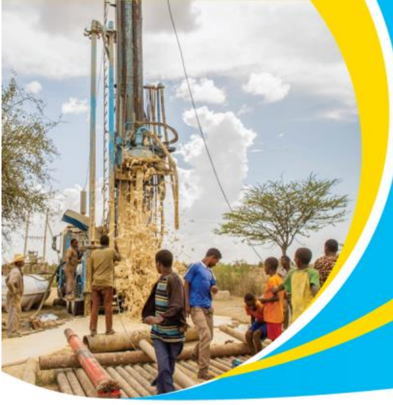


WASH Field Note FN/03/2018

unicef for every child

Using GIS and Remote Sensing to Access Water in the Drought-Prone Areas of Ethiopia and Madagascar

SUMMARY BOX

- Remote sensing uses satellite technology to scan the earth and identify 'high potential' sites for the extraction of groundwater through the drilling of boreholes.
- In Ethiopia and Madagascar, UNICEF is combining these remote sensing techniques with hydrogeological, meteorological and geophysical data in order to develop groundwater suitability maps for drought-prone regions.
- As a result of these projects, drilling success rates have been increased from less than 50% to above 90% in Ethiopia. In Madagascar, the groundwater suitability map is being used to effectively site 25 new boreholes in drought-prone regions, with positive results so far.
- Both initiatives are helping to significantly increase efficiency and cost effectiveness of borehole drilling, ultimately allowing UNICEF to reach more communities and strengthen climate change resilience.

Introduction

The changing climate is one of many forces contributing to an unfolding water crisis in Eastern and Southern Africa. As temperatures increase, water scarcity and drought are becoming more prevalent and intense in the region. Eastern and Southern Africa have been hit particularly hard, not least because the region has the worst access to safe water globally.

Two of the countries most affected by the water crisis are Ethiopia and Madagascar. In Ethiopia, 61% of the population still do not have access to basic water supply whilst in Madagascar 49% do not have access. Combined, more than 72 million people are currently living without access to basic water in the two countries.

As these countries continues to develop and populations grow, pressure on existing water resources is set to intensify, increasing the need to find new, safe sources of water.

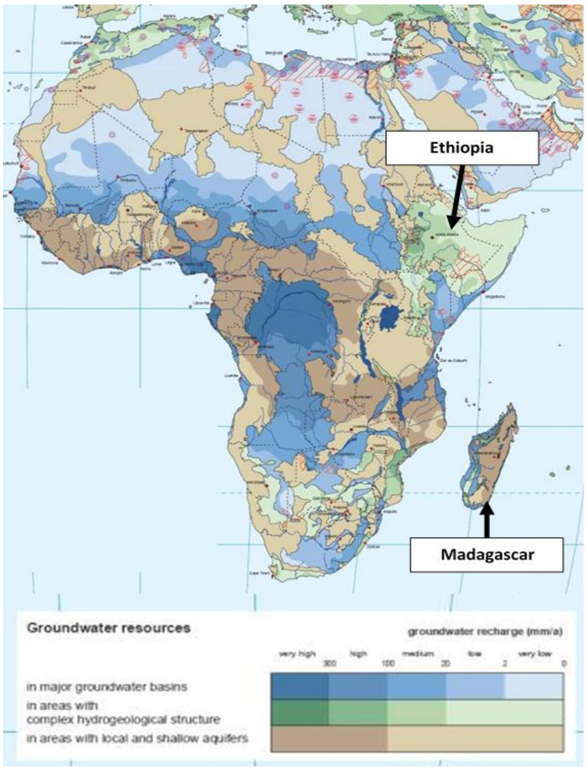
Africa in general, has a high availability of groundwater resources (Fig.1).

In the case of Ethiopia, much of this groundwater is located in regions with highly complex hydrogeological structures which are prone to geochemical contamination (saline and fluoride).

In the case of Madagascar, major groundwater basins exist close to the coasts and are subject to the intrusion of saline water whilst inland local and shallow aquifers are more common.

Water scarcity exists, predominantly because communities are not able to access these groundwater sources, due to lack of infrastructure and economic constraints.

Fig. 1 Groundwater Resources of Africa



At the same time, drilling success rates are often low in many regions, largely due to the hydrogeological complexity. Even where the data and information are available; it is often incomplete, uneven and often of a poor quality, which further complicates the situation. Often, drillers require multiple (expensive) attempts to locate water. With the correct hydrogeological information and mapping, drilling success rates can be increased drastically, reducing costs and allowing more communities to access safe water supply.

KEY POINTS

- *Ethiopia and Madagascar have two of the worst levels of water access globally, despite having plentiful groundwater sources.*
- *The two countries also suffer from recurrent drought and water scarcity, exacerbated by climate change.*
- *Drilling success rates are low due to water scarcity, hydrogeological complexity, a weak knowledge base and capacity within the drilling sector.*
- *Remote sensing combined with geophysical 'ground-truthing' is an alternative to the use of expensive hydrogeological field studies. It supports the exploration of groundwater and the identification of the most suitable sites for boreholes siting and drilling.*

Description of Intervention

1.1 Remote Sensing

In order to improve drilling success rates, it is vital to undertake reliable groundwater investigations. However, conventional methods of generating large scale hydrogeological maps require a huge amount of time, manpower, logistical and financial resources.

Remote sensing (RS) is a precursor to detailed hydrogeological field studies. The technique utilizes satellite technology to scan the earth and identify the most favorable sites for borehole drilling. The advantage of using RS data includes its large spatial coverage and homogeneous data acquisition.

Although there is no satellite-based sensor to measure the occurrence and amount of groundwater directly, different RS-derived parameters (e.g., elevation, precipitation, evapotranspiration, vegetation, geological features, etc.) can be utilized in the assessment of groundwater potential as several studies have demonstrated that the occurence of groundwater is associated with many surface and subsurface factors such as topography, vegetation, and geological properties that can be derived from satellite imagery.

It is important to note that the use of RS data does not eliminate or exclude the collection of ground-based data, which is needed to verify the accuracy of RS data and to aid interpretation, but RS data helps to minimize the costs and time associated with field data collection.

Fig. 2 Simplified GIS Model

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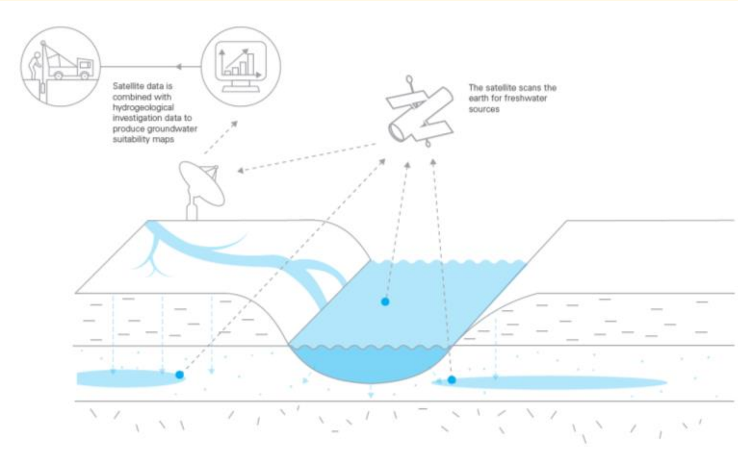
<tr><th>Schematic</th><th>Technologies/infrastructure</th></tr>
<tr><td>
</td><td>Remote sensing (scanning of the Earth by satellite) is combined with hydrogeological investigation techniques to look freshwater sources located deep in the ground.
Satellite-derived and in situ information on factors affecting groundwater occurrence are overlaid to produce groundwater suitability maps to determine the best locations for drilling successful boreholes.</td></tr>
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Case Study 1: Ethiopia

Water access is critically low in the lowlands of Ethiopia. Here, people often rely on temporary solutions such as water from birkas (water storage tanks stocking rain water) and in times of emergency water trucking is the only alternative.

Groundwater is the main source of rural and urban water supply in the arid lowlands which are characterized by complex geology, low rainfall and highly variable topography.

These environmental settings represent challenging conditions for groundwater supply as drilling success rates are controlled by various factors including the geological conditions, level and depth of baseline hydrogeological knowledge, and the expertise of the hydrogeologists and the drillers involved.

In recent years, the number of drilled water wells has dramatically increased through the intervention of various international and local initiatives. However, the success rate of productive wells in the arid lowlands has been low (30-50 per cent).

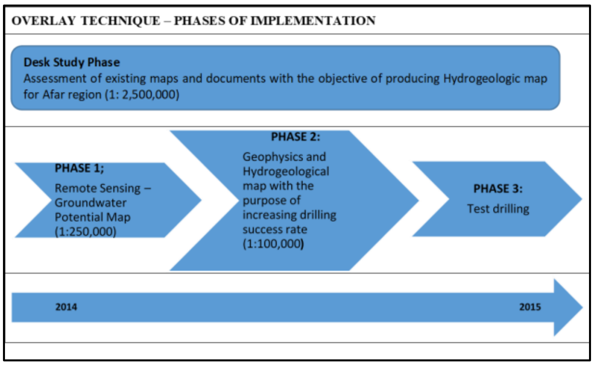
The failure in pinpointing productive sites is primarily attributed to the complexity of hydrogeology in the Rift Valley region that requires adequate scientific information to precisely explore the availability of groundwater.

In anticipation of a major 2015 drought, UNICEF, in collaboration with UNESCO and the Government of Ethiopia, began piloting the use of remote sensing in order to locate water located deep in the ground.

The first test was carried out in northern Ethiopia, in the Elidar district of the Afar region. Elidar is one of the areas most affected by water insecurity, and there is growing evidence that the lack of water is being caused by climate change. The remote sensing project aimed to improve drilling success rates and ensure that more people, particularly children, have access to safe water closer to home.

The project consisted of three stages (Fig.3).

Fig. 3 Stages of UNICEF Ethiopia Remote Sensing Project



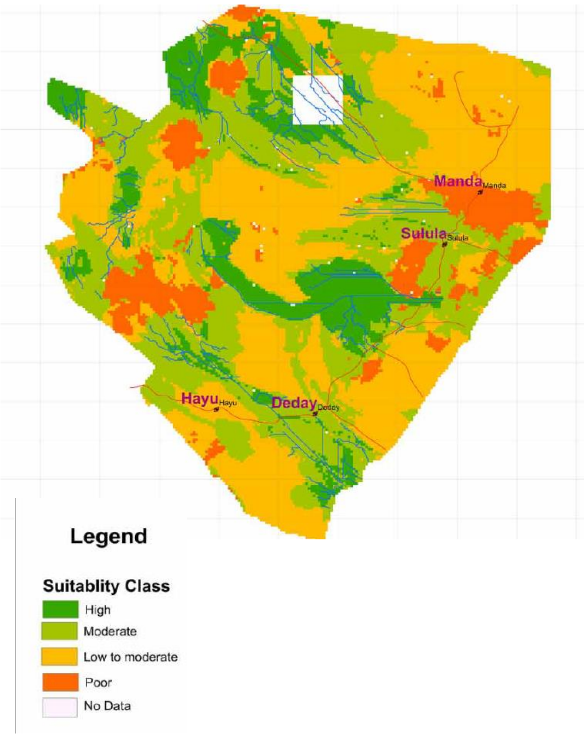
The first phase of the project combined satellite data with additional sources of hydrogeological, meteorological and geophysical data in order to develop maps for nine drought-prone districts which showed the best locations for groundwater drilling.

During phase 2 of the project, UNICEF Ethiopia contracted a consortium led by UNESCO and other private consultancy firms to undertake a hydrogeological field study which included a water point inventory, water quality survey, groundwater recharge estimation and geophysical investigations at the 'high potential sites' identified by the remote sensing technology. Resistivity surveys were undertaken using the vertical electrical sounding technique.

Additionally, 50 water quality samples were collected and analysed to determine the hydrogeochemical characteristics of the district. Geological and hydrogeological maps were then developed, leading to the identification of groundwater suitability zones.

A probability model was then presented and test drilling took place through the use of a private contractor.

Fig.4 Groundwater suitability map of Elidar



The results of the test drilling (phase 3) of 11 boreholes to date have shown a 92 per cent accuracy rate compared with less than 50 per cent previously. The resilient boreholes are currently suppling multi-village piped systems, providing safe water for thousands of people.

While initial capital costs can be high, viewed over its lifetime, the average annual costs of piped water supplies are four times less expensive than hand dug wells, considering the cost of emergency water trucking when these wells dry up.

This success has meant that approximately 42,000 people have now gained access to safe water.

UNICEF is now working with partners to scale up the remote sensing project to an additional 39 arid and semi-arid districts with the aim of ensuring safe water access for thousands more children living in the most drought-prone areas.

Case Study 2: Madagascar

Madagascar has one of the lowest levels of access to safe water globally. Just 51% of the population have access to basic water supply, with this figure dropping to just 34% in rural areas. The semi-arid southern regions of Madagascar have the lowest rates of water supply coverage and are highly vulnerable to chronic drought.

Some of the main challenges involved in improving access include:

i) The very low borehole drilling success rates due to water scarcity and a high level of groundwater salinity, bothing relating to the complexity of regional hydrogeology;

ii) Limited knowledge of the regional hydrogeological context, and;

iii) Weak capacity of the drilling sector.

In order to tackle the issue, in 2017 UNICEF teamed up with the European Union/Joint Research Centre (EU/JRC) to begin using satellite imagery to map groundwater availability.

Inspired by the experiences of UNICEF Ethiopia, the Madagascar's remote sensing techniques are now being used to produce thematic layers of groundwater occurrence zones.

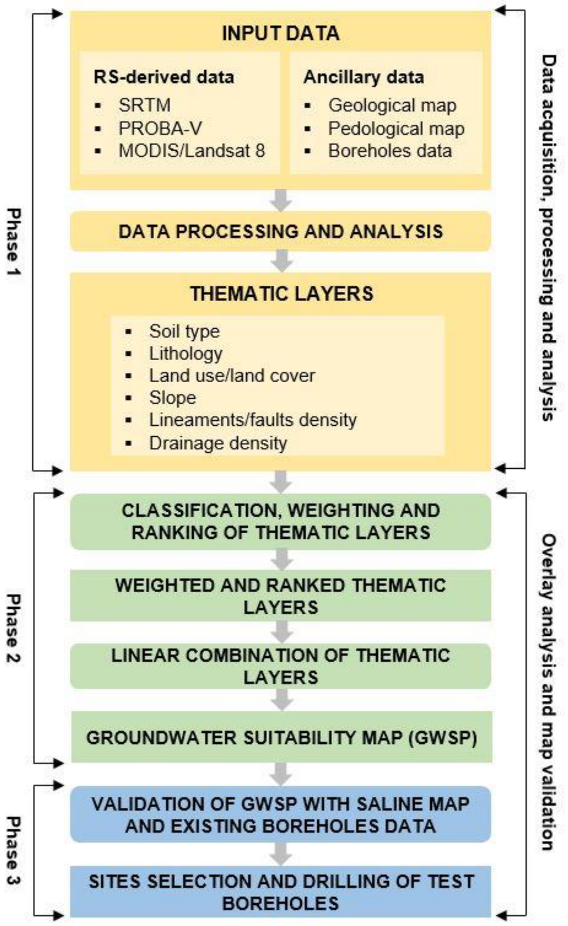


Fig.5: Methodology of UNICEF Madagascar Remote Sensing Project

Four assumptions were made to guide the selection of layers that influence aquifer recharge. Groundwater potential increases with;

i) Increasing recharge (infiltration/precipitation) ii) Higher soils/rock permeability (geology)
iii) Higher density of lineaments/faults (geological structures), and;
iv) Flat/gentle slopes (topography)

The satellite-derived layers are then overlaid with ground-based hydrogeological data to create a map of groundwater potential to identify priority areas for further water exploration, borehole siting and drilling (Fig.6).

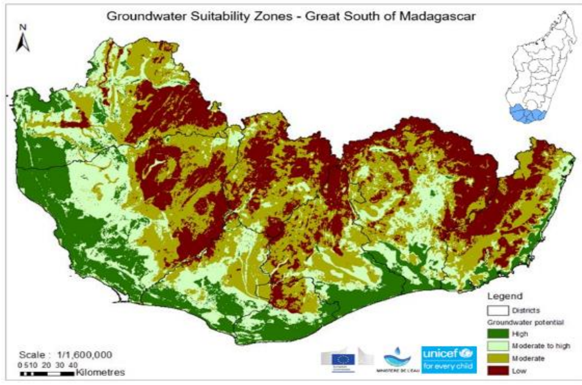


Fig.6 Groundwater suitability map of southern Madagascar

The project is also supporting the development of an online database for boreholes and hydrogeological data, which will improve the knowledge on the region's geological and hydrogeological and hopefully lead to improvements across the drilling sector.

A recent development has also been the use of the Google Earth platform to develop a public web mapping and sharing tool, allowing borehole and hydrogeological data accessible to the entire sector.

OUTCOMES

Ethiopia

As a result of the remote sensing and groundwater mapping projects, drilling success rates have increased from 50% to 92% in the lowland areas of Ethiopia.

The projects have ensured that at least 42,000 people have now been able to access safe water in Ethiopia.

Madagascar

In Madagascar, the groundwater suitability map is now being used by UNICEF and partners to identify the best sites for 25 new boreholes in the southern regions of Androy and Atsimo Andrefana.

Handpumps will be installed on these boreholes to provide clean and safe water to about 7,000 people in rural communities.

It is envisaged that the improved drilling success rates will improve programme efficiency, ultimately decreasing costs and allowing UNICEF to reach more communities in need.

At the same time, increased access to safe water in drought prone regions has increased community resilience to the impacts of climate change.

As a result of safe water access, community health and livelihoods are protected, even in the face of drought.

LESSONS LEARNED

Ethiopia

The capacity of drilling firms to work in remote and difficult geological terrains has so far been a limiting factor for the project. In response to this challenge, UNICEF has worked closely with a number of firms to strengthen their ability to work in the rift valley and has developed an incentive based contract arrangement where only positive boreholes are paid for.

In the new phase of mapping, water quality (excluding salinity) are now investigated within the RS and GIS analysis. Also, demographics and water demand will now provide an additional map layer that will help to identify priority areas for detailed studies.

Madagascar

Reliable hydrogeological data and groundwater suitability maps are vital to reduce the risk of drilling failure. The limited knowledge of regional hydrogeological contexts and lack of recent ground-based data are major challenges.

In order to scale-up the project to other regions it will be vital to ensure an intensive and effective data collction campaign takes place in order to gather sufficient data to validate results.

THE WAY FORWARD

Moving forward, a major priority for UNICEF Madagascar and Ethiopia will be the scale-up of multi village pipelines in order being a higher level of service to more households and improve utility management services.

Additional specific activities will also include:

Ethiopia

- Finalisation and validation of the groundwater maps, through the Ministry of Water-led technical committee.
- Transfer of results and knowledge to government partners, allowing nationwide scale-up of the initative.

Madagascar

- Capacity building of partners (technology transfer through training), especially for the Ministry of Water, Sanitation and Hygiene technicians.
- Scale up the study to other regions of Madagascar where lack data and limited knowledge of the regional hydrogeological context is impacting drilling success rates and access to safe water.

REFERENCES

Godfrey, S. and Hailemichael, G. (2016) Three-phase approach to improve deep roundwater supply availability in the Elidar district of Afar region of Ethiopia, *Journal of Water, Sanitation and Hygiene for Development*, 06.3, IWA Publishing https://iwaponline.com/washdev/article-abstract/6/3/414/30138/Three-phase-approach-to-improve-deep-groundwater?redirectedFrom=fulltext

Josephs-Afoko, D., Godfrey, S., and C Campos, L. (2018) Assessing the performance and robustness of the UNICEF model for groundwater exploration in Ethiopia through application of the analytic hierarchy process, logistic regression and artificial neural networks. South African Water Research Commission V 44 No. 3, July 2018 https://www.ajol.info/index.php/wsa/article/view/175449

Serele C. (2018) Mapping of Groundwater Suitability Zones in the Drought Affected Areas of South Madagascar using Satellite Imagery and GIS, UNICEF/EU-JRC, Sector-wide workshop, March 2018, Madagascar https://bit.ly/2Mr9GnA

UNICEF and JRC (2016) Hydrologic Study in drought affected areas of Afar, Samali, Oromia and SNNPR Regions of Ethiopia https://ec.europa.eu/jrc/en/publication/hydrogeological-study-drought-affected-areas-afar-somali-oromia-and-snnp-regions-ethiopia-part-1

CREDITS

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AUTHORS

- Dr Samuel Godfrey, East and Southern Africa WASH Advisor, UNICEF ESAR
- Michele Paba, WASH Specialist, UNICEF Ethiopia
- Charles Serele, PhD., WASH Specialist, UNICEF Madagascar

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UNICEF's water, sanitation and hygiene (WASH) country teams work inclusively with governments, civil society partners and donors, to improve WASH services for children and adolescents, and the families and caregivers who support them. UNICEF works in over 100 countries worldwide to improve water and sanitation services, as well as basic hygiene practices. This publication is part of the UNICEF WASH Learning Series, designed to contribute to knowledge of best practice across the UNICEF's WASH programming. The documents in this series include:

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United Nations Children's Fund
3 United Nations Plaza, New York, NY 10017, USA

For more information, please contact: WASH@unicef.org

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