# Producing Climate Change Scenarios and Risk Assessments for Africa: Gambia




## L5: Recommendations for improvements to GIS capacities of MFWR


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# LIST OF ACRONYMS

**DWR:** Department of Water Resources of The Gambia

**DWR-M:** Meteorological Division of the Department of Water Resources of The Gambia

**EWS:** Early Warning System(s)

**FEWS**: Flood Early Warning System

**GIS:** Geographic Information System

**MECCNAR**: Ministry of Environment, Climate Change & Natural Resources of The Gambia

**MFWR**: Ministry of Fisheries and Water Resources of The Gambia

**NDMA**: National Disaster Management Agency of The Gambia

**NEA:** National Environment Agency of The Gambia

**TO**: Task Order

**UN**: The United Nations

**UNON**: United Nations Office Nairobi

# 1. Introduction

## 1.1. Background

The geographic location and topography of The Gambia make it highly prone to natural hazards, including flooding (seasonal flooding, flash floods and coastal storm surges), sea level rise, droughts and windstorms. The country also experiences high rates of land degradation with a rate of erosion of the coastline estimated at 1–2 m per year. The country's relatively flat topography means that no location is 90 m above sea level. As reported in The Gambia National Adaptation Programme of Action (NAPA) in its Climate Change 2007 report, nearly 50% of the total land area of The Gambia is less than 20 m above sea level, ~30% is at or below 10 m above sea level and 10-20% is intermittently flooded. The capital city of Banjul is itself situated at one of the country's lowest elevations and faces significant risk from sea level rise (Rivera et al., 2020). Future climate change threatens to exacerbate the risks posed by sea and river level rise, seasonal flooding and coastal degradation.

Climate-related natural disasters have historically led to significant human cost, economic losses and damage to infrastructure assets. Droughts in particular, which have increased in persistence and severity in recent decades, may be responsible for direct economic losses of up to US $7 million annually by 2100 (CIMA/UNISDR, 2018). The Gambia may be especially vulnerable to the adverse effects of droughts due to a relatively high economic dependence on agriculture (20% of GDP in 2017). Vulnerability to projected sea level rise may also be quite high due the country's low-lying topography. In coastal areas, sea level rise may lead to coastal erosion, submerged beaches, damage to coastal ecosystems and estuaries, saline intrusion into aquifers and widespread destruction of infrastructure throughout greater Banjul (World Bank, 2020). Projected increased severity of extreme flooding events will also adversely impact the large proportion of the population that lives within The Gambia River floodplain.

## 1.2. Project goals and implementation

UNON is committed to providing support to countries severely impacted by climate change and natural hazards in Africa. The aims of this project are:

- to strengthen capacities for climate surveillance in The Gambia through the development of a GIS/data management system
- to support the development of an early warning system (EWS) for extreme climatic events in the country
- to develop a framework for the dissemination of available information regarding extreme events
- to help in planning climate change risk mitigation and adaptation strategies

This assignment aims to summarize the vulnerabilities of key sectors of The Gambian society and economy to climate and natural hazard risks, drawing from both historical data and future climate projections. The project will also

- create a workflow for the transfer of technologies linked to meteorologic and environmental observations
- strengthen capacities for analysis and modeling of climatic data

- support communication of predictive warnings and alerts to local stakeholders and populations

The results are intended to support the offices of the government of The Gambia, including the National Environment Agency (NEA) and the National Disaster Management Agency (NDMA), in maintaining financial viability while providing predictive meteorological services to the population. The results will also be used to identify needed maintenance and upgrades to the country's hydrometeorological infrastructure to ensure optimal EWS performance.

The project also aims to ensure that a critical mass of qualified human resources is able to operate the EWS and carry out medium and long-term adaptation planning beyond the project. Personnel from local government agencies will be instructed in effective and efficient use of hydrometeorological and environmental information in order to issue early warnings and long-term development plans.

The current study consists of 3 principal tasks:

1. Task Order 1 (3 deliverables)
    - Development of an inception report outlining the conceptual framework for the assignment, a detailed methodology and a clear timeline (deliverable 1)
    - Specification of user requirements for the GIS/data management system (deliverable 2)
    - Outline training on GIS and remote sensing technology and identify online and/or open-source GIS tools available for hydrometeorological applications (deliverable 3)
2. Task Order 2 (2 deliverables)
    - Development of GIS data repository platform (with user guide/training) including databases, thematic layers and gridded data such as maps of land elevation and slope, as well as current and projected climatic variables (deliverable 4)
    - Add to the repository new layers of hydrometeorological data and information, maps, satellite images and GIS data in accordance with the structure and coding system used by NEA and MECCNAR
    - Recommendation of methodology/initiatives to improve the GIS capacities of MFWR including how to input, update and maintain GIS databases (deliverable 5)
3. Task Order 3 (2 deliverables)
    - Report on the spatial analysis of the geographical statistics required by MFWR on rainfall, runoff, groundwater recharge and salinity (deliverable 6)
    - Fully-functional GIS web-based portal including hazard maps and associated information such as hydrometeorological data, water resources information, and telemetric and FEWS data (deliverable 7)

This report corresponds to the fifth deliverable of this consultation and discusses our recommendations for improvement of the GIS capacities of MFWR.

# 2. GIS tools for building Early Warning Systems

## 2.1. Effective Early Warning Systems

Early warning systems (EWS) can be used to reduce risk by sending out alerts to the general public, giving them enough time to prepare for a response. In general, the term EWS in relation to climatic hazards refers to not only monitoring networks or climate forecasts, but also public awareness, emergency action plans, risk scenario identification, and so on. The balance and symphony of all of these components is critical to the operation of any EWS. Any of the elements failing could cause the entire system to fail. The importance of redundancy cannot be overstated, and all chain links must function properly.

An EWS, when properly designed, can aid in the reduction of risk and its associated consequences. Once a strategy is in place, the data from monitoring devices can be conceptually modified over time. The following are the activities that an effective EWS should perform (DiBiagio and Kjekstad, 2007):

a) Monitoring including data acquisition, transmission, and instrument maintenance.
b) Analysis and forecasting, which can be accomplished through the use of thresholds, expert judgment, forecasting methods, and other techniques.
c) Warning, i.e., the distribution of understandable messages alerting the public to an impending threat.
d) Response regarding whether people understand the warning and how they react to it
e) Appearance clear, comprehensible and effective

An early warning system would be a device capable of monitoring the safety of the water supply in questioning, analyzing, interpreting, and communicating that data to the appropriate people so that decisions to protect public health could be made (Kroll 2021). An early warning system should have certain characteristics in order to meet these objectives. These desirable characteristics are as follows (Di Biagio and Kjekstad, 2007):

- The system should be able to respond quickly.
- The system should be able to detect a wide variety of potential contaminants.
- The system should have a high level of automation, including automated sample archiving.
- The system should be affordable for acquisition, maintenance, and upgrades.
- The system should be simple to use and require little training.
- The system should be able to accurately predict the location and concentration of the contaminant downstream of the detection point and identify the source of the contaminant.
- The system should be sensitive enough to detect contaminants at the levels of interest.
- The system should have a low number of false positives and false negatives.
- In order to operate continuously in a water environment, the system must be robust and rugged.
- The system should be able to be operated and adjusted remotely.
- The system should be always operational.
- Third-party testing, evaluation, and verification should be possible with the system.

Even with a properly designed EWS, the best results can only be assured in capacities for implementing EWSs and managing the existing systems within relevant institutions and among key stakeholders. These capacities can be wide-ranging – from information management and governance challenges to geospatial competencies.

## 2.2. GIS capacities for EWS operation

### *2.2.1 Current capacities*

The DWR's long-term goal for implementing an EWS system is to more effectively deploy GIS resources in support of disaster risk management. The goal is to transition from the current model of informal sharing and cooperation to a more formalized enterprise structure characterized by a centralized geographic information office collaborating with all levels of government to: (1) reduce duplication through the use of centralized and distributed shared services; (2) improve efficiencies involving data storage, retrieval, and discovery; and (3) improve integration through the establishment of common standards. The table below summarizes the roles of various government agencies of the Gambia with regard to GIS data collection, analysis and sharing.

| Institution | Technical skills / Nature of data collected |
|---|---|
| National Environment Agency | ▪ Technical capacities in geospatial mapping and analysis by using remote sensing, aerial and satellite imagery, surveying and GIS mapping. Establish the geodetic networks and triangulation points which cover the entire country. Provides necessary data and information to the Department of Lands and Survey for the cadastral maps. Produces maps and data on topography, vegetation cover, infrastructure, river basins, urban zones, WASH and school facilities, geological maps. |
| Gambian Bureau of Statistics | ▪ Collects population, socio-economic and environmental vulnerability data disaggregated by municipality through household surveys and census population. |
| Department of Water Resources | ▪ Produces a wide range of products on water resources and ground water products. |
| National Disaster Management Agency | ▪ Coordinates the collection of disaster losses and damages data across sectors.<br>▪ Produces vulnerability maps on water losses, unserved population and risk associated with climatic and hydrological disasters. |
| National Environment Agency | ▪ Conducts land use mapping/vegetation cover assessment in collaboration with the key stakeholders in the environment sector.<br>▪ Collects and assembles data from a wide range of intersectoral partners and maintains a database in support of assessments and development efforts nationally. |

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| Ministry of Health | ▪ Has technical capacities to conduct Integrated Case-based<br>▪ Disease Surveillance and produces weekly epidemiological public reports |
| Meteorological Department | ▪ Collects data on rain fall and temperatures and has technical capacities to produce weather forecasts (up to four-day forecast) through met stations. |

### 2.2.2 Dimensions of the geospatial skills shortage in The Gambia in relation to EWSs

Organizations that employ geospatial professionals come from a wide range of industries (e.g., government, manufacturing, agriculture and transport). GIS can be used in a variety of ways within these organizations. GIS, for example, can be used to store and analyze geographic information. The importance of geospatial techniques and technologies to these organizations in these various sectors varies. Organizations may provide or consume geospatial skills and services, and the demand-supply divide for geospatial skills and services is not absolute. Organizations, for example, may create datasets for internal use but also sell them externally.

A survey was conducted as part of this project to assess the availability of geospatial capacity for the implementation of EWS among key institutions involved in climate-related disaster risk management in the Gambia. The survey used Likert scale qualifiers to assess the level of competence for some of the main institutions related to EWS in the Gambia. The skills qualification are: *No skills*, meaning no contact with geospatial knowledge; *Basic*, meaning can open and read maps in a GIS; *Lower intermediate*, meaning can create maps using vector and raster data and present them in a proper visualization; *Upper intermediate*, understanding basic theoretical concepts behind geospatial data, including GIS and remote sensing; *High*, can perform relevant analyses in geospatial sciences; and *Advanced*, has had high level formal training and relevant experience to work with GIS and remote sensing as well as train others on the methods and use of geospatial products. The institutions that have undergone this initial assessment include the Department of Water Resources (DWR); the National Disaster Management Authority (NDMA); the Meteorological division of the DWR (DWR-M) and the National Environment Agency (NEA). Table 1 summarizes the results.

*Table 1. Geospatial skills profile for the NEA in understanding and using web-based EWS*

| Department | Staff Category | # | Geospatial Competence |
|---|---|---|---|
| National Disaster Management Agency | GIS Technician | 5 | High (1); Basic (4) |
| | Field Staff | 19 | No skills (19) |
| Department of Water Resources | Hydrologists | 3 | High (1); Basic (2) |
| | Senior Technicians | 10 | Basic (4) No skills (6) |
| | Support staff | 15 | No skills (15) |
| Department of Water Resources - M | Meteorologist | 11 | Upper Intermediate (3); Basic (8) |
| | Technicians | 42 | No skills (42) |

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|---|---|---|---|
| National Environment Agency | Program Assistants | 12 | Lower intermediate (3); Upper intermediate (1); No Skills (7); High (1) |
| | Program Officers | 6 | Lower Intermediate (1); Basic (1); No skills (4) |
| | Senior Program Officers | 6 | No Skills (4); Basic (2) |
| | Program Managers | 3 | No Skills (3) |
| | Senior Program Assistants | 13 | No Skills (13) |
| | Environment Inspectors | 13 | No Skills (13) |
| | Senior Environment Inspectors | 7 | No Skills (7) |

A summary of the above table shows a serious deficiency of skills among these institutions directly associated with EWS in the country. A significant portion of the staff (more than 90%) have no skills in geospatial sciences.

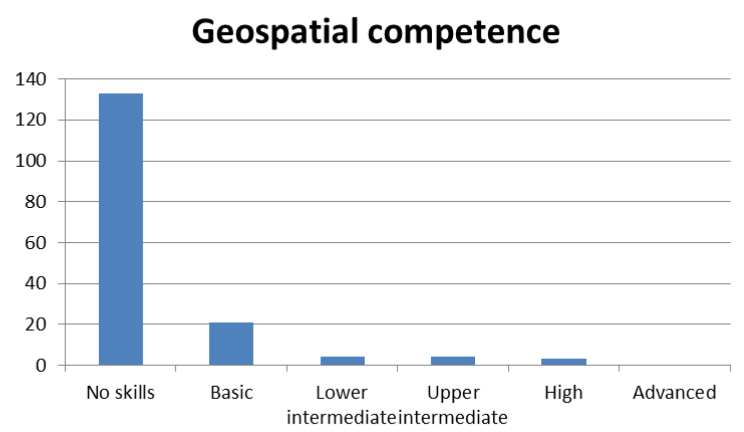


*Figure 1. A summary of geospatial competence among key institutional stakeholders on EWS in the Gambia.*

A consultation meeting was conducted with eight key stakeholders to discuss the importance of different geospatial skills to support the implementation of EWS in the Gambia.

Participants were also asked to rank the importance of specified geospatial skills relative to how they consider their importance in EWS from 1 (extremely important) to 5 (extremely unimportant). Of the eight skills, 5 were deemed important (both mean and median values less than 3), with familiarity with at least one geospatial software program rated as extremely important.

*Table 2. Importance of different geospatial skills for the implementation of EWS in the Gambia.*

| Geospatial skillset | Mean | Median | Importance |
|---|---|---|---|
| Familiarity with at least one geospatial software | 1.285714 | 1 | Extremely important |

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|---|---|---|---|
| Spatial reasoning and spatial problem-solving | 1.428571 | 1 | Extremely important |
| Geospatial database familiarity | 2.857143 | 3 | Unimportant |
| Cartographic skills | 2 | 2 | Important |
| Familiarity with servers | 3.714286 | 4 | Unimportant |
| End-user programming (coding to automate processes) | 2.857143 | 3 | Important |
| Application development programming | 3.857143 | 4 | Unimportant |
| Remote sensing | 3.571429 | 4 | Unimportant |

Of the eight skills, four were deemed important (both mean and median values less than 3) with familiarity with two (Geospatial software program, and Spatial reasoning and spatial problem-solving) rated as extremely important. The rest of the skills (Geospatial database familiarity; Familiarity with servers; Application development programming; and Remote sensing) were seen as less relevant (Table 2). Based on the two analyses above, clear capacity challenges remain with regard to the implementation of effective EWS in the Gambia.

# 3. Recommendations

## 3.1. Recommendations for improvements to GIS capacities for data collection and storage

To understand the demands for and nature of capacities required for the operation of EWS in the Gambia, it is important to first look at recommendations for an EWS to be effective in disaster management and risk reduction (especially within the context of data collection, creation, storage and sharing, see Table 3). The main recommendation is to set up the disaster information database – a task already being undertaken within the current project. It is however important to highlight several key attributes that can ensure that the database supports disaster risk management and reduction to a better extent (see Recommendation 1, below). For example, the open-source disaster risk information database/platform should have a sole focus on disaster risk (meaning not associated to a database used for security issues): flash floods, extreme weather events (drought), etc. The need to separate from any security database that may also be supporting decisions in times of crises is to ensure that the privacy of citizens is not infringed upon through the open data sharing format necessary to ensure adequate response in disaster situations. Such a disaster risk information database/platform shall provide free-of-charge access to risk information to public and private sector stakeholders with the view to inform preparedness and prevention efforts. The database can have different access rights depending on the sensitivity of the information.

*Table 3. Recommendations for improving institutional capacity to collect, store and share EWS related data.*

| **Recommendation 1 -** ***Set up a disaster and climate risk information management system to facilitate data collection, sharing and accessibility of disaster data for stakeholders*** |
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| 1. Establish the Open source/Closed disaster risk information database with different user access rights for: i) national security institutions, ii) sector ministries, municipalities and governorates, and iii) general public and private sector |
| 2. The disaster risk information database should integrate data sets and analysis from: i) sector ministries; ii) humanitarian and development actors; iii) climate change research (Ministry of Environment, Climate Change & Natural Resources - MECCNAR). Key sectors (i.e., agriculture, tourism, urban development, rural development, water resources, health) must commit to have their datasets connected to the central system at no cost. |
| 3. Formalize the Risk Information Management Platform, to include sector ministries, the National Environment Agency, Gambian Bureau of Statistics, bilateral and multilateral agencies, academia and NGOs i.e., all actors producing risk information (hazard and vulnerability data). |
| 4. Prepare appropriate tools to collect, consolidate and analyze data related to risk mapping. |
| 5. Review and harmonize all datasets collected by, and available from ministries and key stakeholders relevant to disaster risk management and reduction. |
| 6. Conduct a mapping of the geo-spatial data and capacities within the different ministries. |
| 7. Standardize data collection templates tailored to each ministry through a participatory and consultative process and agree on data collection periodicity with clear roles. |

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| 8. Establish clear data sharing protocols including legal framework, data formats, metadata, and security measures to protect selected confidential security information on risk that should not be accessible to the general public. |
| 9. Formalize MOUs with key stakeholders on data sharing protocols and access to information free of charge, elevate the initiative as a matter of public policy with the Prime Minister and above |

Table 4 summarizes potential actions required to strengthen the EWS to support the roles of the Department of Water Resources and partners associated with risk management and prevention – especially in the domains of data collection, management, storage and sharing.

*Table 4. Recommendations to improve the technical capacity for the analysis of EWS data and collaboration in converting EWS data analysis to action through collaboration with relevant stakeholders.*

| **Recommendation 2:** ***Strengthen the risk information system for the water management sector as well as risk analysis and early warning system*** |
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| 1. Integrate database system on risk information for drought and flash floods using the future drought monitoring unit and early warning system as a foundation. The database must be linked with NDMA database and surveillance system to ensure the availability of updated information. |
| 2. Promote synergies between NDMA, NEA, MoA and MECCNAR on early warning system for drought i.e., allocate clear roles and responsibilities based on analysis of comparative advantage and complementarity |
| 3. Strengthen the technical capacity of the Department of Water Resources, the NDMA, NEA, and other key stakeholders on the use and application of disaster and climate data in water resources management for drought/floods mitigation and preparedness |
| 4. Empower relevant central and local government institutions to apply risk information to preparedness, response and recovery plans through provide free and systematic access to existing hazard and risk maps and training on use and application of risk information for preparedness purpose |
| 5. Ensure that risk and hazard analysis data are gender disaggregated |
| 6. Establish thresholds and activation protocols linked to forecasts; Clarify triggers for early action and allocation of roles and responsibilities for early action at central and local level |
| 7. Disseminate information on capacities and responsibilities of each monitoring Agency to Agencies mandated for emergency service provision, to ensure appropriate early warning and safety to the public at large |
| 8. Conduct public / community awareness campaigns on what to do in case of warning with the involvement of various actors in the disaster management and reduction space with a special attention on the role of women in community preparedness and response |
| 9. Standardize data collection for emergency preparedness purpose from relevant ministries, charities, NGOs, bilateral and multilateral agencies including their stocks and human resources |
| 10. Establish official protocols on Information Management for preparedness and response purposes, that define roles and responsibilities, reporting mechanisms and accessibility and accuracy of data |

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| 11. Establish a National Platform for the application of risk information for preparedness for response, and develop guidelines and training for its operation |
| 12. Establish capacity to support data collection, analysis on post disaster damage assessments with technical readiness to produce damage maps using available satellite data and aerial photography. |

## 3.2. Minimum skills for GIS database maintenance

To arrive at the capacities described in Tables 3 and 4 above, a set of minimum skills are required in the field of Geographic Information Systems. The skills listed in Modules 1 – 3 below assume a prerequisite knowledge of basic GIS training. This can include courses such as: (i) Introduction to Geographic Information Systems; and/or (ii) Introduction to Remote Sensing. Module 1 introduces the disaster profile of the Gambia, the types of data commonly used in disaster risk management, and how they are derived. Module 2 provides skills of the EWS database with specific focus on that of the Gambia – its structure, contents (data), how to update and management the data in it, and the format in which reporting is done. Module 3 relates data and their associated outputs to actionable information for policy and decision-makers.

***Module 1 – Data for disaster risk management***

Unit 1: Introduction to disaster management and vulnerability profile of the Gambia

Unit 2: Data for disaster management

Unit 3: Data sources and accessibility

***Module 2 – The EWS database***

Unit 1: Structure of the EWS database

Unit 2: Data types, structures and their sources

Unit 3: Updating data in the database

Unit 4: Reporting formats

***Module 3 – Outputs from the EWS system specific to the Gambia***

Unit 1: Risk knowledge

Unit 2: Warning service

Unit 3: Information dissemination tool

## 3.3. Recommendations for improvements to GIS capacities – physical infrastructure

The Department of Water Resources currently has no dedicated geospatial service. Hence, GIS and remote sensing activities are being undertaken by a limited number of individuals on their laptops, with no centralized data repository or analysis structure. The table below is a summary of the physical requirements identified by the Department that can support the enhancement of their capacity to collect, store, analyze and work with EWS data.

*Table 5. Requirements in physical infrastructure to enhance the capacity of the Department of Water Resources to collect, store, analyze and work with EWS data.*

| No. | Qty/Item | Purpose | Specification |
|---|---|---|---|
| 1. | 5 Large LED TV Screen | For wider viewing, analysis and interpretation of geospatial layers | **Panel Size:** 75-85’’<br>**Interface Type:** USB, LAN, VGA, Digital Audio, Wifi<br>**Resolution:** HD1080(1920*1080)<br>**Standard VESA:** 100x100<br>**TV System:** PAL NTSC SECAM<br>**Refresh Rate:** Ntsc(60Hz)<br>**ANT in (IEC terrestrial/cable):** 2 pieces |
| 2. | 10 Desktop Computers with monitors | For data processing and analysis | **CPU:**<br>**Intel Core:** i7, Processor: ~ 4GHz<br>8GB DDR3-1600 RAM, 1TB 7,200RPM Hard Drive<br>Intel HD, 16x DVDRW Drive<br>Wireless facility<br>64-bit operating system<br>Other Accessories: Mouse and headset<br>**Monitor:**<br>Size -32”, HD-LED Type, 1080p |
| 3. | 10 Strong Laptop Computers | For data collection from the field | Processor: Intel Core i7<br>Installed RAM: 16GB<br>System Type: 64-bit Operating System<br>Hard Drive: 1TB<br>**Other Accessories:** Wireless mouse and headset |
| 4. | 2 Advanced Differential GPS | To use for precise field hydrometeorological surveying | **Operating Principle:** Code Related Type<br>**Type:** Geodesic<br>**Carrier Frequency:** Dual<br>**Port Number:** 220<br>**Chip:** Trimle<br>**Differential Format**: Cmr.Cmr+. Rtcm23.Rtcm3.X<br>**Transport Package:** Plastic carrying case + Hard Carbon<br>**Specification:** 50*40*20cm, 8.2kgs<br>**Origin:** G10 |
| 5. | 5 Handheld GPS units | For collecting data outdoors | Garmin eTrex 10<br>WAAS enabled GPS receiver with HotFix and GLONASS support |

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