European Commission

JRC TECHNICAL REPORTS

ACEWATER2 Regional Hydro-Climatology Database Prototype

Crestaz, E.
Cordano, E.
Ronco, P.
Farinosi, F.
Ameztoy, I.
Iervolino, A.,
González Sánchez, D.
Carmona Moreno, C.

2017 **LIMITED**

This publication is a Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication.

Contact information
Name: César Carmona-moreno
Address: JRC-Water and Marine Resources Unit
Email: cesar.carmona-moreno@ec.europa.eu
Tel.: +39 0332.78.96.54
Fax: +39 0332.78.90.73

JRC Science Hub
https://ec.europa.eu/jrc

JRC109900

Ispra: European Commission, 2017

Contents

Foreword

Transboundary water resources management, integrated water resources management and conflict prevention have been identified by the European Parliament as issues the European Commission should address in the water sector in Africa as enablers to socio-economic development. In particular, one of the key limitations to a harmonious development and management of water resources in Africa is the lack of human and institutional capacity to assimilate the modern advances in science and technology necessary to deal with the complex interactions between the hydrological cycle and the societal needs, while conserving the environment.

At present, research and development in the water resource sector in Africa is highly dependent on developed countries expertise both in terms of knowledge and human resources. African countries can, however, find innovative solutions for sustainable development if and when they mobilize and direct their different capacities towards common research and development challenges.

Within its strategy, the Commission supports different continental institutions in the water sector, including the AU and its water arm, AMCOW (African Ministers' Council on Water), and ANBO (African Network of Basin Organisations).

In particular, the "Joint Africa-EU Strategy Roadmap 2014-2017" established at the 4th EU-Africa Summit, held in Brussels on 2-3 April 2014, by the Heads of State and Government of the EU and Africa, the President of the European Council, the President of the European Commission, the President of the AU and the Chairperson of the AUC explicitly stated:

a. The need for the EU to support the development of the Centers of Excellence in Africa in the framework of priority area 3 "Human development";
b. The need to include water amongst the strategic priorities for cooperation and urged actions in the water sector to ensure, through institutional strengthening, sustainable and efficient management of water resources, contributing to growth, peace and security in the framework of priority area 4 "Sustainable and inclusive development and growth and continental integration";
c. The will to strengthen African capacity to monitor environment in the framework of priority area 5 "Global and emerging issues" including water resources through GMES/MESA (Global Monitoring for Environment and Security / Monitoring for Environment and Security in Africa) EU programmes.

In this framework, EuropeAid launched the pilot project "Support to the New Partnership for Africa's Development (NEPAD) Centres of Excellence (CoEs) in Water Sciences and Technologies". The pilot phase of the project (2011-13) was implemented by the Joint Research Centre on the European Commission's behalf. This pilot initiative aimed at fostering the capacity development and the ownership of south to south networking and cooperation in water science in the African high education, training, research, advocacy and consultancy communities, in line with the principles of the multi-stakeholder participatory approach fostered by the European Union cooperation policies. The EU Commission supported these CoEs, identified by NEPAD and organized in two networks: the NEPAD Southern African Water Centres of Excellence (SANWATCE coordinated by the University of Stellenbosch) and the NEPAD Western African Water Centres of Excellence (WANWATCE coordinated by University of Cheick Anta Diop of Dakar).

By scaling up the method and approach of the pilot phase, the "NEPAD African Network of Centers of Excellence on Water Sciences and Technology (II phase) 2016-2019", thereafter "ACEWATER2" project is aimed at fostering the NEPAD CoEs in their development of a collaborative approach improving their capacities and strengthening their role in supporting

water sector development. This action focuses on higher education, scientific research, consultancy and advocacy in the water sector.

The target groups include a range of different users/beneficiaries: the students as users of the Centres of Excellence, the continental institutions such as NEPAD and AMCOW, other African institutions such as the RECs (Regional Economic Communities) and in particular ECOWAS and SADC, river basin authorities (OMVS, ZAMCOM, etc.), development and cooperation agencies, governments, water users, local authorities, etc.

The analysis of the impacts of water resources use on energy and food security has been broadly identified as the ultimate frontier in the water management literature (among others: Giupponi and Gain, 2017; Namara and Giordano, 2017; SEI, 2011). Suboptimal allocation of water resources among the different consuming sectors could be responsible of large economic damages and, especially in the most vulnerable socio-economic systems, could cause food and energy insecurity and, in the most extreme cases, ignite social and political tensions (WEF, 2016). Competition over water is particularly intense in the transboundary water basins, where international agreements between the countries sharing the watershed are needed to ensure a cooperative and efficient use of the water resources (De Stefano et al., 2017, 2012, 2010; Dinar, 2004; Dinar et al., 2013, 2015; Wolf, 2009; Wolf et al., 2003). Development also in the water resource sector in Africa is highly dependent on developed countries expertise both in terms of knowledge and human resources. African countries can, however, find innovative solutions for sustainable development if and when they mobilize and direct their different capacities towards common research and development challenges. Therefore, the ACEWATER2 project is aimed at fostering the AU/NEPAD African Centres of Excellence (CoE) in their development of a collaborative approach improving their capacities and strengthening their role in supporting water sector development. This action focuses on higher education, scientific research, consultancy and advocacy in the water sector. One of the most relevant objective of the ACEWATER2 initiative, is to strengthen institutional networking and improving research support to policy making in the water sector. Currently, the project is implementing a policy-driven dialogue with relevant River Basin Organizations in Africa (ZAMCOM, OMVS and NBA) leading to the implementation of research and technical activities to support decision making processes. In particular, the three different networks of CoEs in Western, Eastern and Southern Africa (WANWATCE, CEANWATCE and SANWATCE) are currently developing innovative research projects in pilot river basins, selected for their relevance at regional level (the Senegal, the Niger, the Nile and the Zambezi respectively). Within these projects, the WEFE nexus as well as the climate change/variability assessments will be performed, according to the needs and priorities as set up by the relevant regional policy and decision makers. In this framework, all available transdisciplinary data that can be useful for collaborative research are collected. The data collection is designed to support the development of the regional African Atlas of Water Cooperation (Farinosi et al, 2017b) and any other technical activities on environmental modelling supporting the decision making process in the water sector, including: environmental and resource sustainability; climate variability impact analysis; water resource security and in particular aspects related to water/energy/food security nexus.

The goal of the report is to develop a conceptual framework for a database on hydro-climatology and WEFE at basin scale,

The database described in this report is the first steps for the construction of the solid source of data and metadata for environmental (mainly hydro-climatic) and socio-economic project research activities for a sustainable development of water sector, Economic Green Growth Poverty reduction in African countries for peace and security (Farinosi et al, under submission).

The collected information is integrated into a spatially referred system allowing the analysis of the dynamics of water-related extreme events, water availability, water quality, health, access to water, and energy and agricultural production. The queries to the database, for getting or accessing to the data required by the specific analysis, can be created with external software tools.

Authors

Crestaz, Ezio; Cordano, Emanuele;Ronco, Paolo; Farinosi, Fabio; Ameztoy, Iban; Iervolino, Andrea; González Sánchez, David; Carmona Moreno César.

Abstract

The report, after a brief summary of key African initiatives on Water Resources Management, discusses the architecture and contents of the regional hydro-climatology database, developed in the framework of ACEWATER2 project, in collaboration with the networks of the AU-NEPAD Water Centres of Excellence.

The database is a collection of metadata about public (freely available or available upon registration) and private environmental and socio-economic datasets, relevant to WEFE (Water-Energy-Food-Ecosystems) nexus assessment in Africa and to ACEWATER2 analysis objectives at river basin scale (i.e. Senegal, Niger, Nile and Zambezi).

Metadata cover different descriptive and quantitative information, as spatial extent, resolution and temporal frequency, and provide url (where available) to access original data sources, as maintained by reference Organizations.

Scope of the activity is to provide an overall harmonized review of existing data sources, acting as an entry point for downloading of datasets of interest for WEFE analysis and modelling.

As such, the database is open to updates, as new data sources are spotted or are made available, further to proposing a directory structure for local information organization.

1 Introduction

The hydro-climatology database is, at current stage of development, a collection of metadata about public (freely available or available upon registration) and private environmental and socio-economic datasets. As such, the concept of hydro-climatology is intended here in an extended way, including data relevant to water availability (i.e. from rainfall to rivers and groundwater discharge), water uses and related potential impacts on socio-economy.

The database is relevant to ACEWATER2 project objectives, covering both world/continental and river basins scale (i.e. Senegal, Niger, Nile and Zambezi) data sources.

The database as a metadata collection includes, among others and on a data source basis, such different information as:

- textual short and extended dataset description;
- data types (i.e. vector, raster, text);
- keywords, relevant to browsing purposes;
- spatial resolution and temporal frequency;
- geographic and temporal extent;
- use limitations (i.e. copyright) and citation references;
- url references, to access official web sites and datasets repositories (if available).

These metadata serves different objectives:

- Information harmonization, based on the review of a large number of available datasets, knowledge being often scattered in different Organizations, Departments and even Working Groups, depending upon specific scientific research interests and expertise;
- Access to original datasets, virtually acting as an entry point to access a web distributed database, whose nodes are official datasets repositories, maintained by original responsible Institutions (**Figure 1**).

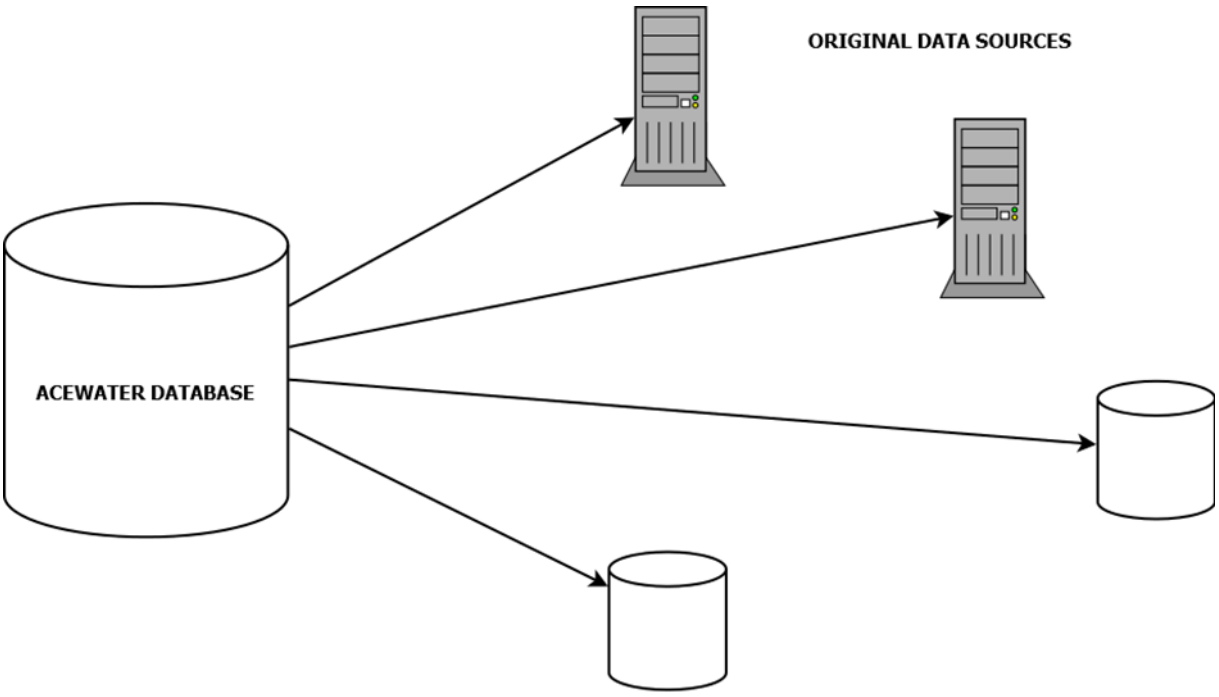

Figure 1 - Metadata acting as entry point to a distributed web database.

Datasets can be downloaded locally on the basis of provided urls (where available) and organized in directories, on local computers or on servers, with enough facilities for efficient and large data storage (some datasets are extremely huge), querying and retrieving.

Metadata table proposes, through its '*category*' attribute, a possible efficient and homogenized organization of top directories (Figure 2), to be implemented on local or server(s) hosting downloaded data.

On the other hand, it is clear that the organization of subdirectories (below main directory) is somehow dependent upon different considerations about original data formats, organization and complexity. Just to provide few examples, data can be downloaded on a daily or monthly time frequency basis, provided as GeoTIFF (i.e. one file per each time step) or as multi-temporal NetCDF files. Such a complexity inevitably affects and shapes subsequent *naming* choices and adopted convenctions.

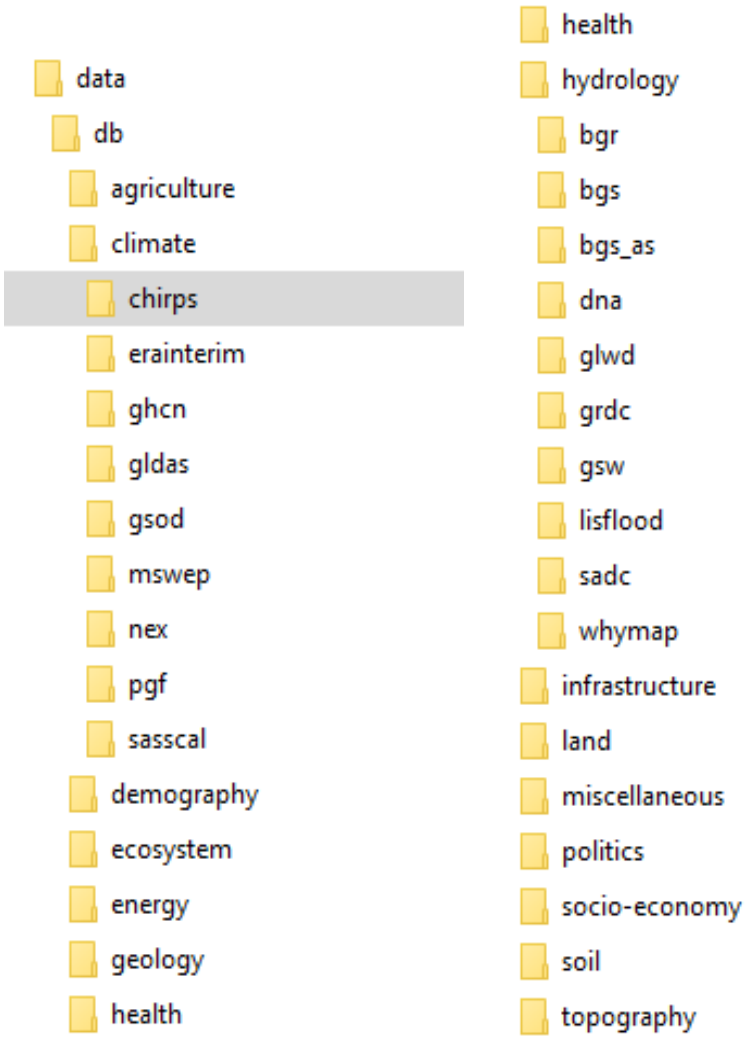

Figure 2 – Proposed directories tree for data organization

The need for having datasets locally accessible is related, among others, to:

- pre-processing requirements, otherwise not supported by remote servers (i.e. reprojecting, format change, etc…);

- difficult or discontinued remote servers accessibility;
- computation needs and/or performance (i.e. computation times too long, model unable to access data remotely);
- datasets harmonization.

Further to the above, local datasets replication makes sense for:

- Huge datasets, implying long downloading (and possibly some pre-processing) time;
- Datasets of high relevance and frequent usage (in order to limit overload of repeated downloading and pre-processing);
- Time invariant datasets, i.e., for most of the applications (except subsidence analysis), topographic elevations models;
- Time variant datasets, for which first two points above hold true, and incremental update is available.

On the other hand, local data replication also poses challenges inherent to data duplication risks, as potential lack of consistency (i.e. remote original data source being updated for whatever reason) and waste of disk space and resources (both technical and human power).

Most of the data sets currently reported in the metadata table derive from remote sensed data sources, they are provided in raster formats (i.e. geoTiff, NetCDF) and are particularly suitable to be organized as distinct files in a directories-tree structure. From this perspective, the metadata table suggests, through the '*category*' attribute, a possible directory structure for local information organization.

Vector datasets (i.e. shape files reporting location of ground monitoring stations) and text/spreadsheet files (i.e. monitored time series) can be downloaded locally as well, they can be maintained in their original format. They could be further processed (i.e. data tidying, cleaning, and any other pre-processing) and migrated to a dedicated relational and/or spatial databases for efficient maintenance and querying. For the moment being, no specific relational or spatial database development have been addressed.

The database is open to updates, as new design and data sources are spotted or are made available, acting as a living data source to support ongoing ACEWATER2 project activities.

Contents of current database can be integrated at any stage within other existing Water Information Systems (i.e. ZAMWIS from ZAMCOM).

2 African Initiatives on Water Resources Management

In the early phase of ACEWATER2 project, a review of few African initiatives on water resources management (terminated or ongoing) has been conducted (ref. report STIS IV Framework Contract DI/07446-00 Lot 3, 2016; Table 1). By providing a preliminary list of datasets/databases made available in the framework of the projects, the report contributed as a starting point to current report and development of the hydro-climatological database.

Initiative list (Table 1) and a short synoptic table per each reported initiative is provided here below.

Table 1 - Table of African Initiatives on Water Resource Management.

PROJECT NAME	OBJECTIVE	REGION	MAIN PRODUCT
FRIEND-Water (Flow Regimes from International Experimental Programme and Network Data)	Understand of hydrological variability, model and techniques sharing.	Worldwide, with sub-projects at regional scale	Niger-HYPE (Andersson at al, 2014)
FRIEND-NILE	Cooperative research on water resources in Nile river Basin	Nile River Basin Countries	See project URL
TIGER-NET	Satellite based assessment and monitoring of water resources	Africa	WOIS Open-Source Water Observation and Information (https://github.com/TIGER-NET)
ISARM	Improving the understanding of scientific, socio-economic, legal, institutional and environmental issues related to the management of transboundary aquifers.	worldwide	WHYMAP
African Flood and Drought Monitoring System	Development of a webgis	Africa	Webgis (http://stream.princeton.edu/AWCM/WEBPAGE/interface.php
HyDIS/G-WADI	Global Capacity to manage the Water Resources of Arid and Semi-arid areas	worldwide	Precipitation Mapping Server: http://hydis.eng.uci.edu/gwadi/

CSIR/SADCO	Dataset (hydro-climatology, weather station,ecc…)	Africa	Dataset url: http://sadco.csir.co.za/data.html

Source: STIS IV Framework Contract DI/07446-00 Lot 3 (2016).

2.1 FRIEND-Water

The FRIEND-Water programme (Flow Regimes from International Experimental and Network Data) is an international research programme that helps to set up regional networks for analysing hydrological data. It aims to develop better understanding of hydrological variability and similarity across time and space, through the mutual exchange of data, knowledge and techniques at the regional level. The advanced knowledge of hydrological processes and flow regimes gained through FRIEND-Water helps to improve methods applicable in water resources planning and management. A generic overarching scientific objective has been to improve the understanding of the similarity and hydrological variability across different regions of the world, and to share models and techniques between countries, organizations and researchers. The current research covers a diverse range of topics including low flows, floods, variability of regimes, rainfall/runoff modelling, processes of stream flow generation, sediment transport, snow and glacier melt, climate change and variability and its uncertainties, and land-use impacts. FRIEND-Water also provides support to researchers and operational staff of hydrological services in developing countries, thereby contributing to their capacity to assess and manage their own national water resources. It thus contributes to the goal of providing a reliable supply of freshwater to the world's poor. In Table 2 a summary of the action is illustrated.

Table 2 - FRIEND-Water resume table

TITLE	FRIEND-Water
OBJECTIVE	Understand of hydrological variability, model and techniques sharing.
GEOGRAPHICAL SCOPE	Worldwide, with sub-projects at regional scale
PARTNERS	UNESCO, Division of Water Sciences, Wageningen University
DURATION	25 years prior to 2014 (latest report available on line)
OUTCOMES	See proceeding in FRIEND-Water 2014 conference (see URL)[1]
URL	https://en.unesco.org/themes/water-security/hydrology/programmes/friend

[1] Among tha abstracts, reference is made to HYPE-Niger Hydrological Model (Andersson at al,2014)

2.2 FRIEND-Nile

The FRIEND/Nile project is a member of the Global FRIEND family. The FRIEND/Nile is a cooperative research project in the field of water resources management in the Nile basin given the complex hydro-politics and conflict situation. The project was initiated by UNESCO in March 1996. The project aims at creating a better understanding and quantification of the river Nile system to enhance the management of the Nile water resources. This is also done to improve the planning of water resources projects in the Nile Basin countries. This is in addition to understanding the flow regimes on various scales based on regional data of experimental basins and hydrological networks. The FRIEND/Nile aims at enhancing an integrated management of the water resources of the Nile and its tributaries through enhanced cooperation amongst the Nile countries. This will ultimately contribute to meet the basic human needs of safe water supply. It will also help in promoting sustainable development of the region.

Immediate objectives:

- To enhance the capacity building and collaboration between the water experts of the existing Nile basin countries;
- To enhance research cooperation among Nile Basin countries through hydrological research projects on selected topics, conducted by researchers from all participating countries;
- To increase the number of trained personnel in the region with the view to improve the sustainability of the present initiative and to reduce, in the longer term, the dependence on external support agencies;
- To enhance the networking between training institutions in the countries of the region;
- To enhance the linkage with similar institutions worldwide.

Participating Countries:

Six Nile basin countries showed interest and willingness to participate in the project. These countries are: Ethiopia, Uganda, Kenya, Tanzania, Sudan, Egypt. Recently, however, the project has been opened to all interested other Nile basin countries. The Water

Resources Research Institute (WRRI) of Egypt is the overall coordinator of the project.

In Table 3 a summary of the action is illustrated.

Table 3 - FRIEND-Nile resume table.

TITLE	FRIEND-NILE
OBJECTIVE	Cooperative research on water resources in Nile river Basin
GEOGRAPHICAL SCOPE	Nile River Basin
PARTNERS	UNESCO + Ethiopia,Uganda,Kenya,Tanzania,Sudan,Egypt
DURATION	2001-2006 (first phase)

OUTCOMES	See URL
URL	http://www.unesco.org/new/en/cairo/natural-sciences/hydrology-programme/friendnile/friendnile-first-phase/

2.3 TIGER-NET

TIGER-NET is a major component of the TIGER initiative of the European Space Agency (ESA), whose main goal is the Support of the African Earth Observation Capacity for Water Resource Monitoring in close collaboration with African water authorities and experts. TIGER-NET supports the satellite based assessment and monitoring of water resources from watershed to cross-border basin level delivering indispensable information for Integrated Water Resource Management (IWRM) through:

1. Development of an open-source Water Observation and Information System (WOIS) for monitoring, assessing and inventorying water resources in a cost-effective manner;
2. Capacity building and training of African water authorities and technical centres to fully exploit the increasing remote observation capacity offered by current and upcoming generations of satellites, including the ESA Sentinel's.

The project is built upon a close collaboration with the host institutions for the specification, testing and demonstration of the WOIS. The initial key host institutions already actively involved in TIGER-NET are the Nile Basin Initiative, Lake Chad Basin Commission, Volta Basin Authority, Department of Water Affairs South Africa and the Hydrologic Division of the Namibian Ministry of Agriculture, Water and Forestry and the Department of Water Affaires of the Zambian Ministry of Mines, Energy and Water Development, Instituto Nacional de Meteorologia, International Water Management Institute, United Nations World Food programme, the Zambezi Watercourse Commission and the Action against Hunger.

In Table 4 a summary of the action is illustrated.

Table 4 - TIGER-NET resume table.

TITLE	TIGER-NET
OBJECTIVE	Satellite based assessment and monitoring of water resources
GEOGRAPHICAL SCOPE	Africa
PARTNERS	ESA , in collaboration with Nile Basin Initiative, Lake Chad Basin Commission, Volta Basin Authority, Department of Water Affairs South Africa and the Hydrologic Division of the Namibian Ministry of Agriculture, Water and Forestry and the Department of Water Affaires of the Zambian Ministry of Mines, Energy and Water Development, Instituto Nacional de Meteorologia, International Water Management Institute, United Nations World Food programme, the Zambezi Watercourse Commission and the Action against Hunger.
DURATION	2015-Present

OUTCOMES	WOIS Open-Source Water Observation and Information (https://github.com/TIGER-NET)
URL	http://www.tiger-net.org/

2.4 ISARM

ISARM (Internationally Shared Aquifer Resources Management). An initiative to set up a network of specialists and experts to compile a world inventory of transboundary aquifers and to develop wise practices and guidance tools concerning shared groundwater resources management. The worldwide ISARM (Internationally Shared Aquifer Resources Management) Initiative is an UNESCO and IAH led multi-agency effort aimed at improving the understanding of scientific, socio-economic, legal, institutional and environmental issues related to the management of transboundary aquifers. The issue of shared international waters is as old as the national borders that make those waters international. During the last century, a significant progress has been made in regulation of joint management of surface watercourses; many international river-, lake- or basin commissions have been set up and the legal treaties signed. Although some of these activities address "a groundwater component" as well, major comparable efforts related to the invisible groundwater have started just a several years ago with the ISARM Programme. Since its start in 2002, ISARM has launched a number of global and regional initiatives. These are designed to delineate and analyse transboundary aquifer systems and to encourage riparian states to work cooperatively toward mutually beneficial and sustainable aquifer development. In Table 5 a summary of the action is illustrated.

Table 5 - ISARM resume table.

TITLE	ISARM (Internationally Shared Aquifer Resources Management)
OBJECTIVE	Improving the understanding of scientific, socio-economic, legal, institutional and environmental issues related to the management of transboundary aquifers.
GEOGRAPHICAL SCOPE	worldwide
PARTNERS	UNESCO and IAH
DURATION	2002-Present
OUTCOMES	WHYMAP
URL	https://isarm.org/

2.5 African Flood and Drought Monitoring System

Drought is one of the leading impediments to development in Africa. Much of the continent is dependent on rain-fed agriculture, which makes it particularly susceptible to climate

variability. Monitoring drought and providing timely seasonal forecasts are essential for integrated drought risk reduction. Current approaches in developing regions have generally been limited, however, in part because of unreliable monitoring networks. Operational seasonal climate forecasts are also deficient and often reliant on statistical regressions, which are unable to provide detailed information relevant for drought assessment. However, the wealth of data from satellites and recent advancements in large-scale hydrological modelling and seasonal climate model predictions have enabled the development of state-of-the-art monitoring and prediction systems that can help address many of the problems inherent to developing regions. An experimental drought monitoring and forecast system for sub-Saharan Africa is described that is based on advanced land surface modelling driven by satellite and atmospheric model data. Key elements of the system are the provision of near-real-time evaluations of the terrestrial water cycle and an assessment of drought conditions. The predictive element takes downscaled ensemble dynamical climate forecasts and provides, when merged with the hydrological modelling, ensemble hydrological forecasts. We evaluate the overall skill of the system for monitoring and predicting the development of drought and illustrate the use of the system for the 2010/11 Horn of Africa drought. A key element is the transition and testing of the technology for operational usage by African collaborators and we discuss this for two implementations in West and East Africa. In Table 6 a summary of the action is illustrated. The African Flood and Drought Monitoring System is a Web database provided by Princeton University, the URL is written in Table 6.

Table 6 - African Flood and Drought Monitoring System resume table.

TITLE	African Flood and Drought Monitoring System
OBJECTIVE	mproving the understanding of scientific, socio-economic, legal, institutional and environmental issues related to the management of transboundary aquifers.
GEOGRAPHICAL SCOPE	Africa
PARTNERS	Princeton University
DURATION	Prior to October 2013
OUTCOMES	Web database (see UR)L
URL	http://stream.princeton.edu/AWCM/WEBPAGE/interface.php?locale=en

2.6 HyDIS/G-WADI

The Global Network on Water and Development Information for Arid Lands (G-WADI) was established to strengthen the global capacity to manage the water resources of arid and semi-arid areas around the globe through a network of international and regional cooperation. The network promotes regional and international cooperation in arid and semi-arid areas, and aims to build an effective global community through the integration of selected material from networks, centres, organizations, and individuals. G-WADI's Objectives are:

- Improved understanding of the special characteristics of hydrological systems and water

- management needs in arid areas
- Capacity building of individuals and institutions
- Broad dissemination of information on water in arid zones to the user community and the public
- Exchange of experience
- Promoting integrated basin management and the development and use of appropriate decision
- support tools

Among these objectives, STIS IV Framework Contract DI/07446-00 Lot 3 (2016) cites the Hydrologic Data and Information System (HyDIS), being a precipitation mapping service. This service provides access to precipitation products from the Precipitation Estimation from Remote Sensing Observation using Artificial Neural Networks (PERSIANN) system, which is designed and operated at the Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine. The Precipitation service is based on implementing the "Open-Source" University of Minnesota MapServer along with various JavaScript and CGI codes based on Perl and C language. The objective of the server is to provide interactive access to near-real-time PERSIANN global products. In Table 7 a summary of the action is illustrated.

Table 7 - HYDIS/G-WADI resume table.

TITLE	HYDIS/G-WADI (Global Network on Water Resources Management in Arid and Semi-arid Zones)
OBJECTIVE	global capacity to manage the water resources of arid and semi-arid areas
GEOGRAPHICAL SCOPE	worldwide
PARTNERS	UNESCO, SAHRA,IAEA,
DURATION	2004-present
OUTCOMES	http://hydis.eng.uci.edu/gwadi/
URL	http://gwadi.org/

2.7 CSIR/SADCO

The CSIR is one of the SANWATCE members, The CSIR has in recent years embarked on the development of the first African-based earth system model. This multi-disciplinary effort is driven by CSIR experts in global change research in close collaboration with key international partners in Australia, Japan and France. In Table 8 a summary of the action is illustrated.

Table 8 - CSIR/SADCO resume table.

TITLE	CSIR/SADCO (Sothern Africa Data Centre for Oceonography)
TYPE	Dataset (hydro-climatology , weather station,ecc…)
GEOGRAPHICAL SCOPE	Sothern Africa
PARTNERS	CSIR (NEPAD SANWATCE member), South African Wether Services and other local research institutions
DURATION	2004-present
OUTCOMES	Dataset (see URL)
URL	http://sadco.csir.co.za/data.html

3 Database

3.1 Database Topics Summary

Hydro-climatological database, developed in this framework, addresses a wide range of topics related to water, at global, continental and river basin scale.

Data can be roughly categorized as belonging to groups below:

- **Biophysical** data - water availability as a function of topographic, climatic and hydrological characteristics;
- **Water use** data, as water supply for human consumption, agriculture, industry, mining, energy (hydropower);
- **Socio-Economic and Political** data, relevant to water governance, water management policies and assessment of overall socio-economic dynamics.

Biophysical data include, among others,

- topography (Figure 3) ;
- river network and sub-basin delineation (Figure 4);
- climatic variables, including temperature and precipitation (Figure 5 and Figure 6);
- soils characteristics (Figure 7);
- land cover (Figure 8);
- Runoff (Figure 9);
- Surface Water (Figure 10);
- Groundwater (Figure 11 , Figure 12 and Figure 13).

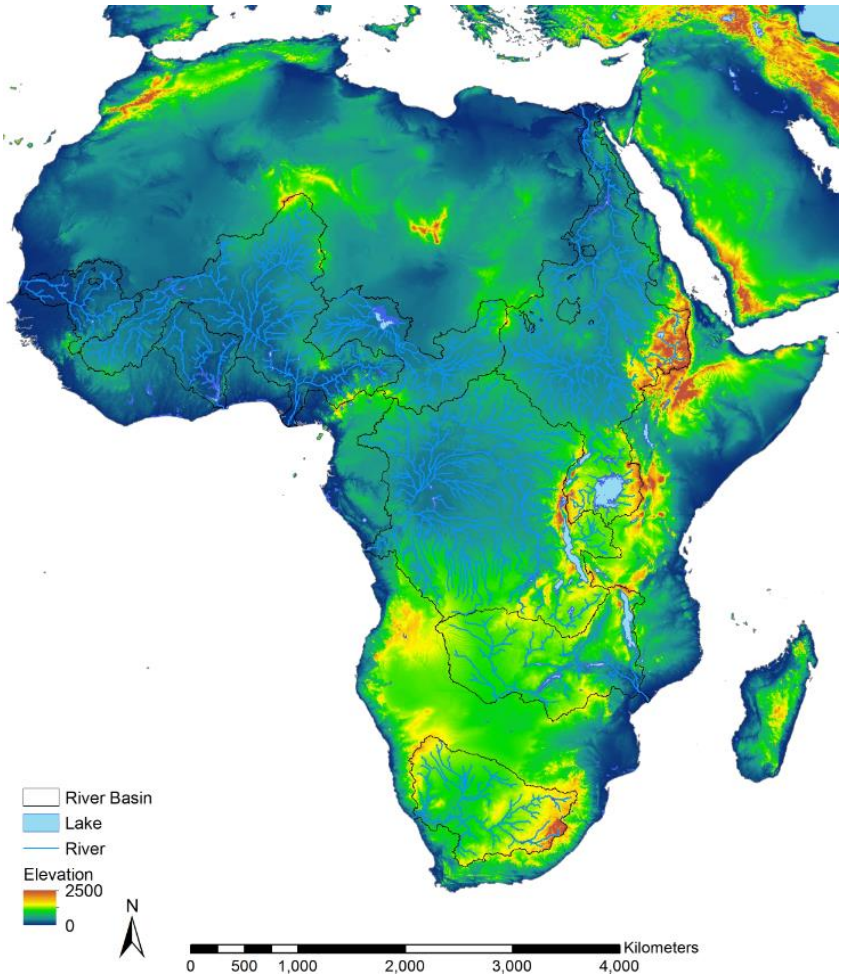

Figure 3 - Digital Elevation Data (Reuter et al., 2007; USGS, 2016)(Figure from Farinosi et al,2017b).

Figure 4 - River network and surface water, i.e. lakes and wetlands, as resulting from the analysis of the Digital Elevation Data (Beck et al., 2014; Lehner and Döll, 2004; Lehner and Grill,2011)(Figure from Farinosi et al,2017b).

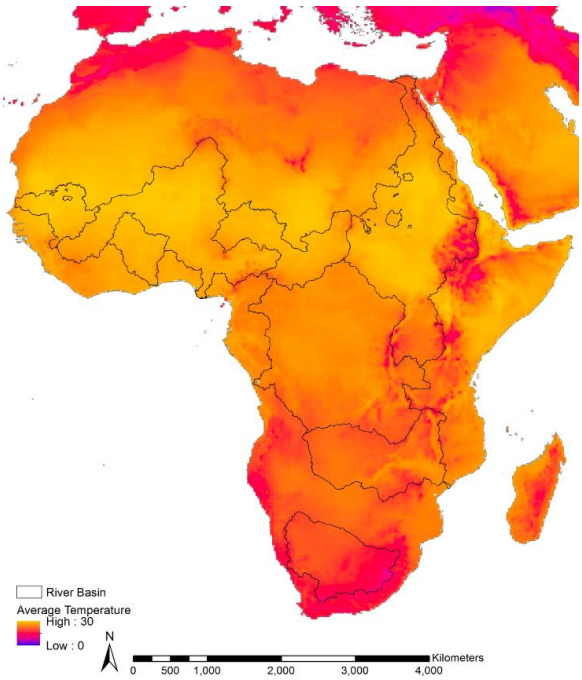

Figure 5 - Average Temperature (°C) in the study domain in the period 1997-2012. (Beck et al., 2017) (Figure from Farinosi et al,2017b)

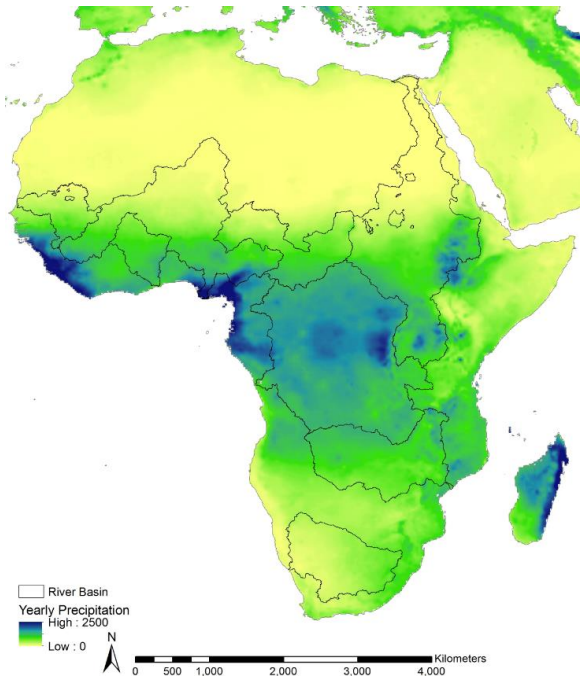

Figure 6 - Yearly total precipitation (mm) in the study domain in the period 1997-2012. (Beck et al., 2017) (Figure from Farinosi et al,2017b)

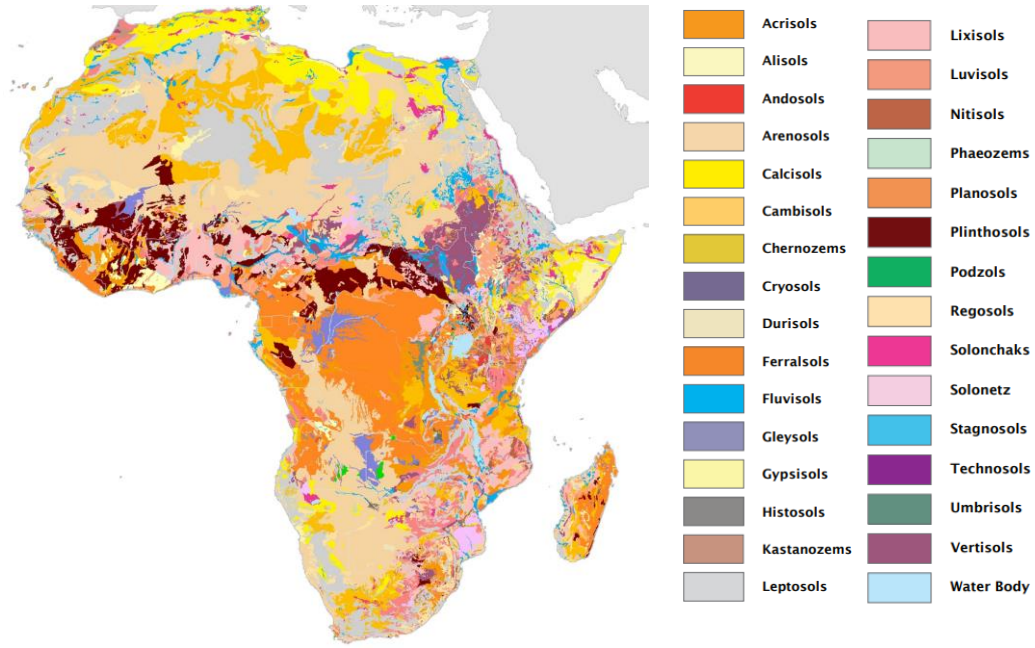

Figure 7 - African Soil, Figure from Jones et al. (2013). (Figure from Farinosi et al,2017b)

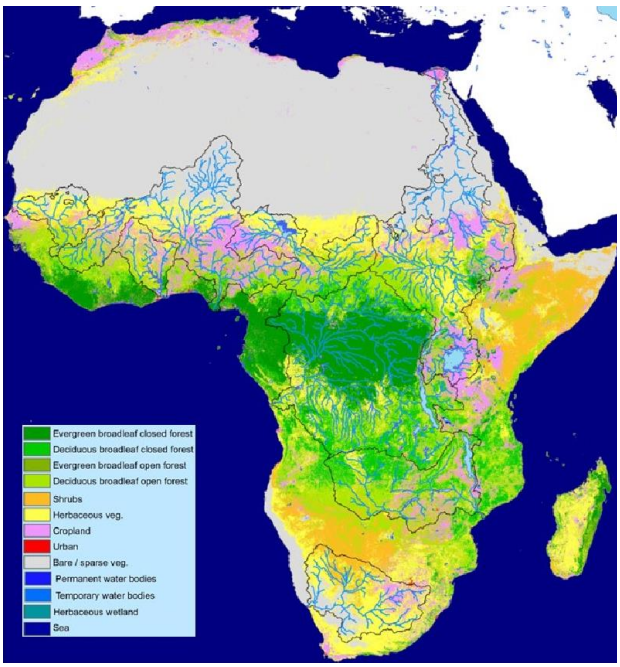

Figure 8 - . Copernicus Global Land Service (CGLS) yearly Land Cover (LC) map at 100m resolution for the African Continent. (Copernicus Service Information, 2017) (Figure from Farinosi et al,2017b)

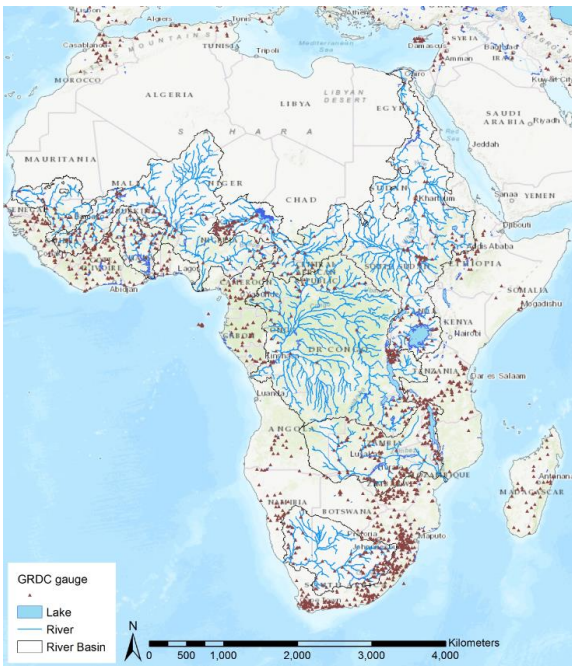

Figure 9 - GRDC gauging stations. (GRDC, 2017) (Figure from Farinosi et al,2017b)

Figure 10 - Global surface water occurrence data. (Pekel et al., 2016)(Figure from Farinosi et al,2017b)

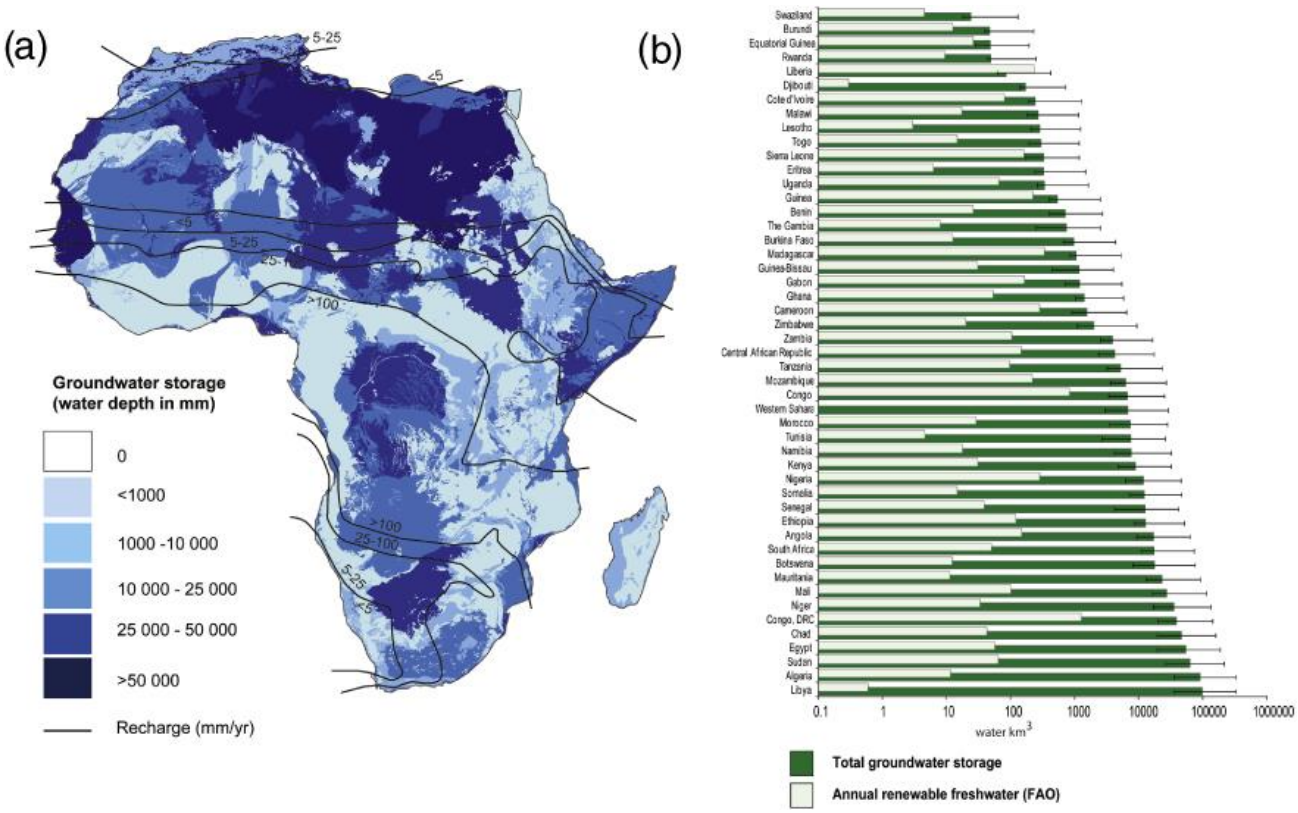

Figure 11 - Recharge, groundwater storage and annual renewable freshwater (Figure from MacDonald et al., 2012)

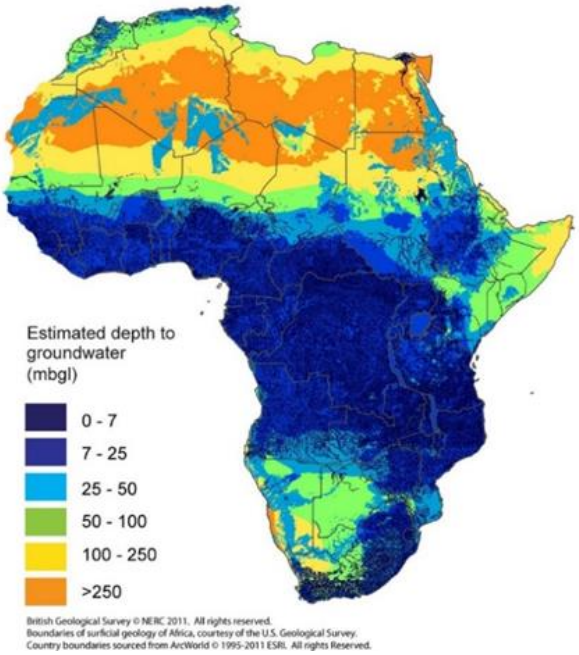

Figure 12 - Estimated groundwater depth (Figure from MacDonald et al., 2012)

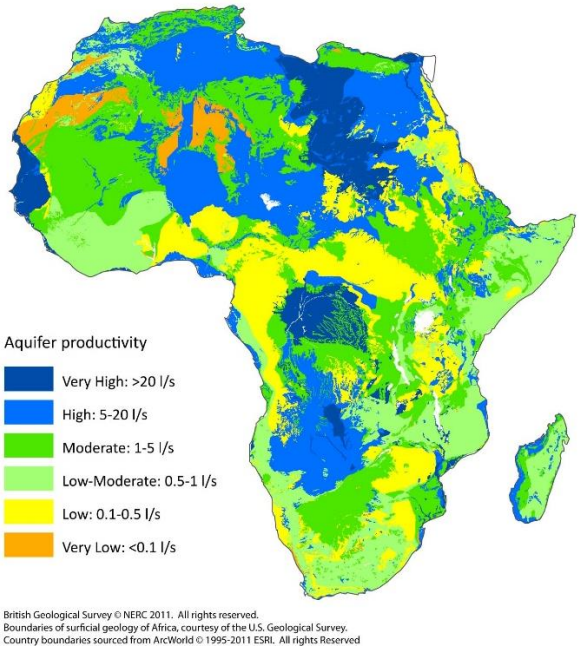

Figure 13 - Aquifer productivity (Figure from MacDonald et al., 2012)

Hydrological analysis supports water availability assessment in space and time.

However water availability, as well as water quality, is also strongly dependent upon socio-economic activities and specifically water use, whose characterization is as complex as key to effective modelling of ongoing WEFE nexus dynamics analysis.

Examples of relevant datasets:

- Agriculture (Figure 14);
- Livestock and fishery (Figure 15 and Figure 16);
- Hydropower (Figure 17 and Figure 18);
- Mining industry.

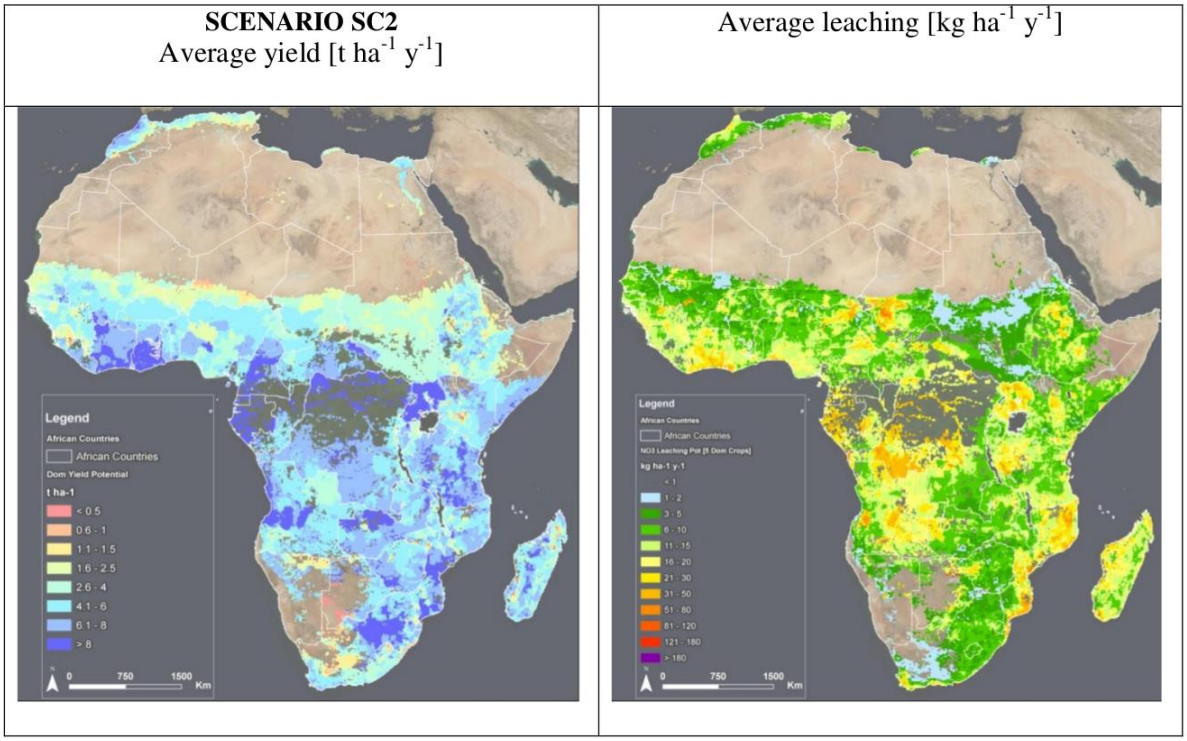

Figure 14 – Comparison of average yields and nitrogen leaching for dominant crops under different manegement strategies in Africa (From Fig. 16 in Patori et al, 2011).

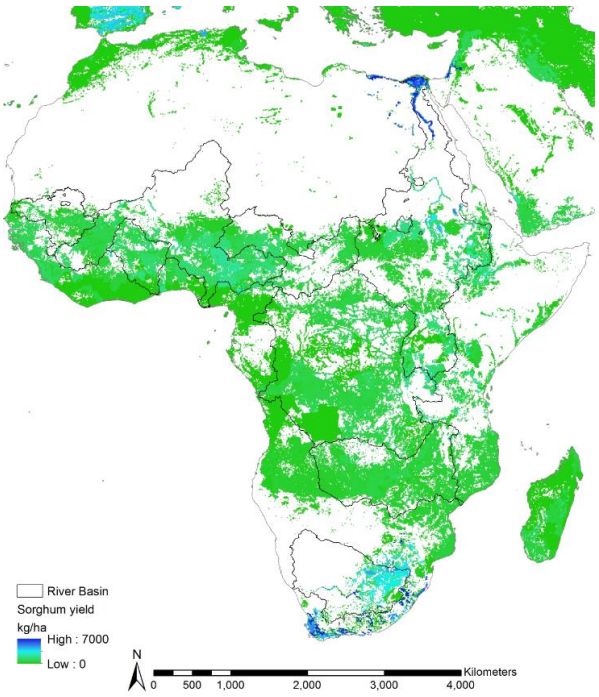

Figure 15 - Example of farming and livestock production spatial distribution in the African Continent: sorghum (IFPRI and IIASA, 2017; Robinson et al., 2014).

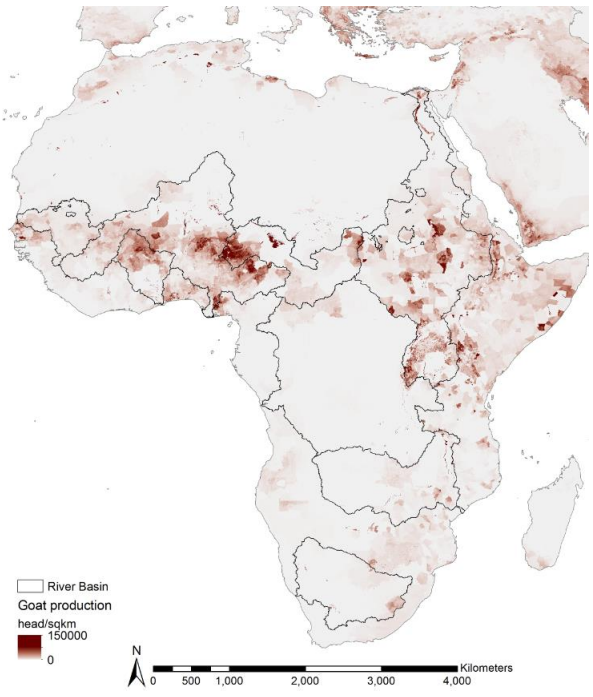

Figure 16 - Example of farming and livestock production spatial distribution in the African Continent: goats heads (IFPRI and IIASA, 2017; Robinson et al., 2014).

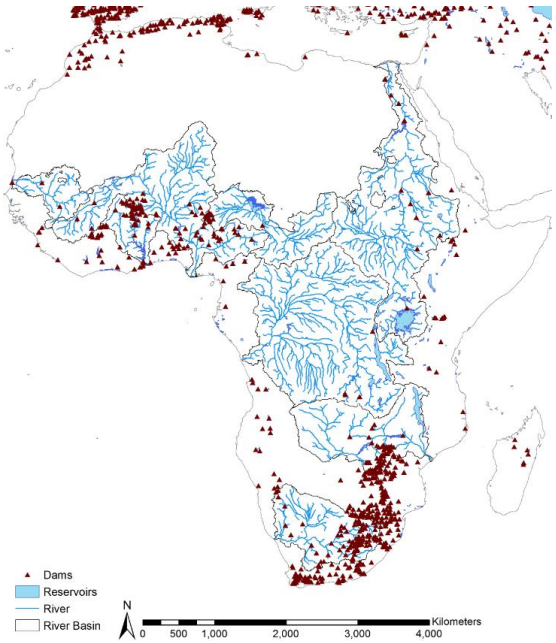

Figure 17 - Water retention infrastructures in the African Continent: Existing dams and impoundments. (Lehner et al., 2011)(Figure From Fariosi et al,2017b).

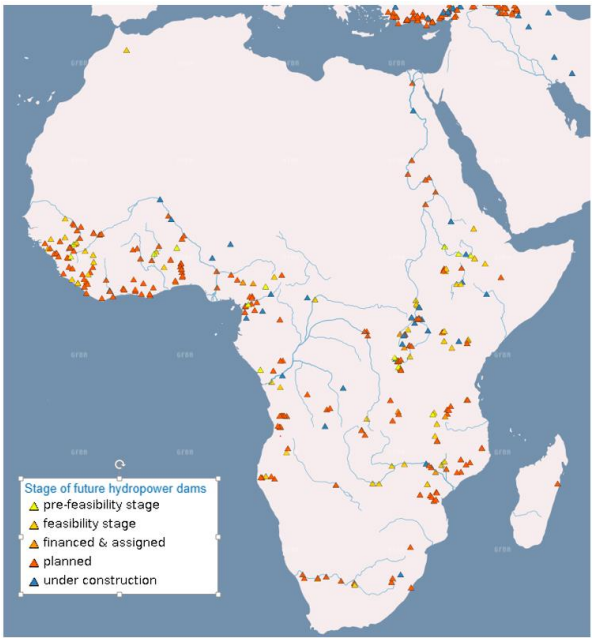

Figure 18 - Future dam developments (Zarfl et al., 2015). Figure credit: Global Freshwater Biodiversity Atlas.

The analysis of the water management in the African continent is completed considering also the socio-economic dynamics that are more likely to impact (or being affected by) water uses.

Therefore, the database include data as:

- gross domestic product and its dependency on the agricultural sector (Figure 19 and Figure 20);
- political and military importance of the countries , represented by the Composite Index of National Capability (CINC) derived from the National Material Capabilities (NMC v5.0) database within the Correlates of War project (COW), and the institutional quality is derived by the Worldwide Governance Indicators (WGI) project (Figure 21 and Figure 22);
- Population dynamics, relevant to understand the historical pressure on water resources and its future evolution (Figure 23 and Figure 24);
- Ethnic groups and other cultural and traditional features are relevant for understanding the social dynamics that are likely to impact on water management at local and national level (Figure 25, Figure 26, Figure 27 and Figure 28).

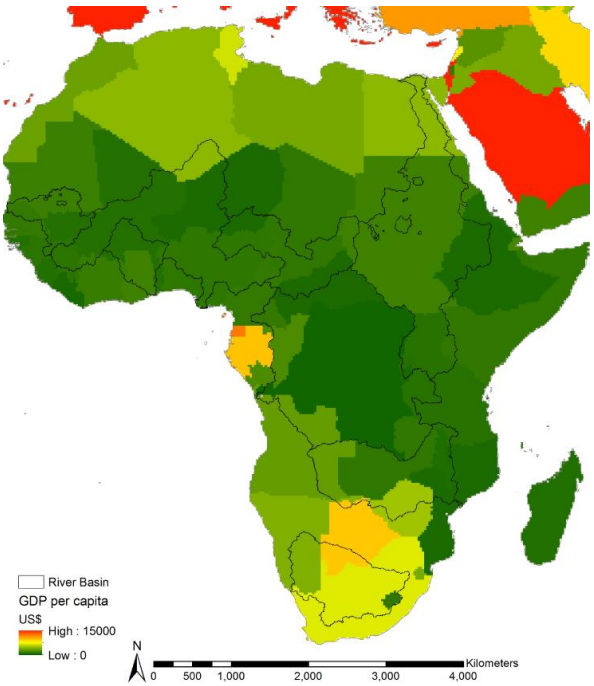

Figure 19 - Per capita gross domestic product (Farinosi et al,2017b).

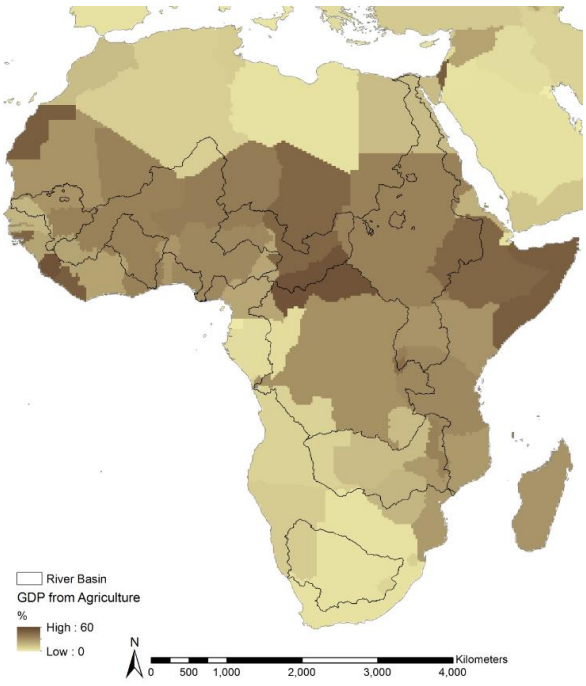

Figure 20 - Economic dependency on the agricultural sector (Farinosi et al,2017b).

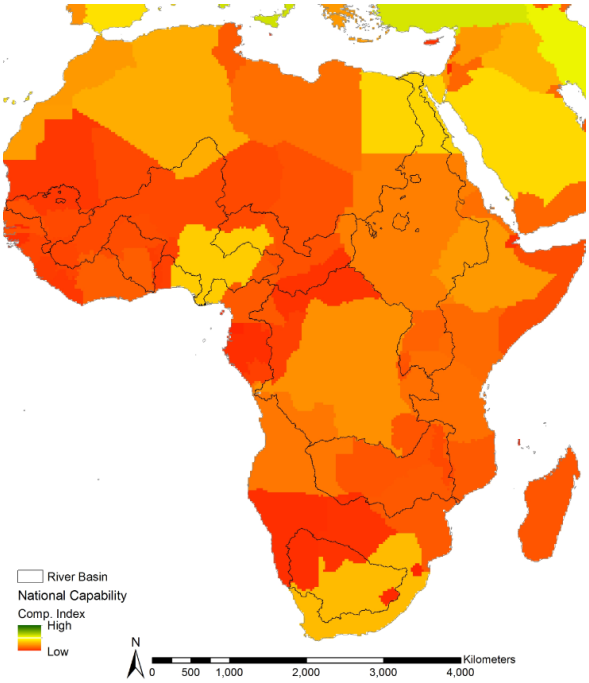

Figure 21 - Composite Index of National Capability. (Kaufmann et al., 2010; Singer et al., 1972)(Figure From Farinosi et al,2017b)

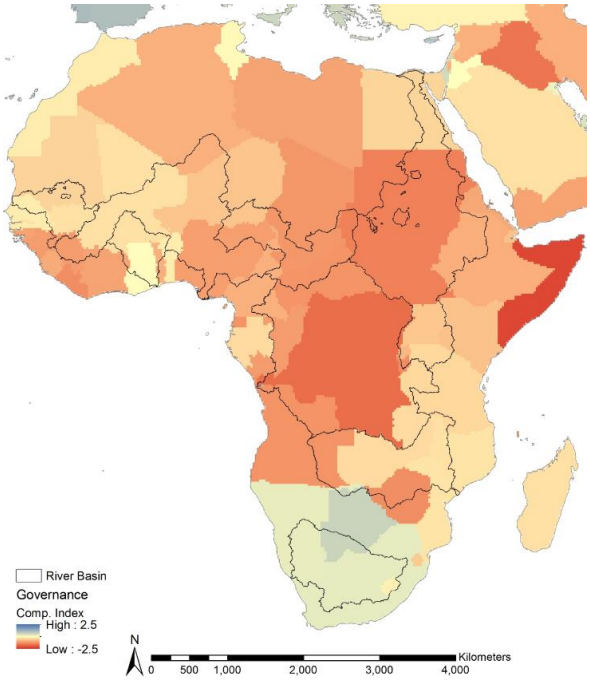

Figure 22 - Governance indicator. (Kaufmann et al., 2010; Singer et al., 1972) (*Figure From Farinosi et al,2017b)*

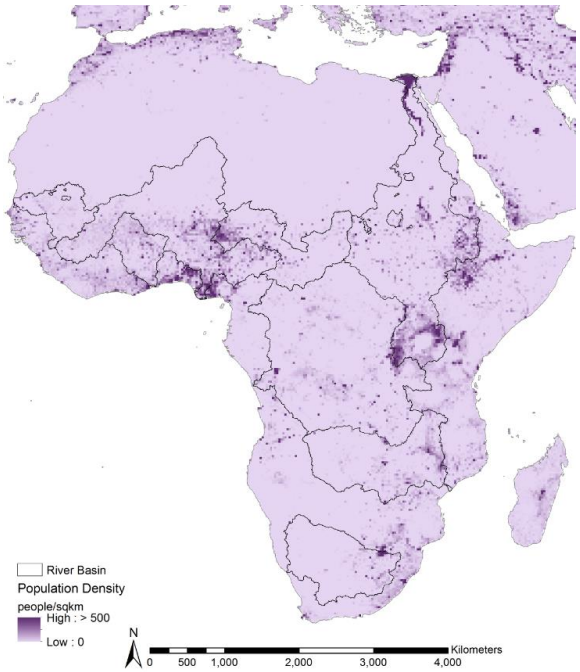

Figure 23 - Population distribution in the African continent. (CIESIN, 2015; Freire and Pesaresi, 2015; World Bank, n.d.)(Figure From Farinosi at al, 2017b)

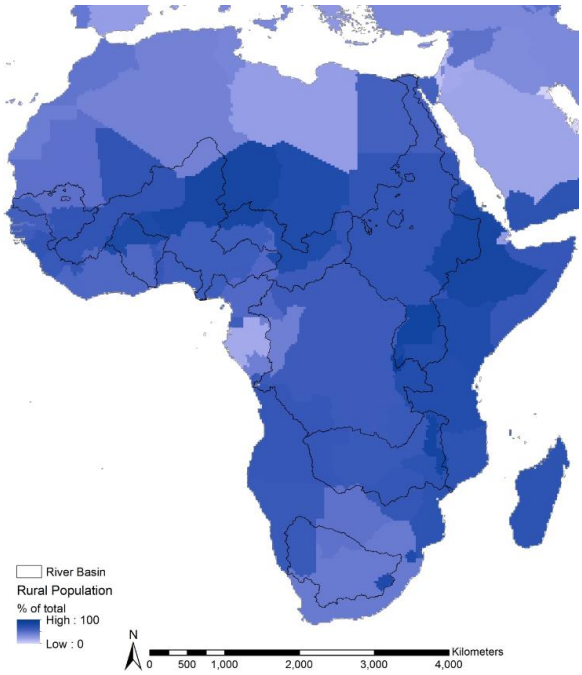

Figure 24 - Percentage of the population living in rural areas at country level (CIESIN, 2015; Freire and Pesaresi, 2015; World Bank, n.d.)(Figure From Farinosi et al, 2017b)

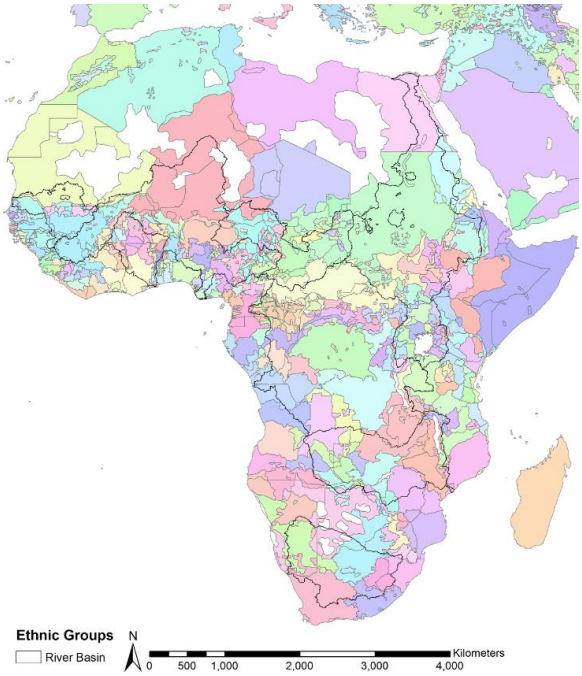

Figure 25 – Ethnic Groups distribution in the African Continent. (Raleigh et al., 2010; Vogt et al., 2015; Weidmann et al., 2010)(Figure From Farinosi at al, 2017b)

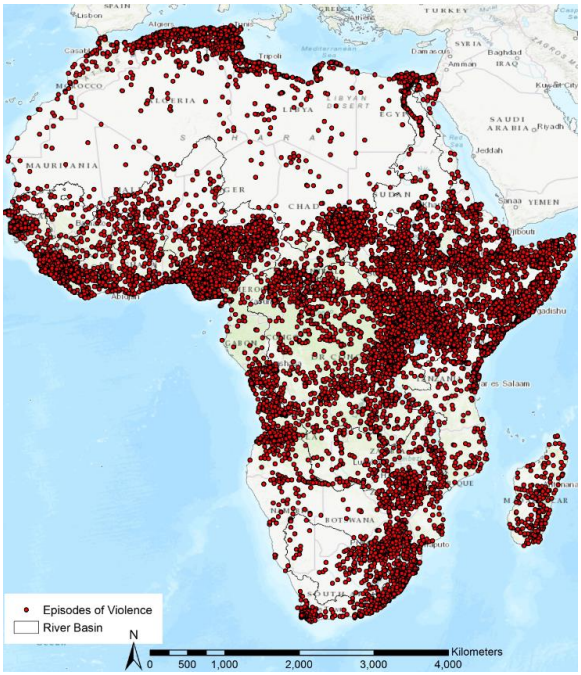

Figure 26 - Spatial distribution of the episodes of violence recorded between 1999 and 2016 (Raleigh et al., 2010; Vogt et al., 2015; Weidmann et al., 2010)(Figure From Farinosi et al,2017b)

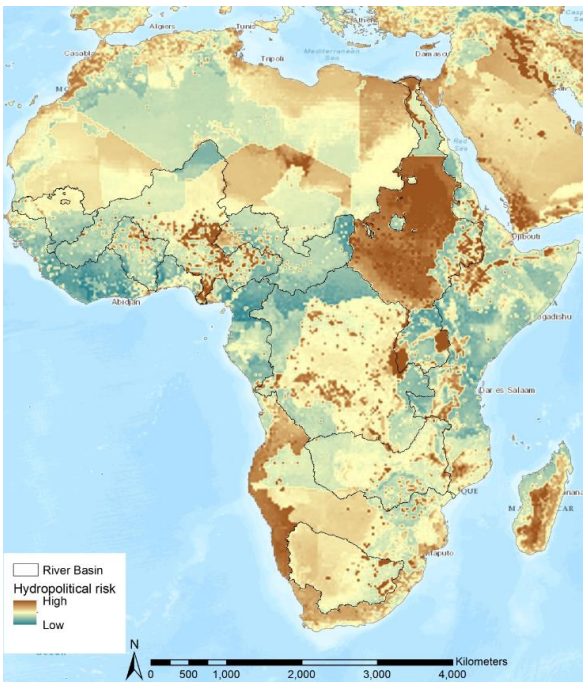

Figure 27 - Hydro-political risk in the African Continent (De Stefano et al., 2012; Farinosi et al., 2017b)

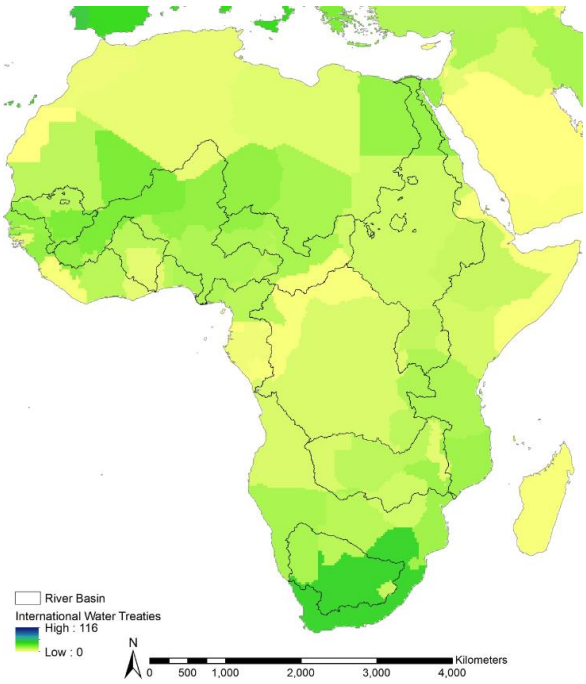

Figure 28 - International (bi- or multi-lateral) Water Treaties) (De Stefano et al., 2012; Farinosi et al., 2017b)

Definitely, the hydro-climatological database is a collection of metadata about public (freely available or available upon registration) and private environmental and socio-economic spatio-temporal datasets. Metadata, that's data about data, include information as data type, format, keywords, spatial and temporal resolutions, geographical extent, temporal frequency, textual definitions and description, use limitations, etc.., acting as efficient entry point to data querying and accessing.

Next sub-sections focus on:

- Metadata database architecture;
- Main reported datasets.

3.2 Database Structure

This section illustrates the metadata database architecture:

- **metadata fields table** provides details of metadata attributes, including extended textual description and/or format issues;
- **metadata table** reports information about datasets, namely all relevant metadata already referred to in previous section (data type, format, keywords, spatial and temporal resolutions, geographical extent, temporal frequency, textual definitions and description, use limitations, url references to access further information and download datasets, etc..). Metadata table attributes are a subset of typical information as defined in standard metadata formats, as FGDC and ISO;
- **category table** lists all categories relevant to datasets classification;
- **keyword table** lists keywords to be attached to datasets and relevant to efficient querying/accessing.

A metadata key attribute is the "*source*", referencing datasets url (http, https, ftp, etc …) through which they can be downloaded, i.e. for analysis.

Database architecture is graphically captured in Figure 29.

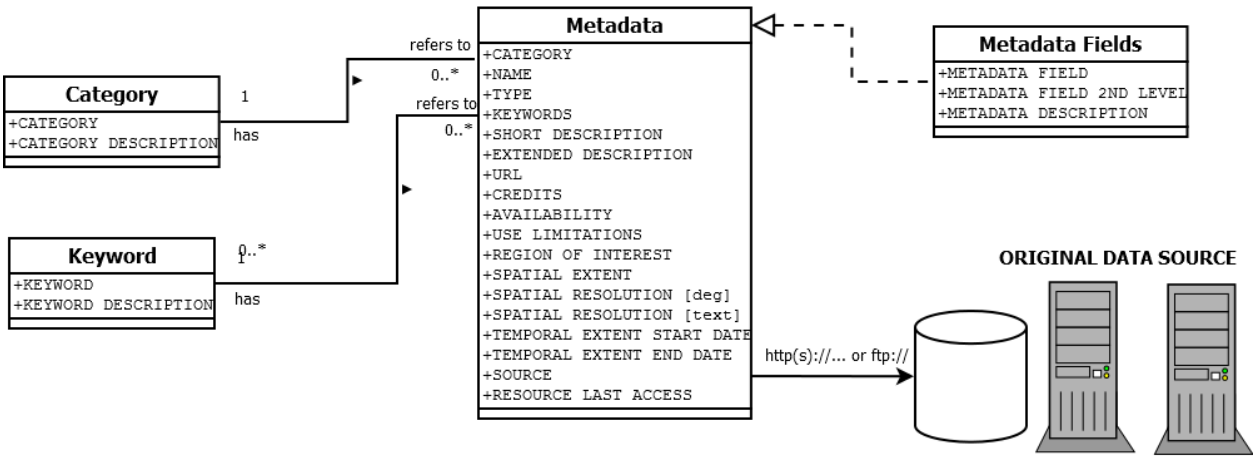

Figure 29 - A graphical representation of database structure

3.2.1 Metadata fields table

The table reports field name and description of metadata attributes (Table 9). As such, the table serves both as guidance and documentation of metadata table architecture, relevant for system final user.

Table 9 - Metadata Fields Table

Metadata Fields	**Metadata Field Description**
CATEGORY	Category of the data set
NAME	Identification Name of the dataset
TYPE	Type of the data set (if specified) (e.g. raster, vector)
FORMAT	Format of the the files contained the dataset that can be downloaded (e.g. tif,shp,txt,xls,zip,...)
KEYWORDS	Keywords of the data set
SHORT DESCRIPTION	Short description of the data set
EXTENDED DESCRIPTION	Extended description of the data set
URL	URL of the data set web page
CREDITS	Credits and references to peer-reviewed publication where the dataset was published.
AVAILABILITY	Brief summary on the availability of the data set (i.e. « FREE », « REGISTRATION REQUIRED », « PRIVATE », « PAID ACCESS » or « NOT ACTUALLY AVAILABLE »)
USE LIMITATIONS	Terms and conditions of use of the data set.
REGION OF INTEREST	Textual description of the area covered by the data set (spatial extent) (e.g. « Africa », »Southern Africa », « Africa and Europe » , « World »).
"SPATIAL EXTENT deg"	Area covered by the data set expresses as a geospatial extent with longitude and latitude coordinates (for instance . « -180, 180, -90, 90 (xmin, xmax, ymin, ymax)(W,E,S,N) » if the region of interest is « World ») . The coordinate reference system is EPSG 4326 (+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs).
SPATIAL RESOLUTION Deg	Spatial resolution expressed in degrees (deg) when available.
SPATIAL RESOLUTION text description	Human-readable textual description of the spatial resolution.
TEMPORAL EXTENT - START DATE	Temporal extent – start date of the data set (if the data set is dynamic). Date format must be in ISO 8601

TEMPORAL EXTENT - END DATE	Temporal extent – end date of the data set (if the data set is dynamic). Date format must be in ISO 8601
TEMPORAL FREQUENCY	Temporal resolution of the data set (i.e. « static », « none », « not specified » « multi-year », « yearly » , « multi-month » , « monthly » , « multi-day » , « daily » , « sub-daily «).
SOURCE	Source of the data set (in most cases it is the URL of the web page where the data set can be directly downloaded).
"RESOURCE LAST ACCESS date ISO 8601"	Date of the latest day when the URL of data set was visited and verified.

3.2.2 Metadata Table

The table contains metadata (annex 1) about available datasets.

Metadata can be accessed by project partners through the Aquaknow web platform at the following url: https://aquaknow.jrc.ec.europa.eu/7551/documents/metadata-environmental-and-socio-economic-public-and-private-datasets.

The Metadata Table can be found in Annex 1. A summary of the collected datasets, corresponding to each row of this table, is reminded to the next section.

3.2.3 Category Table

Category Table reports dataset categories. It contains description of each category. There are identified 16 category values:

- **Biophysical data,** split into the following categories: *climate, hydrology, land, soil, geology, topography*;
- **Water Use** data, split into *infrastructure, energy, agriculture* ;
- **Socio-Economic and Political** data are split into *socio-economic, demography, politics, health*;
- Other categories of data, e. g. *ecosystem, transport* and *miscellaneous*.

A representation of *Category Table* can be found in Table 10 .

Table 10 - Category Table

Category	**Category description**
agriculture	Crop production statistics – Irrigation – Livestock production statistics – Freshwater fishery activities
climate	Precipitation and temperature Profile – Analysis of Climate Variability – Indicators about water availability.
demography	Population Dynamics – Population spatial distribution – Demographic profile
geology	Geological Maps
ecosystem	Protected areas – Endangered species – Water pollution data
energy	Energy Production in the basin or in the country – Hydropower – Biomass
health	Health Indices – Parasite rate maps – Spatio-Temporal distribution of main diseases
hydrology	Gauge station data – water resource mapping (remote sensing) – Groundwater resources – Surface Water Occurrence
land	Land Cover (agricultural areas, forested areas, human settlements)
politics	Data about Civil Conflicts – Possible criticalities related with water management
infrastructure	Water Infrastructure – Dams and reservoirs location and basic characteristics
miscellaneous	All data which cannot be categorized in only one category
socio-economy	Basin institutional management – Governance – Population characteristics - Main social indicators - SDGs related data.
soil	Soil and Pedology Data
topography	Digital Elevation Model – GeoMorphological Data
transport	Road map – Transport Information – Estimation of travel times

3.2.4 Keyword Table

The *Keyword Table* is built to retrieve the data based on its own specific keywords. Datasets can include values of variables potentially belonging more than one category. The *keyword* metadata are introduced in order to assign zero or more keywords to a dataset. The keywords contain information on which variables are evaluated within data or a dataset.

This allows the database easy to be queried when the user searches a specific variable to solve a specific problem. The *Keyword tabl*e is shown in Table 11 . This table is intended to be dynamic and can be changed after a dataset is analysed and new keywords are introduced.

Table 11 Keyword Table

Keyword	**Keyword description**
RAIN	Rainfall Precipitation
WEATHER	Variables describing the state of weather (Precipitation/Rainfall is included)
ELEVATION	Terrain Elevation
RIVER_DISCHARGE	Volumetric Water Discharge in rivers and/or channels
WATER_LEVEL	Volumetric Water Discharge and Height of Water Level in rivers and/or channels
RIVER_BASIN_SHAPE	Geomorphological Information about the shape of basin
RIVER_NETWORK	Geomorphological Information about the spatial distribution of river network
CROP	Physical variables needed for crop modelling or crop detection
GROUNDWATER	Physical variables needed for groundwater modelling and analysis (e.g. water table depth)
LAND_COVER	Categorical or descriptive type of variable containing information on land cover
DAM	Dam Information
POPULATION_DENSITY	Population Density
DISEASE	Rate of incidence of a disease or virus or an infection
WATER_OCCURRENCE	Occurrence of (surface) water
WATER	Soil water content and any other index/variable related to water
VEGETATION	Variables related to vegetation dynamics
FISHERY	Variables related to fishery data
ADMINISTRATIVE_REGIONS	Geometric shapes of administrative regions/areas (e.g. countries, districts, states, provinces, ...)
Keyword	Keyword description
RAIN	Rainfall Precipitation
WEATHER	Variables describing the state of weather (Precipitation/Rainfall is included)
ELEVATION	Terrain Elevation
RIVER_DISCHARGE	Volumetric Water Discharge in rivers and/or channels

WATER_LEVEL	Volumetric Water Discharge and Height of Water Level in rivers and/or channels
RIVER_BASIN_SHAPE	Geomorphological Information about the shape of basin
RIVER_NETWORK	Geomorphological Information about the spatial distribution of river network
CROP	Physical variables needed for crop modelling or crop detection
GROUDWATER	Physical variables needed for groundwater modelling and analysis (e.g. water table depth)
LAND_COVER	Categorical or descriptive type of variable containing information on land cover
DAM	Dam Information
POPULATION_DENSITY	Population Density
DISEASE	Rate of incidence of a disease or virus or an infection
WATER_OCCURRENCE	Occurrence of (surface) water

3.3 Main Datasets grouped by categories

This section reviews few relevant datasets grouped by *Category* field of *Metadata* table. Reference must be made to the database for a full list.

3.3.1 Agriculture

This category collects all datasets proving the following variables related to agriculture, fishery and livestock:

- Crop production statistics;
- Irrigation;
- Livestock production statistics;
- Freshwater fishery activities.

Within this category, the following datasets are actually listed:

a. MapSPAM - Spatial Production Allocation Model - Global Spatially-Disaggregated Crop Production Statistics Data for 2005 (IFPRI and IIASA, 2017; Wood-Sichra et al., 2016), as concerns Crop production statistics, cultivated area, irrigation**.**

b. Gridded Livestock of the World (GLW) (Robinson et al., 2014) as concerns Livestock production statistics**;**

c. FAO Fisheries and Aquaculture Department Dataset - Global Aquaculture Production as concerns freshwater fishery activities.

3.3.2 Climate

Under climate heading, reference is made to datasets providing both observed and estimated (past and future scenarios) meteo-climate information, including, among others:

- Ground observed data (e.g. time series of precipitation and temperature)
- Estimated historical data, i.e. based on models or analysis of remote sensed images with possible integration with ground stations.
- Maps deriving from climate variability analysis and/or future climate change projections/scenarios.

Key meteo-climate datasets include:

a. CHIRPS, a quasi-global (50N-50S, 180W-180E) (Funk at al, 2015) gridded precipitation distribution, based on integrated analysis of remote sensed data sources and in-situ ground stations, with spatial resolution of about 5 km (at equator), starting from 1981 and, among others, daily and monthly temporal frequency. CHIRPS are of high interest due to both spatial coverage/resolution and temporal frequency and the implicit cross validation against ground observations. Examples of studies recently conducted at JRC and involving the use of CHIRPS include climate variability assessment (Ceccherini at al, 2015).

b. MSWEP (Beck at al, 2017) , a global gridded precipitation dataset, based on integrated analysis of remote sensed data sources and in-situ ground stations with corrections for orographic effect and gauge under-check, with spatial resolution of about 25 km (at equator), starting from 1981 to 2015, with 3-hourly frequency. MSWEP is of interest for the potential use in distributed hydrological modelling, due to its 3-hourly frequency (see LISFLOOD output on "Hydrology" *Category* subsection).

c. ERA-INTERIM (Dee at al, 2011), a global atmospheric (e.g. temperature, precipitation, evapotranspiration and other turbulent fluxes, etc.) gridded distribution with spatial resolution of about 80 km (at equator), starting from 1979, at a sub-daily frequency (6 hours). The product is the outcome of a reanalysis process based on remote sensed images, continuously updated in real time.

d. GSOD (Global Summary of the Day), a global network of ground weather-climate stations, operated by NOAA, reporting daily observed time series of, among others, precipitation, temperature, relative humidity, wind speed and direction.

e. GLDAS and PGF (Sheffield et al, 2006): two global spatially gridded coverages of re-analysed weather variables starting from about 1979 that can be used for distributed land surface modelling.

3.3.3 Demography

This header is associated to demographic data, in particular:

- Spatio-temporal distribution of population and population density (historical data and future projections), often derived by census data;
- Data containing information on ethnic groups.

Demography datasets are:

a. GPW4, a global spatially gridded coverage of population density provided by NASA and relating to the period from 2000 to 2020 (extrapolated) ;
b. GHS (JRC/European Commission,2015) , a global spatially gridded coverage of population density derived by NASA provided by JRC and covering from 1975 to 2015;
c. WorldPop, a web portal containing population distribution data, widely used in literature (Pezzulo et al,2017, Tejedor-Garavi et al.,2017, Thomson et al,2017, Weber et al,2017, http://www.worldpop.org.uk) ;
d. GEOEPR (Vogt et al,2015, Wucherpfennig at al,2011), a spatially global coverage of the ethnic groups by administrative areas (e.g. countries).

3.3.4 Geology

This section covers geology. This category does not concern groundwater whose data are categorized as hydrology. Among the useful datasets or web portals, there is:

a. OneGeology (http://portal.onegeology.org/OnegeologyGlobal/), an international initiative of the geological surveys of the world. This ground-breaking project was launched in 2007, it contains a collection of globally maps of geological units.

3.3.5 Ecosystem

In this category, reference is made to the following dataset types:

- Protected areas;
- Endangered species;
- Water pollution data;
- Ecological data;
- Ecosystem services.

Among the collected spatial coverages, there is:

a. Biofresh Altas, (Global Freshwater Biodiversity Atlas)(Oberdorff et al, 2017) a collection of published and open access maps of freshwater, reporting links to publications and data sources related to freshwater biodiversity at the global, continental and local scale.

3.3.6 Energy

Under this header, reference is made to all data containing energy production information. In details data concern:

- Renewal Energy Production in the basin or in the country;
- Hydropower;
- Biomass.

Among the available data or web portals, there is:

a. ECOWAS Observatory for Renewable Energy and Energy Efficiency, a portal containing energy production/consumption at a country level for the Western African region. It also provides access to a webgis focused on thermal and renewable energy power plants in Western Africa.

3.3.7 Health

In this category, the following topics are considered:

- Health Indices
- Spatio-Temporal distribution of parasite and main diseases

Among the available datasets, there is:

a. MAP (Malaria Atlas Project) (Bhatt et al, 2015), a web portal contains mapping of P.vivax global endemical areas referred to 2010.

3.3.8 Hydrology

Hydrological data, in this category, concern:

- river gauge station data;
- natural water resource mapping from remote sensing;
- groundwater resources;
- surface water occurrence.

Key hydrological data include:

a. GRDC (Global Runoff Data Centre, WMO – UNFCC)(GRDC, 2017, Poméon et al,2017, Schneider et al, 2017), a global network of river discharge gauges reporting observation and estimations from 1979 to 2012, with both daily and monthly frequency;
b. Water Level and discharge data by DNA and Ara Zambeze, daily time s eries from 1946 to 2005 in 3 sites in Zambezi River Basin (Revubue in Chingoze, Zambezi in Zumbo and in Tete),Mozambique (Ronco et al,2010,Nones at al,2012);
c. LISFLOOD (Burek at al, 2013), a spatially distributed hydrological model, capable of simulating the hydrological processes that occur in a catchment, applied to Africa, and also providing as output a spatially gridded map with discharge values from 1979 to 2012 with daily frequency;

d. The Global Surface Water (GSW)(Pekel at al,2017), a global spatially-gridded dataset is a coverage of surface water occurrence estimated by an analysis of remoted sensed data from 1984 to 2015.
e. WHYMAP, a web portal funded by UNESCO containing global mass of groundwater resources.
f. BGS, (British Geological Survay), a spatially gridded coverage of groundwater productivity, storage and depth and groundwater depth of Africa with a 5 km spatial resolution (at equator).(MacDonald et al. ,2012).

Among the collected dataset GRDC constitutes a discrete starting point for the analysis of river discharge and model calibration. Groundwater plays a key importance for Africa management of water resources, an atlas from BGS and other materials have been collected. GSW is a good tool to detect small/medium reservoirs (natural and artificial), often used for irrigation or water supply.

3.3.9 Land

This category deals with data describing land surface, in particular:

— land cover (agricultural areas, forested areas, human settlements);
— land use, which instead involves the management and modification of natural environment or wilderness into built environment such as settlements and semi-natural habitats such as arable fields, pastures, and managed woods.

Key land cover/land use datasets include:

a. Globeland30 (http://www.globallandcover.com), a global spatially gridded coverage for land cover categorized in only 10 classes (water bodies, wetland, artificial surfaces, tundra, permanent snow and ice, grasslands, barren lands, cultivated land, shrub lands and Forest) with a resolution of 30 m ;

b. GlobCover (ESA, 2010), a global coverage of land cover classes with 300 m (at equator) resolution, this product has been developed in 2009 by ESA using MERIS FR mosaic;

c. GLC2000 (Global Land Cover 2000 Project), developed by JRC, is a global coverage of land cover with a spatial resolution of about 1 km (at equator);

d. the portals www.landcover.org (University of Maryland) containing MODIS data;

e. www.geo-wiki.org, a portal that merges results fromGLC2000 and MODIS data with addition of crowdsourced information (See at al, 2015); the article also illustrates a state-of-art review of land-cover products at the global scale.

f. Recently, a Prototype land cover map of Africa v1.0 based on 1 year of Sentinel-2A observations from December 2015 to December 2016 (http://2016africalandcover20m.esrin.esa.int) , has been produced by the ESA CCI land cover team. It has a spatial resolution of 20 m. and covers all Africa, describing 10 generic classes that appropriately describe the land surface.

3.3.10 Infrastructure

Under this heading, reference is made to water infrastructure like dams and reservoirs location with basic characteristic. In particular, it contains data focused on the following topics:

— Hydropower;

— Mining industry.

Infrastructure datasets include:

a. GRanD (The Global Reservoir and Dam)(Lehner at al, 2011), global database providing the location and main specifications of large global reservoirs and dams with a storage capacity higher than 0.1 km³ both in point and polygon format.

b. AQUASTAT (Lehner et al,2008), a portal gathering detailed information about dams and their associated reservoirs; AQUASTAT's data was an important input into the Global Reservoirs and Dams (GRanD) database, especially for African dams.

3.3.11 Politics

Under this header, reference is made to the following types of dataset:

— Country/State border;

— Data about international treaties on water;

— Data about Civil Conflicts;

— Possible criticalities related with water management and similar other topics.

This category includes the following datasets:

a. GADM (http://gadm.org/), a spatial database of the location of the world's administrative areas (or administrative boundaries) for use in GIS analysis and environmental/climate/hydrologic modelling or similar;

b. IISS, an Armed Conflict Database containing statistical data, analytical reports and daily timeline updates on the political, military and humanitarian developments in 41 active and 47 archived conflicts, as well as information on selected non-state armed groups and a compilation of annual trends in the ACD Index; (http://acd.iiss.org/en/about/demo)

c. COW (Bernauer at al, 2012), Correlates of War (COW), a project seeking to facilitate the collection, dissemination, and use of accurate and reliable quantitative data in international relations. Key principles of the project include a commitment to standard scientific principles of replication, data reliability, documentation, review, and the transparency of data collection procedures;

d. TFDD (Wolf at al,2012), Freshwater Dispute Database TFDD, The Transboundary Freshwater Dispute Database (TFDD), a database intended for use in aiding the process of water conflict prevention and resolution, it is developed by the Oregon State University College of Earth, Ocean, and Atmospheric Sciences, in collaboration with the Northwest Alliance for Computational Science and Engineering;

e. IFTD (Wolf at al, 2012), Transboundary Freshwater Treaty Database collected within IFTD;

f. IRCC, International Water Cooperation and Conflict, a new event dataset on international river basin cooperation and conflict worldwide for the time-period 1997-2007: Water-related events between riparian countries are characterized on a scale ranging from -6(most conflictive) to +6 (most cooperative);

g. ACLED (Raleigh et al., 2010) Armed Conflict Location and Event Dataset (ACLED) tracking the actions of opposition groups, governments, and militias across Africa and Asia, specifying the exact location and date of battle events, transfers of military control, headquarter establishment, civilian violence, and rioting (https://www.strausscenter.org/strauss-articles/acled-3.html);

h. SCAD - the Social Conflict Analysis Database (SCAD)(Salehyan et al, 2012) – a database including protests, riots, strikes, inter-communal conflict, government violence against civilians, and other forms of social conflict not systematically tracked in other conflict datasets: it currently includes information social conflicts from 1990-2015, covering all of Africa and now also Mexico, Central America, and the Caribbean; (https://www.strausscenter.org/scad.html)

i. RBO, deriving from TFDD, a web interface where to search international treaties on river basin organizations (http://gis.nacse.org/tfdd/rbo_new.php).

3.3.12 Socio-Economic

Under this heading, reference is made to socio-economic datasets. In particular, it includes data focused on the following topics:

- Gross Domestic Product (GDP) and other related indicators;
- World Development indicators (WDI);
- Worldwide Governance Indicators (WGI).

Key socio-economic datasets include:

a. WDI from the World Bank Open Data (https://data.worldbank.org/data-catalog/world-development-indicators), an open data portal providing the world development indicators (WDIs) at the country level covering all the world per each year from 1960 to 2016;
b. Expanded GDP (v6.0)(Kaufmann et al,2010) , a global dataset with yearly country GDP from 1950 to 2011;
c. WGI, a global dataset of World Governance Indicators at a country resolution from 1996 to 2015 (Kaufmann et al,2010).

3.3.13 Soil

Soil and pedology data are important for agricultural activities and hydrological models. In most cases, these kind of data are static. Focusing on Africa, most datasets are mainly gridded coverages from remotely sensed data. They include:

— quantities for estimation of current and future land potential productivity, help to identify land and water limitations, and enhance assessing risks of land degradation, particularly soil erosion (e. g. nutrient availability/capacity, rooting condition, excess salts, toxicity, ...);
— soil characterization variables (e. g. carbon content, nitrogen content, organic matter, soil bulk density, soil depth, soil horizons/profile, soil pH, soil salinity/sodicity, texture, soil water holding capacity, soil erosivity, …);
— any other information on soil and terrain below the land surface;

Among the available datasets, there are:

a. HSWD (Fisher et al,2008), a global spatially gridded coverage of soil nutrient availability, nutrient retention capacity, rooting condition, oxygen availability, excess salts, toxicity and workability;
b. SOTER (Engelen et al, 2013), a database specified for Southern Africa containing soil characterization variables e. g. carbon content, nitrogen content, organic matter, soil bulk density, soil depth, soil horizons/profile, soil pH, soil salinity/sodicity, texture, soil water holding capacity,…);
c. ESDAC (Panagos at al, 2012,2017, Dewitte et al,2013), an atlas of soil data published by JRC for Africa and a globally spatially gridded map of soil erosivity.

3.3.14 Topography

Topographic datasets include:

— Digital Elevation Model or Digital Terrain Models;

— Geomorphological analysis by products.

Key data source are:

a. SRTM, the global DTM (Digital Terrain Model)(Reuter et al,2007, Jarvis et al,2008, USGS, 2016) with a spatial resolution of about 90 m (at equator).
b. SRTM30 (https://lta.cr.usgs.gov/SRTM1Arc) : A more recent version of global SRTM with higher resolution, about 30 m at equator;
c. ASTER (NASA LP DAAC, 2015): a Global Digital Elevation Model (ASTGTM) developed jointly by the U.S. National Aeronautics and Space Administration (NASA) and Japan's Ministry of Economy, Trade, and Industry (METI); it has a spatial resolution of about 30 m (at equator) and is capable of collecting in-track stereo using nadir- and aft-looking near infrared cameras

d. HYDROSHEDS (Lehner et al, 2013), a set of geomorphological elaborations from SRTM30 for hydrological applications:

    i. Void-filled global digital elevation model (Europe and Africa have been downloaded) to be utilized to simulate hydrological processes
    ii. Derived maps of river network at 15 second or 30 second resolution;
    iii. Hydrobasin, a series of polygon layers that depict watershed boundaries and sub-basin delineations at a global scale and at different hierarchical levels.

3.3.15 Transport

Under this heading, any data concerning the following topics are considered:

— Road map;
— Transport Information;
— Travel times estimation;
— Connections among regions and/or with the main point of interests.

Currently the following dataset is reported:

a. GAM (Global Accessibility Map)(Nelson et al,2008), developed by JRC, a global spatially gridded coverage with a 1 km resolution of the current travel time to the nearest major cities: the algorithm is based on a friction-surface raster map, previously estimated by the type of roads/channels. Currently it is the only unique dataset that can provide an estimate of the travel cost and time between two locations.

3.3.16 Miscellaneous

All data that cannot be arranged in only one of the listed category are categorized as miscellaneous.

4 Knowledge sharing

As new information (i.e. reports, papers, as well as data, databases, modelling outcomes) is made available, the need for the adoption of efficient practices for knowledge sharing becomes evident. Among main objectives, the need to avoid or minimize duplications and being more effective in sharing information (i.e. among different Organizations, within and among different Working Groups).

State-of-the-art knowledge sharing platforms provide relevant facilities, as the creation of working groups and effective information protection (i.e. access via private credentials, uploaded information access reserved to registered users), as well as remote access via web.

Above considerations hold particularly true in the framework of ACEWATER2 project, due to the complexity of tasks to be addressed and the large number of Institutions and experts involved. From this perspective, Knowledge sharing web platform Aquaknow is presented here below, with the aim to promote its use during the project (Figure 30).

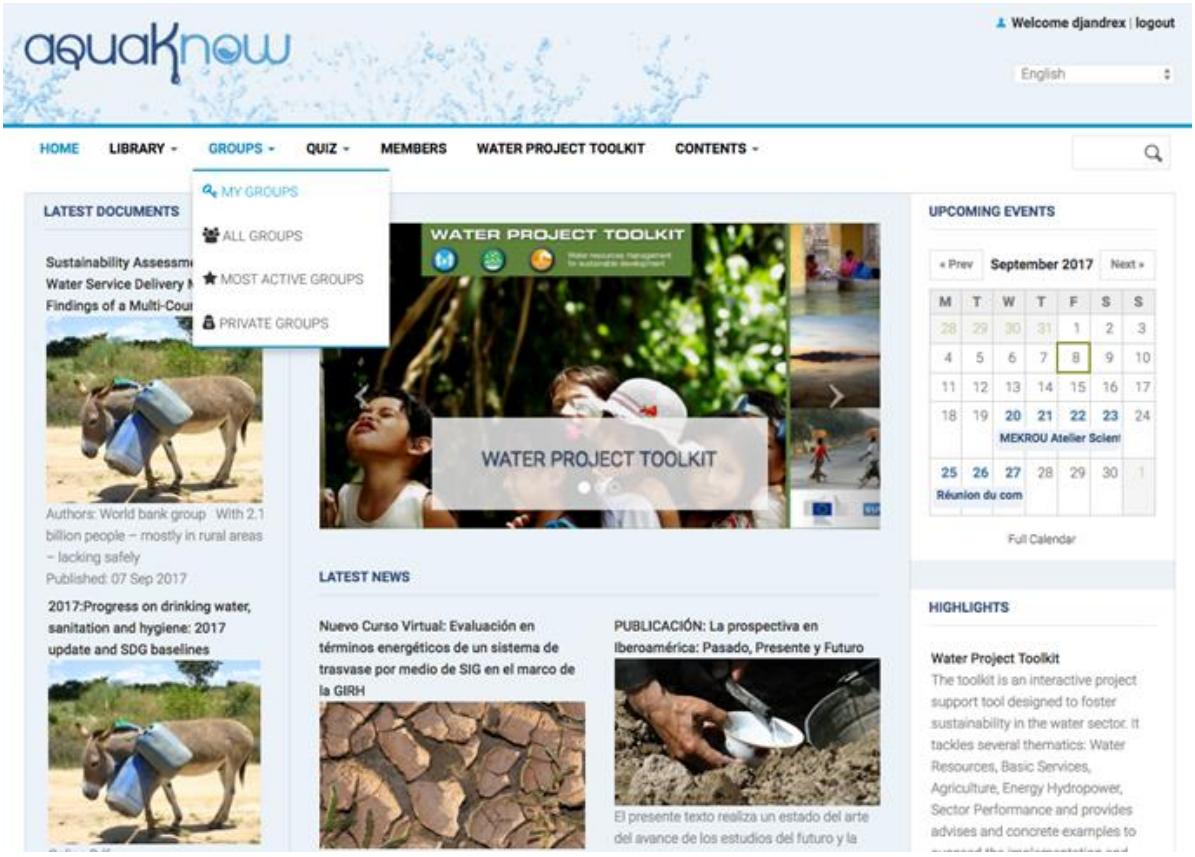

Figure 30 - Screenshot of Aquaknow web page

AquaKnow has been developed in the framework of European Union Water Initiative (EUWI) with a specific focus on water sector and it is managed by JRC, with the following aims:

- To provide knowledge management and capacity building tools, relevant to effective sharing of documents, data, information, ideas and experiences, turning to be an ideal platform for promoting collaborative work and support design and implementation of sustainable water management policies;

- To provide, further to a public space, the option to create private groups, in order to share confidential information (i.e. on a project basis).

More details on Aquaknow architecture and practical tips on its usage are available at http://aquaknow.jrc.ec.europa.eu/ and https://www.youtube.com/watch?v=a6zuimbOQjk .

In the framework of ACEWATER2 project, NEPAD CoE members, once registered, can make use of the platform to share information (documents, reports, data).

In order to efficiently manage the process and promote groups privacy, three different groups for each one of the three distinct networks have been created:

- NEPAD SANWATCE, dedicated to NEPAD CoEs of Southern Africa;
- NEPAD WANWATCE, dedicated to NEPAD CoEs of Western Africa;
- NEPAD CEANWATCE , dedicated to NEPAD CoEs of Central and Eastern.

A list of people accessing each network is maintained centrally, provided that any other access request can be submitted to Aquaknow Administrators for validation.

Users can access their own private group(s), logging in to Aquaknow platform with their own credentials. They can access existing information and/or data, and they can upload files to be shared, privately with other group members. At current version, supported files include documents/spreadsheets (Word, Excel) and compressed zip archives. File size is limited to 64 MB.

Particularly, the need for integrating global and/or continental scale datasets and data collected, processed and analysed in the framework of the ACEWATER2 project can be partly addressed by Aquaknow platform. Spatial datasets and related time series (i.e. monitoring data) can be uploaded to the system through one or more ZIP files, i.e. containing both geographic data, as shape files, and textual data. CoEs involved in project activities are immediately aware about their availability and they can assess relevance to their own specific tasks.

Next steps imply data cleaning, tidying, harmonization and migration to project reference database(s).

5 Conclusions

A database of metadata documenting relevant Africa freely available and private data sources has been presented, further to a brief review of key African Initiatives in Water sector, leading to the implementation of relevant databases and modelling activities.

Metadata provides both descriptive information and licensing limitations, as well as quantitative data, as spatial extent, spatial resolution and temporal frequency. Metadata acts also as the main entry point to accessing raw data from original Organizations/Institutions. The idea is that it would not make sense to duplicate all data locally, except for specific reasons as long downloading and processing times, recurrent use, need to integrate with local data or more effective processing.

Data categories enable user to perform a fast screening of available data sets by topic, further to assessing their suitability for the tasks at hand, as a function of, among others, spatial cover, resolution and covered time window. References to maintaining Organizations/Institutions web sites provide a further opportunity to go deeper in detail.

User can efficiently query the metadata table, which is currently provided as a MsExcel file but which could be easily migrated, at a later stage, to a relational database. Actually the EAR (Entity-Attribute-Relationship) diagram, documenting the details of underlying metadata logical structure, is provided.

Most of the referred data are actually in raster format (i.e. GeoTiff, NetCDF), being raw (or originated by processing of) remote sensed images and/or outcomes of models operating on a raster basis. Other datasets are in vector format (i.e. shape files) and/or textual/spreadsheet formats (i.e. time series), both free (i.e. classic comma delimited) or structured following specific provisions (i.e. GRDC data, with specific header structure).

A directories tree structure is proposed, based upon dataset category name, in order to facilitate organization and homogenization of data, once downloaded to local or other server(s). The tree structure acts as a sort of skeleton template, accommodating both documents and data, provided that dataset specificities often require customized sub-directories (i.e. daily and monthly data for CHIRPS dataset).

At current development stage, the database can be assimilated to a root node pointing to multiple servers, hosting original datasets and managed by their own Institutions/Organizations.

Finally, document introduces Aquaknow, a dynamic web knowledge sharing platform hosted at JRC and dedicated to water topics. Based on key concepts and challenges in knowledge sharing, Aquaknow relevance and practical use in the framework of ACEWATER2 project has been discussed.

6 The way forward

The metadata database is intended as a living document, open to continuous updates, as long as new datasets are spotted or made available. As such, the database will be populated with references to datasets and databases implemented and made available by CoE in the framework of ACEWATER2 project activities. This is in line with the contractual provision for most CoE to provide a state-of-the-art report covering their own topics of interest, complemented by relevant databases.

Following previous discussions, further topics to be investigated and possibly addressed will include:

- Download and organization of relevant datasets, i.e. following and/or refining proposed directories tree, depending upon criteria discussed in current report (i.e. download time, recurrent use, static coverages, …) and specific needs/requirements (i.e. modelling)
- Provide continuous and effective support to data cleaning, tidying and organization, as data are made available in the framework of ACEWATER2 project activities at river basin level (i.e. Senegal, Niger, Nile, Zambezi), addressing homogenization and effective data sharing requirements;
- Design, implementation and delivery of utility tools (i.e. in Python, R), relevant to such different tasks as data validation, uploading, processing (i.e. cleaning, tidying, data organization and management; tasks referred to in previous point), analysis and modelling;
- Investigation, design, implementation and delivery of mature data management infrastructures, involving relational database(s), geodatabases and/or native spatial databases, GIS integration and loose or tight-coupling of modelling tools, as long as these activities could contribute to more effective data access and usage;
- Analysis of data exchange and/or integration issues and challenges, while coping with key Water Information Infrastructures (i.e. ZAMWIS from ZAMCOM, NBA and AGRHYMET Information Systems).

References

1. Andersson, J.C.M., Ali A., Arheimer B., Gustafsson D., Minoungou B. (2017). Providing peak river flow statistics and forecasting in the Niger River basin. Physics and Chemistry of the Earth, http://dx.doi.org/10.1016/j.pce.2017.02.010
2. Andersson, J.C.M.; Ali, A.; Arheimer, B.; Gustafsson, D.; Minoungou, B. (2015) Providing infrastructure design variables and flood forecasting in the Niger River basin, in Proceedings of the 16th WaterNet/WARFSA/GWP-SA Symposium "Infrastructural Planning for Water Security in Eastern and Southern Africa", 28–30 October 2015, Pointe Aux Piments, Mauritius. Available under http://www.waternetonline.org/downloads/proceedings,16th Symposium Full Papers - Water Resources and Infrastructure Management for Oral Presentation.
3. Andersson, J.C.M.; Ali, A.; Arheimer, B.; Traoré F. (2014) Niger-HYPE: How may climate change affect floods and droughts in the Niger River basin? / Comment le changement climatique pourrait affecter les inondations et sécheresses dans le bassin du fleuve Niger?, Paper no. 2. in van Lanen H.A.J.; Demuth, S.; van der Heijden, A. (eds.) Poster proceedings of the 7th Global FRIEND-Water conference "Hydrology in a Changing World: Environmental and Human Dimensions", held in Montpellier, France, 7-10 October 2014. Wageningen University, Wageningen and UNESCO, Paris. Click here to download the poster in English. Cliquez ici pour télécharger l'affiche en français.
4. Andersson, J.C.M.; Ali, A.; Arheimer, B.; Traoré F. (2015) Strengthening resilience through collaborative research and open information. Poster presented at the World Water Week conference in Stockholm, Sweden, 23-28 August 2015. Available online at http://poster.worldwaterweek.org/Default.aspx?s=E3-32-26-82-95-BA-7F-76-44-BC-FC-75-C9-20-85-59.
5. Andersson, J.C.M.; Andersson, L.; Arheimer, B.; Bosshard, T.; Graham, L.P.; Nikulin, G.; Kjellström E. (2014) Experience from Assessments of Climate Change Effects on the Water Cycle in Africa, in Proceedings of the 15th WaterNet/WARFSA/GWP-SA Symposium "IWRM for harnessing socio-economic development in Eastern and Southern Africa", 29–31 October 2014, Lilongwe, Malawi. Available under http://www.waternetonline.org/downloads/proceedings -> 15th symposium -> Hydrology for Oral Presenations.
6. Andersson, J.C.M.; Arheimer, B.; Traoré, F.; Gustafsson, D.; Ali, A. (2017). Process refinements improve a hydrological model concept applied to the Niger River basin. Hydrological Processes, http://onlinelibrary.wiley.com/doi/10.1002/hyp.11376/full
7. Andersson, J.C.M.; Pechlivanidis, I.G.; Gustafsson, D.; Donnelly, C.; and B. Arheimer. (2015) Key Factors for Improving Large-scale Hydrological Model Performance. European Water, 49, 77-88, http://www.ewra.net/ew/pdf/EW_2015_49_06.pdf.
8. Beck, H.E., van Dijk, A.I.J.M., Levizzani, V., Schellekens, J., Miralles, D.G., Martens, B., de Roo, A., 2017. MSWEP: 3-hourly 0.25° global gridded precipitation (1979-2015) by merging gauge, satellite, and reanalysis data. Hydrol. Earth Syst. Sci. 21, 589–615. doi:10.5194/hess-21-589-2017
9. Beck, L., Bernauer, T., Siegfried, T., Böhmelt, T., 2014. Implications of hydro-political dependency for international water cooperation and conflict: Insights from new data. Polit. Geogr. 42, 23–33. doi:10.1016/j.polgeo.2014.05.004
10. Bernauer, T., Böhmelt, T., Buhaug, H., Gleditsch, N. P., Tribaldos, T., Berg, E., Wischnath, G. (2012): Water-Related Intrastate Conflict and Cooperation (WARICC): A New Event Dataset. International Interactions, DOI: 10.1080/03050629.2012.697428.

11. Bhatt S., D. J. Weiss, E. Cameron, D. Bisanzio, B. Mappin, U. Dalrymple, K. E. Battle, C. L. Moyes, A. Henry, P. A. Eckhoff, E. A. Wenger, O. Briët, M. A. Penny, T. A. Smith, A. Bennett, J. Yukich, T. P. Eisele, J. T. Griffin, C. A. Fergus, M. Lynch, F. Lindgren, J. M. Cohen, C. L. J. Murray, D. L. Smith, S. I. Hay, R. E. Cibulskis & P. W. Gething. The effect of malaria control on Plasmodium falciparum in Africa between 2000 and 2015 Nature 526, 207–211 (08 October 2015) doi:10.1038/nature15535

12. Burek P.,van der Knijff,J. , da Roo A. (2013) LISFLOOD Distributed Water Balance and Flood Simulation Model, Revised User Manual, 978-92-79-33190-9. 10.2788/24719

13. Ceccherini, G.; Ameztoy, I.; Hernández, C.P.R.; Moreno, C.C. High-Resolution Precipitation Datasets in South America and West Africa based on Satellite-Derived Rainfall, Enhanced Vegetation Index and Digital Elevation Model. *Remote Sens.* **2015**, *7*, 6454-6488.

14. Copernicus Service Information, 2017. Copernicus Global Land Service [WWW Document]. African Yrly. L. Cover map 100m Resolut. URL http://land.copernicus.eu/global/content/first-release-land-cover-map-100m

15. De Stefano, L., Duncan, J., Dinar, S., Stahl, K., Strzepek, K., Wolf, A.T., 2010. Mapping the Resilience of International River Basins to Future Climate Change-Induced Water Variability. Washington DC, USA.

16. De Stefano, L., Duncan, J., Dinar, S., Stahl, K., Strzepek, K.M., Wolf, A.T., 2012. Climate change and the institutional resilience of international river basins. J. Peace Res. 49, 193–209. doi:10.1177/0022343311427416

17. De Stefano, L., Petersen-Perlman, J.D., Sproles, E.A., Eynard, J., Wolf, A.T., 2017. Assessment of transboundary river basins for potential hydro-political tensions. Glob. Environ. Chang. 45, 35–46. doi:10.1016/j.gloenvcha.2017.04.008

18. Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F. (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., 137: 553–597. doi:10.1002/qj.828

19. Dewitte, O., Jones, A., Spaargaren, O., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Gallali, T., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Michali, E., Montanarella, L., Thiombiano, L., Van Ranst, E., Yemefack, M., Zougmore, R., 2013. Harmonisation of the soil map of Africa at the continental scale. Geoderma, 211-212, 138-153

20. Engelen V.W.P. van and J.A. Dijkshoorn (eds.),2013. Global and National Soils and Terrain Databases (SOTER). Procedures Manual, Version 2.0, ISRIC – World Soil Information, Wageningen. 198 pages,10 figures and 9 tables.

21. ESA (2010) DUE GlobCover 2009 project, http://due.esrin.esa.int/page_globcover.php

22. European Commission, Joint Research Centre (JRC); Columbia University, Center for International Earth Science Information Network - CIESIN (2015): GHS population grid, derived from GPW4, multitemporal (1975, 1990, 2000, 2015). European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-ghsl-ghs_pop_gpw4_globe_r2015a

23. Farinosi, F., Giupponi, C., Reynaud, A., Ceccherini, G., Carmona-Moreno, C., Gonzalez-Sanchez, D., Bidoglio, G., n.d. An innovative approach to the assessment of hydro-political risk: a spatially explicit, data driven indicator of hydro-political issues. (Under Submission). Glob. Environ. Chang.

24. Farinosi, F.,Gonzalez-Sanchez, D,Crestaz, E.,Cordano, E., Carmona-Moreno, C., Bidoglio, G. (2017b) Towards an African Atlas of Water Energy Food Cooperation – Data collection, JRC Technical Report no. JRC108695, Under Editing and Publishing Process.

25. Fischer, G., F. Nachtergaele, S. Prieler, H.T. van Velthuizen, L. Verelst, D. Wiberg, 2008. Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). IIASA, Laxenburg, Austria and FAO, Rome, Italy.

26. Funk, Chris, Pete Peterson, Martin Landsfeld, Diego Pedreros, James Verdin, Shraddhanand Shukla, Gregory Husak, James Rowland, Laura Harrison, Andrew Hoell & Joel Michaelsen. "The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes". Scientific Data 2, 150066, 2015 doi:10.1038/sdata.2015.66 2015. http://chg.geog.ucsb.edu/data/chirps/index.html

27. Giupponi, C., Gain, A.K., 2017. Integrated spatial assessment of the water, energy and food dimensions of the Sustainable Development Goals. Reg. Environ. Chang. 17, 1881–1893. doi:10.1007/s10113-016-0998-z

28. GRDC, 2017. Long-Term Statistics and Annual Characteristics of GRDC Timeseries Data. River Flow Data.

29. IFPRI, IIASA, 2017. Global Spatially-Disaggregated Crop Production Statistics Data for 2005 Version 3.1. doi:10.7910/DVN/DHXBJX

30. Jarvis A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT), available from http://srtm.csi.cgiar.org.

31. Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., Gallali, T., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Michéli, E., Montanarella, L., Spaargaren, O., Thiombiano, L., Van Ranst, E., Yemefack, M., Zougmore, R., 2013. Soil Atlas of Africa. Publications Office of the European Union, Luxembourg. doi:10.2788/52319

32. Kaufmann, Daniel and Kraay, Aart and Mastruzzi, Massimo, The Worldwide Governance Indicators: Methodology and Analytical Issues (September 2010). World Bank Policy Research Working Paper No. 5430. Available at SSRN: https://ssrn.com/abstract=1682130 Lehner, B., Grill, G., 2013. Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrol. Process. 27, 2171–2186. doi:10.1002/hyp.9740

33. Lehner, B., Grill G. (2013): Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186. Data is available at www.hydrosheds.org

34. Lehner, B., Liermann, C.R., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Döll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J.C., Rödel, R., Sindorf, N., Wisser, D., 2011. High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management (GranD database). Front. Ecol. Environ. 9, 494–502. doi:10.1890/100125

35. MacDonald, A.M., Bonsor, H.C., Dochartaigh, B.É.Ó., Taylor, R.G., 2012. Quantitative maps of groundwater resources in Africa. Environ. Res. Lett. 7, 24009. doi:10.1088/1748-9326/7/2/024009

36. Namara, R.E., Giordano, M., 2017. Economic rationale for cooperation in international waters in Africa: a Review. Washington DC, USA.

37. NASA LP DAAC, 2015, ASTER Level 1 Precision Terrain Corrected Registered At-Sensor Radiance. Version 3. NASA EOSDIS Land Processes DAAC, USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov), accessed January 1, 2016, at http://dx.doi.org/10.5067/ASTER/AST_L1T.003.

38. Nelson, A. (2008) Travel time to major cities: A global map of Accessibility. Office for Official Publications of the European Communities, Luxembourg. DOI:10.2788/95835, ISBN:978-92-79-09771-3.

39. Nones, M., Ronco, P., Di Silvio, G., (2012) MODELLING THE IMPACT OF LARGE IMPOUNDMENTS ON THE LOWER ZAMBEZI RIVER. Journal of River Basin Management. 11 (2) 221-236, Special Issue: Integrated Management of Large River Systems. doi:10.1080/15715124.2013.794144

40. Oberdorff Thierry, Céline Jézéquel, Pablo A. Tedesco & Clément Tisseuil (2013). Global Diversity Patterns in Freshwater Systems. Accessed through the Global Freshwater Biodiversity Atlas (atlas.freshwaterbiodiversity.eu) on 04/12/2017.

41. Panagos P., Borrelli P., Meusburger K., Yu B., Klik A., Lim K.J., Yang J.E, Ni J., Miao C., Chattopadhyay N., Sadeghi S.H., Hazbavi Z., Zabihi M., Larionov G.A., Krasnov S.F., Garobets A., Levi Y., Erpul G., Birkel C., Hoyos N., Naipal V., Oliveira P.T.S., Bonilla C.A., Meddi M., Nel W., Dashti H., Boni M., Diodato N., Van Oost K., Nearing M.A., Ballabio C., 2017. Global rainfall erosivity assessment based on high-temporal resolution rainfall records. Scientific Reports 7: 4175. DOI: 10.1038/s41598-017-04282-8.

42. Panagos P., Van Liedekerke M., Jones A., Montanarella L., "European Soil Data Centre: Response to European policy support and public data requirements"; (2012) Land Use Policy, 29 (2), pp. 329-338. doi:10.1016/j.landusepol.2011.07.003

43. Pastori, M.,Bouraoui.F., Aloe, A.,Bidoglio, G., 2011, GISEPIC AFRICA: A modeling tool for assessing impacts of nutrient and water use in African agriculture Database, Model and GIS System development and testing, JRC 63230, doi:10.2788/48571.

44. Pekel, J.-F., Cottam, A., Gorelick, N., Belward, A.S., 2016. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422. doi:10.1038/nature20584

45. Pezzulo Carla, Graeme M. Hornby, Alessandro Sorichetta, Andrea E. Gaughan, Catherine Linard, Tomas J. Bird, David Kerr, Christopher T. Lloyd & Andrew J. Tatem. Sub-national mapping of population pyramids and dependency ratios in Africa and Asia. Scientific Data 4, Article number: 170089 (2017) doi:10.1038/sdata.2017.89

46. Poméon, T., Jackisch, D. & Diekkrüger, B. (2017) Evaluating the performance of remotely sensed and reanalysed precipitation data over West Africa using HBV light, Journal of Hydrology, 547, 222–235, DOI:10.1016/j.jhydrol.2017.01.055. - To link to this article: http://dx.doi.org/10.1016/j.jhydrol.2017.01.055

47. Raleigh, C., Linke, A., Hegre, H., Karlsen, J., 2010. Introducing ACLED: An Armed Conflict Location and Event Dataset. J. Peace Res. 47, 651–660. doi:10.1177/0022343310378914

48. Reuter, H.I., Nelson, A., Jarvis, A., 2007. An evaluation of void-filling interpolation methods for SRTM data. Int. J. Geogr. Inf. Sci. 21, 983–1008. doi:10.1080/13658810601169899

49. Robinson, T.P., Wint, G.R.W., Conchedda, G., Van Boeckel, T.P., Ercoli, V., Palamara, E., Cinardi, G., D'Aietti, L., Hay, S.I., Gilbert, M., 2014. Mapping the

Global Distribution of Livestock. PLoS One 9, e96084. doi:10.1371/journal.pone.0096084

50. Ronco, P., Fasolato, G., Di Silvio, G. (2010). MORPHOLOGICAL EFFECTS OF DAMMING ON LOWER ZAMBEZI RIVER. Geomorphology 115 (1-2), 43-55 http://www.sciencedirect.com/scidirimg/clear.gifdoi: 10.1016/j.geomorph.2009.09.029

51. Salehyan, Idean, Cullen S. Hendrix, Jesse Hamner, Christina Case, Christopher Linebarger, Emily Stull, and Jennifer Williams. "Social conflict in Africa: A new database." International Interactions 38, no. 4 (2012): 503-511.

52. Schneider, U., Finger, P., Meyer-Christoffer, A., Rustemeier, E., Ziese, M. and Becker, A. (2017) Evaluating the Hydrological Cycle over Land Using the Newly-Corrected Precipitation Climatology from the Global Precipitation Climatology Centre (GPCC), Atmosphere, 8, 52; DOI:10.3390/atmos8030052. - To link to this article: http://dx.doi.org/10.3390/atmos8030052

53. See Linda, Dmitry Schepaschenko, Myroslava Lesiv, Ian McCallum, Steffen Fritz, Alexis Comber, Christoph Perger, Christian Schill, Yuanyuan Zhao, Victor Maus, Muhammad Athar Siraj, Franziska Albrecht, Anna Cipriani, Mar'yana Vakolyuk, Alfredo Garcia, Ahmed H. Rabia, Kuleswar Singha, Abel Alan Marcarini, Teja Kattenborn, Rubul Hazarika, Maria Schepaschenko, Marijn van der Velde, Florian Kraxner, Michael Obersteiner, Building a hybrid land cover map with crowdsourcing and geographically weighted regression, In ISPRS Journal of Photogrammetry and Remote Sensing, Volume 103, 2015, Pages 48-56, ISSN 0924-2716, https://doi.org/10.1016/j.isprsjprs.2014.06.016. (http://www.sciencedirect.com/science/article/pii/S0924271614001713) Keywords: Land cover; Validation; Crowdsourcing; Map integration; Global land cover; Geographically weighted regression

54. SEI, 2011. Understanding the Nexus.

55. Sheffield, J., G. Goteti, and E. F. Wood, 2006: Development of a 50-yr high-Table 1resolution global dataset of meteorological forcings for land surface modeling, J. Climate, 19 (13), 3088-3111

56. Singer, J.D., Bremer, S., Stuckey, J., 1972. Capability distribution, uncertainty, and major power wars, 1820-1965, in: Russett, B.M. (Ed.), Peace, War, and Numbers. Sage, Beverly Hills, CA, pp. 19–48.

57. STIS IV Framework Contract DI/07446-00 Lot 3 (2016)– Information system and web infrastructure solutions development, support, engineering and testing – Deliverable 2 – Identification of the contribution and input for the database for regional precipitation data for the Wastern and Southern NEPAD CENTRES of Excellence, JRC / Institute for Environment and Sustainability,

58. Tejedor-Garavi Natalia, Nomcebo Dlamini, Deepa Pindolia, Adam Soble, Nick W. Ruktanonchai, Victor Alegana, Arnaud Le Menach, Nyasatu Ntshalintshali, Bongani Dlamini, David L. Smith, Andrew J. Tatem and Simon Kunene. Travel patterns and demographic characteristics of malaria cases in Swaziland, 2010–2014. Malaria Journal 24 May 2017 16:359, https://doi.org/10.1186/s12936-017-2004-8

59. Thomson Dana R., Forrest R. Stevens, Nick W. Ruktanonchai, Andrew J. Tatem and Marcia C. Castro. GridSample: an R package to generate household survey primary sampling units (PSUs) from gridded population data. International Journal of Health Geographics (2017) 16:25 https://doi.org/10.1186/s12942-017-0098-4

60. USGS, 2016. Shuttle Radar Topography Mission (SRTM).

61. Vogt, M., Bormann, N.-C., Rüegger, S., Cederman, L.-E., Hunziker, P., Girardin, L., 2015. Integrating Data on Ethnicity, Geography, and Conflict. J. Conflict Resolut. 59, 1327–1342. doi:10.1177/0022002715591215

62. Vogt, Manuel, Nils-Christian Bormann, Seraina Rüegger, Lars-Erik Cederman, Philipp Hunziker, and Luc Girardin. 2015. "Integrating Data on Ethnicity, Geography, and Conflict: The Ethnic Power Relations Dataset Family." Journal of Conflict Resolution 59(7):1327-1342.

63. Weber Eric M., Vincent Y. Seaman, Robert N. Stewart, Tomas J. Bird, Andrew J. Tatem, Jacob J. McKee, Budhendra L. Bhaduri, Jessica J. Moehl, Andrew E. Reith. Census-independent population mapping in northern Nigeria. Remote Sensing of Environment (2017) https://doi.org/10.1016/j.rse.2017.09.02

64. Weidmann, N.B., Rød, J.K., Cederman, L.-E., 2010. Representing ethnic groups in space: A new dataset. J. Peace Res. 47, 491–499. doi:10.1177/0022343310368352

65. Wucherpfennig, Julian, Nils B. Weidmann, Luc Girardin, Lars-Erik Cederman, and Andreas Wimmer. 2011. "Politically Relevant Ethnic Groups Across Space and Time: Introducing the GeoEPR Dataset." Conflict Management and Peace Science 28(5): 423–37.

66. Zarfl, C., Lumsdon, A.E., Tockner, K., 2015. A global boom in hydropower dam construction. doi:10.1007/s00027-014-0377-0

List of abbreviations

ACEWATER	African networks of Centers of Excellence in Water
ACLED	Armed Conflict Location and Event Dataset
AGRHYMET	Centre Regional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle
ANBO	African Network of Basin Organisations
AQUASTAT	FAO's Information System on Water and Agriculture
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTGDEM	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM)
AU	African Union
CEANWATCE	Central Eastern African Water Centres of Excellence
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CoE(s)	Centre(s) of Excellence
COW	Correlates of War
CSIR	Council for Scientific and Industrial Research
EC	European Commission
ECOWAS	Economic Community of West African States
ESDAC	European Soil Data Centre
EU	European Union
FAO	Food and Agriculture Organization
FGDC	Federal Geographic Data Committee
FRIEND	Flow Regimes from International Experimental and Network Data
GADM	Global Administrative Areas
GAM	Global Accessibility Map
GDP Gross Domestic Product	Gross Domestic Product
GeoEPR	Geographical Ethnic Power Relations dataset
GeoTiff	Geographical Tagged Image File Format
GHS	Global Human Settlement
GLC2000	Global Land Cover 2000
GLDAS	Global Land Data Assimilation System
GLW	Gridded Livestock of the World (GLW)
GMES	Global Monitoring for Environment and Security
GPW4	Gridded Population of the World version 4
GRanD	Global Reservoir and Dam
GSOD	Global Summary of the Day
G-WADI	Global Network on Water Resources Management in Arid and Semi-arid Zones
HSWD	Harmonized World Soil Database
HyDIS	Hydrologic Data and Information System
HydroSHEDS	Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales
IFPRI	International Food Policy Resaerch Institute
IFTD	International Freshwater Treaties Database

IIASA	International Institute for Applied Systems Analysis
IISS	International Institute for Strategic Studies
IRCC	International Water Cooperation and Conflict
ISARM	Internationally Shared Aquifer Resources Management
ISO	International Organization for Standardization
IWRM	Integrated Water Resource Management
JRC	Joint Research Centre
LISFLOOD	LISFLOOD - Distributed Water Balance and Flood Simulation Model
LP DAAC	Land Processes Distributed Active Archive Center
MAP	Malaria Atlas Project)
MapSPAM	Spatial Production Allocation Model
MCOW	African Ministers' Council on Water
MESA	Monitoring for Environment and Security in Africa) EU programmes
METI	(Japan's) Ministry of Economy, Trade, and Industry
MSWEP	Multi-Source Weighted-Ensemble Precipitation
NASA	National Aeronautics and Space Administration
NBA	Niger Basin Authority
NEPAD	New Partnership for Africa's Development
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
OMVS	Organisation pour la mise en valeur du fleuve Sénégal
PGF	Priceton Global Meteorological Forcing Dataset for land surface modeling
RBO	River Basin Organizations
REC(s)	Regional Economic Communitie(s)
SADC	Southern African Development Community
SADCO	Sothern African Data Centre for Oceonography
SANWATCE	Southern African Water Centres of Excellence
SCAD	Social Conflict Analysis Database
SEI	Stockholm Environment Institute
SOTER	SOil and TERrain database programme
SRTM(30)	Shuttle Radar Topography Mission (30-meter)
TFDD	Transboundary Freshwater Dispute Database
TIGER-NET	component of the TIGER initiative of the European Space Agency
WANWATCE	Western African Water Centres of Excellence
WDI	World Development Idicators
WEFE	Water Energy Food Ecosystem
WGI	World Governance Indicators
WHYMAP	World-wide Hydrogeological Mapping and Assessment Programme
WOIS	Water Observation and Information System
ZAMCOM	Zambezi Watercourse Commission
ZAMWIS	Zambezi Water Information System

World Development indicators (WDI);

List of figures

List of tables

Annexes

Annex 1. ACEWATER2 Regional database Hydro-Climatology Database: MsExcel file JRC109900_db_metadata_v2.xlsx .

Europe Direct is a service to help you find answers to your questions about the European Union.

Freephone number (*)**:**

00 800 6 7 8 9 10 11

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

More information on the European Union is available on the internet (http://europa.eu).

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
  via EU Bookshop (http://bookshop.europa.eu);
- more than one copy or posters/maps:
  from the European Union's representations (http://ec.europa.eu/represent_en.htm);
  from the delegations in non-EU countries (http://eeas.europa.eu/delegations/index_en.htm);
  by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm) or
  calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

  (*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu).

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office