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Overhauling the Activities of Ghana Meteorological Agency through ICT

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Abstract

Faced with the growing risks of weather and climate disasters to economic and social development, the global community needs to act quickly to strengthen National Meteorological and Hydrological Services. This strengthening must be done in a way that transforms the agency, especially in developing Ghana into a robust professional agency capable of delivering the right information to the right people at the right time. Although the cost of modernizing and sustaining the Ghana Meteorological Agency will be huge, the rewards for Ghana and its citizens will be much significant.

This analytical work assesses the Ghana Meteorological Agency (GMET) for Hydrometeorology based on the user community needs. The analysis identifies gaps and challenges such as a deterioration of hydro meteorological observation networks and outdated technologies, and a lack of modern equipment and forecasting methods in producing and delivering weather, climate and hydrological information and services, and it lays out a technical technological and strategic framework for policy and decision makers in the Ministry of communication and the government at large.

The Road Map postulates three scenarios, which are institutional strengthening and capacity building; modernization of observation, ICT and forecasting infrastructure; and enhancement of service delivery system for modernizing the GMET based on the potential cost and benefits of each while aiming at a greater national, regional and public good.

The proposed scenarios target the GMET capacity: (i) to produce, manage, translate and communicate hydro-meteorological information to the user community; (ii) to assist the community in accessing, interpreting and using the information; (iii) to better disseminate and respond to warnings for public safety and economic security; (iv) to inform planning and decision making for cost-effective investments in climate-resilient development; and empowering its human resource; (v) identify red zone regions with these muddles. Strengthening these five pillars can help solidify Ghana's resilience to natural hazards and climate change and help enhance the economic performance of such weather dependent sectors as agriculture, energy, transport and water resources management. This study recommends that, low-cost, high-priority activities are provided to achieve critical minimal capabilities to provide weather, climate and hydrological services and monetary investments are also needed to facilitate full modernization and bring the Ghana Meteorological Agency to the level of advanced middle income countries' capabilities for providing data, forecasts and warning services to meet user needs.

Keywords: *Hydro-meteorological, Overhauling, ICT, Modernization, Sustainability.*

Introduction

The global hydro-meteorological enterprise consists of all entities contributing to production, delivery, and use of weather, climate, and water information and services (<https://www.moc.gov.gh/agencies/ghana-meteorological-agency-gma>). It includes government, academia, and the private sector; intergovernmental organizations; and specialized global and regional meteorological and hydrological forecasting, training, and support centers such as the WMO and ICAO. At the heart of this system in Ghana is the Ghana Meteorological Agency (GMET). They are to provide efficient and reliable meteorological information by collecting, processing, archiving, analyzing and dissemination of findings of meteorological information to end users to protect lives, property and for improving economic well-being through timely forecasts and warnings of high-impact meteorological and hydrological events.

The importance of meteorological information is rising because of the need to serve more elaborate societal needs, minimize growing economic losses, and help countries adapt to climate change. Weather, climate, and water affect societies and economies through extreme events, such as tropical cyclones, floods, high winds, storm surges, and prolonged droughts. These affect demand for electricity and production capacity, planting and harvesting dates, management of construction, transportation networks and human health amongst others.

A key player is Ghana Meteorological Agency (GMET), which is the backbone of the Ghana's weather and climate enterprise. By international agreement under the auspices of the WMO, they are the government's authoritative source of weather, climate, and water information, providing timely input to emergency managers, national and local administrations, the public, and critical economic sectors.

GMET is a small but important public sector—with budgets of usually about 0.01–0.05 percent of national gross domestic product. The problem is that their capacity has become degraded in many regions over the past years; primarily owing to underfunding, low visibility, economic reforms, inadequate human resources and primitive mode of operation. As a result, GMET needs to be modernized by: introducing ICT in a most diversified way and ameliorating the existing systems to improve efficiency and service delivery.

The complicating glitch is; government and internationally supported organizations such as the WMO and ICAO rejuvenation efforts in Ghana have achieved only limited success so far, owing to the following reasons:

- Lack of government and development partners' understanding of the value of hydrometeorology and a lack of commitment to maintain their operations
- A preoccupation with project time-scale installation of hardware without adequate provision for training, ongoing maintenance, consumables, and other continuing technical support

- A multiplicity of uncoordinated projects from different donors, each with its own assistance policies, objectives, and equipment suppliers, without sufficient regard to the individual synoptic and agro stations' needs, circumstances, and priorities.
- Derisory number of staff due to retirement, death amongst others and the government reluctance to resuscitate GMET by recruiting new staff and improving the skillset of its current staff.

What can be done to improve the track record of modernization efforts and help policy makers realize the urgent need to overhaul the Ghana Meteorological Service (GMET)? To help answer this question, we undertook a study that analyzes the country's meteorological system, its importance for the effectiveness of service delivery, the obstacles to modernization, and possible desirable operating models.

Our study combines interactive analyses based on existing documentation with expert opinion and the experience of several leading meteorological technicians, meteorologists and forecasters in Ghana. It synthesizes recent experiences of the World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR), the WMO, and other development partners. It also builds on key recent World Bank strategic documents, including (a) World Development Report 2010: Development and Climate Change (World Bank 2009); (b) the 2012–22 environmental strategy, which argues for green, clean, resilient development (World Bank 2012c); and (c) the 2012 green growth strategy, which articulates the case for both inclusive economic growth and environmental sustainability (World Bank 2012a).

This paper underscores the urgent need to strengthen hydro-meteorological services and GMET especially through the use of Information and Communication Technology (ICT). It also offers a recommended approach that has been tested and implemented in Europe, in Central and South Asia, and in other countries.

It has been conservatively estimated that upgrading all hydro-meteorological information production and early-warning capacity in developing countries would save an average of 23,000 lives annually and would provide between US\$3 billion and US\$30 billion per year in additional economic benefits related to disaster reduction (Hallegatte 2012).

Framework

The Ghana Meteorological Agency operates within five main domains: Hydrometeorology, Agrometeorology, Climatology, Aeronautic and Marine meteorology. These five areas are supported by a Technical Assistance unit, the Administrative, Data processing, Human Resource, Operations, Maintenance and finance Units.

GMET operates a significant observation network that monitors: meteorological and climate parameters at 22 manual stations, performing basic synoptic observations, hydrological posts, including recording and data transmission and assessing agro meteorological parameters (at more than 40 substations). It also operates 6 stations that provide data for international exchange; 5 automatic weather stations and 1 (outdated) meteorological radar. Although in disrepair, a calibration facility that services the observation equipment. Information and communication technology enable the transmission, processing and management of data produced by the observation network.

The main products of GMET include basic weather forecasts for the public and other users on an uninterrupted basis (24 hours, seven days a week) even though most of these forecasts and weather warnings are mostly untimely and inaccurate probably because, the Ghana Meteorological Agency does not use the main forecasting tools such as the CliWare; widely used by global Meteorological and Hydrological Services and numerical weather prediction software in all its synoptic stations. It has no technical means to run forecasts with less than three hours lead time (now casting), which is particularly important for flash floods, strong winds and hail. The Agency does not run hydrological or hydraulic models, critical to operating reservoirs and irrigation schemes and mitigating floods. GMET does not run any climate models internally and its ability to produce seasonal outlooks at least at its major synoptic stations and climate projection is very restricted and dependent on international feeds.

In the last two decades, the Ghana Meteorological Agency workforce has been downsized nearly by 40 percent, with one-quarter of those reductions occurring since 2018. It currently has less than 300 staff directly engaged in hydro-meteorological activities. The well-educated staff includes less than 3 percent Doctors of Philosophy, less than 40 percent university degree specialists (technicians), and the remaining with secondary school graduates or with no certificates at all that is: cleaners and security guards. About 200 staff manually observe and transmit data. GMET, however, suffers a shortage of qualified technicians, forecasters and ICT specialists as permanent staff even though the agency has about 120 NABCO personnel trained to assist in its operations. Beyond these, the Agency relies on individual volunteers to record rainfall data on behalf of the agency manually.

The GMET annual budget in 2018 was about GH¢12.1 million. Staff and modernization costs absorbed less than 20 percent of the budget; assets, use of goods and services absorbed almost 50 percent of the budget leaving inadequate resources for operations and maintenance expenditures; for instance investing in (i) a local area network comprising computers and several servers that communicate with all stations and facilities; (ii) a meteorological database such as the (CliWare); (iii) management systems in place of the excel sheets to store hydro meteorological data; and (iv) a limited website hosted by the GMET and a more reliable data transmission system instead of relying on What Sapp platforms. In short, there has been no significant or systematic investments to modernize the GMET in the past 20 years.

Challenges Identified

Despite their importance, the Ghana Meteorological Agency lacks the capacity to provide even their basic level of services. The massive underfunding of GMET has led to (a) a deterioration of hydro meteorological observation networks and outdated technologies, (b) a lack of modern equipment and forecasting methods, (c) poor quality of services, (d) insufficient support for research and development, and (e) an erosion of the workforce (resulting in a lack of trained specialists). As a result, substantial human and financial losses have occurred, which could have been avoided if agency was critical attention is given.

Climate resilient development requires a strong institution and a higher level of observation, forecasting, and service delivery capacity. In addition, successful adaptation to the existing and future weather and climate variability in Ghana is impossible without reliable and well-functioning meteorological service department.

These challenges cannot be addressed solely by Ghana Meteorological Agency. Therefore, the government, the WMO regional, specialized, and global partners would have to play a significant role in designing and implementing the necessary strategies and infrastructure to promote and enhance the activities of GMET.

This is because a concerted effort from different stakeholders will ensures reliable and readily accessible and available data for effective decision making and hence strategic planning.

Modernization of GMET through ICT

Information and Communications Technology (ICT) has become an integral part of the human life as it plays a significant role in the day to day activities of an individual as well as in most sectors of the economy: education, finance, business, health and entertainment. ICT has increased productivity, revenue, profit, through competitive advantage and globalization.

Digital computing and networking continue to expand and transform economies resulting in economies with no boundaries. This has impacted most of the economies of the world: a lot of advantages for economic development due to millions of transactions been conducted through easy and fast channels. On the other hand, the lack of appropriate, reliable, accurate and readily available information has result in low productivity, low quality research works, and waste of time to pursue information and certainly waste of resources. As one of the pillars driving economic development, ICT has gained national competitive advantage: improving the quality of human life through learning and education media, mass communication media promoting practical and important issues, for instance in the health and social sectors. The GMET unfortunately has not been impacted by ICT as it still carries out its functions without ICT.

The paper proposes a substantial modernization program for the National Meteorology and Hydrology Service to include three components, namely: (i) institutional strengthening and capacity building; (ii) modernization of observation, ICT and forecasting infrastructure; and (iii) enhancement of service delivery system. The activities proposed in the Road Map are in line with

this principle. They aim to strengthen the GMET's institutional basis: to enhance a legal, regulatory and technological framework and to develop the capacity of staff; to technically modernize the observation, ICT, data management and hydro meteorological forecasting infrastructure and facilities; and, most importantly, to improve the delivery of hydro meteorological and early warning services to the Ghanaian people and weather-dependent sectors.

The Road Map lays out three scenarios for modernization. Each contributes to a system capable of producing and delivering (i) timely warnings of extreme and hazardous weather events and (ii) forecasts for operations and planning in vulnerable economic sectors, particularly agriculture and water resources management.

A brief overview of the major requirements for each component is presented below.

Institutional Strengthening:

1. Improving the GMET internal management system, including the introduction of a Quality Management System (QMS) and internal workforce planning and management;
2. Increasing communication and coordination between all synoptic stations, agro stations, the airport stations the Headquarters and all other Meteorological & Hydrological Centers;
3. Establishing a hydro meteorological user group to specify user needs and priorities and gather feedback;
4. Building the capacity of staff in technical and management aspects of the Ghana Meteorological Agency, including modern observing networks; use of modern tools for weather and hydrological observation and forecasting; application of downscaling methods for long-range forecasting and climate prediction.

Improving the Observing Network, ICT infrastructure and forecasting:

1. Enhancing network design; rehabilitating the meteorological and hydrological observation networks; and operationalizing a maintenance program;
2. Strengthening the ICT infrastructure;
3. Introducing modern forecasting tools and methodologies for weather and hydrological forecasting to improve accuracy, lead time and spatial resolution of forecasts;
4. Introducing downscaling techniques for long-range forecasts and climate prediction;
5. Establishing a national flood database.

Enhancing service delivery:

1. Developing a national framework for climate services;
2. Developing an agriculture advisory service, including drought monitoring;

3. Improving the visibility, utility and credibility of the GMET by facilitating access through modern communication technologies; and developing stronger relationships with users, including feedback mechanisms.

Three scenarios of the agency's modernization have been presented in this Road Map as follows:

Scenario 1 of the modernization Road Map:

Four areas for immediate high-impact priority activities have been identified that need support by the government of Ghana, the WMO, and the agency's IGF amongst other sources. These activities include priority training packages and technical assistance to procure low-cost ICT equipment and software such as:

- Improvement of short-range weather forecasting through the introduction of an open-source meteorological workstation application (e.g. the ECMWF and Metview) and training staff on the maintenance, use and manipulation of the application and on the use and interpretation of Numerical Weather Prediction (NWP) products;
- Improvement of (monthly and seasonal) long-range weather forecasting through the application of the Regional Climate Downscaling (RCD) methods to provide detailed and accurate representation of localized extreme climate events, and training of staff in downscaling of climate models techniques;
- Improvement of hydrological forecasting through training of staff on hydrological data management, the use of hydrological statistical packages, hydrological modelling and analysis, and visualization of geospatial datasets;
- Low-cost, high-priority communication and computer equipment and software.

These activities are expected to result in: (i) better and reliable weather and hydrological forecasting capability of the GMET; (ii) improved access to forecasts by public and government stakeholders; and (iii) better support to the early warning system in Ghana.

Scenario 2 of the modernization Road Map.

Intermediate modernization activities implemented on a medium -term perspective to focus on strengthening infrastructure of meteorological observation, data analysis and forecasting as follows:

1. Rehabilitation of meteorological observing stations;
2. Introduction of Ensemble Prediction System for forecasting, including probabilistic forecasting.
3. Optimization of the hydrological network for water management and installation of new gauges to meet new operational needs;
4. Replacement of water-level recording systems at selected gauges and implementation of data transmissions.

Scenario 3 of the modernization Road Map.

Full modernization implemented over longer period (hopefully before 2030) will focus on providing data, forecasts and services to ensure of safety of life and property and promote economic development. These activities will require substantial investment and will include institutional strengthening and capacity building; modernization of technical infrastructure for meteorological and hydrological observations, deployment of data management and ICT facilities, modernizing meteorological and hydrological forecasting techniques; and service delivery, including introduction of impact based forecast and warning services, strengthening early warning systems (EWS), improving advisory services for agriculture and enhancing a national framework for climate services.

Recommendation

A modernization program for any hydro meteorological service provider should include the three interrelated activities components: (i) institutional strengthening and capacity building, (ii) modernization of observation, ICT and forecasting infrastructure; and (iii) enhancement of service delivery system. These components are described in some detail in the case of the GMET. In order for the above to be fully functional, government must play the role of regulating these intuitions and agencies by allocating funds for both facilities and human capacity building.

Institutional Strengthening and Capacity Building**Institutional Strengthening**

The main objectives of meteorological and hydrological service providers are: to provide information on weather, climate and hydrological conditions to promote safety in the air, on land and at sea; to mitigate natural disasters; to provide services to weather-sensitive economic sectors; and to support national development. A modernized GMET following the Road Map above is recommended to embark on the following:

1. State-of-the-art ICT and computing facilities;
2. Comprehensive, high-quality and robust observational networks;
3. Efficient data collection and management, and rapid information exchange;
4. Sophisticated data analytics schemes and powerful simulation and forecasting models;
5. Improved understanding of meteorological and hydrological phenomena through ongoing scientific research;
6. Effective tailoring of services to user needs;
7. Effective dissemination systems using multiple channels to assure the widest dissemination of warnings, forecasts and advisory information;
8. Efficient public and private service delivery arrangements;

9. Effective communication of the science, including its limitations, uncertainties and applicability;
10. Capacity building across the entire Agency and for the users and stakeholders;
11. Improved methodologies and algorithms for use of meteorological, hydrological and related information in decision-making.

At the moment, GMETs activities mainly focus on observation and data collection. As a result of the limited resources, the Agency has even fallen behind in collecting critical data, producing forecasts and delivering services and in making the technological and scientific progress needed to use best practices and standards in delivering reliable services to a set of users based on their diverse demands. This is especially the case for hydrological assessments, forecasting and planning. The step from data collection to information production demands a strengthening of the rest of the “system of systems” (i.e. modelling, forecasting and service delivery systems supported by the ICT, QMS, capacity building and technology infusion systems). The institutional strengthening component of the Road Map will aim to invest in the improvement of institutional arrangements at the GMET for enhancing its performance in line with international best practices.

Modernization of Observation Infrastructure, Data Management Systems and Forecasting

This component aims to upgrade and expand the meteorological, agro meteorological and hydrological observations networks and ensure that these networks are well functioning and are interoperable; modernize data management, communications and ICT systems; improve weather and hydrological forecasting processes and numerical prediction systems; and refurbishing GMETs offices and facilities.

Modernization of GMETs Data Management, Communications and ICT System

A readily accessible, historical, digital database of hydrological and meteorological parameters is urgently needed to develop a range of warning and forecast services related to extreme weather and flood events that impact all sectors of Ghana’s economy. The modernization and expansion of the GMET’s observation network and improvement in forecasting and service delivery will require significant improvements in its ICT capacity. Communications equipment and computers, harmonized database management systems for weather, climate and hydrological data, including servers, software, web access and social media; GMET remote sensing and GIS, including the satellite downlink system, will be needed to establish a modern software/hardware environment. Such an environment will provide efficient and timely collection of data from the observational network and will speed up reception and processing of information products from leading international meteorological centers enabling higher resolution products and more information to be available to the forecasters.

Meteorological Forecasting

Forecasting at GMET is based on deterministic model outputs available on the internet with coarse spatial resolutions from various global forecasting centers such as WMO. No objective verification is performed and there is no quality control of observations, which could be used *inter alia* for model verification. There is no visualization tool for blending the in-situ, remote-sensing and model data to produce forecasts of various time scales, from now casts (forecasts of 0–3 hours lead time) to long-range forecasts. To address these gaps in the immediate future, one possible solution might be to acquire an open-source meteorological workstation application software designed to be a complete working environment for the operational forecaster.

The longer-term plans should aim to achieve a forecasting process as is practiced in a modern national forecast center. Such a modernization process will allow access to NWP digital data and products and uninterrupted broadband internet. Other tools for the modernization of forecasting will include forecast workstation software products, implementation of real-time forecast process monitoring and verification, quality control of observations, now casting and impact-based forecasting techniques. Training is required both in the use and interpretation of these products and tool, as well as in the overall forecasting process.

In addition to the short-range forecasts, there is an urgent need to develop (monthly and seasonal) long range forecasts (LRF). Currently, there is a lack of skilled experts on LRF and poor technical capacities at the GMET in applying downscaling techniques. The GMET should be able to access LRFs, for example on the ECMWF website. This includes the ECMWF, UKMO, Météo-France, NCEP and JMA multi-model seasonal forecasts products, and on the WMO Lead Center for Long Range Forecast Multi-Model Ensemble at (<https://www.wmolc.org/>) which provides access to LRFs from the 12 Global Producing Centers. The GMET should develop expertise also in Regional Climate Downscaling (RCD) techniques, which will allow it to provide high resolution climate information on a more regional and national scale and with much greater detail and more accurate representation of localized extreme events.

As part of the longer-term forecasting, it is necessary to establish a comprehensive process for operational weather forecasting. This includes the interpretation and communication of products and forecast verification and the introduction of Ensemble Prediction Systems (EPS) and probabilistic forecasting at the Agency. Training in handling (use and manipulation) of the digital data from the other websites will also be essential for sequential implementation of real-time forecasting. This process consists of collecting observations, quality control of observations, model verification and calibration, now casting and NWP post-processing, production of regional and site-specific forecasts, impact-based forecasting techniques, and NWP dynamic downscaling.

Delivery of Services

The objective is to enhance the GMET service delivery system by enhancing public weather and hydrometeorological services; strengthening end-to-end early warning systems, including impact

-based forecast and warning services; developing agriculture and climate advisory services; and creating a National Framework for Climate Services. This provides for the implementation of a systematic upgrade of the weather, climate and hydrological-related end-to-end services provided to all agencies, communities and individuals.

The GMET needs to evolve from a data provider to a demand- and customer-driven, knowledge-based organization that emphasizes service provision across many socioeconomic sectors. Such a shift to user-based products and service delivery requires a mechanism to facilitate communication and understanding between the GMET and the user sectors. Developing a marketing strategy for the current and potential clients and establishing a hydro meteorological user group are useful tools. The user group needs to develop and implement a strategy for service delivery with engagement of stakeholders and users. The strategy should outline user needs; priorities for needed products and services; design and generation of those products and services; dissemination of products and delivery of services; evaluation of the impact of the new products and services on the country; and improvement of products and services.

Since user needs change periodically, existing and potential new key users should be surveyed on a regular basis. This activity will serve to communicate the needs of users to the provider.

Furthermore, the user community should be educated in understating the products and services offered by GMET and their application in the sectors.

Aspects of a marketing strategy would be:

1. Identify the most suitable mode of delivery of the product or service to the client, for example, use of the Internet to provide access to real-time data;
2. Specify the types of staff involved in delivering the product or service;
3. Describe the processes for product or service delivery according to the needs of the clients;
4. Promote such services to attract potential clients;
5. Determine a pricing policy for different products and services and for different clients to ensure a certain level of recovery of costs.

The establishment of a pricing policy is essential, particularly in the case of clients such as the aviation sector where cost recovery by GMET is supposed to be a norm.

Strengthening Public Weather Services

The Public Weather Service (PWS) is the main channel for liaising with the public, the media and the sectors impacted by weather and climate. It is the principal interface between the technical provider of products (GMET) and the users. It interprets and translates technical meteorological forecasts into socially and economically relevant and understandable information, then provides this information to actors. Under a PWS program, standard operating procedures should be developed and implemented by the GMET in partnership with key stakeholders. This is especially important in the case of warnings to ensure that such information is consistent among partners and

stakeholders, permitting clear decision-making and timely action. Implementing PWS effectively at the GMET would ensure that all users receive timely information available on all time scales. The wide dissemination of hydro meteorological data, forecasts and warnings to all users is a key element of a modern PWS. An essential tool is an improved GMET website. The existing website is inadequate for access to important meteorological and hydrological information needed by the user community; the website needs to be completely restructured as a priority. It should be managed on an operational basis and kept up to date. Consideration should be given to developing color-coded information and pictograms, which are often the most effective way of communicating warnings.

Conclusion

The strategic steps needed to modernize hydro meteorological products and services in Ghana are primarily driven by the needs of the user community. Extensive discussions with GMET and technical staff and key stakeholders dealing with the most pressing issues in the country, such as food and water security; and emergency management and response, have revealed that the provision of hydro meteorological information at present does not fully meet those needs. At present, the activities of GMET are mainly focused on observation and data collection. The existing situation in Ghana shows that due to lack of resources since 1990's, the Ghana Meteorological Agency (GMET) has fallen behind even in this task as well as production of forecasts and delivery of services and making the technological and scientific progress needed to use best practices and standards in delivering services.

The Law of the Republic of Ghana on Hydro meteorological activities authorizes the GMET as the state organization for issuing warnings and provision of hydro meteorological services. The GMET's main products include basic weather forecasts for the public and other users; warnings of severe weather events;

Agro meteorological forecasts and information; and flood forecasts. The GMET does not use, on an operational basis, numerical weather prediction (NWP); it has no technical means to produce newscasts needed for timely warnings; it does not run any hydrological or hydraulic models necessary for flood forecasting; it does not run any climate models and its ability to produce seasonal outlooks and climate projection is very restricted.

Many requests by stakeholders in the GMET clearly reflect the need for modernization of the entire infrastructure of the Agency, to produce fit-for-purpose services. This implies building a meteorological and hydrological observing system of adequate spatial coverage and technical diversity; a robust data management system; a forecasting system with increased accuracy, lead time and time scales from very short- to short-, to long-range and seasonal forecasts; an ICT system capable of archiving, storing and transmitting data; and an effective service delivery system. As a public service, the Agency is expected to deliver socioeconomic benefits to the welfare of Ghanaian society. Analysis has been undertaken to demonstrate that the benefits of GMET services are significantly larger than the capital and operational costs needed to modernize, produce and

deliver them by the World Meteorological Organization (WMO). Options proposed in this Road Map for modernization of the GMET exhibit effectiveness, even under assumptions leading to conservative estimate of the investment's economic effectiveness. The potential benefit–cost ratios of different options depending on the level of investment.

Three scenarios to modernize the GMET have been presented, progressively from provision of technical assistance for a set of low-cost, high-priority activities option focused on improvement of basic public services based on strengthening GMET's capacity and introducing basic affordable new technologies, to full modernization option of investment to bring the Agency up to the level of advanced middle income countries' capabilities for providing data, forecasts and warning services. A second option, is proposed which falls in between the two, with investment to achieve a modest improvement in capabilities to provide hydrological, weather and climate services to meet three most important user needs. Naturally, the level of complexity and required resources increases with each scenario.

Scenario 1: Low-cost, high-priority activities needed to achieve critical minimal capabilities to provide weather, climate and hydrological services (focused on improvement of basic public services based on strengthening the agency's capacity and introducing basic affordable new technologies). Most activities in this scenario are focused on training; access to Numerical Weather Prediction (NWP) data and products; procurement of some basic computing and communication equipment, developing for transitional period CONOPS, improvement of design, content and access to the Ghana Meteorological Agency's website; and establishing a user group.

The following areas for immediate high-impact priority activities have been identified for the improvement of the capability of the GMET relating to the following:

- Improvement of short-range weather forecasting through building capacity of staff in the use and interpretation of NWP products and forecasting techniques;
- Improvement of long-range (monthly and seasonal) weather forecasting through building capacity in climate downscaling methods; and low-cost computing equipment;
- Improvement of hydrological forecasting through training of staff on hydrological data analysis and management; and low-cost, high-priority computing equipment;
- Revision and modification of the design and contents of the GMET website to enable operational use.

Scenario 2: Intermediate modernization includes investment needed to achieve a modest improvement in capabilities to provide hydrological, weather and climate services to meet the three most important user needs (i.e. focused on strengthening hydrometeorological observation, data analysis and forecasting).

This scenario, which falls between technical assistance in Scenario 1 and comprehensive modernization of Scenario 3, is tentatively estimated to be naturally expensive and its scope and composition will be finalized based on discussions with GMET.

Scenario 3: Full modernization includes investment needed to bring the Ghana Meteorological Agency to the level of advanced middle income countries' capabilities for providing data, forecasts and warning services to meet user needs (i.e. focused on improving hydrometeorological and climate services). This scenario, which is much more comprehensive and ambitious modernization option, will raise the level of capability of GMET. This option will be guided by three main modernization components:

1. institutional strengthening and capacity building;
2. modernization of observation infrastructure, data management systems and forecasting; and
3. Enhancement of service delivery.

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