

Africa Groundwater Atlas

Making African groundwater information more available

<http://www.bgs.ac.uk/africagroundwateratlas/index.cfm>



Unlocking the
Potential of
Groundwater
for the Poor



**British
Geological Survey**
NATURAL ENVIRONMENT RESEARCH COUNCIL



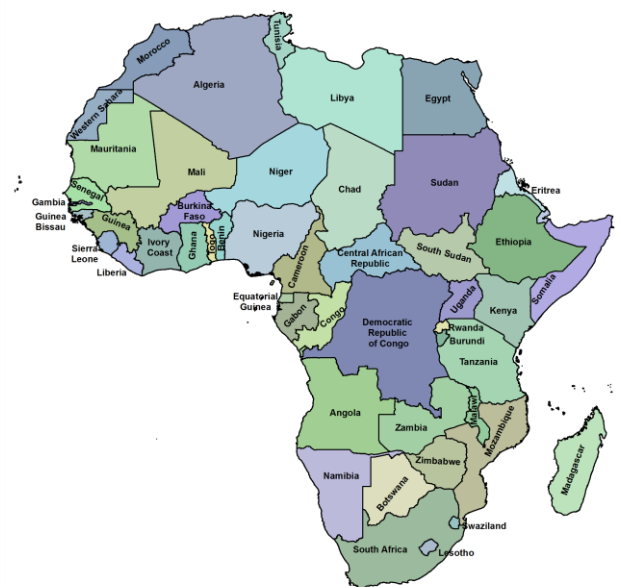
NERC
SCIENCE OF THE
ENVIRONMENT

E·S·R·C
ECONOMIC
& SOCIAL
RESEARCH
COUNCIL



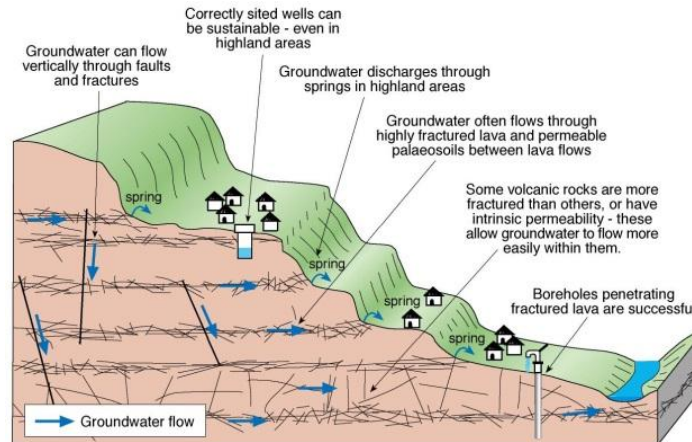
What is the Africa Groundwater Atlas?

- A starting point for **understanding groundwater resources at a country-scale**
- Brings together groundwater information from many sources in a consistent way
- Makes Africa groundwater information more visible and accessible
- Allows comparison & learning between different countries



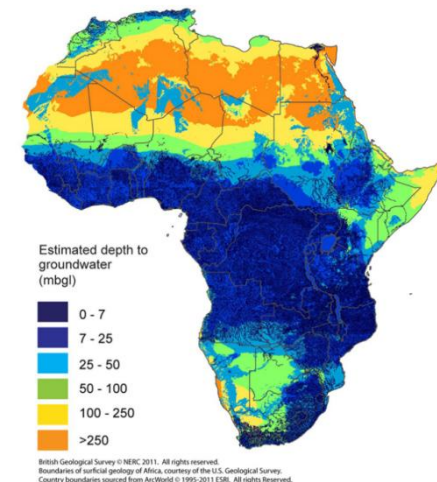
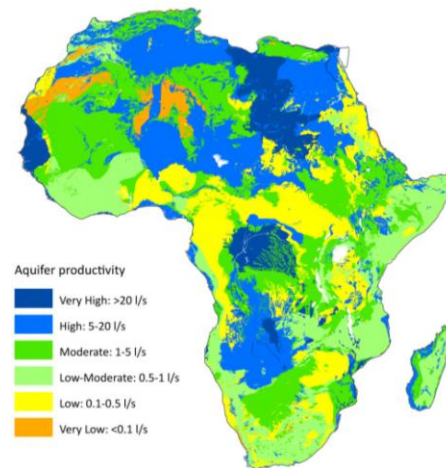
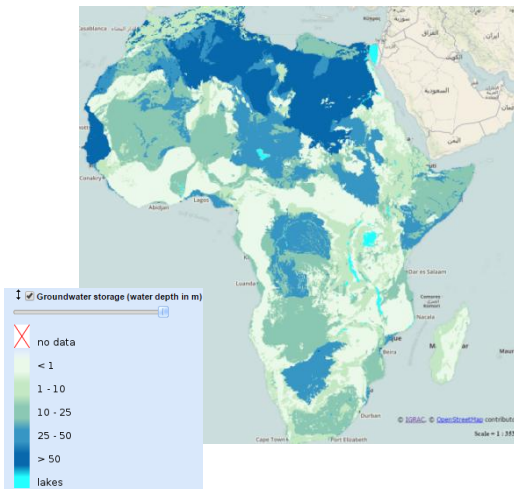
Why is the Atlas important?

- For safe, sustainable groundwater development we need to **understand groundwater**
- To understand groundwater we need **good information** – which is hard to find!
- **BUT** there is lots of good information out there – it's just not always easily **visible** and **accessible**



Background to the Atlas

- In 2012 – new maps of all-Africa **aquifer productivity**, **groundwater storage** and **depth to groundwater** – for a continental-scale overview



Download maps from BGS as GIS files
or

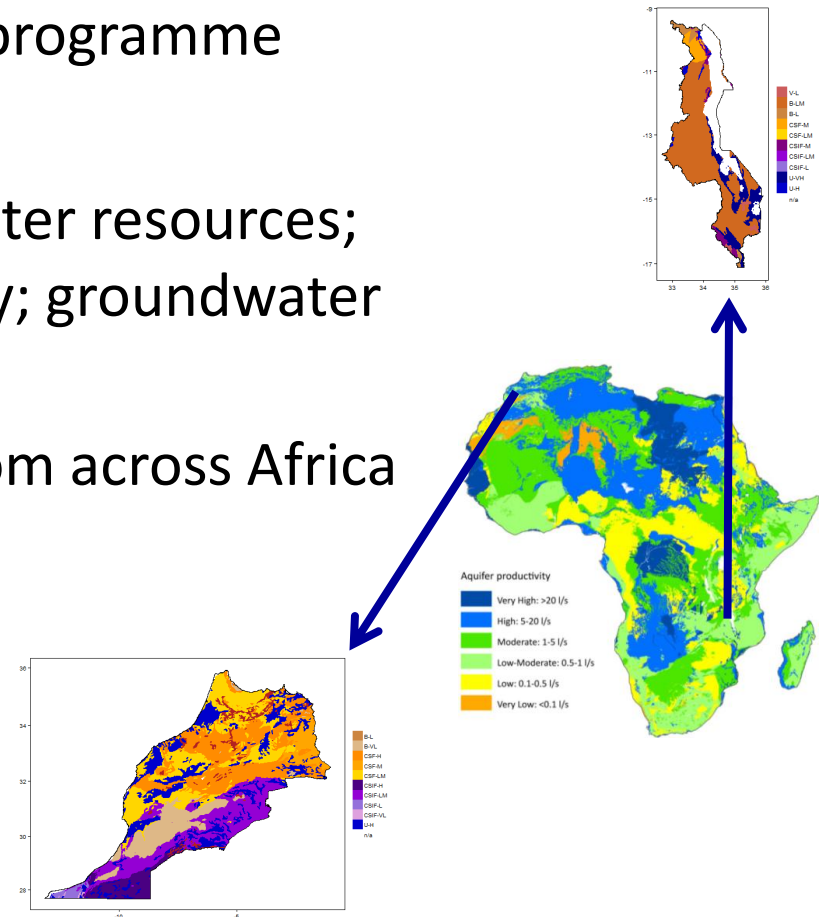
View IGRAC's **Groundwater Resources in Africa** webpage

<http://www.bgs.ac.uk/research/groundwater/international/africanGroundwater/maps.html>

<https://ggis.un-igrac.org/ggis-viewer/viewer/groundwaterafrica/public/default>

Developing the Africa Groundwater Atlas

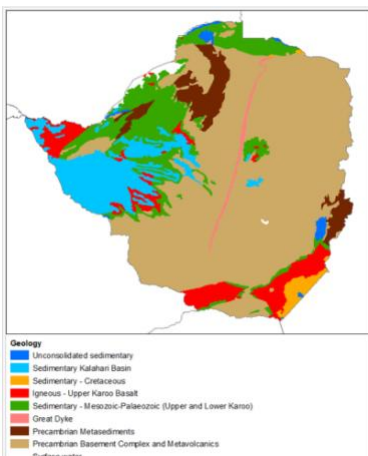
- To meet demand for **country-scale** information
- Funded by UK government **UPGro** programme
- For **51 countries**
- A **consistent overview** of groundwater resources; key aquifers and their hydrogeology; groundwater status and management
- Co-written with hydrogeologists from across Africa
- Online and free
- Offline version available



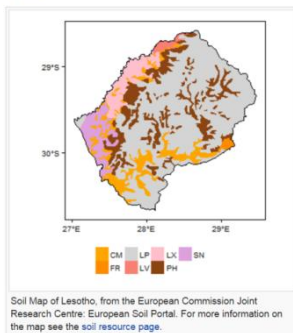
What's inside the Atlas?

Information on:

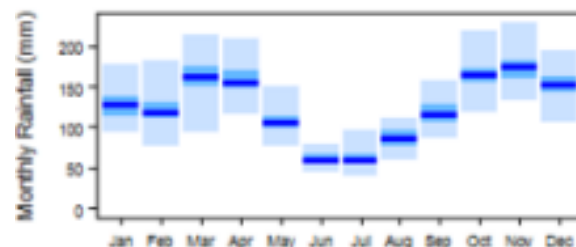
- How geology, hydrogeology and groundwater resources vary across each country
- Climate – rainfall and temperature
- Soil, land cover and surface water
- Groundwater status – quality and quantity
- How groundwater resources are managed



Soil [edit]



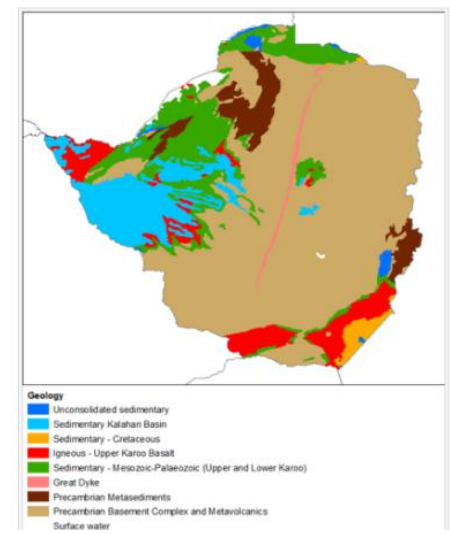
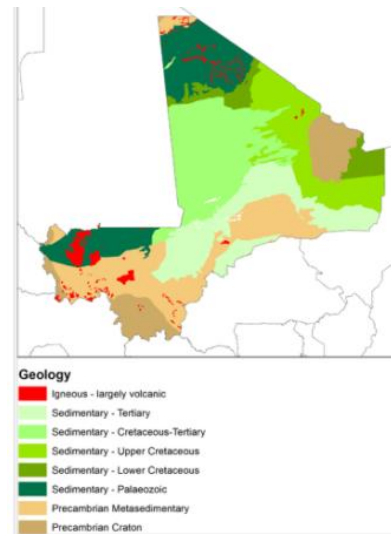
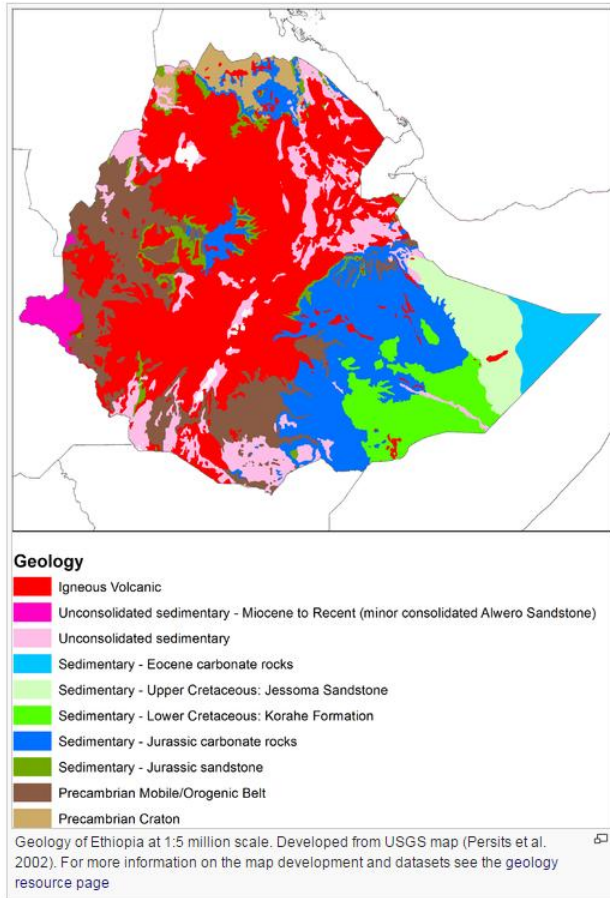
Maps



Descriptions
Graphs

Sedimentary - intergranular and fracture flow [edit]				
Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
Cenozoic sandstones and limestones	Semi-consolidated marine sedimentary rocks with relatively high porosity in which groundwater is stored and flows through both intergranular matrix and fractures.			
Jurassic and Cretaceous limestones - Northern (Atlas) domain	Consolidated marine sedimentary rocks with relatively high karstic porosity, in which groundwater is stored and flows dominantly through fractures and karst conduits. This is often a highly productive aquifer. Yields of more than 100 l/s are seen from the Zibans karst, and greater than this from the Neritic formation of Constantine (100 l/s at Hamma springs, 400 l/s at Fourch, 650 l/s at Boumeroug). In some parts there is extensive groundwater discharge via springs, e.g. at Zaccar (Mifana sources), Djurdura, and its extension to Bejaia.		Thermal waters. The groundwaters are generally of calcium bicarbonate or calcium sulphate type.	Direct recharge, mostly occurring during periods of exceptionally heavy rain. Some recharge by horizontal flow from other aquifers.
Complex Terminal Late Cretaceous to	These two aquifers together form part of the transboundary Northern Saharan Aquifer System (SASS), also known as the North-west Sahara Aquifer System (NWSAS) (see section on Transboundary aquifers, below). These are largely deeply buried, and can be at least 2000 m thick. Much of the aquifer is siliclastic, and is often a highly productive aquifer. Analysis of its is the Continental Intersolvent in the Adrar region indicates conductivity values of between 3×10^{-4} and 3×10^{-3} S/m.	The groundwater resource is generally considered to be fossil - many thousands of years old - and in areas is known to be overexploited, with	Water quality ranges from good, with relatively low levels of mineralisation, to poor, in some areas, groundwater in the Complex Terminal has salinity levels between 4 and 9 g/l (FAO, 2009).	Recharge is minimal, due to the generally deep burial of the aquifers and the arid climate. Small amounts of recharge occur from episodic

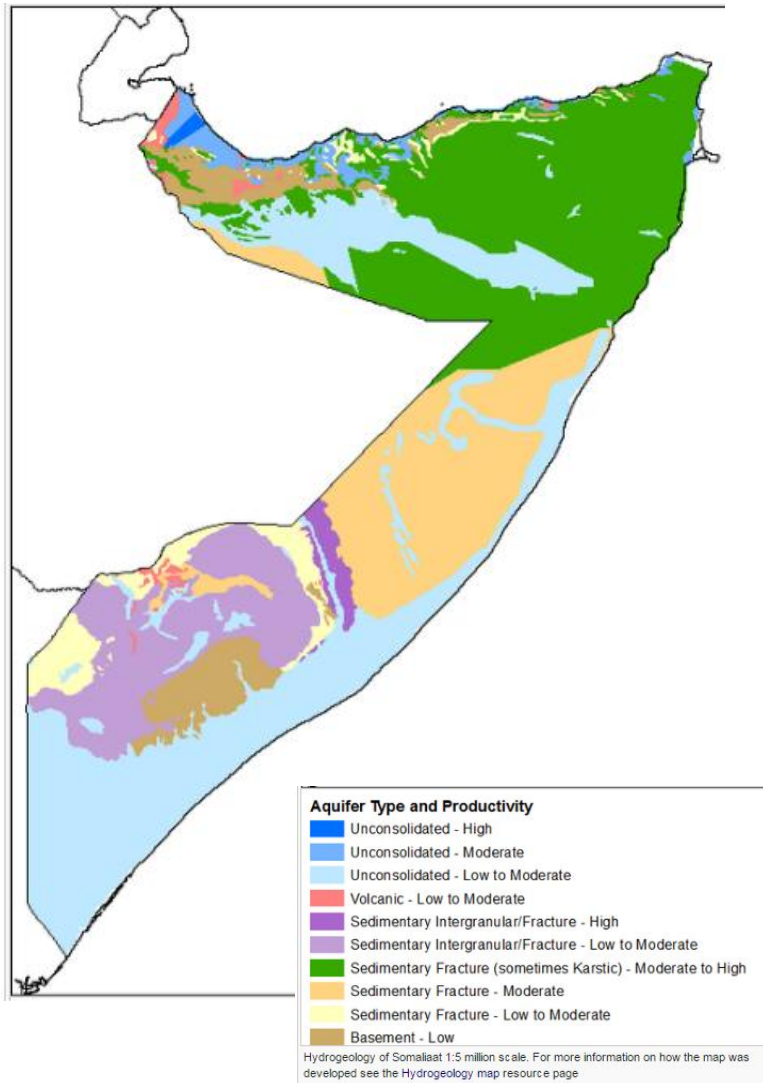
National geological map



Geological Environments			
Key Formations	Period	Lithology	Structure
Igneous - volcanic			
Lesotho Formation (Drakensberg Group)	Jurassic	Massive basalts which overlie the sedimentary rocks of the Karoo Group.	Reaches thickness of 1600m at Mount-aux-Sources in the north of Lesotho (Schmitz and Rooyani 1987).
Igneous - intrusive			
Dolerite intrusions	Jurassic	Numerous dykes cross the country in two dominant directions: NW-SE and NNE-SSW. Most dykes are near vertical, plate-like bodies, but some dip as shallowly as 60° (Schmitz and Rooyani 1987). Some dykes cut across all geological formations and others die out within the basalts. Sills (plate-like, near-horizontal intrusions) occur in older Karoo sedimentary strata, especially in the southwest of Lesotho.	
Sedimentary - Karoo			
Clarens Formation (Cave Sandstone) (Stomberg Group)	Late Triassic to Early Jurassic	This is the youngest sedimentary formation underlying the basalts of the Jurassic Lesotho Formation. It occurs across the central and eastern parts of Lesotho, but crops out only in central Lesotho and in major valleys within the Lesotho Formation. The sandstones are of aeolian origin. Generally pale white and cream coloured, although darker beds occur. The formation can be subdivided into three zones: 1. Zone I: thickly to very thickly bedded, light brown and light red, very fine grained sandstone, silty sandstone and sandy siltstone. 2. Zone II: alternating beds of massive and cross-bedded sandstone. 3. Zone III: massive to very thickly bedded, very fine grained sandstone to massive silty sandstone, sandy siltstone and siltstone.	Thickness from 15 to 250m. Outcrops in the form of plateaux in the lower foothills and as cliffs overlooking the lowlands.
Elliot Formation (Red Beds) (Stomberg Group)	Late Triassic to Early Jurassic	Underlies the Clarens Formation and characterised dominantly by red and purple mudstones and shales and medium to fine grained sandstones. The strong red and purplish coloration differentiates it from the underlying Molteno Formation and from the white and cream coloured overlying Clarens Formation. The transition from the underlying Molteno Formation to the Elliot Formation is gradual, indicating continuous sedimentation.	Thins from a maximum of 250m in the south to 15m in the north.
Molteno Formation (Stomberg Group)	Late Triassic to Early Jurassic	White arkosic grits and gritty sandstones, mainly pebbly, with occasional thin shaly sandstones and bluish mudstone (Schmitz and Rooyani 1987). The Molteno Formation underlies the whole of Lesotho and outcrops in the lowlands, where it comprises up to 50m of massive, coarse sandstone.	Thins out northwards (Schmitz 1984): from 35m in the north to 150m in the south.
Burgersdorp Formation (Beufort Group)	Mid Permian to Lower Triassic	Green, purple and red shales and mudstones with some buff sandstone; occasional carbonaceous shales with thin coal seams; some ferruginous concretion beds. Only the uppermost part of this formation is exposed in Lesotho, with its maximum exposed thickness in the Mokare (Caledon) River Valley in the extreme western part of Lesotho (UNDP 1984).	Maximum exposed thickness of 200 to 250m

Summary of main geological formations

National hydrogeological map



Igneous [edit]

Named aquifers	General description	Water quantity issues	Water quality issues	Recharge
	Igneous aquifers exist in Zaccæ, Djurdjura, Collo and l'Edough in the east, and in Hoggar. Groundwater flows through fractures and altered horizons, and discharges naturally through springs. In Hoggar, borehole drilling has shown that groundwater is encountered at between 20 and 50 m depth. The aquifers generally have low productivity.		Average total dissolved solids in Hoggar are 500 mg/l	Important recharge occurs in northern igneous aquifers.*

Sedimentary - intergranular and fracture flow [edit]

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Complexe Terminal (Late Cretaceous to Cenozoic) and Continental Intercalaire (Palaeozoic to Late Cretaceous)	These two aquifers together form part of the transboundary Northern Saharan Aquifer System (NWSAS), also known as the North-west Sahara Aquifer System (NWSAS) (see section on Transboundary aquifers, below). These are largely deeply buried, and can be at least 2000 m thick. Much of the aquifer is siliclastic sandstone; some parts are karstic; and there are some evaporates. This is often a highly productive aquifer. Analysis of pumping tests in the Continental Intercalaire in the Adrar region suggests hydraulic conductivity values of between 3×10^{-4} and 3×10^{-5} m/s.	The groundwater resource is generally considered to be 'fossil' - many thousands of years old - and in areas is known to be overexploited, with	Water quality ranges from good, with relatively low levels of mineralisation, to poor. In some areas, groundwater in the Complexe Terminal has salinity levels between 4 and 9 g/l (FAO, 2009).	Recharge is minimal, due to the generally deep burial of the aquifers and the arid climate. Small amounts of recharge occur from episodic rainfall where the

Summary of key aquifers

Answers to questions like:

- Where are the high yielding aquifers?
- Is groundwater storage and flow in pores or weathered zones or fractures?
- What are typical borehole yields from an aquifer?
- What is the groundwater quality?

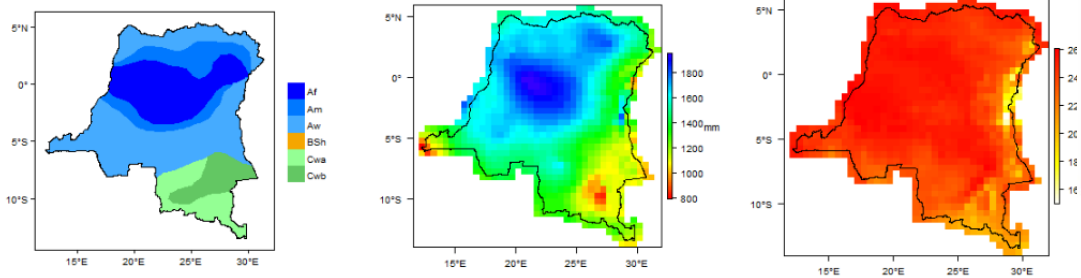
Summaries of climate, surface water, topography, soil and land cover

- Derived from 3rd party data
- Easily compare from one country to another

Climate [\[edit\]](#)

The Democratic Republic of the Congo lies on the equator. Average temperatures across much of the country are around 25 degrees C, except in the eastern mountain temperatures are around 20 degrees C. There is much cloud cover over much of the year, with the maximum sunshine in the dry season.

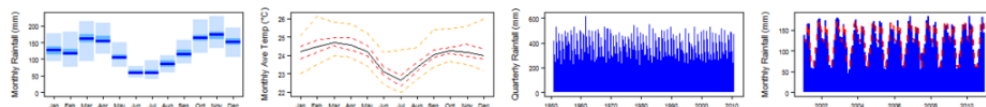
Average annual rainfall for the whole country is over 1,200 mm, rising to more than 2,000 mm in the central basin, and falling to a minimum of around 850 mm at the



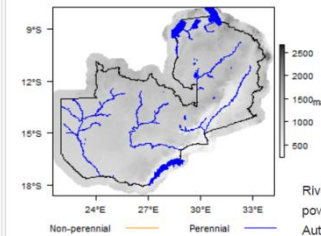
Koppen Geiger Climate Zones

Average Annual Precipitation

Average Temperature

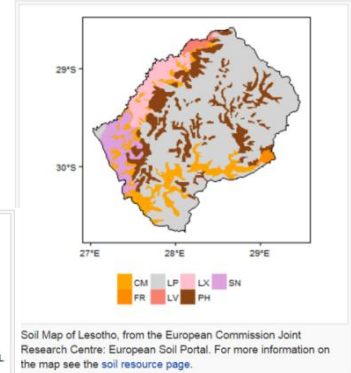


Surface water [\[edit\]](#)



Major surface water features of Zambia. Map developed from World Wildlife Fund HydroSHEDS; Digital Chart of the World drainage; and FAO Inland Water Bodies. For more information on the map development and datasets see the [surface water resource page](#).

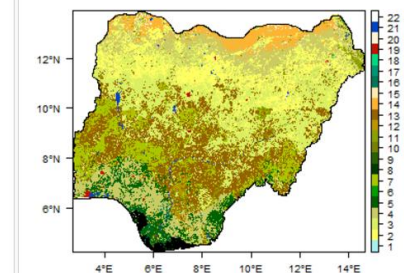
Soil [\[edit\]](#)



Soil Map of Lesotho, from the European Commission Joint Research Centre; European Soil Portal. For more information on the map see the [soil resource page](#).

River flow gauging is undertaken by Zesco, Zambia's power generating company, and the Zambezi River Authority (ZRA). Zesco's gauging stations are mainly on the Kafue River, while the ZRA gauges the Zambezi and stretches of the Kafue.

Land cover [\[edit\]](#)



Land Cover Map of Nigeria, from the European Space Agency GlobCover 2.3, 2009. For more information on the map see the [land cover resource page](#).

Answers to questions like:

- When is the recharge season?
- Have there been droughts in recent years?
- Are there areas with no surface water resources?

Groundwater status, use & management

Groundwater Status [\[edit\]](#)

Groundwater quantity [\[edit\]](#)

The recent FAO/SWALIM study (2012) considered that in the northern provinces of Somaliland and Puntland, where there is no perennial surface water, 'total annual groundwater (although not necessarily available for abstraction) in the major aquifer systems is theoretically equal to some 4.3×10^9 m³. Although this amount of water of 139 m³/s looks very promising, the large area of these two regions - more than 289 000 km² - means that groundwater water is still scarce. Estimated specific less than 0.5 l/s/km², which classifies northern Somalia as having extremely poor groundwater reserves.

Most drilled boreholes provide yields in the range 1 to 5 l/s, but there are many with lower or higher yields. In some cases, boreholes can't sustain high pumping rate aquifer could yield more groundwater if higher capacity pumps or pipe diameters were installed to increase borehole capacity.

The highest known aquifer potential is illustrated by the most productive well known in northern Somalia, in the Auradu karstic limestone aquifer in Ceerigabo, which had a test yield of 50 l/s for a drawdown of only 2.43 m (Faillace and Faillace 1986). Another known high productivity aquifer is the terrace and alluvial sediments used for the water supply of Hargeysa (the capital of Somaliland). Average boreholes yields are 15 l/s with drawdown not larger than 5-10 m.

Groundwater quality [\[edit\]](#)

Groundwater quality is a major issue in many parts of Somalia. The natural quality of groundwater depends in part on aquifer lithology and the soluble products of aspects such as seasonal recharge, so that groundwater quality can vary from season to season. Many boreholes are abandoned because of poor water quality. This in individual aquifers is summarised in the relevant tables above.

A FAO/SWALIM survey in 2012 showed that in the northern Somaliland and Puntland regions, across all aquifers, only 30% of groundwater samples were below the limit of 1500 microS/cm, with 29 % of the samples in the range 1500 to 3000 microS/cm and 41 % of the samples above 3000 microS/cm.

Recharge [\[edit\]](#)

Recharge occurs only if the rainfall regime is favourable. In areas with scarce and uneven rainfall, infiltration may occur only along stream beds and floodable debris thunderstorms covering small areas usually occur in the northern regions and generate spate flows in foggas (wadis or seasonally dry streambeds), which last for a couple of days (Faillace and Faillace 1996).

Groundwater dependent ecosystems [\[edit\]](#)

There are numerous springs in the north of Somalia in the study area of the FAO/SWALIM programme. A total of 267 springs were registered, which tend to be in karstic and/or karstic aquifers. They are of crucial for local ecosystems.

Groundwater use and management [\[edit\]](#)

Groundwater use [\[edit\]](#)

Given the lack of perennial streams and the arid climate in much of Somalia, groundwater is the sole water resource in most of the country. Approximately 95% of the population use groundwater for drinking water. Most groundwater is used for drinking, and also a significant groundwater use. Irrigation is not widely developed, except along the two major perennial rivers. There are no large groundwater industrial sector.

The most productive groundwater sources are boreholes drilling into unconsolidated alluvial terrace aquifers and karstic aquifers. Boreholes alluvium in foggas (wadis), to a few hundred meters in Eocene karstic aquifers or the Nubian (Yessoma) sandstone aquifer. Submersible hand pumps are used to tap water from shallow aquifers.

Due to limited reserves related to very low effective rainfall; a very deep groundwater table in many areas; and/or increased water salinity limited access to it in most of the country. The water supply situation in many parts of Somalia is therefore exceptionally severe. A large access to safe, sufficient groundwater. Several deep drilling projects have been undertaken with the aim of developing groundwater resources hydrogeological knowledge, the success rate of groundwater development has been very low.

Fourteen water utilities serve major towns and settlements in the Somaliland and Puntland regions, with a total around 2,544,000 inhabitants Somalia. However, not more than 25% of this population is connected to water distribution systems and pipelines (FAO/SWALIM 2012). is in Sheikh, at 4%, but most problematic is Hargeysa where over 750,000 of residents, mostly in suburban areas, have no proper access

Groundwater management [\[edit\]](#)

Key groundwater institutions include:

The Ministry of Water Resources in Mogadishu

The Ministry of Water Resources in Somaliland

The Puntland State Agency for Water, Energy and Natural Resources

After the end of the former government of Somalia there was no legal framework. Somaliland and Puntland have made significant steps towards re-establishment in 2013, and put into use, with the Ministry of Water Resources issuing permits for strengthened for the laws and policies to be fully implemented.

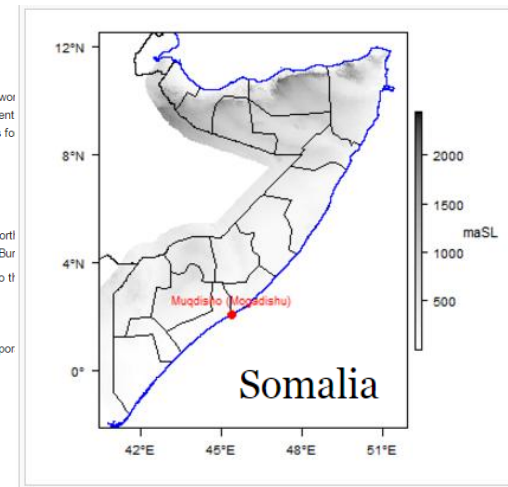
Groundwater monitoring [\[edit\]](#)

Groundwater level monitoring [\[edit\]](#)

FAO/SWALIM established an initial groundwater monitoring network in the north. 8 groundwater level loggers are installed in Hargeisa, Borama, Berbera and Bur Data from this network will help to prevent future depletion of aquifers due to the water for domestic use and watering livestock.

Groundwater quality monitoring [\[edit\]](#)

No systematic groundwater quality monitoring is done. Local water utilities spor



Answers to questions like:

- What are the main uses of groundwater?
- Are there any big groundwater problems? (water quality? over-abstraction?)
- Which institutions are involved with groundwater management?
- Is there groundwater monitoring?
- Are there national groundwater databases?

Where to find more information

- Key geological & hydrogeological references
- Links to other websites

Africa Groundwater Literature Archive

Home

Introduction

Welcome to the Africa Groundwater Literature Archive. The Archive is a searchable database providing full bibliographic references for published and unpublished groundwater literature about Africa, including reports, journal articles, conference papers and maps.

If the document is digital, where possible the Archive provides a web link to the full text of the document freely available to download. A few documents are available as a pdf download directly from the Archive. If the full document is not freely available, for example because of copyright restrictions, a web link is provided to an online abstract where possible. If there is no online link, it means we have no information about whether a digital, online version of the document exists. The Archive does not hold hard copies of documents.

The current Archive is by no means an exhaustive list of groundwater literature for Africa. If you have, or know of, other documents which you would like to see in the Archive, please feel free to get in touch, whether they are already online and/or digital or whether they are in hard copy. If you hold the copyright to any items in the Archive that are not currently available to download, and you would like them to be provided through the Archive, please get in touch via the contact page.

Please feel free to send us any feedback you have on the content, functionality and format of these webpages and the Archive, via the contact page. Your comments and input help to improve the Archive.

See the About this site page for more information about this project and the Archive.

Searching the Archive

Search Form

Use the search form to look for references.

Map Search

Search geographically using the interactive map.

IGRAC [edit]

The UN International Groundwater Resources Assessment Centre (IGRAC) produces information on groundwater resources development and management, and produces a number of publications. Tuinhof, A, Foster, S, van Steenberg, F, Talbi, A, and Wishart, M. 2011. *climatic variability*. Strategic Overview Series, No. 5, GW-MATE/World I

WaterAid [edit]

WaterAid produces information on managing water resources, including groundwater, and provides support to communities to water stress. Other WaterAid publications can be found on the WaterAid website.

International Association of Hydrogeologists [edit]

The International Association of Hydrogeologists (IAH) works to raise awareness of groundwater. IAH publishes academic research through the *Hydrogeology* journal.

IUCN [edit]

The IUCN publish the handbook *Spring: managing groundwater sustainably*.

Groundwater Governance [edit]

The Groundwater Governance project aims to improve groundwater management in averting the impending water crisis in Africa.

RWSN [edit]

The Rural Water Supply Network (RWSN) promotes rural water supply development.

Furey, S G, and Danert, K. 2014. *Sustainable Groundwater Management*. Gallen.

Africa Groundwater Network [edit]

The Africa Groundwater Network (AGW-Net) has produced a training manual in English and French. The manual is designed to support the international community in a range of other activities relating to its key aims of increasing awareness of groundwater and promoting communication within the African groundwater sector in Africa. *AGW-Net* promotes communication within the African groundwater sector.

UPGro [edit]

The UPGro programme (Unlocking the Potential of Groundwater for the Poor) is a multi-partner initiative aimed at improving groundwater management and use in Africa.

UP Gro Unlocking the Potential of Groundwater for the Poor

Prepared by: British Geological Survey, Natural Environment Research Council

Jointly funded by: UKaid, NERC

INSTITUTE OF MINERAL RESOURCES
DEPARTMENT OF MINES
REPUBLIC OF SOUTH AFRICA
WATERLOGGING PROPERTIES
OF THE NEW FORMS
GEOLOGICAL FORMATIONS
IN THE
UNION OF SOUTH AFRICA

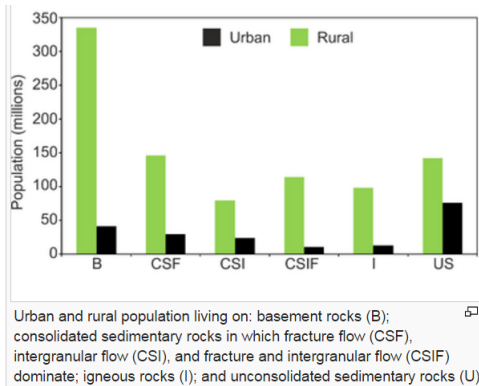
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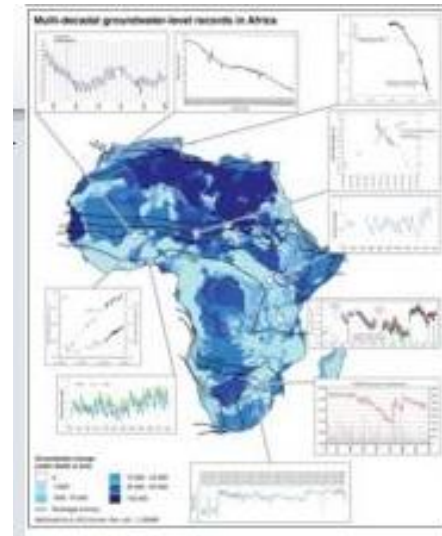
Resource Pages

Background information and technical explanations on key issues, e.g.:

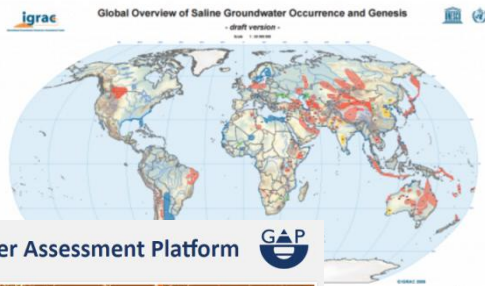
Groundwater use



Groundwater monitoring



Groundwater quality

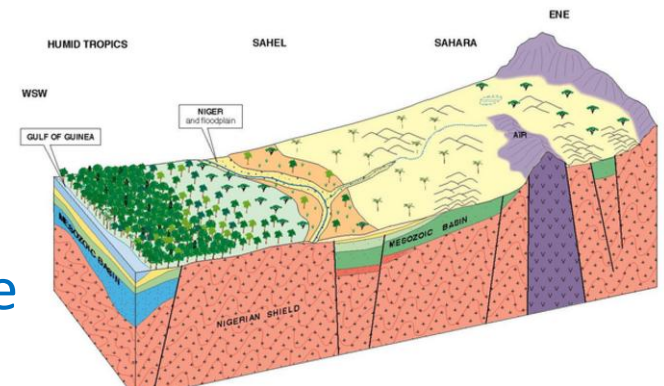


Groundwater Assessment Platform



Mapping and information platform for geogenic groundwater contamination

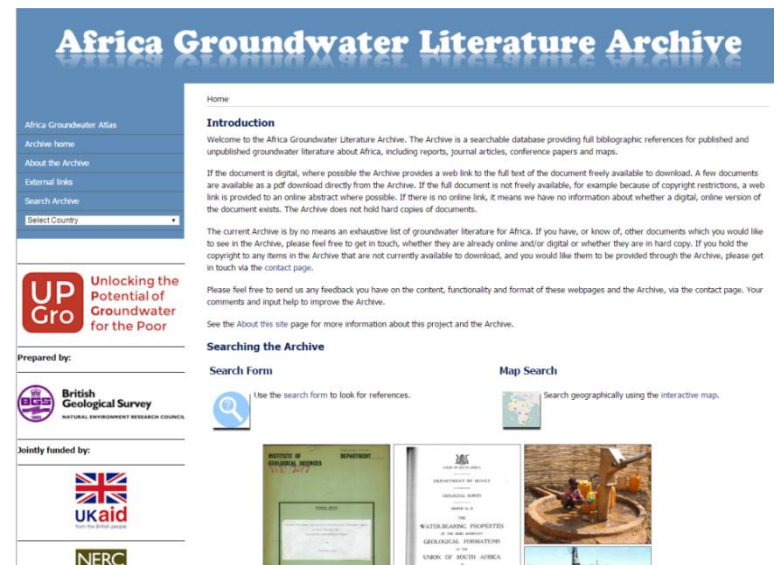
MAIN LANDSCAPE ELEMENTS, GROUNDWATER RECHARGE AND WATER QUALITY EVOLUTION IN THE SAHARA/SAHEL



Recharge

Africa Groundwater Literature Archive

- The most comprehensive yet index of African groundwater literature
- ~7000 entries (so far!)
- Full text download if available; or for copyrighted documents, link to online abstract if available
- Full bibliographic references
- Complements other literature archives: e.g. WRC; IRD; SADC Grey Literature Archive



What's in the Archive?

- **Reports** (e.g. by geological surveys, governments, development organisations); **journal articles**; **conference papers**; **academic theses**; **books**; **hydrogeological maps** (mostly pdf or image files)
- Documents from 1897 to today



Using the Archive

Powerful search options:

- **Keyword:** >200 hydrogeological keywords
- **Free text:** search or filter results by Title and Authors
- **Geographically:**
 - Every relevant reference is tagged by **country**
 - As many as possible are **georeferenced** – searchable on interactive map

Search the Africa Groundwater Literature Archive
Use this form to search the archive.

Country Search
To search for all available references for a specific country, select the relevant country, or more than one if appropriate. Click the 'Search' button to view the results. You can also search by continent.

Keyword Search
To search for references on a particular topic or combination of topics, use the keyword search option. The options to search titles and authors.

Map Search
You can also search references that have been georeferenced using an interactive map.

Search Form
Title: All of Page
Author: All of Page
Keyword: Any Keyword
Country: Any Country
Search to **ONLY** include documents with PDF download or external resource

Search Results
Filter titles: permeability Filter authors:

The following 22 results are available for your search.

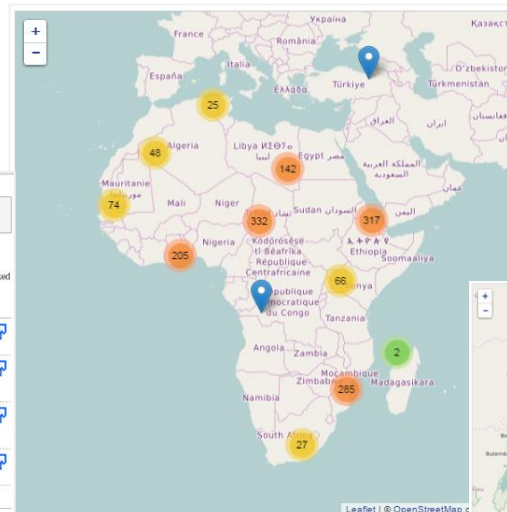
Click a report title to view full details. Reports marked with have a PDF available to download from this site. Those marked with have a link to an external resource.

Not Country Specific

- Guendouz, A.; Michélot, J.-L., 2006 *Chlorine-36 dating of deep groundwater from northern Sahara*. Journal of Hydrology 326, 572-580. Elsevier.
Keywords: Radioactive Isotopes, Groundwater Flow, Recharge, Groundwater Dating, Permeability, Sedimentary
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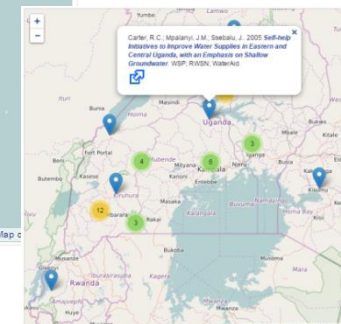
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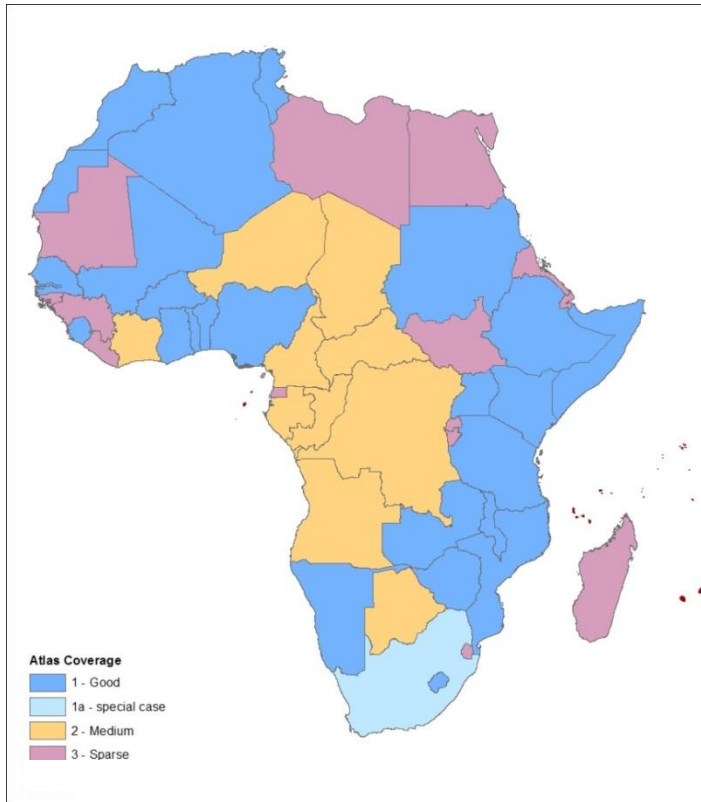


Self-help Initiatives to Improve Water Supplies in Eastern and Central Uganda, with an Emphasis on Shallow Groundwater
Carter, R.C.; Mubanyi, J.M.; Seebalu, J., 2005 *Self-help Initiatives to Improve Water Supplies in Eastern and Central Uganda, with an Emphasis on Shallow Groundwater*. WSP/RWSN/WaterAid

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