of U.S. government donor funding into agriculture and the presence of private sector WCIS companies.

Private-sector companies are providing WCIS in many countries of SSA. International and local companies are investing in automated weather stations and infrastructure, NMHS capacity building, and delivering WCIS to more than 2.36 million end users, most of whom are smallholder farmers.

Gender inclusion is limited. Some companies take gender into consideration in their decision-making or service offerings, especially with how data content is presented to the end user.

Private sector companies use a wide variety of business models, and no single model is dominant. Businesses are the most active buyers of WCIS, both for their own use and for that of the public. Among the 14 companies Winrock interviewed, we identified 8 different business models. The business-to-business-to-consumer model was the most common, while direct services to donors, governments, or consumers was least common.

WCIS technology and services from developed economies can transfer successfully to SSA. Private companies and other partners are successfully adapting WCIS technology from more developed economies to fit local contexts in Sub Saharan Africa. Companies that transfer technologies build local capacity in the process, both in the public and private sectors.

1. INTRODUCTION

1.1. Climate Change in Sub-Saharan Africa

According to the Intergovernmental Panel on Climate Change (IPCC), Africa is one of the most vulnerable continents to climate change[7]. SSA will experience severe effects disproportionate to its role in causing climate change. African countries contribute only a small share of global greenhouse gas emissions, but SSA will experience more climate stress and extreme weather events than most other parts of the world. At the same time, the region has little capacity to adapt to climate change. Poor infrastructure, limited access to markets, high illiteracy rates, and widespread poverty will hinder any efforts to mitigate the effects of climate change in Africa[8].

In SSA, the changing climate will have far-reaching effects that differ widely across countries and regions. The impacts could be especially devastating on a continent that relies heavily on agriculture. Between 60 and 70 percent of people in SSA depend directly or indirectly on agriculture for food security and income. These rural families generally spend 50 percent of their household incomes on food, making them very vulnerable to increased food prices or decreased incomes from agriculture.[9] The IPCC predicts that heat and drought stress will decrease crop productivity in Africa, with strong adverse effects on regional, national, and household livelihoods and food security. Flooding and increased pest and disease damage will also negatively impact the continent's food system infrastructure.[10]

Agriculture in SSA is particularly vulnerable to changes in rainfall patterns because irrigation is rare. Even small changes in inter- or intra-annual rainfall can have devastating impacts on agricultural productivity. In some parts of SSA, 95 percent of agriculture is rain-fed.[11] Most rural families depend on rain-fed agriculture for their livelihoods, and rain-fed agriculture generates a significant portion of national GDPs. Rain-fed agriculture is especially important to the extreme poor, who are disproportionally women[12].

In the coming decades, the situation will only become even more dire as rapid population growth and climate change threaten food security for families throughout SSA. Failure to address and adapt to climate change, especially changes in rainfall patterns, could jeopardize decades of development investments and improvements in livelihoods in SSA.

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[7] IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[8] Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart, 2014: Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[9] Pinstrup-Andersen, P., R. Pandya-Lorch, and M. W. Rosegrant. 1999. World Food Prospects: Critical Issues for the Early Twenty-First Century. International Food Policy Research Institute, Washington D.C.

[10] IPCC, 2014: (ibid)

[11] Alexandratos N and Bruinsma J. 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working Paper No. 12-03. Rome: FAO.

[12] Wani, S.P.; Sreedevi, T.K., Rockstrom, J; Ramakrishna, Y.S. 2009; Rainfed Agriculture – Past Trends and Future Prospects. http://publications.iwmi.org/pdf/H041990.pdf

1.2. Weather and Climate Information Services

Weather and climate information services (WCIS) can help SSA cope with climate change. Governments, businesses, and farmers in the region will need timely, reliable weather information to make informed decisions.

WCIS is a broad term for the "flow and use of information, rather than the source of the data."[13] WCIS encompasses both data and analysis across a range of service platforms. Data measured includes temperature, rainfall, wind, soil moisture, and extreme weather conditions.

This report treats WCIS as a single category, but they are two distinct types of services. Weather information is shorter-term, measured on a time scale between minutes and seasons. Users need weather information for operations, logistics, and profiling short-term risk. Early-warning systems, for example, rely on weather information to issue extreme-weather alerts.

Climate information services require information gathered over years and decades. Climate information is used to profile longer-term risk[14]. For example, a water company could use climate information to learn how watercourses—the channels followed by flowing bodies of water—are likely to change with the changing climate. The company could use that information to inform future watercourse development.

High-quality WCIS provides accurate, location-specific forecasts and advisories on a daily, ten-day, monthly, and seasonal basis and includes historical trends, monitoring and forecast products. To be useful, WCIS must provide timely information accessible to those who need it. WCIS systems can deliver information to a range of end users, including decision makers at regional, national, and local levels, down to individual smallholder farmers. WCIS can strengthen the adaptive capacity of communities, reducing their vulnerability to climate change and weather variability.

WCIS is valuable in weather-sensitive economic activities like construction, aviation, transport, and mining. Agriculture, the dominant source of employment in SSA, is particularly dependent on weather and climate, so timely WCIS is critical. WCIS can help farmers with both short- and long-term planning, such as deciding which crops to grow, when to plant, when to harvest, and which investments to make. More broadly, WCIS can build a foundation for national and regional information systems to help SSA adapt to longer-term and larger-magnitude climate shifts.

WCIS can also help insurers create products tailored to the needs of small farmers. Insured farmers receive payments when specific weather events (e.g., drought) decrease their yields. Insurance can facilitate access to credit, enabling farmers to invest in their farms.

Developing effective WCIS requires access to reliable climate and weather information. Accurate forecasting depends on a network of global, regional, and national remote and *in situ* observations of the atmosphere, oceans, and land. In most cases, a country's NMHS is the primary source of data. NMHSs commonly serve a national mandate to observe, forecast, and issue warnings for pending weather, climate, and water threats.

[13]Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. S*cience Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

[14] Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. S*cience Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

The NMHS typically works with multiple partners to conduct observations. Government agencies in specific sectors (e.g., agriculture, aviation, water, and energy) and private-sector companies also gather climate and weather information, but efforts may not be coordinated. In many SSA countries, the result is the WCIS enterprise is unable to meet basic needs for emergency warnings, timely and reliable local and seasonal weather forecasts, and global climate observation.

Improving WCIS in SSA will require an understanding of the existing WCIS market and sustainable WCIS models. Over the past two decades, researchers have attempted to assess the size and state of the global WCIS market. Unfortunately, no single authoritative source tracks and documents annual WCIS market data. In addition, the studies that do exist vary widely in how they define the WCIS market. Some conflate public expenditure and private revenues. Some sources combine climate and weather; others treat the two separately.

Governments, donors, and private-sector companies will need better information about the WCIS market to bring high-quality WCIS to SSA.

1.3. Investment in WCIS

Cost-to-benefit analysis. Investing in WCIS yields benefits that greatly outweigh the costs. In the United States, Europe, and Australia, the cost-to-benefit ratio of national meteorological services ranges from 1:3 to 1:10.[15] In other words, every dollar invested in WCIS yields between $3 and $10 in benefits. In lower-income countries, WCIS investments have also been reported to achieve very high returns, including:[16]

- Improvements in NMHSs to reduce loss from disasters have cost-to-benefit ratios between 1:4 and 1:36.
- A drought early-warning system in Ethiopia installed to decrease livelihood losses and dependence on assistance achieved cost-to-benefit ratios between 1:3 and 1:6.
- In a five-state region of Mexico, an El Nino early-warning system designed to improve decision-making in agriculture had cost-to-benefit ratios ranging from 1:2 to 1:9.

Impact of investment in WCIS. Developed economies invest heavily in WCIS infrastructure, technology, and capacity. In 1992, under the Weather Service Modernization Act, the U.S. government began making significant investments in the National Weather Service (NWS). In the 1990s, the U.S. government invested $4.5 billion to modernize the national WCIS infrastructure and restructure its weather service operations. As of 2018, the U.S. government spends about $1 billion per year to sustain the NWS[17]. The U.S. government's investment in WCIS, combined with an open-data policy, helped create a $7 billion market for private weather and climate information products.

A blend of finance from public-sector investment and ongoing public operational support, along with private sector revenues, has created sustainable WCIS for end users. Excess funds (e.g., profits)

[15] Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research, 10*, 65–70. doi:10.5194/asr-10-65-2013

[16] WMO. (2015). Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. http://www.wmo.int/pages/prog/amp/pwsp/documents/wmo_1153_en.pdf

[17] National Research Council. (2012). The National Weather Service Modernization and Associated Restructuring: A Retrospective Assessment. Washington DC: National Acadamies.

are used to support ongoing research, development, and innovation. Public and private services complement and reinforce one another. The system's foundation is the network of publicly generated, freely available data, with substantial additional value (and, frequently, enhanced data collection) from private-sector weather products. A cycle of investment, service enhancement, research and development, and re-investment has created a market for WCIS in the United States and other developed economies.

Lack of WCIS investment in Sub-Saharan Africa. Despite the clear benefits of public investment in WCIS, many governments in SSA do not yet have the resources to invest in operating and maintaining—much less upgrading—their meteorological and hydrological services. SSA's network of weather observation and communication infrastructure has steadily degraded over time. As of 2016, the majority of stations in the region were not reporting data, and large areas had no coverage.[18] In 2013, the World Bank estimated that it would cost between $1.5 billion and $2 billion to make high-priority modernizations to WCIS systems in Sub-Saharan Africa. Operations and maintenance would require an additional $400 million to $500 million per year,[19] and these estimates do not include funding for training and capacity building.

Public investment in NMHSs – the primary source of data for WCIS in SSA - is low for what are likely to be a wide variety of reasons. Governments may prioritize other investments or fail to fully account for the far-reaching economic impacts of under- investing in WCIS. In some cases, governments struggle to mobilize international finance. Governments may allocate funding for weather and climate observations across many different agencies. Agriculture, water, and disaster relief agencies often have higher standing than NMHSs, so they often receive more of the funding.

Under-investment in WCIS has created a vicious cycle among NMHSs in Sub-Saharan Africa. With insufficient funding, NMHSs fail to produce timely and accurate information. This poor performance discourages governments from investing in NMHSs, so products and services deteriorate further.[20] The private sector can help fill the investment gap, but if governments do not recognize the role the private sector can play, they may fail to support or enable market involvement and could even restrict activity.

1.4. Sustainable Climate Information Services Project

The USAID-funded Assessing Sustainability and Effectiveness of Climate Information Services (CIS) in Africa Sustainable CIS project (Sustainable CIS project) supports research on how to design and implement sustainable CIS models within and alongside NMHSs. The project focuses on five countries: Senegal, Ethiopia, Rwanda, Malawi, and Mali. Winrock International leads the project in partnership with the International Research Institute for Climate and Society (IRI), the Climate System Analysis Group (CSAG), the AGRHYMET Regional Center, and the Global Framework for Climate Services (GFCS)[21].

[18] UNDP, "A New Vision for Weather and Climate Services in Africa" (2016)

[19] Sacko, J.L. (2017). Understanding Weather and Climate Boosts Economies and Saves Lives. AMCOMET Africa Hydromet Forum OpEd. https://www.gfdrr.org/sites/default/files/documents/OpEd_Africa_Hydromet_Forum_AUC_commissioner.pdf

20 Rogers, D. P., & Tsirkunov, V. V. (2013). Weather and Climate Resilience: Effective Preparedness Through National Meteorological Services. Washington, DC: World Bank.

[21] GFCS is a global partnership that includes the World Meteorological Organization (WMO), UN International Strategy for Disaster Reduction, World Health Organization, World Food Programme, Food and Agriculture Organization of the UN.

The project's objectives are to:

- Develop models for the sustainable delivery of CIS in SSA; and
- Consolidate and extend knowledge on existing CIS in SSA.

The Sustainable CIS project will help identify and improve existing CIS programs implemented by the public and private sectors as well as design and assess new CIS appropriate for local contexts.

The project has three components:

1. **Sustainability assessments**. The project will develop metrics to assess the effectiveness and sustainability of NMHSs to deliver CIS, including a baseline metrics (assessment) of select NMHSs and recommendations for improvements.
2. **Identify options for improving the sustainability of CIS**. The project will assess the market for CIS in Sub-Saharan Africa, private-sector business models for CIS, and financial models for CIS delivery in the region.
3. **Partnership-building and knowledge-sharing.** The project will promote collaboration, synthesize lessons learned, and disseminate information about CIS.

1.5. Research Objectives

The research presented in this report is part of the Sustainable CIS project's second component: identifying options to improve the sustainability of WCIS in Sub-Saharan Africa.

The research had two objectives:

1. Review the current market for WCIS in SSA; and
2. Identify promising business models of private sector engagement in WCIS in SSA.

1.6. Methodology

Terminology. For the purposes of this report, we use the combined term "weather and climate information services (WCIS)" to encompass the full range of information and services for both weather and climate. The report identifies cases where data is separated into either weather or climate. We use the term "climate and weather enterprise (CWE)" to refer to the WCIS sector and all actors who participate in the WCIS market.

To meet the research objectives, the research team conducted a market assessment and review of business models used to deliver WCIS in SSA.

The team used these primary research methods:

1. Desk research and review of existing literature.
2. Analysis of data from the World Meteorological Organization (WMO) on staffing and funding for NMHSs.
3. Preliminary interviews with a NMHS director or representative in each of seven target countries: Cote d'Ivoire, Malawi, Mali, Niger, Nigeria, Senegal, and Rwanda. This information is being further developed in the Sustainable CIS Project activity with an in-depth baseline metrics assessment in select countries.

4. Case study analysis based on interviews with 14 private-sector companies working in SSA. To gain global context and insights, additional discussions were held with IBM, Vodacom South Africa, the U.S. National Oceanic and Atmospheric Administration (NOAA), Earth Networks in Latin America and Caraga State University in the Philippines (Philippine Atmospheric Geophysical and Astronomical Services Administration[22] activity).

The research consists of two main parts: (1) a market assessment; and (2) a review of private-sector business models. In general, the market assessment relies on the desk research, analysis of WMO data, and preliminary interviews with NMHS representatives, while the review of business models relies on interviews with private-sector companies. All four methods of research, however, informed the analysis in both parts.

1.6.1. Market Assessment

Winrock assessed both the global WCIS market and the market in SSA. The research team relied on quantitative and qualitative data from multiple sources:

1. Analysis of the World Meteorological Organization's baseline metrics data for NMHSs in SSA[23]
2. Global, regional, and sectoral expenditures on WCIS
3. Total Available Market (or Total Addressable Market) calculations, which measures the potential revenue from a WCIS product or service
4. Socio-economic benefit (SEB) analysis
5. Qualitative information from private-sector company case studies
6. Interviews with representatives of the NMHSs in the seven target countries
7. Review of the WMO database (June 2017)

NMHSs Interviews. As part of the market assessment, Winrock assessed the capacity of seven NMHSs in Côte d'Ivoire, Mali, Malawi, Niger, Nigeria, Rwanda, and Senegal. The team used a semi-structured interview method to carry out a preliminary assessment of what NMHSs know about private-sector WCIS companies in their countries, public finance and the current status of the NMHS. Interviews were held between May 1 and July 5, 2017.

1.6.2. Private-Sector Business Model Case Studies

To identify promising business models in the WCIS sector, Winrock interviewed representatives of 14 private-sector companies providing WCIS in SSA, prepared a case study for each company, and analyzed the overall results. The goals of the analysis were to identify (1) common business models; (2) types of WCIS provided by the private sector; (3) geographic and end-user reach; (4) technological innovations; (5) efforts to include women as end users; (6) opportunities and barriers to growth; and (7) models for public-private partnerships.

[22] www.pagasa.dost.gov.ph/

[23] World Meteorological Organization Data Base. https://www.wmo.int/cpdb/. Accessed 29-06-2017.

Identifying companies for case studies. A total of 20 potential U.S., European, and African public entities and private-sector companies providing WCIS in SSA were identified, of which we interviewed 14. The other six companies we did not interview were either unavailable or inaccessible.

Interviews. Researchers created a survey instrument of open-ended qualitative interview questions to gather consistent information across companies. The team interviewed respondents by phone. (See Section 5.1, Company Survey Instrument in Appendix I for the list of questions.)

Case study preparation and analysis. Based on the phone interviews, Winrock prepared a case study for each company (see Appendix I, Section 2). Analyzing qualitative information from interviews is obviously more subjective than statistical analysis. To make the case studies as consistent as possible, Winrock used a common set of interview questions, collated responses from interviews into a consistent format, and wrote a narrative case study for each company built around examples. The case studies rely on limited numerical data (e.g., number of end users), but we were able to draw general conclusions about markets and trends. Winrock's case study analysis focused on private-sector providers of WCIS services, not end users.

The case study analysis explored whether any existing WCIS business models in the private sector are operating effectively in SSA. Winrock's research cannot answer this question definitively, but we identified promising business models and assessed their challenges and opportunities. The case study approach revealed new and unexpected results.

Appendix I contains a brief description of the public sector and private sector companies operating in SSA. It contains their business model, tools and technologies, partners, and market opportunities and revenue resources.

2. MARKETS FOR WEATHER AND CLIMATE INFORMATION SERVICES (WCIS)

This section provides an overview of the size of the WCIS market, both globally and in SSA, as well as a breakdown of WCIS spending by region and sector. Subsequent sections cover the role of governments and the private sector in SSA's WCIS market. The analysis draws from quantitative data generated by public and private organizations as well as Winrock's interviews with representatives of NMHSs and private companies and NGOs in SSA.

2.1. Market Size

Key Findings

- The global market for weather and climate information services (WCIS) varies by region, and is not homogenous.
- Demand for WCIS is growing, but it is unclear how large the global WCIS market is.
- Almost every industrial sector has WCIS-related requirements.
- The current market for WCIS in SSA is new and relatively small.
- Aviation is the largest consumer of WCIS in SSA.

2.1.1. General Findings

Very little information is available about the WCIS market in SSA. None of the available studies, for example, disaggregate the market by industry, although aviation is clearly the largest consumer. Available information indicates that the market for WCIS in SSA, including both public and private expenditures, is approximately $1.4 billion[24]. Given the lack of sufficient, verifiable data, future research is needed to more accurately assess market size.

The WCIS market in SSA is small compared to markets in other regions. Studies share two conclusions: (1) the global market for WCIS is $56 billion and expanding; and (2) investments in the sector generate strong, positive returns on investment.[25] In SSA, WCIS investments are low relative to those in high income economies, and the private sector plays a much smaller role in CIS markets in low and middle-income economies. This is likely due to the relative size, diversity, and maturity of the high income-country market economies.

2.1.2. Methodology

Winrock reviewed three different types of market analysis:

[24] Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. *Science Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

25 Qadir, U. (2017). Toward Sustainable Climate Information Services in Sub-Saharan Africa: A literature review. Developed as part of the USAID project Assessing Sustainability and Effectiveness of Climate Information Services in Africa (Sustainable CIS Project).

1. Market expenditure analysis based on global, regional, and sectoral WCIS expenditures
2. Total Available Market (TAM) or total addressable market analysis, which measure the potential revenue from a WCIS product or service
3. Socio-economic benefit (SEB) analysis

Data. Most market assessments for WCIS in SSA rely on data from kMatrix, an international market analysis company.[26]

2.1.3. Market Expenditure Analysis

Market expenditure analysis calculates market size as the total amount spent in the sector. According to market expenditure analysis, the global market for WCIS is growing rapidly, with a wide range of sectors purchasing services.

Global market size. Figure 1 shows global spending on WCIS, CIS, and weather information services (WIS) over a five-year period (2010 – 2015), calculated from transactional data on private and public spending. According to this market expenditure analysis, total global spending on WCIS increased from $41 billion in 2011 to $56 billion in 2015, an increase of 36 percent over four years. Spending on WIS increased by a similar amount during the same period.[27] Of the $56 billion spent on WCIS in 2014/2015, 54% spent in weather services and 46% spent in climate services[28], $15 billon (27 percent) was public funding for NMHSs.

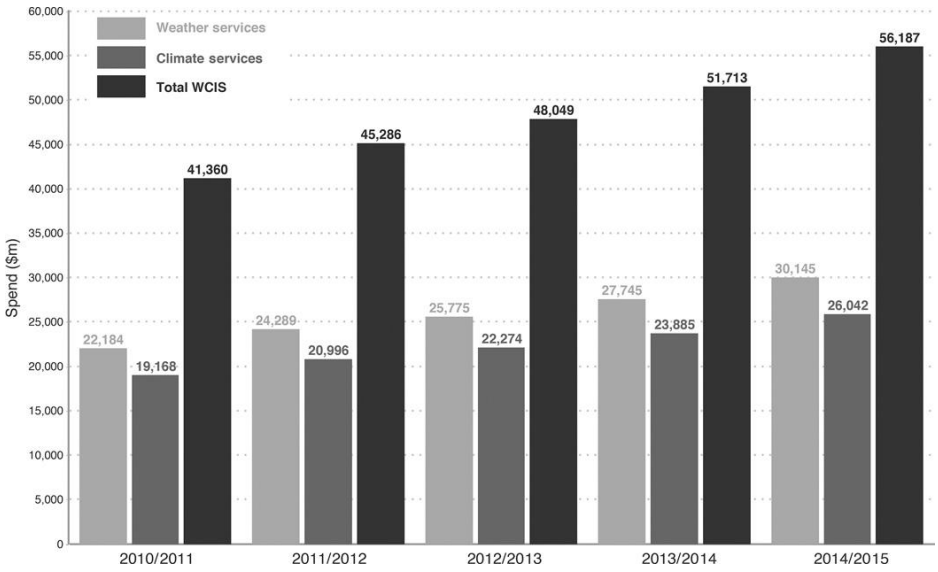


Figure 1. Global spending on weather and climate information services.[29]

Source: Georgeson et al (2017)

[26] https://www.kmatrix.co/. Competitive Market Intelligence making a difference. Accessed November 23, 2017

[27] Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. S*cience Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

[28] http://advances.sciencemag.org/content/3/5/e1602632.full

[29]Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. S*cience Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

Global expenditures by sector. WCIS spending varies widely by industrial sector and region (see below). **Figure 2** shows industry spending on WCIS as a percentage of total spending, disaggregated by weather information services (WIS) and climate information services (CIS). These estimates are based on global aggregated data from 2014-15.[30].

Industries vary in how much they spend on weather information services compared to climate information services. **Figure 2** shows that companies in built environment, agriculture, forestry and timber, exploration and extraction, and tourism spent more on climate information. The agriculture sector, for example, spent $1.2 billion on climate services in 2014-15, compared to $460 million on weather services. These industries rely heavily on human capital, investment, and long-term planning, which makes longer-term climate information more important. This global ratio for agriculture may be different in SSA where access to information is more limited, and weather information is more useful for most farmers.

Weather information services, on the other hand, is more critical for sectors that face shorter-term risks. **Figure 2** shows that companies in the utility, pharmaceutical, and legal and financial industries spent more on weather information than climate information. Utilities in particular are vulnerable to extreme weather events, so weather information is critical. In 2014-15, the utility industry spent $2.8 billion on weather information, compared to $1.6 billion on climate information.

[30] Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. S*cience Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

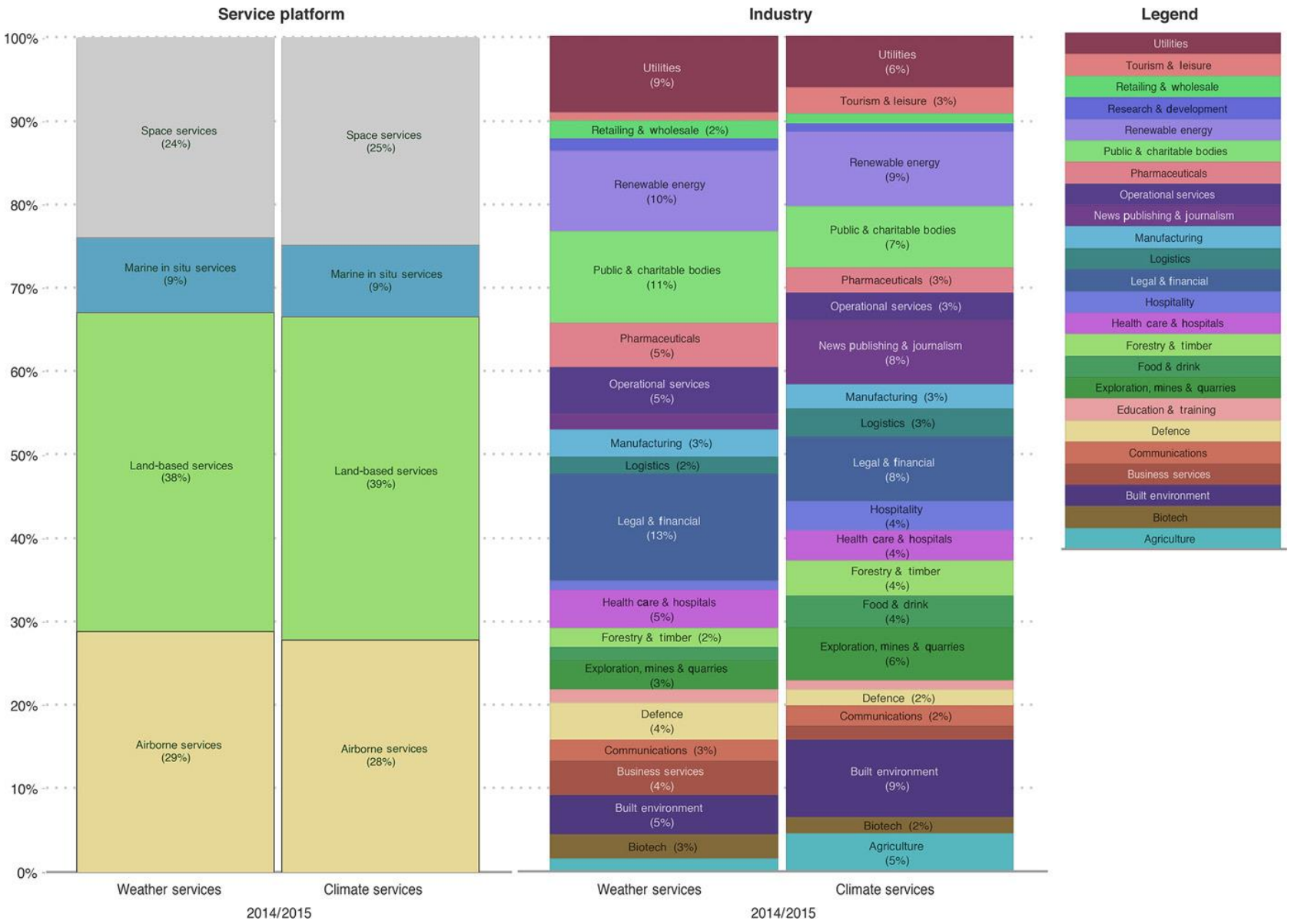


Figure 2. Global CIS and WIS information expenditures by sector, 2014/2015

Source: Georgeson et al (2017)

Total market size, Sub-Saharan Africa. SSA spends less on WCIS than almost every other part of the world. **Figure 3** shows total and per-capita spending on WCIS by world region, calculated based on 2014-15 expenditures. SSA has the lowest overall spending and second lowest per-capita spending. Countries in SSA spend less than 10 percent of what North American countries spend per capita.

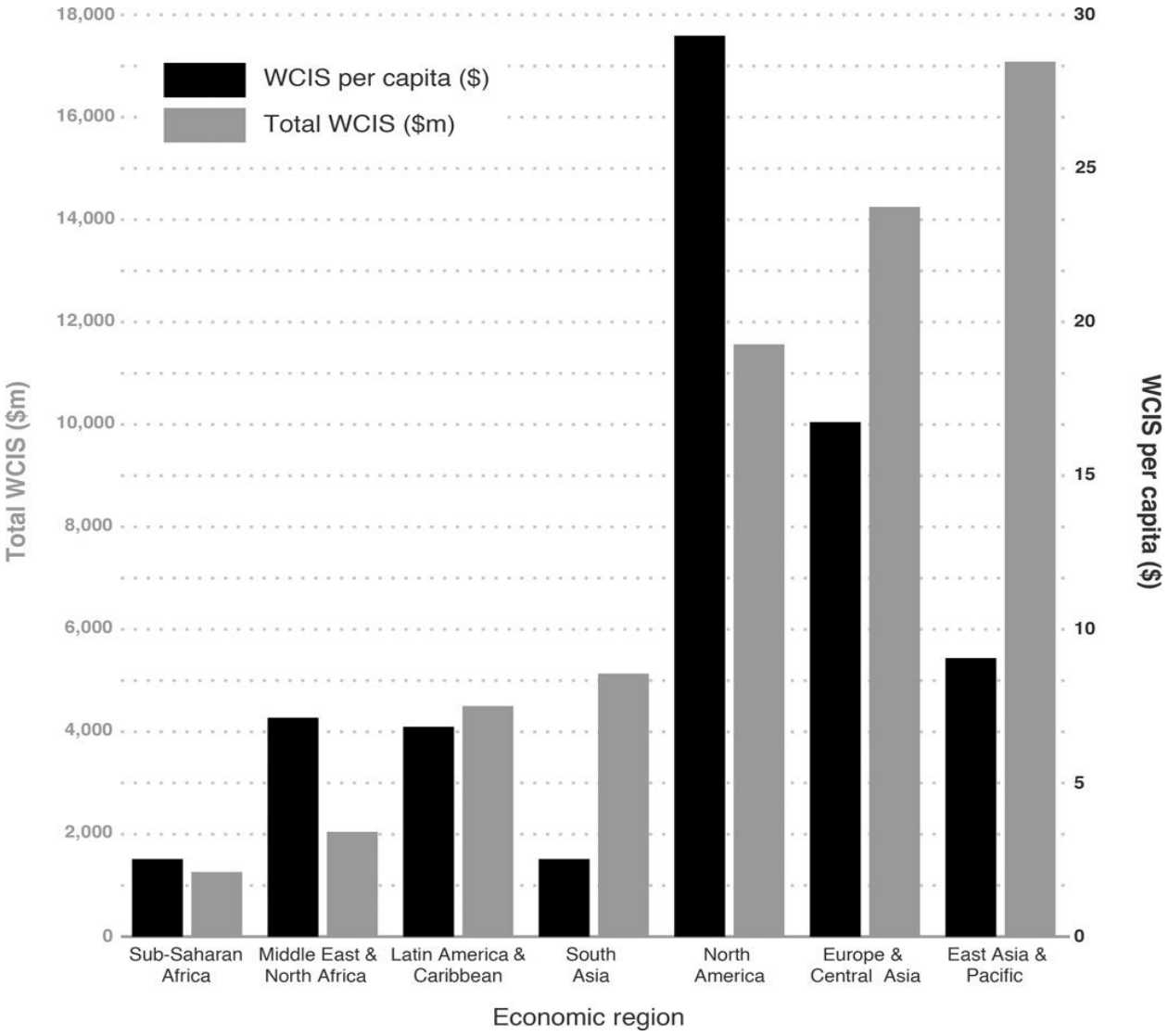


Figure 3. Average per capita spending on commercial WCIS by region[31]

Source: Georgson et al (2017)

Expenditures by sector, Sub-Saharan Africa. Unfortunately, very little information exists about WCIS spending by industry in SSA. Winrock's case studies indicate, though, that a range of industries are purchasing services. All of the 14 companies Winrock interviewed provide at least some climate and weather services to the agriculture sector, with weather services dominating. Other

[31] Georgeson, L., Maslin, M., and M. Poessinow. 2017. Global disparity in the supply of commercial weather and climate information services. S*cience Advances*. 3(5):1-9. http://advances.sciencemag.org/content/3/5/e1602632.full. Accessed 26 September 2017.

sectors served by the companies are the commodities, insurance, finance, infrastructure, and mining industries.

Aviation is currently the largest commercial consumer of WCIS in SSA Commercial aviation needs WCIS to meet the regulations of the International Civil Aviation Organization. In most cases, the aviation sector purchases these services from national governments. The South African Weather Service (SAWS), for example, received $9 million in revenues from aviation in 2015-16, out of a total budget of $22 million.[32]

2.1.4. Total Available Market Analysis

Total available (or addressable) market analysis (TAM) is another way to understand the size of the potential market for specific WCIS products or services. TAM analysis assesses the existing revenue opportunity for a product or service, such as a specific business model. In general, because TAM analysis focuses on market potential for a particular product or service, the result of TAM analysis is a smaller figure than total market size. TAM analysis can therefore be used to assess market potential for a product or service in different markets, but it is not suitable to estimate the total market for WCIS in a particular country or region. For example, according to the Weathernews business model[33], their total available market in SSA was $5.52 billion in 2016 and $56 billion in United States in 2015.[34] These numbers represent the market potential for their business model in these regions rather than the actual market size for their business or the total WCIS market in each.

2.1.5. Socio-Economic Benefit Analysis

Measuring market size does not necessarily capture the broader social and economic benefits of the WCIS sector. Socio-economic benefit analysis is one way to estimate the effects of improved WCIS on safety, health, livelihoods, and the broader economy.

In the United States, for example, Weathernew's TAM analysis assigns the value of WCIS as $56 billion. Socio-economic benefit analysis, however, attributes $1 trillion worth of economic activity to WCIS in 2010.[35]

Several key studies show the benefits of public and private investment in WCIS, but few of them have information from Africa. Socio-economic benefit analysis requires resources and skilled researchers, which likely explains the lack of research from SSA.[36]

Studies that have assessed socio-economic benefits of WCIS in SSA demonstrate benefits to agriculture and food security, drought response, and hydropower, but predominately focus on

[32] Annual Report. South African Weather Service 2015-16. http://www.weathersa.co.za/about-us/2015-09-10-13-04-27. Accessed 23 November 2017.

[35] Weather Derivatives Market. (2010). Retrieved from Climetrix: https://www.climetrix.com/WeatherMarket/MarketOverview/. Accessed November 15, 2017.

[36] Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research*, 10, 65–70. doi:10.5194/asr-10-65-2013

agriculture.[37,38] A USAID-funded meta-analysis of 139 primary studies[39] with quantitative estimates of climate services concluded that investments in WCIS generate important public benefits. A World Bank study found that an annual investment of $1 billion to modernize early-warning systems in NMHSs would generate between $4 billion and $36 billion in socio-economic benefits[40].

A study conducted for the Uganda National Meteorological Authority (UNMA) quantified the benefits of using WCIS for decision-making, accounting for lives saved and economic benefits from avoided losses. The most conservative estimate calculated a 300-percent return on investment over the first 15 years.

2.1.6. Discussion

The research shows that the global WCIS market varies by region, is not homogenous, and demand is growing. The current market for WCIS in SSA is new and relatively small, with aviation the largest consumer of WCIS in SSA. The three different approaches researched to understand the WCIS market in SSA do not produce directly comparable results. Analysis of market expenditure analysis and TAM analysis indicates there is potential for growth in the WCIS market in SSA and globally: Weathernews's TAM analysis found market potential for their business to be $5.52 billion in SSA and $56 billion in the United States – both of which are significantly larger than actual expenditures in corresponding years. Socio-economic benefit analysis and cost-benefit analysis both show that investments into WCIS produce clear economic benefits – though these benefits are not always monetizable by an investor. An examination of the climate and weather enterprise, role of government, NMHSs, and the private sector in WCIS is needed to understand how to stimulate the market.

2.2. The Climate and Weather Enterprise

Key Findings

- Partnerships among different actors in the Climate and Weather Enterprise (CWE) can deliver more cost-effective, sustainable WCIS than those financed and delivered by a single CWE actor.
- Conflicts that arise between the public, private, and academic sectors in the CWE are best resolved through regular dialogue facilitated by a neutral third party.

In SSA, a wide range of actors participate in the WCIS market. For this report, we define the Climate and Weather Enterprise (CWE) as the group of public, private, academic, and development organizations delivering WCIS products and services to end users. (This broader set of actors,

[37] WMO. (2015). Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. http://www.wmo.int/pages/prog/amp/pwsp/documents/wmo_1153_en.pdf.

[38] Clements J., and A. Ray. 2013. The Value of Climate Services Across Economic and Public Sectors: A Review Of Relevant Literature. United States Agency for International Development, Washington DC. http://www.climate-services.org/wp-content/uploads/2016/04/CCRD-Climate-Services-Value-Report_FINAL.pdf

[39] ibid

[40] Hallegatte, S., A Cost Effective Solution to Reduce Disaster Losses in Developing Countries: Hydro-Meteorological Services, Early Warning, and Evacuation (May 1, 2012). World Bank Policy Research Working Paper No. 6058. Available at SSRN: https://ssrn.com/abstract=2051341

including the NMHSs, is also sometimes referred to as the climate and weather sector.) The sustainability of the entire CWE—not just the NMHSs—is critical.

NMHSs are generally the key stakeholders in the CWE since they have national mandates to observe, forecast, and issue public warnings for pending weather, climate, and water threats. NMHSs do not operate in isolation, however. Academic institutions, private-sector companies, non-governmental organizations, and other public-sector institutions all participate in the CWE. Organizations in the CWE are continually developing new technologies, processes, observation and forecasting techniques, and WCIS products for end users.

In some cases, actors within the CWE provide services independently. An organization might design, develop, and deliver WCIS to meet the decision-making needs of a specific end user. In most cases, however, partnerships (either formal or informal) result in a stronger WCIS market. Winrock's research indicates that combining the assets and resources of public, private, and academic institutions collectively within the CWE is a more cost-effective, sustainable way to deliver WCIS.

For example, a partnership between a private provider of Geographic Information Services (GIS) and the NMHS to deliver WCIS to a community of smallholder farmers would be more cost-effective than two separate efforts in the same community. Similarly, organizations that own and operate complementary surface observation networks could combine datasets to develop data content and better services for end users. Models that incorporate this approach are described in the Appendix, including with the companies Kukua and TAHMO. By leveraging the strengths and assets of each actor, public-private-academic partnerships can improve services for end users while reducing costs and avoiding duplication of effort.

Partnerships within the CWE have proved successful in high-income countries. In Japan, for example, a foundation helps coordinate and support the wide variety of actors in the CIS sector. The Japan Meteorological Business Support Center (JMBC) provides a range of services[41]:

- disseminating data, products, and information from the JMA (the public NMHS) to the private sector
- administering the national examination for certified weather forecasters
- conducting official verification of meteorological instruments
- cooperating with international organizations to support official development assistance (ODA) and other activities
- promoting private meteorological business

In the United States, collaboration among actors in the CWE has helped create a sustainable market for CIS. The 2002 publication *Fair Weather: Effective Partnerships in Weather and Climate Service* made recommendations for partnerships in delivering CIS in the United States. The recommendations, adopted since then, have changed the CWE in the United States. One of the most important recommendations in the report was: "The National Weather Service should replace its 1991 public-private partnership policy with a policy that defines processes for making decisions on products, technologies, and services, rather than rigidly defining the roles of the NWS and the private sector."

[41] Japan Meteorological Support Center. (2016). Modernization of Meteorological Services in Japan and Lessons for Developing Countries. http://documents.worldbank.org/curated/en/467421495018952151/Modernization-of-meteorological-services-in-Japan-and-lessons-for-developing-countries.

The report suggested "it is counterproductive and diversionary to establish detailed and rigid boundaries for each sector outlining who can do what and with which tools. Instead, efforts should focus on improving the processes by which the public and private providers of weather services interact."

Within the CWE, actors' capabilities and responsibilities may overlap. This overlap can lead to inefficiency and cause conflict between the key stakeholders and decision makers in the public, private, and academic sectors at the national, regional, and local levels. Nevertheless, multiple sector and actor engagement is required to tackle these challenges.

When conflict arose in the U.S. CWE, the climate and weather sector designated the American Meteorological Society (AMS) as a neutral host and facilitator of discussions about roles and partnerships in the CWE. In early discussions, participants showed hostility and mistrust.[42] WCIS stakeholders disagreed about the roles each actor should play. The public sector wanted to be the central provider of WCIS, whereas the private sector thought the public sector was competing unfairly and claimed to offer better services in certain areas.

Eventually, through concerted efforts and dialogue, the public and private organizations in the CWE created a mutually beneficial partnership. Quarterly meetings convene interested parties to build relationships and resolve conflicts with open debate, discussion, and dialogue. Today, the AMS facilitates discussions about business models, national-security and international implications, the needs of weather-sensitive sectors such as renewable energy, water-resources, and transportation, and WCIS-related issues around policy and advocacy in the executive and legislative branches of government.[43]

These successful approaches to public-private collaboration in Japan and the United States can be transferred to SSA. In particular the United States approach of defining a process for establishing PPPs rather than rigidly defining roles and boundaries, along with a neutral host to help mediate conflicts and facilitate discussions could be applied in SSA. A suitable neutral mediator would need to be identified, along with government commitments to reform policy on roles within the CWE.

2.3. Role of Government in Climate and Weather Enterprise (CWE) in Sub-Saharan Africa

Key Findings

- Because the private sector is not yet well-developed in SSA, governments and NMHSs play crucial roles in the development of the CWE and WCIS markets.
- Funding from governments (country or donor) is an important factor in developing a WCIS market.
- Funding for an NMHS's infrastructure and ongoing operations is critical to create a thriving WCIS market.

[42] Hooke, W. (2013, March 27). Meteorology's Greatest Achievement Over the Past Decade? Its Not What You Think. (L. o. World, Compiler.) Livingontherealworld.org.

[43] Discussion with NOAA team, Washington, D.C. July 18, 2017

- NMHSs are generally stronger when diverse funding sources, including donor support and private-sector revenues, supplement public funding.
- Commercial aviation payments for services mandated by the International Civil Aviation Organization (ICAO) are a good initial source of funding for a country's NMHS.
- A well-developed WCIS market can generate more income for governments through corporate taxes and employment than from direct revenues for NMHS services.
- A government's legal environment and data-sharing policy have more influence on the CWE than the NMHS's operating model.

2.3.1. Sources of Funding for NMHS

Reliable, sufficient funding for the NMHS is crucial for engaging the private sector in WCIS. Private-sector companies need ample, high-quality weather and climate data and are not well positioned to collect this data themselves. Without sufficient and continued funding for modern observation infrastructure and data collection, NMHSs cannot provide the data the private sector needs for its products. Many private companies rely on baseline WCIS data gathered by governments to build value-added products and services. To make this possible, NMHSs must generate robust and timely data and have sufficient funding to operate and maintain their infrastructure. There are a several primary sources of funding for NMHS operations, including:

Government funding. All NMHSs around the world rely on government public funding from the treasury for operation. NMHSs in SSA are no different, Governments should fund the lion's share of long-term operations and maintenance of NMHS infrastructure through direct support from the treasury, though this does not occur in SSA. Direct funding recognizes the public benefits of a strong, equipped, fully developed NMHS. In the United States, the National Weather Service does not receive direct revenues from the private sector. Instead, the government provides annual funding for the National Weather Service.

Donor funding. International development organizations and other donors have funded WCIS projects throughout SSA. Donor funding should be seen as a bridge to more sustainable funding from either government and/or the private sector. Governments can leverage donor funding to establish baseline observations and build NMHS capacity, but investments in infrastructure should include support for ongoing operations costs. In many cases, donor projects have funding allocations or procurement mechanisms that allow capital expenditures, but not spending for operations and maintenance, including the telecommunications and staffing required to maintain the purchased equipment. Donors expect governments to pay for operations and maintenance. When funding is not available from the government, though, expensive infrastructure purchased by donors goes unused or under-used.

Commercial revenues. NMHSs sometimes receive commercial revenues, either directly or as pass-through payments from the government. Charging for WCIS services helps the NMHS recover its costs. Commercial aviation is often the point of entry into the WCIS market.

The South African Weather Service (SAWS), for example, indirectly receives revenue from commercial aviation companies for providing services mandated by the International Civil Aviation

Organization (ICAO). These revenues are received through a budget allocation from the national treasury based upon an agreed transfer mechanism that has been negotiated by multiple stakeholders within the country. Using this support, SAWS has expanded infrastructure as well as its human and technical capacity. (See **Section 2.4.3**

Case Study: South African Weather Service (SAWS) on page 38 for a detailed discussion of the SAWS model.)

The SAWS model could work for other countries in SSA. In most SSA countries, commercial aviation companies purchase WCIS from the government. If the government were to designate those funds for the NMHS, the NMHS could recover some of its costs and invest in infrastructure, operations and maintenance, and capacity building.

2.3.2. NMHS Operating Models

A country's NMHS is a fundamental part of the national infrastructure. The NMHS's observation infrastructure and data collection is essential for weather and climate monitoring, forecasting, and issuing severe-weather warnings.[44] The NMHS plays a vital role in ensuring public safety, supporting socioeconomic development, and sustaining government functions.

NMHS organizational structures and operating models vary widely from country to country. Factors that influence the choice of operating model include the government's approach to public services, country size and characteristics, availability of trained staff and technology, financial resources, and end users and their needs.[44] Governments use legal structures to establish an NMHS and define the agency's mission, mandate, operating model, and allocation of public resources. Legal structures can provide a basis for funding and may include policies that govern revenue generation and investment.

NMHSs typically use one of the following five operating models[45,46]. In order of increasing autonomy, the models are:

1. Government department (Departmental unit)
2. Contract agency
3. Public body
4. State-owned enterprise (SOE)
5. Private company

Figure 4 below summarizes how the operational models can vary in practice.

Government department. Most NMHSs in SSA operate as government departments. These NMHSs receive funds from the national budget to provide weather and climate? information and products to citizens or other government agencies, usually at no cost. A parent ministry oversees the NMHS when it operates as a department. About 40 countries worldwide continue to use the

[44] WMO. (2007). World Meteorological Organization Statement on the Role and Operation of National Meteorological and Hydrological Services for Directors.

[45] Rogers, D. P., & Tsirkunov, V. V. (2013). Weather and Climate Resilience: Effective Preparedness Through National Meteorological Services. Washington, DC: World Bank.

[46] Greve, C. Flinders M., and S. van Thiel. (1999). *Governance*, 12(2):129-146. Accessed 11 September 2017.

government department or agency model, although many are in transition to different operating models.[47]

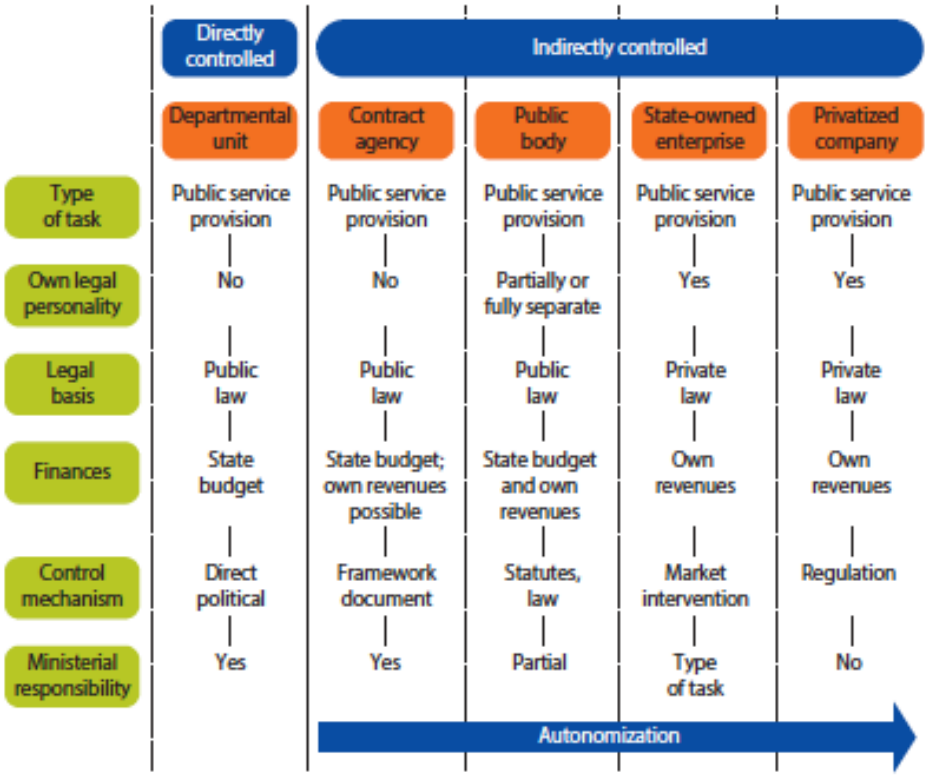


Figure 4. Graphic comparing five NMHS operating models

Source: Rogers and Tsirkunov (2013)

Contract agency. A contract agency is a semi-autonomous part of a government department or ministry. Contract agencies have strong relationships with their ministries, but unlike departments, they are not controlled directly by the ministry. In most cases, the government provides primary funding, but many contract agencies are also allowed to generate revenue for cost recovery. This model gives the NMHS more budget flexibility.

Public body. NMHSs that operate as public bodies have more autonomy than government departments or contract agencies. Public bodies operate at a distance from the central government. As a result, they face less political and hierarchical influence and have more operational and managerial freedom[48]. When an NMHS operates as a public body, both the central government and the NMHS are responsible for its performance. Some public bodies are fully funded by the government, whereas others generate revenues to supplement state funding. European NMHSs are often organized as public bodies, and several African countries are transitioning their NMHSs to the public body model.

47 Rogers, D. P., & Tsirkunov, V. V. (2013). Weather and Climate Resilience: Effective Preparedness Through National Meteorological Services. Washington, DC: World Bank.

48 Rogers, D. P., & Tsirkunov, V. V. (2013). Weather and Climate Resilience: Effective Preparedness Through National Meteorological Services. Washington, DC: World Bank. Pages 102-104.

State-owned enterprise (SOE). State-owned enterprises (SOEs) are legal entities created by the government to conduct commercial activities on its behalf. Legally, most SOEs qualify as businesses, meaning they must follow laws and regulations governing their business type, and they can be held liable for their actions[49]. NMHSs do not often operate as SOEs. New Zealand is one of the few countries to transition its NMHS into a SOE (see text box).

New Zealand's MetService: State-Owned Enterprise

In 1992, New Zealand transitioned its NMHS – MetService – from a department under the Ministry of Transport to a wholly state-owned, commercial enterprise. Initially, MetService faced mistrust from citizens and the private sector. Since then, however, MetService has proven that an SOE operating as a commercial company can provide high-quality public services and meet a government's international obligations while also providing returns to investors.

Today, MetService, is a fully commercial operation that competes successfully in multiple markets and sectors around the world, while also providing a comprehensive range of weather services to New Zealanders.

Through its cornerstone contract with the Ministry of Transport (MoT), MetService receives public financing for public-good forecasting services such as severe weather warnings. The MoT contract fulfills New Zealand's obligations as a member of the World Meteorological Organization (WMO). MetService operates as a commercial company under the Companies Act. A board of directors supervises MetService's operations and sets the company's strategic direction.

Private company. The last operating model is a fully privatized company. SOEs in other sectors often transform to this model eventually, especially in highly competitive markets. Private NMHSs manage their own performance and operate freely in the market. They have a great degree of autonomy but are still subject to regulation and law.

The NMHS operating model does not appear to increase or decrease private-sector involvement in the WCIS market in SSA countries surveyed. In the seven countries Winrock surveyed, the NMHSs largely function as government departments, but private-sector involvement varies widely.

This suggests that other factors may be more important for generating commercial activity in the WCIS sector. Factors that could influence private-sector participation include the country's business climate and environment for investment,[50] the legal framework governing ownership of weather data, presence of paying customers (e.g., large agricultural companies), and the level of donor and NGO involvement as risk-reducers for private companies.

Selling WCIS to private-sector companies requires more than a supportive policy environment. In order to generate income, the NMHS must have the technical and managerial capacity to engage private-sector clients and develop tailored, value-added products and services. The NMHS will need staff dedicated to marketing and contract management.

2.3.3. Legal and Policy Environment

A government's impact on the CWE is broader than just the NMHS's performance: the national policy and legal environment can significantly impact private-sector involvement in WCIS. Government policies and laws that govern data sharing and market participation can encourage or discourage private-sector involvement. In general, governments that have more open data policies lead to increased private-sector involvement.

[49] PWC. (2015). State-Owned Enterprises: Catalysts for Public Value Creation.

[50] As reflected in evaluations such as the World Bank "Doing Business" rankings.

The WCIS market in SSA is constrained by limited public and private investment, legislation that restricts private-sector activity, and policies that prohibit sharing NMHS data. The government of Uganda, for example, prohibits private-sector operators from delivering weather forecasts directly to end users. (Private data providers can contract with the government and potentially share revenues from the sale of WCIS[51]). It is unclear how effectively Uganda's law against private forecasts is enforced, but the legal framework might discourage private companies from entering the market.

A government's policy and legal environment can be characterized as prohibitive, constrained, or permissive:

- In a **prohibitive** environment, a government department or agency provides all WCIS services. Private companies can only participate under contracts with the government (e.g. Ethiopia).
- In a **constrained** environment, laws permit some organizations other than the NMHS to supply commercial products and add value to public data services. NMHSs operate as semi-autonomous organizations, and private-sector participation depends on the legal status of the NMHS (e.g. United Kingdom, France).
- In a **permissive** environment, the NMHS has an open-data policy. The government allows private companies to develop and own proprietary networks for weather data collection or weather models for prediction services. The private sector may or may not contribute to data collection and is free to participate in the market without restrictions (e.g. New Zealand, United States, Ghana, Nigeria).

The type of policy and legal environment is independent of the NMHS operating model; different countries have different combinations of the two. For example, both the United States and New Zealand have permissive environments for WCIS, but the U.S. National Weather Service is a government department, while New Zealand's NMHS is a State Owned Enterprise (SOE). In the United States, a well-funded NMHS that operates as a government agency, combined with open data, has helped develop strong private-sector involvement in WCIS.

Many European governments use a constrained parastatal system. A semi-autonomous NMHS protects the public interest by providing data and information products the private sector might not necessarily provide. In SSA, both Uganda and South Africa both have NMHSs that function as parastatals (agencies, public bodies, or SOEs), but Uganda's policy and legal environment is prohibitive, whereas South Africa's is constrained.

With adequate public support, countries can develop sustainable WCIS using any of the three legal and cultural environments and any of the five operating models. In a prohibitive environment, however, the public sector will need to invest more than it would in a permissive or constrained environment.

Constrained laws and policies allow for private-sector involvement in WCIS, but permissive laws and policies create an enabling environment for WCIS market development. With either construct, private-sector development and market growth can amplify public-sector investments, but a

[51] Uganda National Meteorological Authority Act, 2012, Part IV
http://www.parliament.go.ug/images/stories/acts/2012/Uganda%20National%20Meteorological%20Authority%20Act,%202012.pdf

permissive environment is likely to achieve faster market development and growth and a larger overall market. In the United States, the government-funded NMHS has an annual operating budget of $1 billion. In addition to funding a range of free WCIS for end users, the investment of $1 billion in public funds helps support a $7 billion market for paid CWIS services provided by the private sector[52].

2.4. Capacity of National Meteorological and Hydrological Services (NMHS) in SSA

Key Findings

- After many years of neglect and decline, NMHS in SSA are beginning to use development and government funding to modernize and automate their observation and forecasting systems.
- NMHSs in the seven countries Winrock surveyed all provide national forecasts at least once per day and largely prepare WCIS seasonal forecast data at national levels, and some provide local forecasts at the city/village level, e.g. Rwanda and Senegal.
- The South African Weather Service (SAWS) is a promising model for other NMHS in SSA.
- NMHS revenue stability, when properly allocated for infrastructure maintenance, is essential for making WCIS services sustainable.

Methodology. Winrock assessed the capacity of the NMHSs in Côte d'Ivoire, Malawi, Mali, Niger, Nigeria, Rwanda, and Senegal. The research team reviewed self-reported NMHS baseline information in the World Meteorological Organization's database[53] and interviewed the director (or a representative) of each NMHS.

Initial observations from this research indicate significant gaps in NMHS infrastructure, operations, and financial-management capacity across the seven countries surveyed.

Lack of local forecasts. All seven NMHSs provide national weather forecasts for their countries. Rwanda and Senegal, however, provide local forecasts at the city/village level. Private-sector WCIS companies and end users often want frequent local forecasts. Through its interviews with private companies, Winrock learned that city and village forecasts, while not necessarily essential to all products, are critical inputs to most products requested by market participants. Without regular local forecasting, NMHSs do not have the data they need to sell or package for the market.

Reliance on non-automatic weather stations. All seven countries have at least some automatic weather stations (AWS), but their observation networks rely at least in part on manual data collection from conventional weather stations often reporting only monthly data.

Underuse of automatic weather stations. Even when they have them, NMHSs cannot always afford to operate AWS. AWSs require communications services to transmit information, but data

[52] Discussion with NOAA team, Washington, D.C. July 18, 2017.

[53] World Meteorological Organization Data Base. https://www.wmo.int/cpdb/. Accessed 29-06-2017.

transfer can be prohibitively expensive. Similarly, NMHSs sometimes lack the information technology necessary to support the weather prediction models used by international centers.

Insufficient funding for operations and maintenance. Large-scale development projects are providing funding to countries to modernize infrastructure, but usually without sufficient funds for operations and maintenance.[54]

Limited daily and weekly forecast frequency. Five of the seven countries provide national forecasts either three or four times per day. Senegal provides two forecasts per day, and Malawi only one.

Limited forecast dissemination. End users receive forecasts largely through radio and television, although the NMHSs in Nigeria and Rwanda also use social media.

Insufficient, poorly maintained observation equipment. Radars are either non-existent or not operational. Most of the countries Winrock surveyed lack sufficient lightening detectors. Coverage is too sparse to form functional lightning detection networks. Rwanda, for example, has only one lightning sensor that provides poor resolution, and the NMHS would need a network of four or more sensors to cover the whole country.

Low revenue generation. In many countries, NMHSs are allowed to commercialize services, but NMHS representatives were not sure how much revenue they generated. NMHSs do not typically have specialized staff or business plans to generate revenue.

Insufficient financial information. Across countries, NMHS financial information was limited, sparse, and incomplete. This made it difficult to determine the impact of funding on WCIS market development.

2.4.1. WCIS Infrastructure

WCIS infrastructure varied among the seven countries Winrock surveyed, but in general, these select countries of SSA have very limited infrastructure compared to wealthier countries. **Figure 5** shows the number of automatic and non-automatic weather stations in the seven countries. The figure includes South Africa, a wealthier country with a more developed WCIS infrastructure, for comparison.

[54] World Bank Operational Seminar, November 29, 2017: Hydromet Business: New Trends and Developments

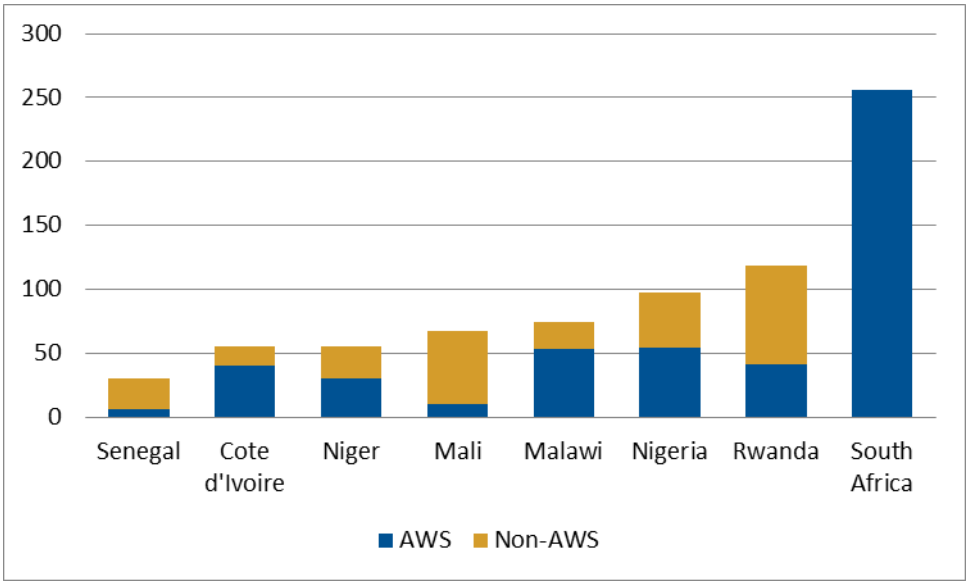


Figure 5. Number of automatic and non-automatic weather stations by country

Source: Winrock International (2017)

The geographic density of weather stations varies significantly among the seven countries Winrock surveyed. **Figure 6** shows the number of weather stations per 10,000 km2 for each country, based on data shared by NMHS representatives. Equivalent data for South Africa was not available.

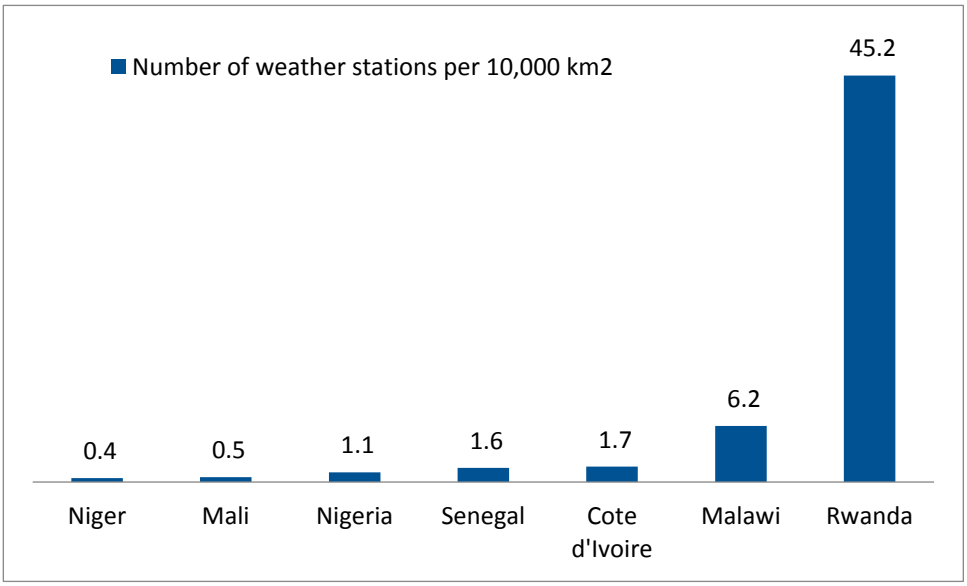


Figure 6. Density of weather stations in select countries of Sub-Saharan Africa

Source: Winrock International (2017)

Together, the two figures provide a better picture of the observation infrastructure in each country. For example, **Figure 6** shows that Rwanda—a country with very small land area—has a much higher density of weather stations than any of the other countries. As shown in **Figure 6**, however, Rwanda has more non-automatic stations than automatic. So the high density of weather stations might not indicate a well-functioning network. Malawi, by comparison, has a much lower density of

stations per km^2 than Rwanda, but a greater share of Malawi's stations is automatic. However, it should be noted that the number of stations needed also depends on the topographic variation within a country, which is not captured in these figures.

2.4.2. NMHS Budgets

Comparing NMHS funding across SSA is difficult given the limited data. Financial information for NMHSs in SSA is sparse, and available data may not be reliable. Winrock used the WMO database and data from its interviews with NMHS representatives to assess the budgets for the seven targeted countries. Both our interview data and the WMO data rely on self-reporting, so it is not sufficient for detailed analysis.

Overall, a healthy private sector for WCIS is more likely to develop in countries where NMHSs have:

- Stable, reliable public funding
- Access to commercial revenue, either from selling services directly or receiving payments made to the national government
- Supplementary, project-based funding from donors
- Sufficient funds to maintain observation infrastructure and purchase the telecommunications services required to operate automated weather stations

Funding sources vary by country. According to the self-reported data in the WMO database, Niger receives 70 percent of its meteorological services financing from non-government sources. Malawi, by contrast, reported to the WMO that the government funds all of its meteorological services. The seven NMHSs Winrock surveyed reported very different levels of involvement with the private sector. While none of the representatives could quantify revenue from commercial sources, five out of the seven NMHSs reported receiving payments from private companies. (See **Table 2**.)

NMHS budgets vary across the targeted countries. Six of the NMHS representatives Winrock interviewed provided annual NMHS budget amounts as of 2016. (Senegal did not provide financial information.) Based on the reported amounts, Mali's NMHS has the largest budget of the seven countries. At $7.8 million, Mali's NMHS budget is about twice that of Cote d'Ivoire's, which has the second largest amount of funding. The NMHSs in Nigeria, Rwanda, and Niger have budgets between $2.1 and $2.8 million. Malawi's NMHS has by far the smallest budget, only $175,000.

The WMO data may require review and verification. For example, the budget Malawi reported for its NMHS was only 10 percent of the average amount reported by countries with similar staff sizes. Malawi is relatively poor, but based on Gross National Income (GNI) per capita comparisons, its NMHS budget should be closer to 50 percent of the average budget[55]. Cote d'Ivoire reported a budget 100 times greater than those of other countries, an unlikely scenario that also contradicts the data reported to Winrock.

These examples might be isolated, or the result of differences in budget tracking and reporting. Given the variation, however, it would be prudent to audit the WMO data to ensure a reliable baseline for decision making by governments, donors, and NGOs.

[55] World Bank Country Data. http://data.worldbank.org/country/malawi. Accessed 29-06-2017. Malawi's per capita GNI is 340 USD compared to 760 USD in Mali and 980 in Senegal.

Only one NMHS representative could estimate the amount of revenue from commercial sales of WCIS. Niger's NMHS earns no more than $19,000 (less than one percent of the total budget) from private-sector revenue. However, this seems inconsistent with Niger's self-reported data in the WMO database, that shows Niger receives 70 percent of its meteorological services financing from non-government sources. Other NMHSs receive revenue from private sources, but it is unclear how much.

NMHSs in the target countries provide services—both free and paid—to a wide range of sectors. Countries vary widely in whether they capture revenue. **Table 1** shows the sectors served by each NMHS, including whether the end user pays for services or receives them for free.

Table 1. Sectors served by NMHSs in select SSA countries

Sector	Cote d'Ivoire	Malawi	Mali	Niger	Nigeria	Rwanda	Senegal
Aviation	**Paid**	Free	**Paid**	**Paid**	**Paid**	Free	**Paid**
Agriculture	Free	Free	Free	Free	Free	Free	Free
Mobile Telecom	Free	N/A	**Paid**	N/A	**Paid**	Free	Free
Insurance	Free	Free	**Paid**	**Paid**	**Paid**	Free	**Paid**
Fishing	Free	Free	Free	N/A	**Paid**	Free	**Paid**
Energy	Free	Free	Paid	Free	**Paid**	Free	**Paid**
Forestry	Free	Free	Free	N/A	N/A	Free	**Paid**
Health	Free	Free	Free	Free	Free	Free	**Paid**
Tourism	N/A	Free	N/A	Free	Free	Free	**Paid**
Transport	Free	Free	N/A	**Paid**	N/A	Free	**Paid**
Mining	Free	N/A	**Paid**	N/A	N/A	Free	**Paid**
Off-shore platform	Free/**Paid**	N/A	N/A	N/A	**Paid**	Free	**Paid**

Paid: Private companies and/or government agencies pay the NMHS for WCIS.
Free: Private companies and/or government agencies receive WCIS for free.
N/A: Information is not available.

Private-sector involvement also varies across the countries, although Winrock's findings sometimes differ from what NMHS representatives reported in interviews. Winrock asked NMHS representatives whether private companies provided WCIS in 12 different industry sectors. **Table 2** shows the responses. (Shaded boxes indicate the presence of private-sector companies.)

Table 2. Private-sector involvement in WCIS, as reported by NMHS representatives

Sector	Cote d'Ivoire	Malawi	Mali	Niger	Nigeria	Rwanda	Senegal
Aviation							
Agriculture							
Mobile Telecom							
Insurance							
Fishing							
Energy							

Forestry							
Health							
Tourism							
Transport							
Mining							
Off-shore drilling							

Source: Winrock International (2017)

Some NMHS representatives did not seem aware of the private-sector WCIS activity in their countries. For example, as shown in **Table 2**, Malawi's NMHS reported no companies providing WCIS. In its research, however, Winrock identified five companies currently providing WCIS in Malawi. (**Figure 11** in Section 3 of the report shows the number of companies Winrock identified in select countries of SSA.)

2.4.3. Case Study: South African Weather Service (SAWS)

In this phase of the research, seven NMHSs provided total budget amounts, and some provided breakdowns by category. None of the interviewees could disaggregate the budget by source, however. To provide a relevant example of NMHS financing, we analyzed data from South Africa.

In contrast with other countries in SSA, South Africa has complete, accurate financial data for its NMHS, the South African Weather Service (SAWS) [56,57]. SAWS maintains publicly available financial records. Winrock used this data to calculate SAWS's sources of revenue for capital and operating expenses. SAWS has achieved sufficient, sustainable funding to maintain high-quality WCIS, so it can serve as a model for other NMHSs. SAWS' budget has four sources of income: direct government payments, aviation revenues, other commercial revenues, and donor payments.

Figure 7 below shows SAWS' total revenue and revenue by funding source over a five-year period. The figure shows that while revenues from one source might decrease in a given year, overall revenues have increased over time. Between fiscal years 2012-13 and 2016-17, SAWS revenues increased from 253 million Rand to 375 million Rand, a compound growth rate of 10 percent per year.

[56] South African Weather Service, Annual Report 2015/16. http://www.weathersa.co.za/about-us/2015-09-10-13-04-27. Accessed 28 August 2017.

[57] South African Weather Service, Weathersmart Newsletter, August 2016. http://www.weathersa.co.za/news-events/weather-smart-newsletter/340-weathersmart-august2016. Accessed 28 August 2017.

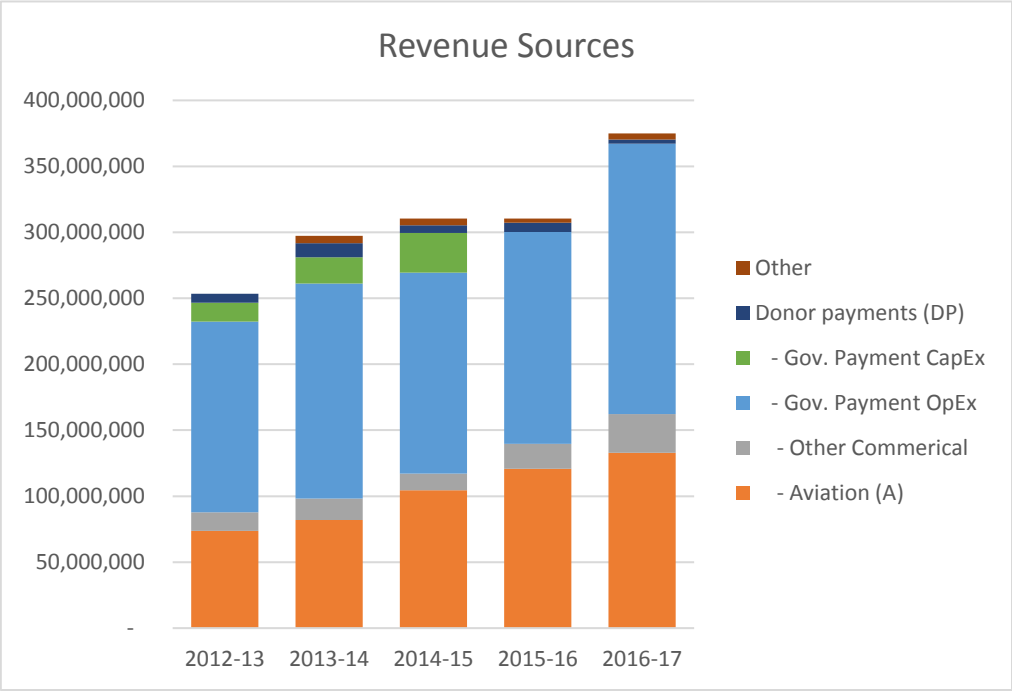


Figure 7. Revenue by source, South African Weather Service (2012-2016)

This diversified business model has generated sufficient, stable revenues to maintain significant investments in observation, radar, and forecast-computing infrastructure. SAWS still depends heavily on government funding, however. In 2016-17, government payments accounted for 55% of SAWS' total revenues. On the other hand, donor payments account for only a small portion of total revenues, making SAWS less vulnerable to changing international development priorities.

This diversified revenue model succeeds because the South African government has structured SAWS to capture commercial revenues. SAWS has a department purely dedicated to revenue-generating partnerships with the private sector. None of the NMHSs Winrock surveyed had staff dedicated to commercial revenue generation.

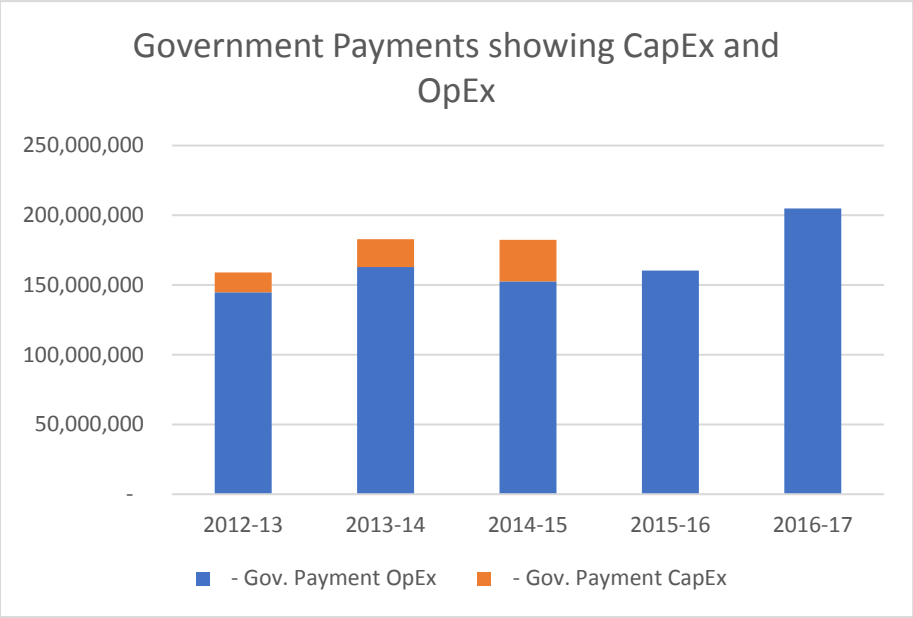


Figure 8. Government payments for operating and capital expenses, SAWS (2012-2016)

For SAWS, commercial revenues are more constant than government funding. **Figure 9** shows that between 2012 and 2017, government payments varied more than aviation revenues. Aviation revenues show linear growth ($R^2 = 0.98$), whereas government payments are more cyclical, increasing or decreasing from year to year.

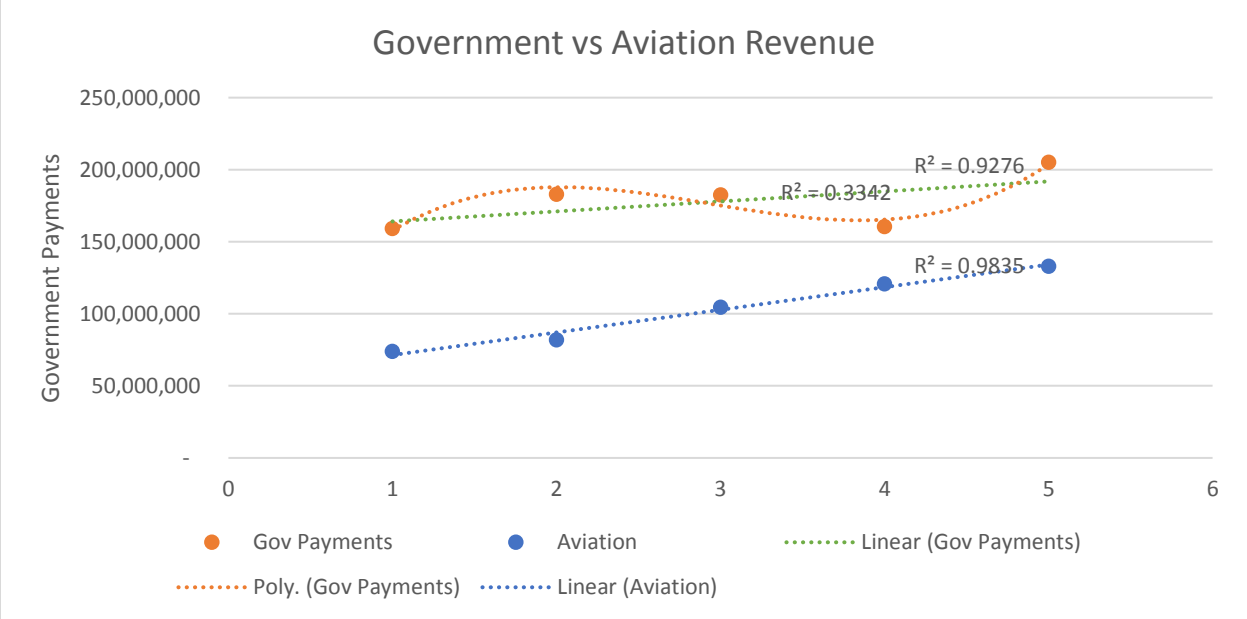


Figure 9. Government payments and aviation revenues, SAWS (2012-2016)

3. PRIVATE-SECTOR BUSINESS MODELS FOR WCIS IN SUB-SAHARAN AFRICA

Key Findings

- Private-sector companies, including emerging national companies, are entering the WCIS market in SSA at most points along the WCIS value chain. Donor funding is helping the WCIS market develop, but it can distort the market at the same time.
- In SSA, more than one million consumers and smallholder farmers currently receive WCIS from private-sector providers.
- Private-sector WCIS providers are using a wide variety of business models in SSA, and no single model is dominant.
- WCIS providers are importing and adapting technological innovations from developed economies to address the environmental, technological, and capacity challenges in SSA.
- Some of the companies take gender into consideration in their decision-making or service offerings, especially with how data content is presented to the end user.
- Most companies are seeking stronger partnerships with NMHSs as a part of their strategies, but they also face challenges working with NMHSs.

Understanding how the private sector engages in the WCIS market can help identify promising strategies that could grow the sector as a whole. This section, part two of the report, explores how the private sector is involved in the WCIS sector in SSA. The review and analysis covers the type of WCIS delivered by the private sector, the targeted end users, private-sector business models used for WCIS, WCIS technologies, geographic and end user reach, gender, barriers and opportunities for growth, and the scope for public-private partnerships within the CWE.

The findings in this section are based largely on Winrock's interviews with representatives of private-sector companies. Winrock identified 20 companies providing WCIS in SSA and interviewed representatives of 14 of these companies. **Appendix I** provides descriptions of all 20 companies as well as information about their business models, tools and technologies, partners, and markets.

3.1. Types of WCIS Provided by the Private Sector

In SSA, the private sector plays a much wider role than using public data to create products and services for end users. The private sector engages in the CWE at many different points along the flow of WCIS information, from observations to forecasts to delivery of products to end users.

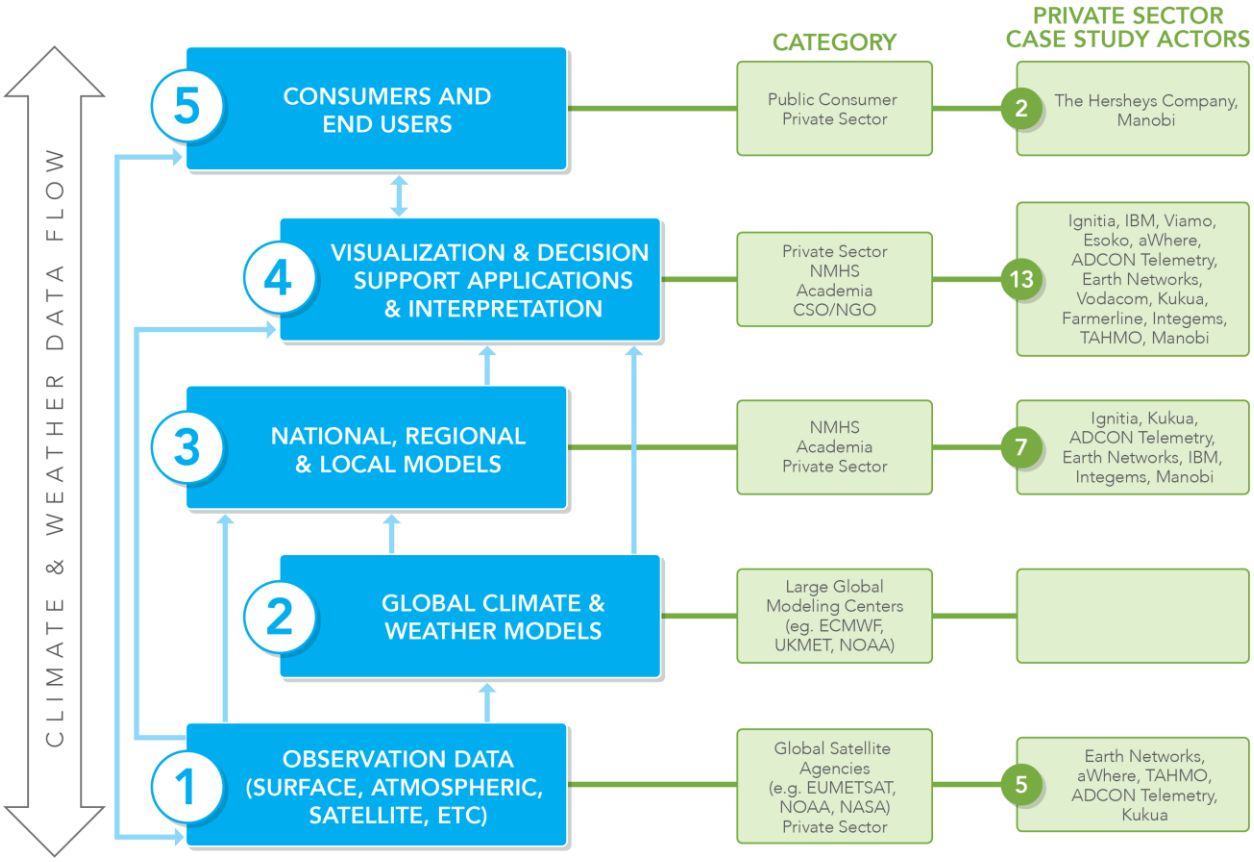
Figure 10 shows how WCIS information flows from observation data to end users. At the first level (box 1, bottom of figure), systems collect weather and climate data on land or in the atmosphere, through in-situ or remote-sensing observation. Next, the information follows one of two paths. In the first path, data is fed into global, national, or local climate and weather models for use in model

initialization and verification (boxes 2 and 3). In the second path, data passes directly to end-user visualization systems or the end users themselves (boxes 4 and 5).

A wide range of actors from the public, academic, and private sectors make this system work. A public agency collects the raw weather and climate data, uses it in global and national weather and climate models, and distributes information to the public. In SSA, the public sector still provides most of the data-collection infrastructure, but some countries are beginning to work with private companies to perform various aspects of this work.

The private sector participates in all stages of information flow, including at the global climate and weather models stage (box 2). Mostly the developed economy governments and institutions, such as the US NWS, the ECMWF and the JMA, create these large, sophisticated models. This may be changing, as companies like the IBM Weather Company are beginning to use high-speed data computing.

Figure 10. Private-sector engagement in climate and weather enterprise and data flow



The companies Winrock interviewed operate at all levels of WCIS information data flow (see Figure 10). Of the 14 companies interviewed for the case studies, five are involved in the deployment of observation systems and networks (box 1) that provide WCIS throughout the CWE. Seven

companies produce national, regional, or local weather and climate models (box 3). The largest number of companies provide visualization and decision-support applications and interpretation services (box 4), although all but five of these companies also collect observations and produce forecasts. Three companies provide information directly to end users (box 5), but many companies tailor weather products to consumers. Information flows back and forth along the value chain (box 5 with box 4 and 1), and some private sector companies have a two-way exchange of information with the public sector (e.g. Integems).

Typically, the public-sector conducts weather and climate observations. In SSA, however, the private sector is also involved in observation and forecasting, probably because governments cannot supply the accurate, reliable data companies need to provide WCIS services. Most of the companies Winrock surveyed target specific and limited customer segments.

The companies Winrock researched provide a wide range of WCIS services, including:

- Automatic weather stations (as part of a weather observation system)
- Observational data from Automated Weather Stations
- Extrapolated observation data
- Forecast information
- Decision-support systems
- GIS data visualization systems
- "Last-mile" end-user access systems
- Weather content for advertisers
- Agricultural decision-support information
- Agricultural data platforms
- Lightning detection systems
- Early-warning systems

3.2. Geographic and End-User Reach

The level of private-sector involvement varies across the countries of SSA. The most concentrated level of private sector engagement is in Ghana, where eight companies operate, followed by Kenya with six companies and Malawi, Burkina Faso, and Uganda, each with five. Higher concentration of companies could be associated with donor funding (e.g., USAID Feed the Future projects), interest in WCIS activities, and/or an enabling government environment (as in Ghana and Nigeria). For analysis of donor funding, see the *Case Study: Impact of Donor Funding* below.

Winrock's sample of 14 companies includes both global and local organizations. Three of the fourteen companies—Adcon Telemetry, Earth Networks, and IBM—operate globally, bringing their core technology and services to SSA. Three other companies—Ignitia, Kukua, and TAHMO—provide technology and services originally developed outside of SSA, but adapted for the SSA and technical realities. The sample also includes four local companies: Esoko, Integems, Manobi, and Vodacom.

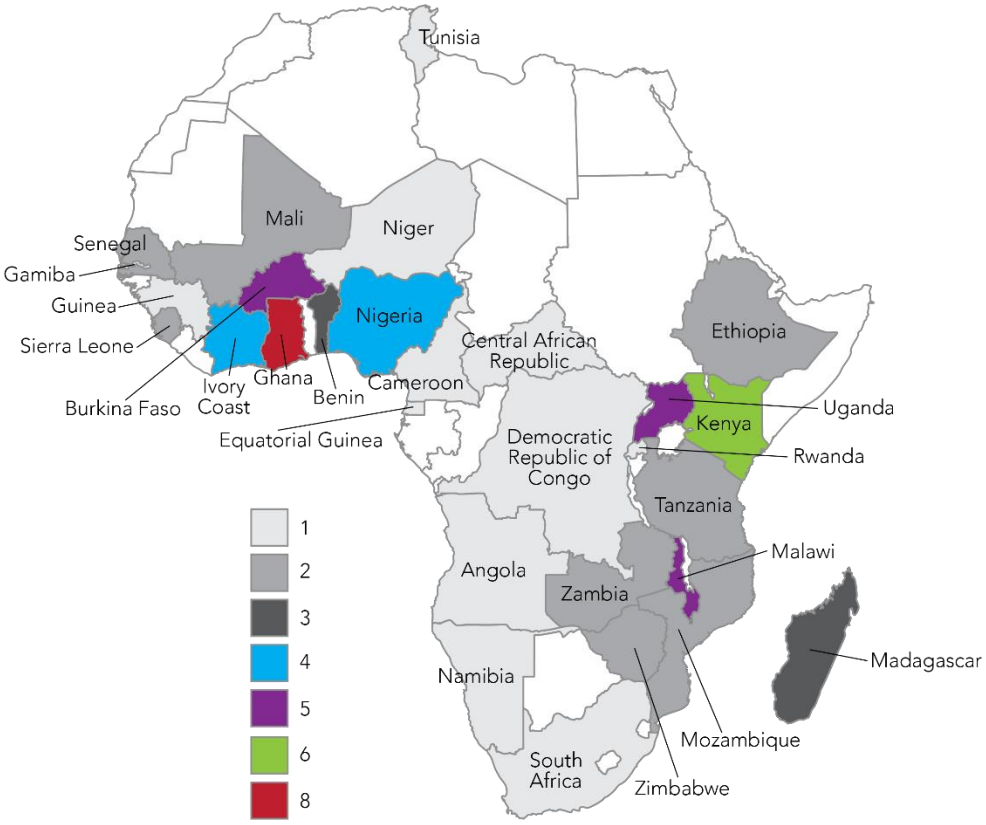


Figure 11: Number of private-sector WCIS companies in select countries of Sub-Saharan Africa

Source: Winrock International (2016)

The number and type of end users varies widely among the companies Winrock surveyed. Six companies —Viamo, aWhere, Esoko, Ignitia, Farmerline and The Hershey Company—mainly serve smallholder farmers. **Table 3** shows that together, these five companies serve more than 2.36 million end users. Ghana, Malawi, Uganda, Nigeria, Senegal, Rwanda, and Kenya are the countries with the largest numbers of end users served by the companies. Four companies— Esoko, Ignitia, Farmerline, and The Hershey Company—serve 645,000 people in those four countries.

Table 3. Number of end users served by select WCIS companies in Sub-Saharan Africa

Company	Number of end users
Viamo	808,658
aWhere	573,792
Esoko	445,771
Ignitia	330,000
Farmerline	200,000
Manobi	3,000
The Hershey Company	1,015
Total	**2,362,236**

Clearly, there is a market for WCIS in SSA, including significant demand from smallholder farmers. The total of more than 2.36 million end users receiving WCIS information from private-sector

providers in SSA shows a developing market for services - even if often times the companies do not directly charge the end user for the service.

3.2.1. Willingness to pay

Winrock's market assessment indicates that only one private sector company (Ignitia) had businesses and consumers who are willing to pay for WCIS services, and the cost was minimal at less than $6 per season. The other companies Winrock surveyed cited low willingness to pay in SSA as a barrier to growth. In its WCIS company interviews, Winrock asked for information about revenues and pricing. Only one of the companies, however, shared that information. Some companies do not disclose their financial information, while the larger conglomerates do not disaggregate revenues by WCIS sector and/or geographical region.

3.3. Business Models

Across business models, end users purchase WCIS products and services in different ways, from many different types of providers. Across the companies Winrock surveyed, no single business model dominated.

The research team defined eight distinct business models. In each business model, private-sector businesses, donors, and governments play different roles as buyers and end users. Buyers include donors (e.g., USAID), government agencies (e.g., NMHSs), businesses (e.g., commodity firms) and consumers (e.g., farmers).

Donors, businesses, and governments can be end users of CWIS. In many cases, buyers do not purchase WCIS for their own use, but instead add value to the information and then offer their products to end users. In addition, actors in the CWIS market sometimes buy on behalf of others. Donors buy on behalf of governments, governments buy on behalf of consumers, and businesses buy on behalf of consumers.

Table 4 shows the business models used by WCIS companies in SSA.

Table 4: Business models used by WCIS companies in Sub-Saharan Africa

Company	B2D	B2D2C	B2D2G	B2G	B2G2C	B2B	B2B2C	B2C
ADCON			X	X		X		
aWhere				X			X	
Earth Networks			X	X		X	X	
ESOKO		X			X		X	
Farmerline		X				X	X	X
IBM						X	X	
Ignitia		X				X		X
Integems			X	X		X		
Kukua	X	X		X	X	X	X	X
Manobi	X			X		X		X
TAHMO	X					X		
The Hershey Company							X	
Viamo	X						X	
Vodacom					X		X	
Manobi	X			X		X		X
Total	**5**	**4**	**3**	**7**	**3**	**10**	**9**	**5**

Table Legend

B: Business
C: Consumer (farmer, producer)
D: Donor (primarily international donors such as USAID)
G: Government (primarily national governments)

In each business model label, the first letter is the seller, and the second letter is the buyer, and the third letter is the end user. Where there are only two letters, the buyer is also the end user. (For example, B2D2G stands for "business to donor to government." The business is the seller, the donor is the buyer, and the government is the end user.)

All of the interviewed companies except one company use more than one go-to-market strategy and between two and four different business models. (The exception is The Hershey Company, which operates only as an end user). Kukua operates seven different business models.

Businesses and individual consumers are the end users of WCIS more often than donors and governments. Winrock's research indicates that businesses play the largest role in the consumption of WCIS, while donors and governments play a lesser role and consumers are largely the end user, such as a smallholder farmer. Donors buy WCIS for their own use as well as on behalf of governments and consumers. Governments buy WCIS from private-sector providers for their use and for consumers, particularly farmers. Businesses are the most active buyers of WCIS, both for their own use and for that of the public. Three WCIS providers (Ignitia, Kukua and Farmerline) directly targeted the consumer as both a buyer and end user of services.

More companies target businesses than donors as their primary customers. The companies that target both received most of their financing (80-90 percent) from donor funding. Donor funding can be direct or indirect. In some cases, companies have direct contracts with donors (e.g., USAID, World Food Programme/United Nations). In others, companies receive funding from an international non-profit organization funded in turn by a donor. More established companies tended to be an exception to this rule of relying on donor funding for the majority of their revenue.

3.4. Technological Innovations in WCIS Data Collection and Dissemination

In SSA, private-sector companies have introduced several technological innovations in WCIS production, processing, and dissemination. In some cases, the private sector transfers technology from outside SSA; in other cases, companies develop technology specifically to address the region's challenges. Key technological innovations include:

- Using cell-tower-mounted or co-located automatic weather stations (AWS) to capitalize on the increasing availability of secure, powered, connected telecommunications infrastructure across Africa (ADCON, Earth Networks, Kukua)
- Using Interactive Voice Response (IVR) systems (as a complement to traditional Short Messaging Service (SMS) systems) to deliver WCIS information to end users who have only basic mobile phones and low literacy levels (Farmerline, Viamo)
- Using lightning as a proxy for radar systems to provide cost-effective early warnings of severe weather (Earth Networks, TAHMO, Ubimet[58] and Vaisala[59])
- Using Application Programming Interfaces (APIs) to deliver real-time WCIS data to systems and businesses (aWhere, Kukua, TAHMO, Earth Networks, Farmerline and ADCON)
- Using cloud computing to decrease expenses and limit the impact of unstable power and air conditioning systems in computer rooms (aWhere, IBM, Ignitia, Earth Networks, ADCON and TAHMO)
- Delivering data on Geographic Information Systems (GIS) to businesses to support their decision-making (Earth Networks, IBM, Integems, Kukua, ADCON, and aWhere)

[58] https://www.ubimet.com/us/

[59] https://www.vaisala.com/en

When private-sector companies bring new technologies to SSA, they help build technical and human capacity in both the public and private sectors. Few global companies operating in SSA establish permanent offices in the region. Instead, these companies prefer to create partnerships that expand their businesses in SSA without directly employing staff. This creates opportunities for new and existing local companies to gain expertise in partnership with advanced technology providers. (e.g., TAHMO)

Viamo

Mobile phone use is increasing rapidly in SSA, but rates still lag behind those in developed economies, and smart phones are less common. Literacy rates are also low, limiting technical ability.

To make WCIS information available to illiterate users and those without smart phones, Viamo created the 3-2-1 service.

This Interactive Voice Response (IVR) system allows users to dial in to automated recordings of publicly available health, agriculture, and WCIS data. Recordings are in multiple local languages. The use of IVR technology – in addition to more widely adopted SMS text messages – is one of the ways the private sector is adapting to the local context in SSA to deliver WCIS.

In countries where Viamo can access WCIS data, this content is by far the most accessed resource on the platform.

3.5. Gender and the Private Sector

To ensure that women have access to WCIS, providers need to consider gender when designing their services. Winrock found that attention to gender equity varied by company type. The companies that engage closely with end users (typically farmers) considered gender in their design and delivery of WCIS. These companies receive funding from donors, organizations that often require partners to emphasize the needs of women. Companies that provide equipment and hardware infrastructure (e.g., weather stations) did not indicate that they consider gender in WCIS projects. With the exception of business-to-consumer (B2C) companies, the other companies did not design or deliver their capacity building training on WCIS with the women as a separate (and different to men) end user.

An example of a business-to-consumer (B2C) company that did consider gender in their delivery of WCIS is Ignitia, which studied how to tailor messages to women and illiterate farmers. Farmerline and Kukua have partnerships with commodity buyers, and they seek ways to reach women farmers as end users. The representative for Kukua described the company's efforts to reach more women with WCIS messages. In many households in SSA, women have only limited access to mobile phones and other technology. To address this issue, Kukua is targeting women through alternative communication channels, including radio, bulletin boards, television, and word of mouth.

Viamo has found that women in its target area were more interested in receiving health information than agriculture, so Viamo has tailored their health services to include additional agriculture WCIS and extension messages to have women receive both. Their system profiles the caller to receive the user's gender, location, and age, thus enabling the company to have data on who is using the Viamo 3-2-1 user platform to provide information that is relevant for the end user.

Farmerline's programs are funded by donors who emphasize women's involvement and 100% female participation. To better target women, Farmerline collects information about each person who accesses their products. Data gathered includes the user's name, gender, age, and language spoken. By analyzing this, Farmerline gains insight into who is using which information. Farmerline found that 39% of the farmers who access its CWIS system are women. The company

representative told Winrock, "Overall, from the last assessment, women are oftentimes much better with engaging with the systems than males."

3.6. Opportunities and Barriers to Growth

It remains unclear if the entrance and early presence of the private sector can or will be sustained in SSA. If governments legislate (and enforce) against private sector participation in the WCIS market, early seeds of market activity may not emerge.

Winrock asked company representatives to identify growth opportunities and barriers to growth in the WCIS sector in SSA. Interviewees suggested opportunities at many parts of the WCIS value chain, and several representatives offered overlapping ideas. Interviewees named agriculture as a sector with growth potential for WCIS although they did not specify whether the biggest growth potential was in agro-business, large farms, or smallholder farmers. Two of the three companies that deliver in the B2C model target smallholder farmers who grow commodity crops at a small-scale. Large scale agricultural production, at a commercial scale, occurs in South Africa where Vodacom does provide WCIS products to large-scale farmers. Interviewees cited agriculture's economic importance in SSA and substantial donor subsidies for providing WCIS to farmers. Companies at each part of the climate and weather value chain identified different opportunities in WCIS for agriculture.

Thirteen companies that provide visualization and decision-support applications and interpretation (box 4) saw growth potential in providing expanded weather services to farmers and companies further along the value chain, such as seasonal forecasts and advice on when to plant. They identified opportunities to bundle weather information with other services to farmers such as access to buyers, health services and information, credit, and other financial services. Companies working in the generating observation data (box 1) and/or national, regional, and local models (box 3) see an opportunity to enhance infrastructure to provide better weather information for agriculture. A few companies suggested expanding into disaster risk management, energy, flood warning, and providing better services to aviation.

Almost all of the companies identified partnering with NMHSs as important for growth but also described ways that NMHSs pose barriers to growth. Companies respected the role of NMHSs; no company stated an intention to replace or displace the NMHS as a partner. Some companies reported benefits from partnerships where they engaged NMHS staff and helped build their capacity, and this helped increase the relationships and access to data.

Some of the companies Winrock surveyed reported challenges when NMHSs did not understand how to partner with the private sector, provided little additional value, operated too slowly, or lacked the ICT infrastructure or technical expertise needed for an effective partnership.

Depending on their business models, companies expressed willingness to buy data from and sell data to NMHSs. They explained, though, that NMHSs do not have the ICT infrastructure or observational data they need and are willing to pay for, such as multi-day and very localized forecasts, validated surface data, and data from high-density weather stations. Addressing these challenges would help foster partnerships between companies and NMHSs. Pricing emerged as another problem as several companies reported that NMHS's over-valued, and therefore, overpriced their own data. Prices for data are increasing, and NMHSs lack expertise in data pricing. Several of

the NMHS representatives interviewed cited access to data–regardless of the source–as a barrier to growth.

Companies cited national policy environments as another barrier to growth. Some governments prohibit other organizations from sharing and/or re-broadcasting weather and climate data, an obvious problem for the private sector. In at least one case, donors required the government to allow data sharing as a prerequisite for a food security project. The companies Winrock interviewed cited a lack of inter-agency collaboration among NMHSs and other government agencies (e.g. health, agriculture, and education agencies) as a missed opportunity. Companies also cited more general challenges, such as difficulty moving profits out of a country and corruption.

The majority of companies cited two additional, related barriers: a lack of willingness to pay for WCIS and market distortions caused by donors and NGOs. Companies noted that users were not willing to pay for WCIS either because they thought climate and weather information should be a free public good or because they did not understand the value of timely, reliable WCIS. Research indicates that smallholder farmers may be willing to pay for reliable weather information.[60,61,62] Only one of the companies surveyed, however, uses a business model in which the end user pays for WCIS; using a business partnership with a telecommunication company. Other studies found that private WCIS firms in Africa have to build a demand for services at the same time as they develop their products.[63] For some smallholders and end users, the lack of willingness to pay is accompanied by a lack of ability to pay.

A final challenge observed is the cyclical nature of demand for WCIS in agriculture. Farmers need WCIS only during agricultural seasons, and at specific times of planting, production and harvesting. As a result, cash flow for WCIS providers in the agriculture sector can vary widely at different times of year. The lack of constant revenue makes it more difficult for companies to attract private investment.

Changing users' perceptions about the value of WCIS will be challenging. Donors and NGOs have subsidized the cost of WCIS to seed the market and demonstrate the value of the services. Some companies rely on these subsidies to develop and deploy products, services, and infrastructure. At the same time, however, subsidies distort the market. Several company representatives described subsidized services as unsustainable. Companies reported difficulty convincing farmers to pay for a service when a donor-funded NGO provides a comparable service for free. The representative of one company criticized donor funding for NMHS infrastructure as inefficient and market distorting, noting they could provide the same services at a fraction of the cost.

If donors' investments are not clearly indicated as time-limited, then the WCIS private sector will not quickly explore further WCIS business models or sources of funds in which to operate. Winrock

[60] Mabe, F. N., Nketiah, P., & Darko, D. (2014). Farmers' willingness to pay for weather forecast information in Savelugu-Nanton municipality of the Northern region. *Russian Journal of Agricultural and Socio-Economic Sciences*, *36*(12).

[61] Onyango, E., Ochieng, S., & Awiti, A. O. (2014, December). Weather and climate information needs of small-scale farming and fishing communities in western Kenya for enhanced adaptive potential to climate change. In *Proceedings of Sustainable Research and Innovation Conference* (pp. 187-193).

[62] Zongo, B., Diarra, A., Barbier, B., Zorom, M., Yacouba, H., & Dogot, T. (2015). Farmers' Perception and Willingness to Pay for Climate Information in Burkina Faso. *Journal of Agricultural Science*, *8*(1), 175.

[63] Mills, A., Huyser, O., van den Pol, O., Zoeller, K., Snyman, D. Tye, N., & McClure, A. (2016). UNDP Market Assessment: Revenue-Generating Opportunities through Tailored Weather Information Products. UNDP. New York, USA. License: Creative Commons. Attribution CC BY 3.0 IGO.

suggests distinguishing between two types of subsidies: (1) subsidizing the development of infrastructure needed to collect and generate useable information; and (2) subsidizing the cost to the end user. Government and donors will probably always need to fund the basic infrastructure to collect and produce weather information as a public good. Subsidies that reduce the cost of WCIS for the end user are more likely to distort the market.

3.6.1. Case Study: Impact of Donor Funding

The case study interviews and desk analysis found that donor funding for WCIS may help increase private-sector participation in the market. It should be noted that donor funding can help create markets, but also distort markets if not programmed carefully. To try and quantify the impact of donor funding the research team evaluated the relationship between the amount of U.S. foreign aid to agriculture and the number of WCIS companies Winrock identified in the countries of interest. We used the complete Foreign Aid Explorer dataset (downloaded from the USAID Explorer[64]) to identify foreign aid amounts.

Table 5 shows the relationship between the amount of U.S. funding in agriculture and the number of WCIS companies in 28 countries of SSA. (Note that many companies operate in more than one country.)

[64] Weiss, P. (2002). Borders in Cyberspace: Conflicting Public Sector Information Policies and their Economic Impacts: Summary Report. http://www.nws.noaa.gov/sp/Borders_report.pdf.

Table 5. U.S. foreign aid to agriculture and number of WCIS companies in countries of SSA

Country	Total Funding in U.S. dollars (2011-2017)	Number of WCIS companies
Ghana	$365,776,160	8
Senegal	$332,397,665	2
Mali	$306,996,064	2
Ethiopia	$296,517,453	2
Kenya	$235,109,820	6
Uganda	$233,350,625	5
Burkina Faso	$181,523,731	5
Tanzania	$181,094,919	2
Rwanda	$150,520,338	1
Malawi	$142,117,884	5
Nigeria	$129,528,672	4
Mozambique	$117,412,015	2
Zambia	$72,030,382	2
Namibia	$50,342,464	1
Republic of Congo	$41,127,536	1
Niger	$38,009,745	1
Benin	$22,371,473	3
Sierra Leone	$11,984,656	2
Guinea	$8,768,528	1
South Africa	$8,209,375	1
Angola	$5,594,530	1
Tunisia	$573,428	1
Madagascar	$542,569	3
Cameroon	$186,954	1
Cote d'Ivoire	$59,022	4
Gambia	$23,324	2
Central African Republic	$2,369	1

Winrock found a weak positive correlation ($R^2 = 0.298$) between U.S. foreign aid to agriculture and the number of WCIS companies operating in a country. Error! Reference source not found.**Figure 1**

2 shows this relationship, with an individual data point for each country. Please note that correlation does not indicate causation, and that this could be the result of multiple different causal chains.

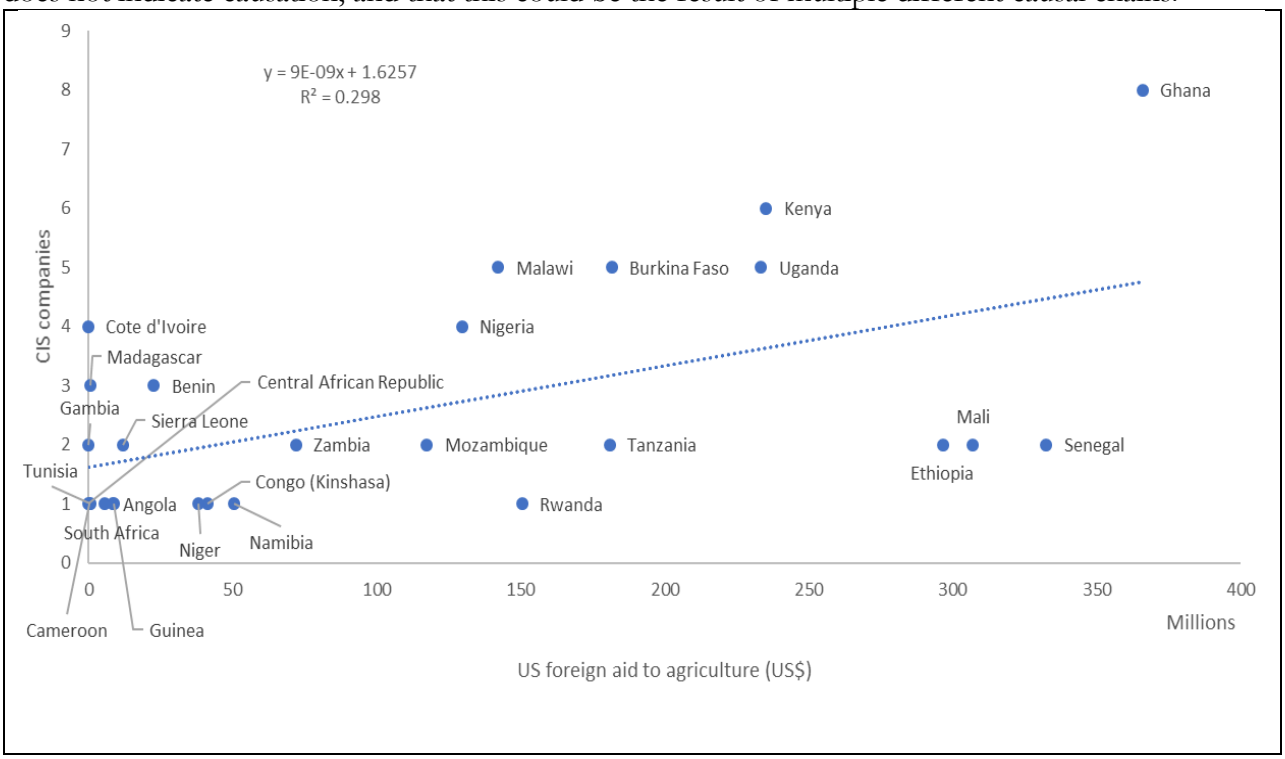


Figure 12. Relationship between U.S. foreign aid to agriculture and number of WCIS companies

3.7. Public-Private Partnerships

Box 2. Public-Private Partnerships in WCIS in Sub-Saharan Africa

In Sierra Leone, an innovative PPP is improving early warnings for extreme weather events. UNDP is working with the country's telecommunications regulatory body and telecommunication companies to share early-warning information on a cost-to-user basis.

In Guinea, Earth Networks is using a PPP with the NHMS and Cellcom Guinea to improve monitoring, prediction, and severe-weather warnings. The PPP has installed lightning sensors and weather stations on cell-phone towers that transmit data to Earth Networks' data centers for processing and analysis. Earth Networks uses its own technologies and information provided by the NHMS to tailor products and services for specific end users.

A public-private partnership (PPPs) is a long-term contract between a private party and a government entity for the purpose of providing a public asset or service, in which the private party bears risk and management responsibility and payment is linked to performance.[65] Historically, PPPs have focused on infrastructure development, particularly in the transportation and energy sectors. Today, PPPs are expanding to encompass a wide variety of industries and services. However, PPPs are not common in the CWE, but they show promise as a way to use public finance to leverage private capital. In addition to attracting financing, PPPs allow the public sector to leverage private-sector technical expertise.

[65] World Bank. (2017). *PPP Reference Guide*. Retrieved from PPP Knowledge Lab: https://pppknowledgelab.org/guide/sections/1-introduction. Accessed August 25, 2017.

A PPP in the WCIS sector has several components: shared initial investment, shared operational responsibilities and data rights, and revenue sharing from ongoing data services.[66] In SSA, only a small number of PPPs are operating in the CWE. Currently, UNDP has a PPP project in Burkina Faso with three telecommunications companies (Telemob Burkina, Airtel Burkina, and Telecel Faso) and a partially privatized state-owned enterprise[67] to create an SMS-based early warning system. The dominant telecommunications partner in the PPP is Onatel, the state-owned enterprise. (See **text box 2** for other examples.)

3.7.1. Case Study: Aircraft Meteorological Data Relay (AMDAR) Program

The global Aircraft Meteorological Data Relay (AMDAR) Program is a successful PPP between the World Meteorological Organization (WMO) and its members in cooperation with commercial and national airlines and/or civil aviation authorities. These PPPs form the basis for the programs that automatically measure and transmit WCIS data from aircraft platforms. The partnerships are usually based on agreements that license the national NMHS to use the AMDAR data in forecast products and services.

AMDAR data improves forecasting services and meteorological products for aviation. The data has improved the quality and accuracy of weather reports, reducing forecast errors by up to 20 percent. Participating airlines and the aviation industry as a whole can use AMDAR data to plan routes to avoid severe weather, select flight altitude to optimize efficiency, and avoid turbulence. The program improves safety and decreases costs for airlines.

In Africa, the AMDAR program is limited by funding constraints, low technical capacity, and a lack of participating airlines. There are currently two national AMDAR programs on the continent, one operational and the other under development. The operational AMDAR program is a partnership between the South African Weather Service (SAWS) and South African Airways (SAA). So far, the program has improved the airline's operations and decreased annual fuel costs by $2-3 million. The second program—located in Kenya—is in the early stages of development. The Kenya Meteorological Department and Kenya Airways have formed a PPP with support from the UK-funded Weather and Climate Information Services for Africa (WISER) program[68].

Several key issues have limited the AMDAR program in Africa and elsewhere:

- difficulty demonstrating the program's value to airline partners
- difficulty committing airline partners to the program's requirements and process
- limited knowledge of AMDAR and its requirements for operation among International Air Transport Association (IATA) partners, suppliers, and applications developers
- lack of efficient, effective ways to integrate AMDAR data into airline operations
- lack of a simple, varied data pricing structure

[66] Rogers, D. P., & Tsirkunov, V. V. (2013). Weather and Climate Resilience: Effective Preparedness Through National Meteorological Services. Washington, DC: World Bank.

[67] http://documents.worldbank.org/curated/en/544581468191970452/712620NWP0Synt0Box370065B00PUBLIC0.docx. Accessed 30 November 2017.

[68] https://www.metoffice.gov.uk/about-us/what/international/projects/wiser

- lack of knowledge about data licensing arrangements, data management, and data security procedures and failure to implement procedures
- lack of coordination of requirements for the provision of AMDAR data by NMHSs
- lack of sustainable funding mechanisms and coordination to support AMDAR development in data-sparse areas and in developing and least developed countries

The WMO has plans to address these issues through a formal partnership with the IATA, which represents different airlines. Improvements will include:

- Promoting the global benefit of providing aircraft observations to different airlines
- Instituting a more robust funding and cost structure that reimburses airlines for their costs and provides a more uniform cost burden within NMHSs globally.
- Creating the AMDAR Programme Operating Fund (APOF) to provide real-time operating resources.
- Creating the AMDAR Programme Expansion Fund (APEF) to support program development and enhancement.
- Establishing principles for a secure data ownership and licensing policy that clearly establishes airlines as owners of the original data and NMHSs as owners of products derived from AMDAR data.

3.7.2. Discussion

The lessons from AMDAR may help explain why PPPs are not more common in SSA in other sectors. If the public and private sector cannot broker and maintain trusting relationships, then more cost-effective services (via functional partnerships) will not be delivered to the public and/or to the private sector. Factors that influence the use of PPPs include the country's legal framework, general investment climate, identifiable demand from paying customers, support from donors and NGOs, and attitudes and capacity within the NMHSs. If governments cannot support operations and maintenance of its investments, then ongoing services that depend upon the availability of WCIS content data cannot be managed or sustained.

Experience shows that "the introduction of highly automated, end-to-end monitoring and forecast systems, focusing on the last mile, and undertaking outreach and sustainability efforts involving private sector partners are seldom successful unless there is careful management of the inevitable cultural shifts within the NHMS[69]." Understanding and addressing country-specific factors is likely to be key to establishing PPPs that can harness public finance to leverage private capital.

Lessons from the United States discussed in the section on the Climate and Weather Enterprise above could be transferred to SSA to help support PPPs. In particular, the recommendation to define a process for decision making on PPPs rather than rigidly defining a static role of NMHSs and the private sector seems particularly useful. Identifying a neutral entity to help facilitate discussions about roles and partnerships in the CWE was also valuable in the United States and should be considered in SSA if PPPs are to be promoted.

[69] UNDP, 2016. A New Vision for Weather and Climate Services in Africa. p. 19

4. CONCLUSIONS AND RECOMMENDATIONS

The organization and structure of the NMHS does not appear to influence the development of the market for WCIS. Throughout SSA there is significant variation in the organization and structure of NMHSs with respect to the responsible ministry, legal authority, and related issues. However, such differences do not appear to be significant factors in the number of market participants or the size of the market (or may be difficult to distinguish from available information).

The WCIS market in Sub-Saharan Africa is small but growing. WCIS has high value for many economic sectors in SSA including agriculture, mining, and shipping but only aviation has established protocols for payment for weather information – and revenue is not always used to support the NHMS.

Limited baseline information for business development. Very few NMHSs in SSA have baseline information on the potential for business development or revenue generation. Business sponsors may help support some end uses, such as index insurance for small farmers, of high value for the country, but they are dependent on public subsidy as well as good WCIS.

Partnerships – implicit or explicit – are important for creation and delivery of WCIS with high economic value to end users and offer the potential for at least some revenue generation to support NMHSs.

Adapting WCIS technology and services from developed economies for applications in SSA offers significant promise. WCIS technology from developed economies, often with support from private companies, is being modified to reflect the different operational requirements and realities within SSA – at least initially with indications of considerable success, although more time and evaluation is required. Capacity development and technology transfer from developed economies is building the capacity of both the public and private WCIS sector in SSA.

Constrained and permissive models for public cooperation with private providers of WCIS appear most promising. There is evidence that constrained and permissive models are more likely to facilitate an enabling environment in which public-private partnerships can develop and sustainable WCIS can be delivered. However, other factors for the development of effective and sustainable services are also likely at play.

More attention needs to be given to navigating the boundaries between the delivery of services by the public and private sector. As the management of WCIS in most of SSA has traditionally been a solely public function, creating new relationships between government agencies and private companies will require time to develop. At least initially it will be necessary for each side to have clear expectations of the other. In developed economies, a neutral, third party has been able to serve as an effective host for dialogue between public and private sector providers of WCIS, reducing tensions and resolving conflicts.

Regional cooperation for the delivery of WCIS requires further evaluation. Multiple studies have proposed regional cooperation among NMHSs for the delivery of WCIS as there appear to be opportunities for operational efficiencies, as well as the production of higher value WCIS products. However, such cooperation has not been easily achieved and as yet there is no demonstration that this will be more effective or sustainable -- more study is required.

Donor funding introduces WCIS options. Donor funding provides the platform, dialogue and opportunity for NMHS and private sector companies to operate business models in WCIS. However, it can also distort the market and act as a barrier to private sector engagement.

4.1. Recommendations for Donors

Predictable funding for NMHSs is critical. Consistent, predictable funding for NMHSs is the foundation for quality WCIS. Donor support and revenue from aviation and other business clients can augment -- but not replace -- public funding. A stable budget and supporting revenue stream for an NMHS, along with adequate investment in data infrastructure, is key to a sustainable WCIS market. Consistent and predicable funding could be ensured with multi-year agreements for donor support. To ensure donor funding has impact and maintained over time, donors could consider tying ongoing support to NMHSs achieving specific and measurable results.[70]

Donor contributions for WCIS should ensure funding for operations, maintenance and training. Donor funding has made significant contributions to WCIS services but sometimes has unintended consequences. Donor support often covers equipment costs only, without adequate funding for training or operations and maintenance. The costs of support for maintenance and operations have also been a concern in proposals for new models of partnerships with private providers of WCIS. New business models to address such costs are needed to achieve sustainable WCIS delivery. Donor funding directly or indirectly supports private and development organizations' delivery of WCIS; and could be a source for innovative partnerships with NMHS.

Seek alternative funding mechanisms. Financial support from donors and development organizations contributes to the establishment of the market for WCIS but also sometimes distorts markets by creating expectations such information will be free or highly subsidized. Willingness to pay depends on both a demonstration of value and an appreciation that services require payment. To avoid undermining markets for WCIS, donors and development organizations can implement projects with a clear plan to transition to a sustainable model based on public and private cooperation. This should include focusing subsidies on those parts of the WCIS that generate information needed for the private sector to flourish.

4.2. Areas for Further Study

Further Sustainable CIS Project Study. In the course of the Sustainable CIS Project, the Winrock consortia is conducting additional analysis of NMHS baseline metrics and capacity; and determining financial models for NMHS.

Regional cooperation for WCIS delivery. Several studies have proposed regional cooperation among NMHSs to leverage operational efficiencies and produce higher-value weather and climate information products. To date, however, efforts to coordinate across regions have been limited.

[70] The Sustainable CIS project supported development of a set of metrics and approach to assess NMHS capacity against the GCFS pillars that could be used to help quantify progress. See : Dinku T., Madajewicz M., Curtis A., Connor S., O'Sullivan R., Phiri P., Steynor A., Tadross M., Traore S., Hauswirth D., Kloppers K., Lennard C., (2018), *Development of Metrics to Assess National Meteorological Services in Africa*, USAID-supported Assessing Sustainability and Effectiveness of Climate Information Services in Africa project. Washington, DC, USA

More on-the-ground pilot efforts are needed to determine whether regional cooperation might improve the quality and sustainability of CIS delivery.

Aviation market revenue. Aviation is a promising source of revenue for NMHSs, but outside of South Africa, it is unclear what role commercial aviation plays in the WCIS market in SSA. Future research could assess the aviation market and identify ways for NMHSs to capture revenue from their internal government revenue, international donors, and the private sector.

5. APPENDIX I: PRIVATE-SECTOR BUSINESS MODELS: CASE STUDIES

5.1. Company Survey Instrument

Could you describe what climate information services you provide, and who is your main user-base for these services?

What type of CIS do you provide? Is it seasonal forecasts, daily/weekly forecasts, historical data?

Could you describe your overall business model and user-base, and where you're operating in more than one country, could you explain the differences?

Who are your main clients, and what sector of the clients affiliated with (e.g. aviation, transport, agriculture, health, etc.)?

Have you seen any changes in the clients using your services in the past 2-3 years?

What is your current and target user-base? Do you collect subscriber fees for your service? Is this a separate fee for the CIS content, or in a bundled package?

What is your technological mode of CIS delivery, e.g. cellphone SMS messages, others?

How have you marketed your services differently to reach the different segments – agriculture, health, individuals/businesses/agencies, etc.?

What considerations does your model take towards differences in end-user regarding gender?

What is your user penetration on a year-by-year basis, and where do you anticipate expanding to in future?

What are the main opportunities you foresee to expand your business and user-base?

What is your current market share in the CIS market in this country?

What do you consider will help to expand your business and user-base?

Where do you see the biggest opportunity(ies) for a private sector CIS provider like your company?

In planning to expand your business model, what steps to do you take to research the market, and how do you go about this?

What are your major barriers to growth?

What were the major factors leading to your decision to provide commercial CIS services in this/these country?

Is the business enabling environment conducive to expanding your business, and if not, why not?

What changes would help alleviate the difficulties of growth?

Are they regulatory, capital, cultural, technological?

Could you describe the source(s) of CIS data, and what is your interaction with the National Meteorological and Hydrological Services staff in your country of operation?

How do you validate the accuracy of the CIS data you provide end-users?

What has been the outcomes of this engagement, if any, and what factors do you consider would encourage greater engagement by NMHS?

5.2. Company Case Studies

The following section provides an overview of 20 private-sector companies working in the WCIS sector in SSA. Winrock developed case studies for 14 of the organizations based on interviews; the remaining 6 profiles are based on desk research. Each case study or profile includes the locations of the company's head office and offices in Africa, a brief overview, and discussions of the company's tools and technology, partners, and market opportunities and revenue streams.

5.3. List of Companies

Companies interviewed by Winrock

Adcon Telemetry
aWhere
Earth Networks
Esoko
Farmerline
Hershey Company
IBM/The Weather Company
Ignitia
Integrated Geo-information and Environmental Management Services (Integems)
Kukua
Manobi
Trans-African Hydro-Meteorological Observatory (TAHMO)
Viamo (formerly Human Networks International
Vodacom Connected Farmer

Other companies profiled

ACRE/Kilimo Salama
Africa Weather
Geospatial Analytical Services
Manstrat Agricultural Intelligence Solutions
MeteoGroup
Olam

Adcon Telemetry (OTT Hydromet Group)

Head Office: Klosterneuburg, Austria
Offices in Africa: N/A

Overview: Adcon Telemetry in its present form was established in October 2003 with its headquarters located in Klosterneuburg near Vienna, the capital of Austria. Adcon Telemetry develops and produces turn-key solutions for all kinds of meteorological data collection, processing, visualization and distribution activities, focusing on agro-meteorology, hydro-meteorology, and hydrographics. In April 2011 the ADCON Telemetry Group was purchased in its entirety by the OTT Hydromet Group, based in Kempten, Germany. OTT Hydromet, a member of Hach Company, is a precision engineering company formed in the 1870's which specializes on providing monitoring and decision support solutions for the Meteorological, Hydrological and Agricultural market. Adcon has expertise in solar powered systems, built around extremely compact and robust data loggers with integrated batteries and a choice of many communication options: UHF, GSM, GPRS or UMTS and supports the construction of small, mid or large-scale networks in all kinds of configurations, from simple rain gauge stations to radar-level stations for flood warning to synoptical, professional weather stations for met offices.

Partners: ADCON have a strong presence in Africa with well documented long-term cooperation with Met Offices, Ministries and international organizations such as UNDP, World Bank (WB) and World Food Program (WFP).

ADCON has supplied automated weather stations (AWS) and capacity building services for national networks for Meteorology, Agro-Meteorology or Hydrology applications in Morocco, Egypt, Mauretania, Burkina Faso, Ethiopia, Kenia, Madagascar, Uganda, Rwanda, Burundi, Ghana, Guinea, Senegal, Liberia, Angola, Zimbabwe Zambia Namibia and South Africa. In addition, ADCON was supplying significant hardware /software solutions and other service to across borders projects such as the Weather Index Insurance project: "Kilimo Salama" with Syngenta Foundation and UAP Insurance in cooperation with European Commission and WB (Kenia and Rwanda), or the climate research project SASSCAL (Angola, Namibia, South Africa, and Zambia. In total ADCON installed about 4500 AWS in the last 15 years.

UNDP/WFP:	Burkina Faso, Cameroon, Congo, Ethiopia, Senegal, Liberia Guinea, Mauretania, Uganda, Madagascar
Syngenta:	Kenya, Burundi, Rwanda, Uganda
GIZ:	Ghana, Uganda
COMESA:	Ethiopia, Malawi, Uganda, Zambia, Zimbabwe
MicroEnsure:	Tanzania
WB,	Ethiopia, Kenia, Zambia
Private Partners:	Morocco, Egypt, Kenia, South Africa

Tools and Technology: Adcon specializes in both hardware and software solutions. Their hardware includes a range of low power low maintenance telemetry units (RTU) from UHF radio or GSM/GPRS/UMTS telemetry to ADCON smart wireless solutions. They also produce low power low maintenance sensors for agro-meteorology, hydrology and environmental observation. Adcon's software, addVANTAGE Professional, is a universal data visualization, processing and distribution platform. It is fully web based, runs on PostgreSQL database engine, and is fully scalable from a

single user version for 5 RTU's to a super server, serving thousands of clients and thousands of RTU's. The software is a tool for weather and environmental data, hydrographics, leakage detection, frost warning, pump monitoring and many other applications. addVANTAGE Pro 6 is programmed in Java and runs best on a Windows 7 or 10 server and can be accessed online through any standard web browser.

Market Opportunities and Revenue Streams: Adcon is a well-established company that is part of a larger group of companies and thus has a robust business strategy and revenue generating model. The primary market opportunity is within the agricultural sector with services including precision farming, decision-support, irrigation management and monitoring, rain monitoring, water management and leak detection.

aWhere

Head Office: Broomfield, Colorado, USA

Offices in Africa: Nairobi, Kenya

Overview: aWhere is a US based Benefit Corporation established in 1999 providing information and analytics for the agriculture market. aWhere offers software and analytical tools to produce hyper-local agricultural intelligence across the entire agricultural earth in near real-time every day. The aWhere platform targets global development and agriculture with evidence-based decision-making tools that can be applied across value chains, from the field-level to corporate and policy-level. aWhere processes and analyses billions of data points a day in a cloud-based platform targeted towards the agricultural sector. A number of value-added services are offered. The company initially focused on supporting sustainable development in developing countries, but is now also providing services to the private sector including large agricultural companies and start-ups that are driving innovation in the agricultural sector around the world.

Technology and tools: aWhere uses a combination of open source and proprietary blending and predictive modeling which incorporate satellite observations, ground radar and public and private weather stations, soils, crop production statistics and agronomic information. aWhere's Base Agricultural Information consists of content on forecast and observed temperature, precipitation, wind speed, humidity, and solar radiation along with hourly conditions and comparisons to historic values. They also collect and organize data regarding soils, crop growing areas, crop calendars and crop production. aWhere's Advanced Agricultural Information include agronomically relevant values such as GDDs, PET, P/PET, along with comparisons to historical data. Lastly, aWhere offers Agricultural Insight products for field-specific, scientifically-vetted agronomic models to drive decision making by automatically identifying plant growth stages, maturity tracking and harvest readiness, pest and disease likelihood, and crop stress. They also provide services such as crop suitability analysis, climate trend analysis, and pest and disease modeling.

Partners: aWhere is a for-profit Benefit Corporation that provides solutions for large and small agribusiness, commodity traders, and governments and NGOs. They have recently partnered with local organizations in developing countries to organize the Hack4Farming hackathon. The Hack4Farming mission is to put underutilized agriculture data, technologies, research, and expertise in the hands of local technologists, and to challenge them to develop solutions to the agriculture sector's recurring challenges. aWhere is also a partner in a consortium led by the Technical Centre for Agricultural and Rural Cooperation (CTA) which was awarded a 4.6 million Euro grant by The Netherlands Space Office (NSO) to implement a project to harness ICTs to supply extension advice in Uganda. The project uses data generated by satellites to improve production and marketing prospects for producers involved in three value chains – maize, soya beans and sesame. aWhere has also been involved in numerous USAID, World Bank and Bill and Melinda Gates Foundation initiatives, recently completing a multi-year Gates Foundation project to engage specifically with ICT4Ag information services. aWhere has worked on over 30 ICT4Ag engagements across Asia and Africa and continues to mature it's Farmer Productivity and Food Security Insight products which are tailored for this market.

Market Opportunities and Revenue Streams: aWhere was certified as a B Corporation in 2014 and officially ratified as a Benefit Corporation in March of 2018. A Benefit Corporation is a relatively new type of corporation that is socially and environmentally orientated and has a mandate

to prioritize impact initiatives. aWhere targets three main markets: agribusiness, commodities, and governments and NGOs. To agribusiness they provide actionable, field-level weather and agronomic information. They also provide information to investors on agriculture commodities to enable them to make informed purchasing and hedging decisions to reduce exposure. Governments and NGOs are provided tools and information to help manage food security and agricultural production, with information often shared with smallholder farmers via SMS.

Earth Networks

Head Office: Germantown, Maryland, United States

Offices in Africa: N/A

Overview: Earth Networks is a weather company established in 1992 based out of the United States. They operate weather observation and lightning networks around the globe and provide a range of value-added weather and environmental services in over 90 countries. They provide services to aviation, media, education, energy and utilities, insurance, parks and recreation, and many other industries. They provide products for improving public safety and emergency management, business continuity, data analytics, and risk management. In Africa, Earth Networks strives to improve severe weather alerting through its total lightning networks in West Africa, East Africa and South Africa. They also have Dangerous Thunderstorm Alerts and Pulse Rad proxy radar to ensure airport operations and National Meteorological and Hydrological Services (NMHS) throughout the region are prepared for severe weather. The company acts as an intermediary between the NMHS and private sector users by developing tailored products and services using its own technologies and information provided by the NMHS.

Tools and Technology: Earth Networks Total Lightning Network is the largest worldwide network of broadband weather sensors for monitoring and detecting both in-cloud lightning and cloud-to-ground lightning in real-time. Introduced in early 2009, the Earth Networks Total Lightning Network now includes more than 1,500 sensors deployed across 90 countries in North America, South America, Europe, Africa and Asia. Using only lightning, no radar, satellite, or human input, Earth Networks generates predicted radar reflectivity, vertically integrated liquid, and precipitation maps somewhat similar to maps made combining rain gauges, satellites, and radar[71]. PulseRad is another key product which builds on the Total Lightning Network. It is a proxy radar resource that utilizes information on total lightning to correlate total lightning flash rate (dBR) and radar reflectivity (dBZ). Many countries in Africa lack the financial resources and technical expertise to deploy, operate and maintain a radar solution and PulseRad offers an alternative. Encast is another Earth Networks products which is a cloud-based forecasting tool that uses current weather and lightning data to improve localized hourly forecasts.

Partners: Earth Networks is a for-profit private company that markets its products to consumers from industries, governments, and NGOs. In Africa, Earth Networks employs a model of joint data processing and information sharing by facilitating partnerships. In 2013, Earth Networks supported the development of the first Early Warning System for severe weather in Guinea, in partnership with the local NMHS and Cellcom Guinea[72]. Earth Network built the capacity of the local NMHS and utilized the cell-phone tower network to install lightening sensors and weather stations. Earth Networks also has a presence in Uganda through the Global Climate Resilient Partnership. This partnership provides a platform through which a broad-based SMS service is linked to disaster risk reduction efforts.

Market Opportunities and Revenue Streams: Earth Networks has a large client base around the world. In Africa, they help develop the business models and revenue streams of African NMHSs by building their capacities to improve the process of collecting information from observation networks

[71] https://www.earthnetworks.com/wp-content/uploads/2017/01/TP_EarthNetworksTotalLightningNetwork.pdf

[72] Revenue-Generating Opportunities through Tailored Weather Information Products, Mills, et. al., 2016

and disseminating this information to the private sector and developing and selling weather products that can generate revenue. The profits of these sales are shared with the NMHS, thereby creating an additional revenue stream for the NMHS.

Esoko

Head Office: Accra, Ghana

Offices in Africa: Dar es Salaam, Tanzania; Accra, Ghana

Resellers in Africa: Burkina Faso, Malawi, Zimbabwe

Overview: Esoko is a social enterprise established in 2008. It provides a suite of applications that a network can use to push and pull information to targeted and profiled users. The service started as a piece of software to push market prices out to farmers via SMS alerts. Esoko now targets agribusinesses, smallholder farmers, network operators, NGOs, and ministries. The basic aim is to reduce the cost of communication and improve value chain management for stakeholders in the agricultural sector. Today the platform is referred to as the "Facebook for farmers" and provides weather forecasts, agricultural tips, crop calendars and market prices and a platform where farmers can share knowledge and localized information.

In July of 2017, the company announced a restructuring. Tulaa, which had been incubated within Esoko, was spun off to create a new business. This new mobile commerce business, enables farmers to access inputs, finance, information and markets in a virtual marketplace. Headquartered in Kenya, Tulaa focuses on growing its market share in Ghana and Kenya initially and eventually expanding into other markets. The restructuring also allowed Esoko to develop its mobile data collection service called Insyt. Today Esoko provides two key services, Insyt – an off-grid data collection service targeted at social protection and agricultural value chain profiling and mapping- and information services including CIS, market information and agronomic advisory services. Esoko is currently developing another product called the Greencard registry which is a centralized registry linking profiled farmers to a variety of services such as CIS, inputs, insurance etc.

Tools and Technology: Esoko is a technology-based market information system (MIS) classified as an agricultural informatics or e-agriculture platform. It is a multi-currency, multi-commodity, multi-market MIS developed for the internet and mobile channels.

Partners: Esoko has evolved from a donor financed project-based endeavor to an independent commercial business. Esoko was initially supported by international development agencies, with USAID being its first partner through the USAID-MISTOWA project (MISTOWA: "Market information systems and traders organizations in West Africa"). Esoko still relies on partnerships with international agencies, government agencies and NGOs, but these partnerships are now more business oriented where Esoko uses a B2B model to sell their services to these partners rather than directly to end-users. Esoko also partners with farmers associations and organized communities who are clients of Esoko subscriptions. Other critical partners include mobile operators that provide the platform for SMS services.

Market Opportunities and Revenue Generation: Esoko has undergone various transformations since it was established to tap into various market opportunities. Esoko employs a differentiated revenue model: subscriptions and revenue share. Subscriptions are paid primarily by enterprise customers to use the platform. Revenue share is with the mobile operators; with mobile operators typically retaining 70-80 percent revenue generated. Farmers and farmer groups are also charged based on a tiered subscription model. Other customers include input suppliers, financiers, agro-processors, exporters, farmer co-operatives, government agencies, and non-governmental

organizations. In 2012 Esoko adopted a franchise model where they licensed their technology platform to partners around Africa. Prices ranged from $18 per year for an individual to $8,000 for a large organization. Each franchise was responsible for seeding the platform with basic content and then selling licenses and consulting services to clients. Esoko at this point was both a cloud-based mobile platform and a suite of consulting services which comprised a 75 percent of their global revenue[73]. Esoko has reached 1 million farmers in ten countries across Africa. Its Insyt service has profiled over 2.2 million rural households and individuals in its social protection program with Government and international agencies. It has sent 30 million messages on market prices, weather and agronomic content, covered one million commodity prices in 170 markets collected by 150 field agents. In 2017, Esoko operated Farmer's call centre had received 180k calls in Ghana, of which 40% were related to weather data[74].

[73] https://www.innovationpolicyplatform.org/system/files/9-Multi-Stakeholder%20Platform__Agri_Profile%20Esoko.pdf

[74] http://webfoundation.org/docs/2016/12/WF-RP-Open-Data-Intermediaries-in-Agriculture-Ghana-Update.pdf

Farmerline

Head Office: Accra, Ghana

Other Offices: Washington, D.C.; Zurich, Switzerland

Farmerline is a Ghanaian social enterprise seeking to leverage technology and data to transform millions of farmers into successful entrepreneurs. Incorporated in 2013, it has built a social business, software technology, and partnership network reaching over 200,000 farmers across 11 countries in Africa (namely: Ghana, Ivory Coast, Benin, Sierra Leone, Cameroon, Mozambique, Malawi, Kenya, Uganda, Nigeria and Tunisia).

Over 700,000 hectares of land have been mapped and farmers have spent over 300,000 minutes learning best practices on Farmerline's Mergdata platform. Farmerline is dedicated to improving the livelihood of farmers through information-based mobile technology services. Mergdata, its innovative information product delivers good agricultural practices, weather reports, and market information systems for nine crops to farmers, to increase their profits and make farming practices more sustainable. Mergdata bridges language, literacy and connectivity gaps among smallholders, as well as reduces the cost of communication and data collection for the companies that work with it.

Hershey Company

Head Office: Hershey, Pennsylvania, USA

Overview: The Hershey Company, headquartered in Hershey, Pennsylvania, is a global confectionery company known for bringing goodness to the world through its chocolate, sweets, mints and other great-tasting snacks. For more than 120 years, Hershey has been committed to operating fairly, ethically and sustainably.

This year, Hershey has launched its Cocoa for Good program, a comprehensive cocoa sustainability strategy designed to address the most pressing issues facing cocoa-growing communities: poverty, poor nutrition, at-risk youth and vulnerable ecosystems. The Cocoa For Good program, set to help thousands of farmers, will focus on West Africa, where about 70 percent of the world's cocoa is grown. Cocoa For Good focuses investments and work in four key areas: Nourishing Children, Elevating Youth, Prospering Communities and Preserving Ecosystems.

Tools, Technology and Partners: In the areas of prospering communities and preserving ecosystems, Hershey continues to use innovative technologies to enhance impact.

Having successfully launched the CocoaLink project in 2011 in partnership with the World Cocoa Foundation and the Ghana Cocoa Board, Hershey reached over 50,000 farmers in over 1,200 communities with SMS and voice messaging on good agricultural practices allowing them to implement agronomic advice in a timelier manner.

In its second phase, CocoaLink is piloting an interactive mobile application and voice messaging to deliver both agronomic advice and weather information to cocoa farmers and agricultural extension agents in Ghana.

Currently, this pilot is reaching over 800 farmers with voice messaging and 215 people using the mobile app, with plans in place for a scale up in 2018.

IBM/The Weather Company

Head Office: Atlanta, Georgia, United States

Offices in Africa: N/A

Overview: The Weather Company, created in 1982 as The Weather Channel, is a weather forecasting and information technology company. . The Weather Company was previously owned by a consortium made up of The Blackstone Group, Bain Capital, and NBC Universal. In 2016, IBM acquired The Weather Company and has retained its possession of The Weather Channel cable network. The Weather Company owns and operates weather.com, intellicast.com, and the Weather Underground. The company offers its forecasts globally, with personalized and actionable weather data and analysis. The company serves millions of consumers. Through API, the company's business solutions division, The Weather Company serves thousands of marketers and businesses. Weather delivers 25 billion forecasts daily and has a network of 250,000 personal weather stations. Their customer base includes aviation, insurance, energy, and media and several other industries. They do not have a direct presence in Africa but are involved in some philanthropic ventures and are interested in expanding their business interests in the continent[75].

Tools and Technology: IBM Business provides weather-driven business solutions that enable decision-making. Their products draw from a number of numerical weather prediction models from agencies including the National Weather Service in the U.S., the U.K. Met Office and the ECMWF in Europe, and also from IBM's own proprietary Deep Thunder model. Their models also use data from surface observations, precipitation, radar, satellite, personal weather stations, lightning sources and data collected from planes on a daily basis. In the developing world, Weather is working to deliver emergency alerts to citizens without access to a mobile or WiFi network by utilizing a mesh network. Through this technology, one device with access to connectivity is able to receive the latest information and distribute it to others nearby, who can then pass it onwards as soon as others are within their vicinity.

Partners: IBM/The Weather Channel has partnered with the Trans-African Hydro-Meteorological Observatory (TAHMO) to deploy more than 300 personal weather stations across Kenya, Nigeria, and various other African nations, in close cooperation with the national meteorological agencies. Each of these stations will be placed in a strategic location to serve a historically underserved community with real-time, accurate weather data. Weather also works in close partnership with NMHSs in Africa and beyond. In March of 2016 IBM participated in a workshop organized by TAHMO and discussed a proposed partnership with the Kenya Met Department to offer information to small farmers in one region of the country, tailored to specific crops. A report of the workshop indicated that IBM was exploring the market and willing to provide support to the Kenya Met Department for free as part of a pilot.[76]

Market Opportunities and Revenue Streams: The Weather Company is the world's largest private weather enterprise. It was purchased by IBM in a deal amounting to $2 billion in 2016. The acquisition combined two big data platforms, IBM's cognitive and analytics business with that of Weather. The company has the fourth-most visited mobile app in the United States and handled 26

[75] Interview with Marc Lemmond, Senior Manager, Public Private Partnerships, Weather Company, Thursday, 29 June 2017

[76] Interview with TAHMO

billion inquiries in 2016 to its cloud-based services daily, generating about 4 GB of data per second. Following the acquisition, IBM was able to tap into more data sets, including Weather's mobile and web properties, which analyze data from three billion weather forecast reference points, more than 40 million mobile phones, and 50,000 flights per day[77]. The two companies also combined their technology and teams in order to serve as the foundation for IBM Watson's new Internet of Things (IOT) unit and the Watson IOT Cloud Platform, following on a $3 billion commitment the company made to invest in its IOT business.

[77] https://techcrunch.com/2015/10/28/ibm-will-acquire-the-weather-companys-digital-business/

Ignitia

Head Office: Stockholm, Sweden

Offices in Africa: Accra, Ghana; Lagos, Nigeria

Overview: Ignitia is a technology-based start-up founded in Sweden in 2010 and commercially launched in 2015. Ignitia has developed a unique algorithm that produces GPS-specific weather forecasts for the tropics that are twice as accurate as existing global models. The algorithm takes into account the convective processes that dictate a majority of tropical weather events (that global models are not calibrated for) to produce highly accurate 2-day rain forecasts, and also offer monthly and seasonal predictions. Ignitia offers a unique platform which uses a proprietary model developed by the company and calibrated to produce highly accurate short-range forecasts for tropical climates. It also provides information at much higher resolutions than most global or regional models are capable and thus provide added value to users. Ignitia partners with telecommunication service providers to reach their primary customer segment comprising smallholder farmers in West Africa. The company plans to target other sectors and customer segments and to expand within Africa and to other regions in the tropics including East Africa, India, South East Asia, South America and Central America.

Technology and Tools: Ignitia has developed a proprietary atmospheric model, claimed to be the first of its kind, which can produce forecasts for the tropics with relative accuracy (twice as accurate as global models). Unlike other regions that are driven by large mesoscale patterns, precipitation in the tropics is produced by small-scale systems where convection is a driving force and can appear rapidly and without warning and is notoriously difficult to model. The Ignitia team spent eight years developing a model which combines proprietary algorithms, uninterrupted 3-D multisource data and predictive artificial intelligence for an improved predictive model[78]. The platform obtains data from satellites and remote sensing data, which precludes the need for major investments in observation infrastructure, making it not only a cost-effective solution but one that can be rapidly scaled-up. The data is processed by the model and produces 48 hour, forecasts for West Africa at a scale of 3km x 3km. This is far more downscaled than global or regional models can reach only 27-50 km square grids. The forecasts are sent via SMS and are tailor made for the end-user based on their location using GPS to identify the users' location.

Partners: Ignitia is structured as a for-profit business but has received support in the form of seed-funding for its development and start-up operations from partners including Swedish International Development Cooperation, USAID and others. The company has several agreements with Mobile Network Operators (MNOs) including MTN in Ghana, Orange in Mali, 9Mobile in Nigeria, and others in Cote d'Ivoire, Niger, Nigeria, Senegal, and Burkina Faso. Through these partnerships, farmers can sign up using a short code (USSD) and pay USD 0.02/day for GPS-specific weather information by SMS[79]. Ignitia also partners with international agriculture and development partners (FAO, WFP, USAID, GIZ) to test and iterate its product and to enter new markets. By interacting directly with farmers, Ignitia is able to continuously improve the information and tools so they are relevant to farmers in a given region and easy for them to access and understand. The products are advertised under locally relevant names (iska™ in Ghana and Sandji™ in Mali).

[78] http://www.undp.org/content/undp/en/home/presscenter/pressreleases/2015/12/22/using-sms-texts-to-provide-weather-forecasts-for-small-farmers-in-west-africa.html

[79] https://www.resourceaward.org/revolutionary-tropical-weather-forecasting-small-scale-farmers-0

Market Opportunities and Revenue Streams: A recurrent pricing mechanism is in place for small-scale farmers while NGOs make a one-time payment that depends on the agreed upon payment schedule. Ignitia charges a nominal fee of about USD 0.02/day. The beta version was launched in 2013 targeting 3,400 farmers. In 2015 it launched commercially in Ghana and in the first year had 80,000 subscribers with a 97% retention rate. In 2016 operations were scaled to include Mali, Nigeria, Senegal and Burkina Faso and in 2017 they served 330,000 small scale farmers on daily bases with forecasts. The company aims to reach 1 million farmers and generating USD 6 million in revenues by 2018. It also aims to expand to other tropical regions.

Integrated Geo-information and Environmental Management Services (Integems)

Head Office: Freetown, Sierra Leone

Offices in Africa: Freetown, Sierra Leone

Website: www.integems.com

Overview: Integrated Geo-information and Environmental Management Services (INTEGEMS), a multidisciplinary consulting firm with its Head Office in Sierra Leone, integrates innovative geographic information systems (GIS) and remote sensing technologies with geo-information, environmental management, research, monitoring & evaluation expertise and experience to effectively and efficiently respond to socio-economic, environmental and natural resources management challenges and opportunities. INTEGEMS provides the following consultancy services and solutions:

- Geo-information Management, including Desktop, Server, Web-Based and Mobile GIS; Remote Sensing and Drone Mapping; Geospatial Data and Information Management Systems; and Management Information Systems (MIS)
- Environmental Management Systems (EMS) and Tools, including Environmental and Social Impact Assessments (ESIA) and Air Quality, Noise and Water Quality Monitoring
- Energy, Climate Change (Mitigation and Adaptation), Climate Information and Early Warning Systems
- Disaster Risk Reduction and Disaster Risk Management
- Research and Monitoring & Evaluation.
- Public Health and Safety and Health Information Systems (HIS)
- Geological and Hydrogeological Mapping and Analysis
- Web Design, Development and Hosting

Tools and Technology: INTEGEMS offers customized solutions to its clients from data capture (e.g., real-time and mobile data collection, scanning, digitizing from mapping and data entry from third party sources), database development, geospatial data and information management, Web-based data visualization and mapping services, quality control and training in value-added applications.

Partnerships: INTEGEMS has a strategic partnership with Earth Networks, a global provider of hyperlocal weather intelligence that offers weather and lightning observations; Feedback Infra, India's leading infrastructure services company, which works in transportation, energy, and urban infrastructure; Hydro Nova, a water resources intelligence and management solutions company that provides customers with bespoke, integrated solutions and tools for success; Zerihun Associates, an international research firm based in greater Washington, D.C. with a regional office in Addis Ababa-Ethiopia; and EHS Data Limited (UK), which provides environmental data management solutions that help organizations monitor, analyze and report on any type of data in one simple application, regardless of frequency, type, format or location.

Market Opportunities and Revenue Streams: INTEGEMS targets governments, non-governmental organizations, businesses, utilities, and educational and research institutions. They offer services to businesses that can improve their competitiveness such as revenue forecasting, business intelligence, and marketing – all using spatial information and data.

Kukua

Head Office: Hilversum, Netherlands

Offices in Africa: Dar es Salaam, Tanzania

Overview: Kukua is a social enterprise/tech company that began operations in 2015 in Tanzania. Kukua's objective is to remedy Africa's severe lack of climate data and weather information due to the decline in weather infrastructure (predominantly, ground weather stations). In order to do so, Kukua installs weather stations, selling the climate observations and weather forecasting services to multinational companies as a package of products. The stations are compact and record a variety of data including wind speed, direction and gust, rainfall rate, and totals, temperature, humidity, barometric pressure and solar radiation. The company has installed over 100 weather stations in Tanzania, Uganda, Mozambique, Kenya, Nigeria and Ghana and has extensive expansion plans. Kukua has won numerous awards, including the €100,000 EU Impact Accelerator Award 2015 and the €15,000 I WILL award from Rotterdam School of Management, Erasmus University. They are the winners of **Microsoft's Affordable Access Initiative 2017** which entails a grant for Kukua's activities, as well as support from Microsoft's technology suite and expertise.

Tools and Technology: Kukua has developed weather station communication technology that is at the forefront of the "Internet of Things": the station is connected to the Internet through GPRS, solar-powered, and cost effective, using frugal innovation suited to the African environment. The World Meteorological Organization-standardized sensors inside a Kukua weather station are connected to a communications device powered by a small solar panel. Data is uploaded to the cloud via an Eseye AnyNet SIM card every fifteen minutes. Kukua also harnesses ConCaVa software: it is a generic, binary payload processor that enables IoT device builders to handle basic data processing in the cloud. This enables those using M2M data connections to reduce the amount of data needed to be sent. The returns in device power savings as well as communications costs savings, reducing the overheads such that the message payload is 1/4 of its original size with the same richness of data. In order to present climate data (live and historic observations) to customers, Kukua tailors dashboards that enable users to gain a clear overview from the devices they are linked to. It is easy to navigate, and the user is able to change the weather parameter, the date range, the time interval and can download the raw data in a CSV format for their own analysis.

Raw data is shared with The European Centre for Medium Range Forecasting, which integrates the data with its global models. Weather data reseller Foreca then creates localized weather forecasts based on GPS location from this global model, sharing them with Kukua. Weather forecasts can be provided on a daily, weekly or seasonal basis and are shared via SMS, App or in a range of forecasting tools.

Partners: Kukua partners with Eseye, which specializes in providing connectivity to Internet of Things (IoT) devices and provides the SIM cards that connect their weather stations to mobile networks. The International Institute of Tropical Agriculture (IITA) is also key to supporting installation and maintenance. Other partners include Solar Powered Data Acquisition (SODAQ), ECMWF and Foreca, TAHMO, Microsoft, UKaid and others. Kukua also works closely with the national hydrometeorological agencies in its countries of operation.

Market Opportunities and Revenue Streams: Kukua's business model is not based on selling hardware, but on monetizing and selling the climate data that their weather stations produce. They

market and sell their data to researchers, governments, multinationals and to commodity traders and insurance companies. The company aims to deploy 1000 units, followed by 300 in the medium-term and 7,000 in the long-term[80]. They plan to offer value-added services to multinationals to support supply chain resilience as well as to a range of non-agricultural sectors.

[80] https://drive.google.com/file/d/0Bxn-cT8a12GjNVZWZ2VqMEppOXM/view

Manobi

Head Office: Dakar, Senegal

Offices in Africa: Mali, Côte d'Ivoire, Benin, Niger, Burkina Faso, South Africa

Overview: Manobi is a private company headquartered in Dakar with offices in 5 other countries in West Africa and South Africa. They provide expertise in integrated GIS systems and web-mobile convergence. Their most successful products target the agricultural sector within which Manobi offers a catalog of integrated services that enable their partners to deploy services in the field. Services including listing and geo-referencing of farmers/producers, providing an online marketplace for trading, price monitoring, providing agricultural information and platforms for collaboration between cooperatives and associations. They also provide services and products targeting water, sanitation, governance, economic development, private businesses, and research institutions.

Tools and Technology: GIS and other digital solutions for risk control and value chain management are at the core of Manobi's services. They have also developed a Multi-Channel Service Platform (MCSP), a software designed to provide cost-effective innovative services within any telecommunication and Internet infrastructure system existing in African countries.

Partners: Manobi partners with ministries, NGOs, telecom operators, and multinationals. They also work with the smaller players including households, individuals, farmers, fishermen, cooperatives, associations, traders. MANOBI's 'Innovative Internet and wireless e-services for the strengthening of Senegalese fisherman artisans' was a project launched in 2003 which used WAP and SMS technology via cell phones to provide fishermen with up-to-date weather reports and market price information. Major international partners that Manoibi works with includes World Bank, Bill and Melinda Gates Foundation, USAID, and LuxDev.

Market Opportunities and Revenue Streams: Manobi customers include farmers, retailers, fishermen, wholesalers, exporters, input suppliers, loan and banking organizations, professional organizations, and NGOs. They provide a range of value-added services in five categories including information, trade assistance, supply chain management, marketing and communication.

Trans-African Hydro-Meteorological Observatory (TAHMO)

Head Office: Delft, Netherlands

Offices in Africa: Nairobi, Kenya, Kampala, Uganda, Accra, Ghana

Overview: The Trans-African Hydro-Meteorological Observatory (TAHMO) is a public-private consortium jointly led by professors from Delft University of Technology and Oregon State University with NGO status in Holland, Kenya, and Ghana. TAHMO aims to install a network of 20,000 automatic weather stations across Africa to make high-quality data available for free to governments, researchers and farmers in real time. TAHMO leverages the mobile telecommunications platform, crowdsourced technology that is durable and cost-effective, and partnerships with local schools to achieve its goals. The first station was installed in 2012 and to date 400 more have been installed. Most TAHMO stations are located in schools (from primary to university), where a teacher "hosts" the station, and gets free access to TAHMO teaching materials and data from their station. TAHMO also works on developing better weather stations appropriate for Africa, educating youth on climate change and supporting local entrepreneurs to cover running costs of weather stations.

Technology and Tools: TAHMO has worked together with METER Group to develop the ATMOS 41, a weather station appropriate for Africa. It uses new sensor and communications technology to measure and report 12 different weather variables including air temperature, relative humidity, vapor pressure, barometric pressure, wind speed and direction, solar radiation, precipitation and lightning. Five-minute data is reported hourly over a single wire to a data logger, where it is then sent to the cloud via the cellular network. Unlike traditional weather stations, the ATMOS 41 uses no moving parts, which are prone to failure from dust, debris, insects, and other wear-and-tear. Due to its design, maintenance costs are limited. The instruments meet or surpass most WMO standards.

Partners: To date, TAHMO has installed over 400 weather stations in Benin, Burkina Faso, Cameroon, Chad, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo, and Uganda. In each of these countries, TAHMO typically signs an MoU with the NMHS which defines the partnership in a country. A key partnership is with the USAID, SIDA, the World Bank, and Rockefeller Foundation funded Global Resilience Partnership. TAHMO also works with other development partners and businesses including a recent agreement with IBM to provide 330 stations. The organization also uses innovative crowd-sourcing methods including design competitions to promote the creation of low-cost and durable weather information solutions.

Market Opportunities and Revenue Streams: TAHMO is a non-profit organization which has a vision to "become a self-sustaining Public Private Partnership curating an international scientific-grade continental-scale weather and climate observatory that support the National Meteorological Agencies and the global research community." Data is free for NMHSs, researchers, and the public whereas fees are incurred for commercial uses of the data. TAHMO estimates that running one station will cost between $600 and $1000/year. This cost can easily be recouped through value-added services in the agriculture, transport, commodities, disaster management and other sectors. TAHMO does not expect to develop these businesses but rather to support the growth of an ecosystem of commercial products across the continent.

Viamo

Head Office: Washington D.C., United States

Offices in Africa: Botswana, Burkina Faso, DRC, Ethiopia, Kenya, Ghana, Madagascar, Malawi, Mali, Mozambique, Nigeria, Niger, Rwanda, Senegal, South Africa, Tanzania, Uganda, Zambia, Zimbabwe, Zambia.

Overview: Viamo is a social enterprise created by development professionals and technologists with a deep understanding of mobile technology and track records of high impact in emerging markets. In 2017, Viamo was established a **US Certified Small Business** called to extend the work of VOTO Mobile and our partners. In 15 countries in Africa and Asia, Viamo launched and manages the 3-2-1 service, a free, on-demand voice and text based mobile information service that is delivered in partnership with Mobile Network Operators (MNOs). The program works with NGOs and government ministries to create local content across a range of topics. Content includes weather information, often in relation to emergency preparedness or agriculture. The 3-2-1 service is provided free of cost to the end user. Among the 15 countries where Viamo has launched the 3-2-1 service, a subset has weather as an option for calls. This subset includes Uganda, Madagascar, Ghana, Mozambique and Burkina Faso.

Technology and Tools: The 3-2-1 service provides access to millions of users to a range of information including public health, agriculture, education, water and sanitation, family planning, microfinance, early warnings and other areas of interest. In Madagascar, users can receive storm warning including information such as timing for a cyclone or storm, areas of potential flooding, and suggested ways to protect individuals and property. By partnering with an MNO, the 3-2-1 service is able to reach millions of people. Users access the service via different channels including IVR (voice), SMS and USSD services. The IVR channel offers access to the richest range of content and is best suited to users with lower literacy levels, yet allows only a fixed number of free calls per subscriber per month (typically 4-10). Other channels have less content, but allow unlimited free access. Access to all channels is heavily subsidized by the MNO.

Partners: With Viamo its development and government partners, Viamo forms committees to develop and approve content for the 3-2-1 platform. Weather information is sometimes an explicit category of service as in Nigeria, or it is part of Early Warning Information as in Madagascar. The following MNOs are providing 3-2-1 service in each respective country: Orange: Botswana, Mali, Niger; Airtel: Burkina Faso, Uganda, Nigeria, Malawi, Madagascar; MTN: Rwanda, Zambia, Ghana; Vodacom: Tanzania, DRC, and Mozambique. A study carried out by GSMA shows that MNOs derive revenue from stickiness of users and their average revenue per user (ARPU).

Market Opportunities and Revenue Streams: The business model provides content to MNOs that is relevant for their users by convening working groups, seeking government approval, and packaging the content to reach the customer segments. Earth Networks, the number two weather app in North America, provides weather information to farmers in 6 languages in Uganda through 3-2-1. Over the whole network of countries, there are 0.5 million engagements per day with the 3-2-1 platform. When the service is mature, 5-8% of an operator's subscriber base is likely to use the service[81].

[81] http://www.noamediacenter.com/africaviamo-mobiles-ivr-services-offer-a-two-way-communications-channel-across-africa-at-scale/

Vodacom Connected Farmer

Head Office: South Africa

Offices in Africa: Lesotho, Tanzania; DRC, Mozambique, and Kenya

Overview: Vodacom is a South African based Mobile Network Operator providing services in South Africa, Lesotho, Tanzania, the DRC, Mozambique and Kenya. Vodacom, in partnership with GIZ, has recently (Feb, 2017) launched the Connected Farmer platform which aims at connecting enterprises, small and commercial agribusinesses, NGOs and farmer associations. With an estimated combined investment about R21 million (USD 1.5 mil) over three years, the 'Connected Farmer' platform, a cloud-based web and mobile software solution, will link thousands of smallholder farmers to the agriculture value chain enabling access to information, services, and markets.

Tools and Technology: The Connect Farmer uses both SMS and internet to provide services. The SMS services provide weather reports and market information, whereas online access provides further information and extra content. Importantly, the app also aims at connecting smallholder famers to agribusinesses, either as individuals or as part of larger groups. The platform will allow retails businesses and food manufacturers to source produce directly from smallholder famers. It can also provide real-time visibility to businesses of their supply chains and allow them to directly contact producers.

Partners: The initiative has been launched with support from GIZ who will provide commercial and operational support to the platform. The key technical partner is Manstrat Agricultural Intelligence Solutions, a southern African developer of cloud based Agriculture Decision Support Systems.

Market Opportunities and Revenue Streams: The project is designed such that agribusinesses will pay a monthly service fee per farmer and per mobile enterprise user, who are provided with the requisite hardware, software, training and support as a managed service.

ACRE/Kilimo Salama

Head Office: Nairobi, Kenya

Offices in Africa: Dar es Salaam, Tanzania; Kigali, Rwanda

Overview: Kilimo Salama began as a pilot project in 2009 offering index based insurance to 200 farmers in Laikipia district of Kenya. The pilot project led to the development of the Kilimo Salama social enterprise incubated by the Syngenta Foundation for Sustainable Agriculture, Kenyan Insurance company UAP and co funded by the IFC managed Global Index Insurance Facility. In 2014 the enterprise was rebranded as the Agricultural and Climate Risk Enterprise (ACRE) Africa and began its operations with 30 former Kilimo Salama employees, based mainly in Nairobi and later expanding to Tanzania and Rwanda. Acre Africa is a registered insurance intermediary, working with local insurers and international reinsurers in Kenya, Rwanda and Tanzania. Syngenta Foundation is the majority shareholder with additional investments by the Lundin Foundation, Grameen Crédit Agricole Foundation and LGT Venture Philanthropy. It operates as a for profit company that is not an insurance company, but rather a service provider working with local insurers and other stakeholders in the agricultural insurance value chain. The ACRE Africa team undertakes risk assessment, product development and risk monitoring to facilitate access to crop and livestock insurance products for smallholders.

Tools and Technology: ACRE Africa provides services related to reinsurance, actuarial, underwriting, product and business development, country-specific knowledge, agronomy and agriculture, insurance training and capacity building, public and private sector resource mobilization. ACRE Africa currently works with ten financial institutions, including SACCOs, banks and microfinance institutions to facilitate access to microinsurance products, insuring USD 5 Million in credit in Kenya, Rwanda and Tanzania. ACRE Africa also has an internal actuarial team that builds and prices insurance indexes, requiring extensive academic training coupled with commercial experience. ACRE Africa has several products including Weather station- and satellite-based weather index, area yield index, hybrid weather index and MPCI, and dairy livestock insurance. Their Weather Index Covers involves daily rainfall data monitoring by satellite or automated weather stations to tailor products specific to small farmers. The Replanting Guarantee product allows for farmers who purchase quality seeds or fertilizer to register for insurance through a card with a unique code in the bag. Each farmer's farm location and planting date are obtained through registration and the cover period begins. If drought affects the crop the farmer can receive a mobile money transfer or discount on next purchase. Acre Africa also have two insurance products for dairy cows that insure against death from accident and diseases. A more recent and innovative product is the Hybrid Index and Multi-Peril Crop Insurance (MPCI) Cover which is a combined insurance product that provides comprehensive coverage of the crop from planting to harvest. In this product, weather index measurements are complemented by ground check and adjustments. ACRE is one the first agricultural insurance programs worldwide to reach smallholders using mobile technologies where payouts are transferred to the farmer's "mobile phone wallet".

Partners: The company partners with a number of insurance companies including UAP Insurance (Kenya), APA Insurance (Kenya), CIC Insurance Group Limited (Kenya), Allianz (Kenya), Soras Insurance (Rwanda), and UAP Insurance Tanzania Ltd (Tanzania) as well as the reinsurers Swiss Re and Africa Re.

Market Opportunities and Revenue Streams: Between 2013 and 2016 the company had approximately 579,669, 377,859, and 168,427 clients in Kenya, Rwanda and Tanzania respectively. The average cost of the insurance is 5% - 12% of value of insured inputs or harvest[82]. Acre Africa also owns two insurance agents, ACRE Tanzania Insurance Agency Limited (ACRE Tanzania) incorporated in 2015 and ACRE Rwanda which was incorporated in 2013. By 2014, over 233,000 farmers in Kenya, Tanzania and Rwanda were insured through products designed by Acre Africa. In 2016 the total insurance portfolio of the company amounted to USD 25.78 million in value of sums insured.

[82] https://www.indexinsuranceforum.org/project/acresyngenta-foundation-sustainable-agriculture-kenya-rwanda-tanzania

Africa Weather

Head Office: Johannesburg, South Africa

Offices in Africa: N/A

Overview: Africa Weather is a weather company based in South Africa offering a number of value-added services to a range of clients. The company, formerly known as WeatherSA, rebranded as Africa Weather to reflect a more pan-African business orientation. The company tracks storms in real-time, provides lightening and storm warnings, and provides reliable and detailed hyper-local forecasts up to seven days in advance. They also offer an online weather portal linked to automated weather stations that are installed and operated at clients' sites.

Tools and Technology: Africa Weather uses the European Centre for Medium-Range Weather Forecasts (ECMWF) for forecasting and storm tracking via EUMETSAT. They also utilise Vaisala's GLD360 lightning detection network installed across Africa which includes largescale lightning detection nodes that provide uninterrupted coverage throughout the continent. They also offer weather data feeds of various sizes and shapes in the form of images and XML feeds that can be purchased by media companies for their own websites. The basic weather feed includes a daily forecast with an overall condition such as 'sunny' or 'cloudy' as well as a seven-day outlook including rainfall, wind speed and direction, temperature and humidity. The company supplies Campbell Scientific Weather Stations though a 2-year operating lease to its clients for hyper-local weather prediction. Many other tailored solutions are developed by Africa Weather that target a large range of customer segments and sectors.

Partners: Africa Weather's products for South Africa come directly from the South African Weather Service, the mandated national meteorological service. For forecasts beyond Africa they partner with the European Centre for Medium-Range Weather Forecasts (ECMWF).

Market Opportunities and Revenue Streams: Africa Weather functions as a for-profit company which has a diverse portfolio of clients. They offer a free app with free content as well as paid-for packages. They cater to media with range of products from a 7-day forecast for one city in one country for R100 per month (7 USD/month) to 7-day forecasts for all cities in the country for R4815 (352 USD/month). Africa Weather targets the golfing business with a Lightning Warning System and Online portal at a cost of R1583 (116 USD/day) with an upfront hardware investment of R15,500 (USD 1136) to install a GSM unit for relaying alerts and warnings. For the logistics industry, AfricaWeather RailGaurd provides insight into conditions that impact the safe running of railway operations using an online portal to provide real-time weather intelligence specific to infrastructure. A similar product is offered to the mining industry. They also provide severe weather and hail notification services to insurance companies that utilize the information to reduce the risks amongst their policyholders by sending fully customizable alerts and warnings. AfricaWeather also helps insurers in verifying damage due to lightning through the provision of historical weather information and lightning verification reports. AfricaWeather Construction is another value-added service including access to meteorologists, accurate rainfall prediction, lightening and storm tracking, and SMS based alerts specific to the construction site.

Geospatial Analytical Services

Head Office: Addis Ababa, Ethiopia

Offices in Africa: N/A

Overview: Geospatial Analytical Services (GeoSAS) is an Ethiopian private consulting company established in 2007. GeoSAS provides professional services in planning, designing, implementing, monitoring and evaluation of development projects in various sectors, with a focus on climate change and agriculture. The firm specializes in acquisition, processing, analysis and synthesis of geospatial data for various applications using GIS and Remote Sensing.

Tools and Technology: GeoSAS specialize in using GIS and Remote Sensing (RS) technologies to solve spatial problems. They also provide geo-data processing, cadastral mapping, standardization services and technical support for researchers. They also provide RS and GIS products including geo-referenced and ortho-rectified Satellite Imageries and Aerial Photographs and are authorized distributers of Geoconsult International products in Ethiopia including QuickBird, WorldView-1, WorldView-2 and Rapid Eye products.

Partners: GeoSAS works with national, regional, continental and international agencies in climate change adaptation and mitigation strategies; agriculture & natural resources management; early warning system and disaster risk management; public health and nutrition; and client-tailored capacity building programs. Partners include VITO (Belgium), Regional Centre for Mapping Resource For Development in Kenya, South Dakota State University (SDSU), Colombia University (International Research Institute for Climate and Society). They also worked with the African Union's NEPAD Agency for the development of a continent-wide Gender, Climate Change and Agriculture Support Program by undertaking need assessment and developing a program document for five pilot countries including Cameroon, Ethiopia, Malawi, Niger and Rwanda. In Ethiopia they developed a Women and Youth Index for measuring participation, empowerment and other socioeconomic factors for the Ministry of Women, Children and Youth Affairs. They also partnered with IOM to develop a GIS database and maps showing IDP movement patterns, as well as training for IOM officers in GIS applications.

Market Opportunities and Revenue Streams: Geishas generates revenues through the provision of consulting services to international organizations, research institutions, and government agencies.

Manstrat Agricultural Intelligence Solutions

Head Office: Pretoria, South Africa

Offices in Africa: Lesotho, Tanzania, DRC, Mozambique, and Kenya

Overview: Manstrat Agricultural Intelligence Solutions is a South African developer of internet based agricultural decision support systems. The team comprises of agriculturists and IT specialists that work to facilitate the implementation of economically viable and sustainable farming systems through the provision of updated, relevant and appropriate information to the agricultural industry. The company has a Software Development and Maintenance Department (SDMD) which develops and maintains software and is responsible for the research, design, testing and implementation of systems, platforms and software The Data Research and Maintenance Department (DRMD) is responsible for the creation, updating and maintenance of product content involving researchers and experts in the animal, plant, economics and environmental fields.

Tools and Technology: Mastrat offers two online resources. The first targets farmers and is called AgriSuite Online. It is an internet based agriculture information system proving information that can guide farmers in making decisions related to animal production, plant production and infrastructure. It provides live data and information on weather and markets and also offers a platform for selling and buying goods and discussion forums. The weather information includes hourly updates of weather at the farm level including wind speed, rainfall, cloud cover, air pressure, humidity and visibility. 5-day weather forecasts at the farm level are also provided. Fungal warning, fire warnings and other hazards are communicated through the online platform. Manstrat also offers a monthly Climate Watch which it posts to its website. The second product is called Extension Suite and is also an online platform. This product targets more professionals working with farmers and provides mechanism to transfer information between Agricultural Research and Extension Services and the farmers that they serve. As such the system facilitates and enhances the transfer of information between these parties by collecting, collating, interpreting and transforming scientific agricultural related data into useful and user-friendly formats for use by Extension Practitioners and Farmers.

Partners: Mastrat partners with governments, private businesses and civil society organizations to fulfil its vision. It also maintains information partnerships with individuals and organization that have relevant and reliable agricultural information and services that are of value and available to all farmers. These content providers include Agricultural Unions, Commodity Organizations, Support Groups, Government Agencies, Research Institutes, Educational Institutions and NGO's. Manstrat is also a key partner in a new initiative launched by GIZ and Vodacom called Connected Farmer, where Manstrat provides agricultural information and content that will be shared with farmers through an SMS based platform hosted by Vodacom.

Market Opportunities and Revenue Streams: Information on business model and charges for the products are unavailable on the website. It is assumed that revenue streams are generated through the sale and/or subscription to propriety software that Manstrat offers.

MeteoGroup

Head Office: London, UK

Offices in Africa: N/A

Overview: MeteoGroup is a private weather company based in London, that is owned by a global equity firm called General Atlantic through a sale of €190 million in 2013. MeteoGroup provides tailored weather information to markets, including transport, marine, agriculture, energy and the media. With several offices in Europe, it has the capability to work through its forecasting offices in 17 countries and with customers worldwide. It owns three weather apps - WeatherPro, MeteoEarth and Magical Weather – and has 100+ meteorologists on staff, and invests in five weather models, including the ECMWF, UKMO, GFS, HIRLAM and WRF. The MeteoGroup in not active in Africa but they have carried out work in the Philippines that may be replicable in Africa.

Tools and Technology: Working alongside its partners the MeteoGroup operates its own private weather measurement network. This has approximately 1,600 stations worldwide. The network of weather stations across Germany and Switzerland are the highest density of private weather stations in Europe. The Meteogroup also works with a non-profit weather service in the Philippines called the Weather Philippines Foundation, and supplies technology for an Early Warning System (EWS) for the Philippines. It provides an interactive web portal with the current conditions that has data drawn from the local automatic weather stations. The data is updated on an hourly basis, and provides local and national forecasts, and severe weather warnings for the population. This website displays detailed satellite analysis, films, access to webcams, and it uses a weather TV station. Under its arrangement with WPF, the MeteoGroup has more detailed data to use in its global commercial weather enterprise.

Market Opportunities and Revenues: In addition to forecasts, the company offers climatology and research services, historic weather data, adverse weather warnings, and weather training and courses; support, monitoring, and consultancy services. It serves the energy, transportation, marine, construction, insurance, agriculture, leisure, water management, and media sectors / markets through its network of sales representatives.

Olam

Head Office: Singapore

Offices in Africa: La Lucia Ridge, South Africa, Lusaka, Zambia, Harare, Zimbabwe, Bobo Dioulasso, Burkina Faso, Douala, Cameroon, Abidjan, Cote d'Ivoire, Libreville, Gabon, Accra, Ghana, Lagos, Nigeria, Ouesso, Republic of Congo, Daka, Senegal, and Lome, Togo

Overview: Olam International is a leading and the third largest agri-business in the world, operating from seed to shelf in 70 countries, supplying food and industrial raw materials to over 23,000 customers worldwide. Olam is one of the world's largest suppliers of cocoa beans and products, coffee, cotton and rice. Since it was established in 1989, Olam has evolved into a multi-product, multi-national, agri-business with 70,000 employees, contract, seasonal and temporary workers from 70 different nationalities. The company manages 2.4 million hectares of land, 204 processing plants and has S$ 20 billion (USD 14 billion) in sales turnover in fiscal year 2016.

In 1995 Olam relocated their operations from London to Singapore where it is now headquartered. Olam began in West Africa in Nigeria with the export of raw cashew nuts to India in 1989. It then expanded into The Republic of Benin in 1993, Ghana and Côte d'Ivoire in 1994 and subsequently to Burkina Faso, Guinea, Guinea Bissau and Senegal. In East Africa, the company began working in Tanzania in 1995 and later expanded into five other East African countries focusing on cashew processing, coffee and cocoa trading, cotton farming and processing, sesame farming and export, the import and distribution of packaged foods. In 2001 Olam also began working in Southern Africa with import and distribution of food grains into South Africa. Subsequently, they expanded operations in Zambia and Zimbabwe. Olam has a Sustainability Standard Framework under which it addresses a number of areas related to social and environmental sustainability, including climate change.

Tools and Technology: One of Olam's targets on climate change is to reduce the agricultural vulnerability to climate risks of Olam farmers through their Olam 2020 Climate Smart Agriculture Program. The company has developed a technology solution for collecting and applying farmgate level data through an MIS system called the Olam Farmer Information System ("OFIS"). The software aims to collect and analyze data that will help streamline Olam's processes and is also designed to support the improvement of livelihoods and strengthen farmer groups, individual farmer management capacity and record keeping. The software also aims at providing services to farmers, including digital financial services and farm development plans. The Farm Development Plan is a module using data uploaded from farm surveys and transaction records, and seeks to maximize farm productivity by making key recommendations on fertilizer use, farm rehabilitation, and Good Agricultural Practice support. SMS functionality also allows users to directly contact farmers with information such pricing, weather and agricultural tips.

Partners: Olam partners with international organizations, research institutions, and local organizations to achieve its Corporate Social Responsibility agenda. http://www.africancashewinitiative.org/For example, they work with the World Cocoa Foundation (WCF) Africa Cocaoa Initiative, a USD 13.5 million 5-year program that forms a public-private partnership, bringing together WCF, cocoa industry members, the Sustainable Trade Initiative (IDH) and the United States Agency for International Development through its Global

Development Alliance, in concert with key government institutions in the four countries of Cameroon, Côte d'Ivoire, Ghana and Nigeria. The goal is to institutionalize effective public and private sector models to support sustainable productivity growth and improved food security on diversified cocoa farms in West and Central Africa. Olam also partners with technical partners including GIZ, TechnoServe, Solidaridad, and SNV. Companies that they partner with include Blommer Chocolate, Costco, Douwe Egberts Foundation, Ferrero, General Mills, Hersheys, Mondelez, Nestle, Unilever, and Walmart Foundation.

Market Opportunities and Revenue Streams: Olam is listed on the Singapore exchange and has 52.2% ownership by Temasek Holdings and 20.3% by Mitsubishi Corporation. It has 14.42 million MT sales volume (FY16) and S$20.59 billion sales turnover (FY16). 15.9% of their revenues are generated in Africa.