Hydrogeological Mapping for Climate Resilient WASH in Ethiopia – LOT 1

15 July 2021

Inception Report Validation Workshop

BDA/ICB/GW01/2021

Arjen de Vries, Theo Kleinendorst

aquacon ENGINEERING PLC

ACACIA WATER

www.acaciawater.com

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- Key team members
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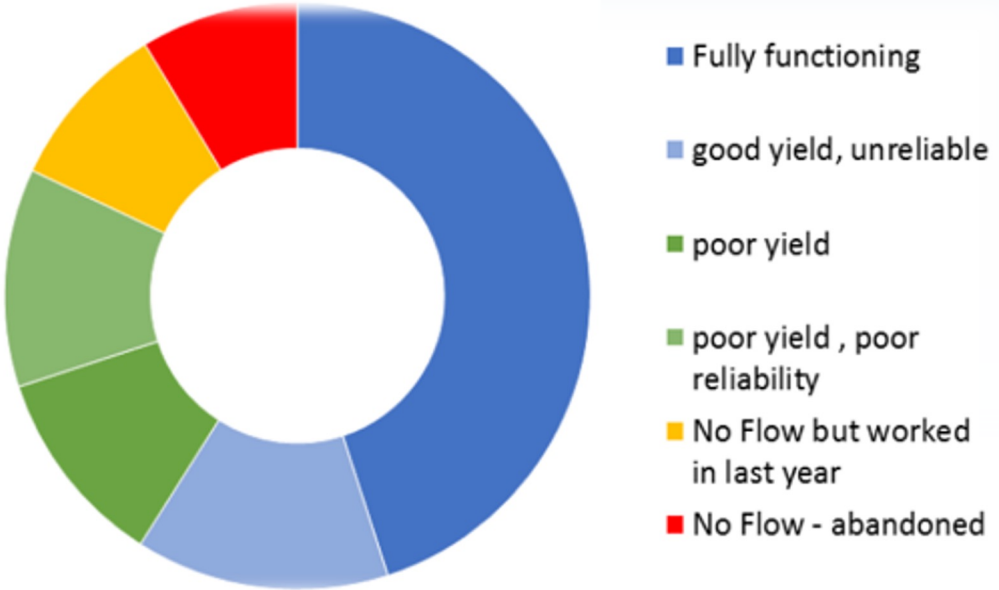


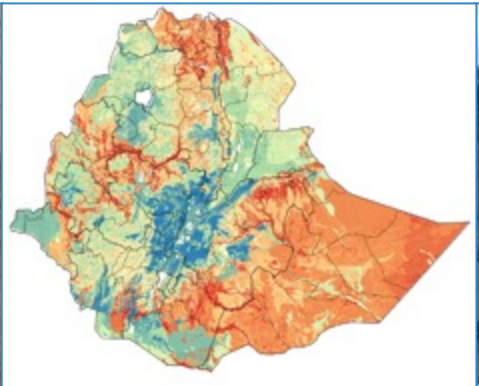
- *Low success rates*
- *Poor sustainability*
- *Technical failures*

Project Objectives

Overall objective

Increase access to safe and sustainable water for the people in drought affected regions by:

1. producing hydrogeological maps at the Woreda level and
2. recommend drilling sites for developing groundwater

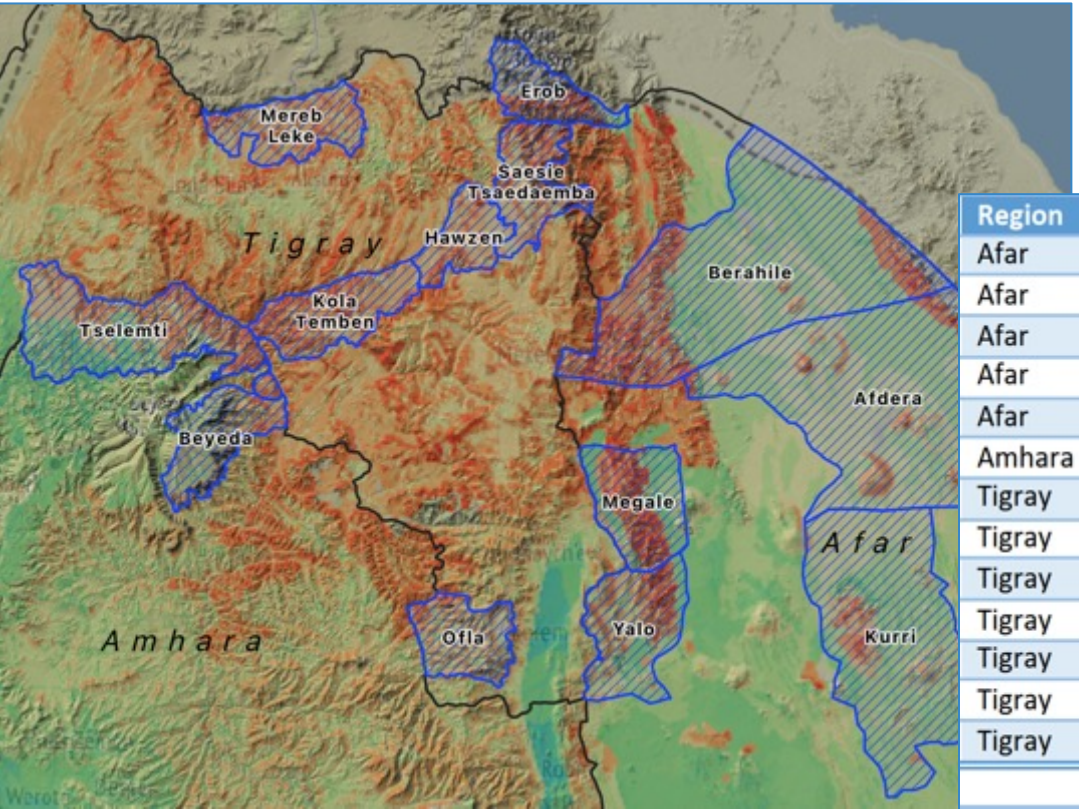


Project Objectives

Specific objectives

1. Create detailed groundwater potential maps for each Woreda.
2. Identify two optimal drilling sites per Woreda
3. Recommend the type of drilling methodology(s) to be employed
4. Build the capacity for stakeholders to use/apply overlay analysis techniques for groundwater potential mapping and borehole siting

Project Area



Region	Zone	Woreda	Area (km2)
Afar	Zone 1	Kurri	2,870
Afar	Zone 2	Afdera	7,435
Afar	Zone 2	Berahile	2,509
Afar	Zone 2	Megale	1,548
Afar	Zone 4	Yalo	823
Amhara	North Gonder	Beyeda	973
Tigray	Central	Kola Temben	1,365
Tigray	Central	Mereb Leke	1,259
Tigray	Eastern	Erob	773
Tigray	Eastern	Hawzen	869
Tigray	Eastern	Saesie Tsaedaemba	963
Tigray	Northwestern	Tselemti	2,656
Tigray	Southern	Ofla	1,085
		Total	**25,128**

Project Team

Acacia Water plc
Gouda, the Netherlands

Aquacon Engineering plc
Addis Ababa, Ethiopia

Joint Venture

External experts

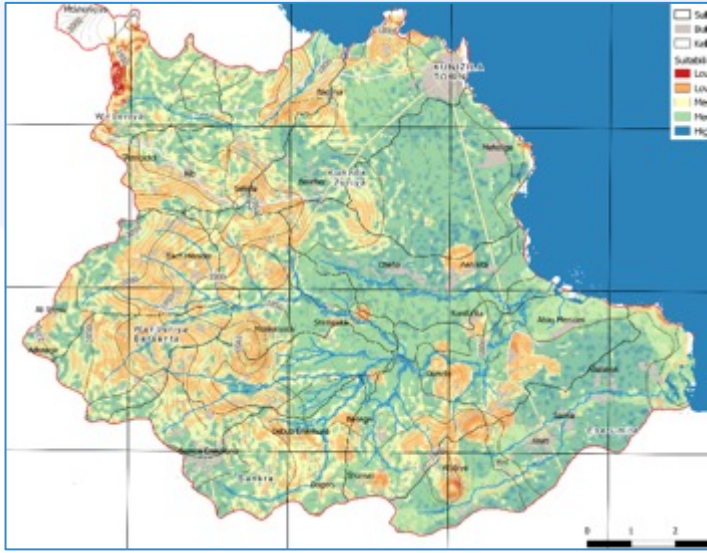
Project Team

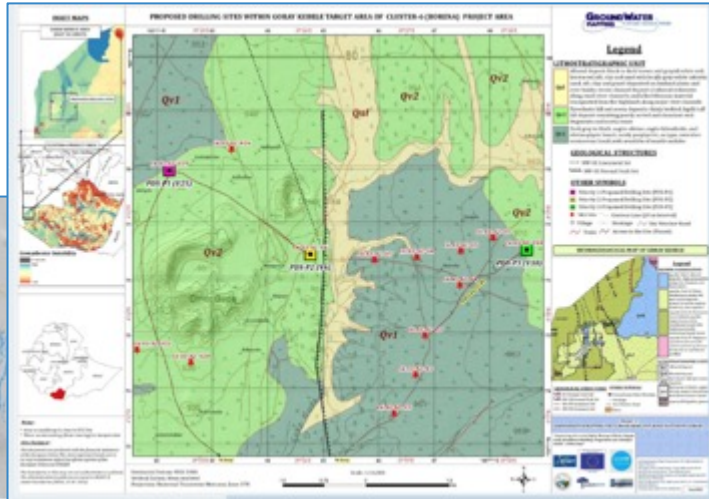
Project management	Team leaders	(Hydro) geologists	hydrologists	Geophysists	GIS/RS
					
		Ermias Abdel wassie		Yigrem	 Shiferaw

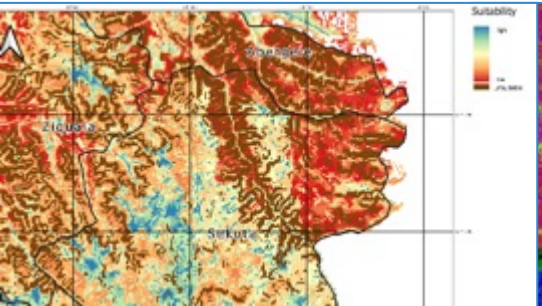
Background and History

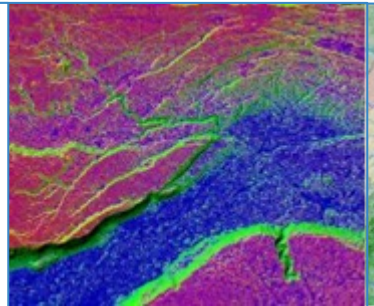
Groundwater feasibility mapping

- Overlay analysis since 2009: India, Indonesia
- Expertise Acacia Water/Aquacon
  - UNESCO/UNICEF 2014: Afar and Tigray
  - UNICEF: RESET-II (2018-2020)
  - WLRC: Kunzila (2020-2021)

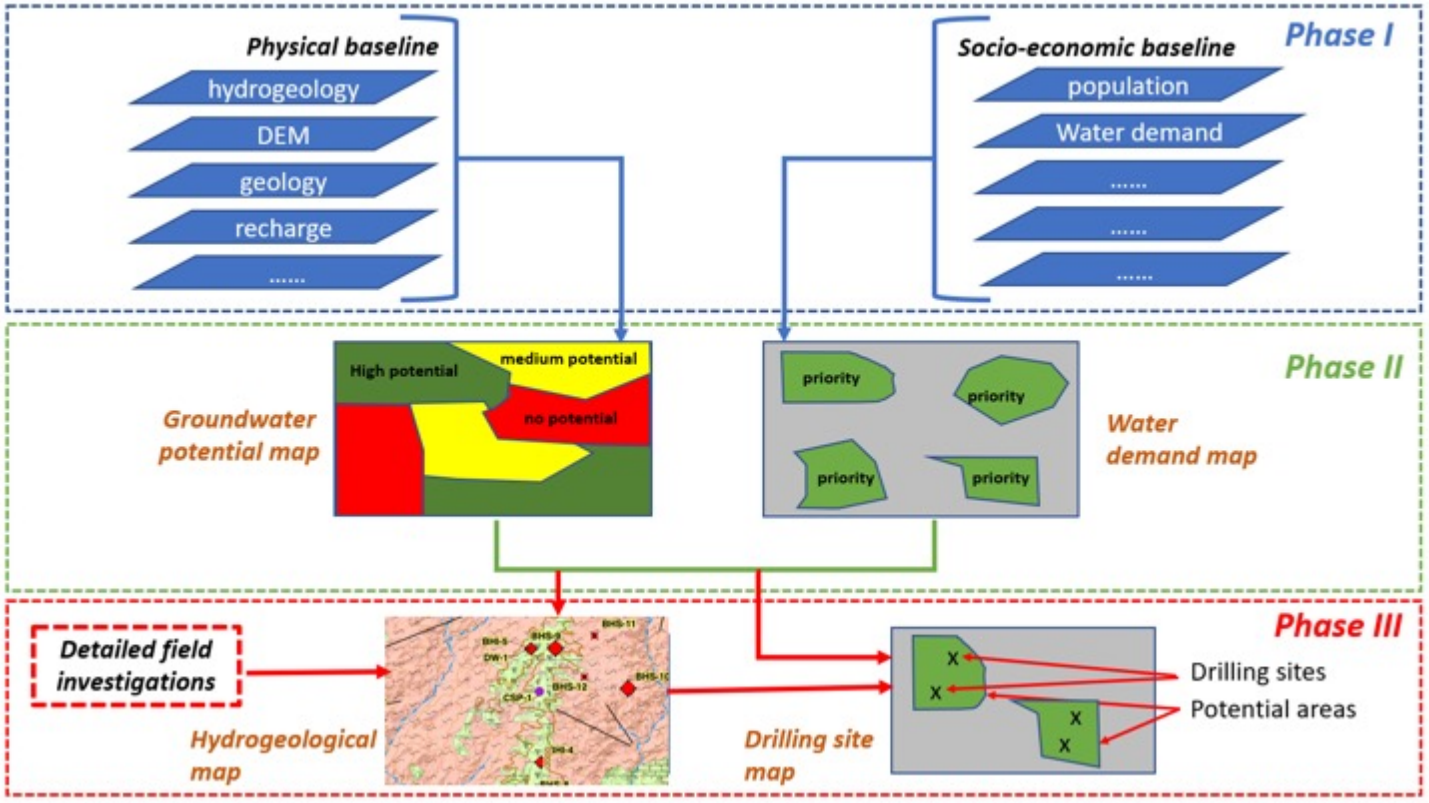








Methodology



Inception
May-Jul 2021

Mapping
Jul-Oct 2021

Siting
Oct 2021 - Feb 2022

Phase 1 Planning

LOT I		2021								2022		
		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1. Phase I: Desk Study and development of relevant conceptual hydrogeological models and maps												
1.1	Data collection analysis and review of information											
1.2	Develop conceptual hydro-geological model											
1.3	Produce demographic map (1:1,000,000)											
1.4	Produce Hydrogeological map of woredas (1:1,000,000)											
1.5	Prepare Inception Report											
1.6	Inception Workshop											
1.7	Final Inception Report											
2. Phase II: Groundwater Potential Mapping												
2.1	Develop thematic maps, overlay analysis, and produce groundwater potential map (1:100,000)											
2.2	Identification of priority population and estimate water demand of target aeas											
2.3	Conduct field visit in all target woredas for collection of ground truth information and data											
2.4	Identification of relevant climatic conditions for climate resilient WASH											
2.5	Develop conceptual model (Hydrogeological section) of the woredas											
2.6	Select target areas for detail study											
2.7	Prepare and submit draft report											
2.8	Organize Validation workshop of the groundwater potential mapping											
2.9	Final groundwater potential mapping report											
3. Phase III: Detail site specific Hydrogeological and Geophysical Investigation												
3.1	Conduct detail Hydrogeological study of selected target areas											
3.2	Conduct detail Geological study of selected area											

Phase 2 Planning

LOT I	2021								2022		
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1. Phase I: Desk Study and development of relevant conceptual hydrogeological models and maps											
1.1 Data collection analysis and review of information											
1.2 Develop conceptual hydro-geological model											
1.3 Produce demographic map (1:1,000,000)											
1.4 Produce Hydrogeological map of woredas (1:1,000,000)											
1.5 Prepare Inception Report											
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3.1 Conduct detail Hydrogeological study of selected target areas											
3.2 Conduct detail Geological study of selected area											

Phase 3 – Field investigations

LOT I	2021								2022		
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
3. Phase III: Detail site specific Hydrogeological and Geophysical Investigation											
3.1 Conduct detail Hydrogeological study of selected target areas											
3.2 Conduct detail Geological study of selected area											
3.3 Conduct Geophysical Survey and prepare Geophysical map (1: 5,000)											
3.4 Determine impact of climate change on groundwater resources in selected areas											
3.5 Prepare Hydrogeological conceptual model and map of target area (1: 50,000)											
3.6 Select optimum site for drilling borehole and corresponding potential climatic sensitivities requiring resilience measures											
3.7 Produce well design, specification and select appropriate drilling technology and BOQ preparation for CR-boreholes											
3.8 Prepare and submit draft report											
3.9 Organize validation workshop of draft report											
3.1 Final report											
4. Capacity Building											
4.1 Training on groundwater mapping, interpretation of the remote sensing overlays & integrating borehole & surface geophysical information for regional experts											
4.2 Training on information management and knowledge dissemination for stakeholders											
4.3 Provide five days training workshop for trainees from federal and regional governments and NGO partners											
4.4 Training for counterparts on groundwater mapping, interpretation of maps and integrating boreholes with geophysics information											
4.5 Organize all Relevant Data, Information, Tools and software, and handing to BDA											

Capacity building

LOT I	2021								2022		
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
3. Phase III: Detail site specific Hydrogeological and Geophysical Investigation											
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Risk mitigation

Major areas	Principle risks	Mitigation measures
Borehole Yield	• Unable to meet demand • Declining yields	• Improved borehole siting • Improved borehole design
Borehole water quality	• Anthropogenic quality issue • Natural quality issues • Nearby land uses that might impact releases, spills or leaks,	• Siting including protective zones • Wellhead drainage works, land use control • Proper borehole construction with protection against contaminant • Fuel storage and spill control plans for fuels.
Borehole functionality	• Operational risks related to borehole malfunctions or breakdowns and availability of power for pumping • Risk of damage due to location, poor security, and theft.	• Contracting professional firms for borehole construction. • Training borehole operators by means of capacity training • Instituting formal O&M procedures. • Developing Wellhead Protection Programs

Borehole monitoring	• Uncontrolled groundwater abstraction
	• Delayed action in case of breakdown/failure
	• Delayed action in case of pollution
	• Non timely mitigation intervention and troubeshooting and troubleshooting.
		• A formal monitoring plan in place
		• Monitoring of a range of parameters, such as:
		  • Condition of equipment
		  • Daily pumpage (rate (Q), duration, volume)
		  • Water levels (static and pumping)
		  • Water level drawdown
		  • Water quality

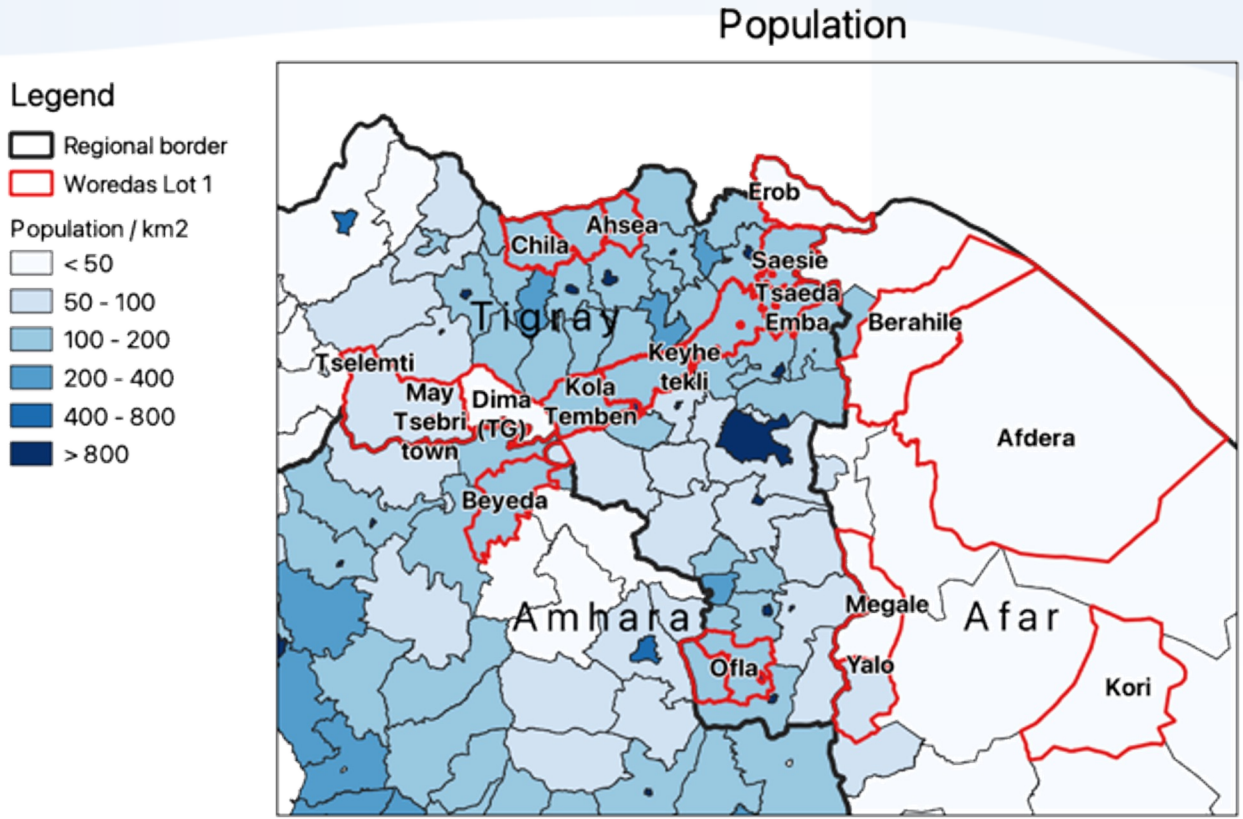
Phase 1 Results

- Socio-economic map 1:1,000,000
- Hydrogeological map 1:1,000,000
- Conceptual hydrogeological model
- Database waterpoints, socio-economy
- Inception report

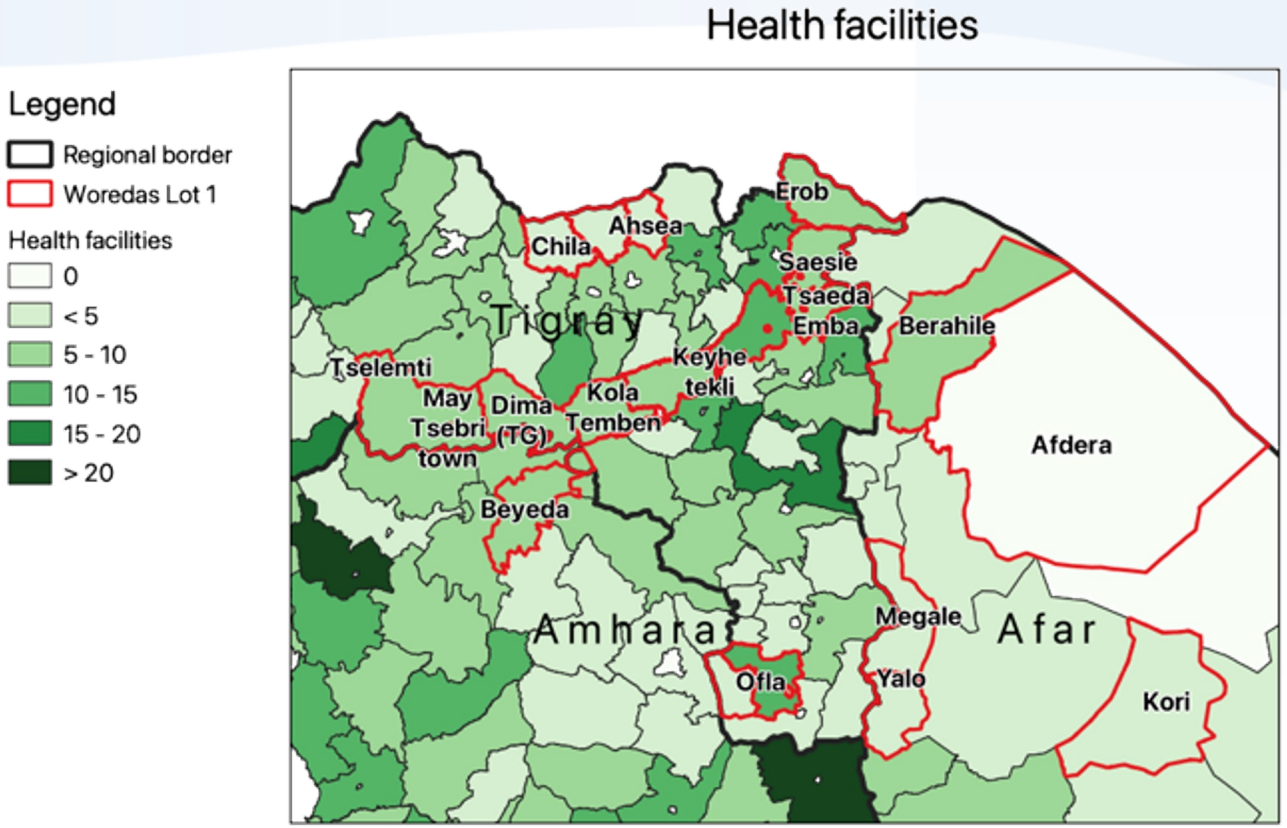
Socio-economic map

- Based on census 2007
- Updated administrative boundaries and population projections from:
  - Central Statistic Agency (CSA)
  - Regional Bureau of Finance and Economic Development (BoFED)
  - UN Office for Coordination of Humanitarian Affairs (OCHA)
- Water point data from:
  - Ministry of Water, Irrigation and Electricity (MoWIE, RWB)
  - National Wash Inventory (NWI)
  - UNICEF Ethiopia (GW4E)

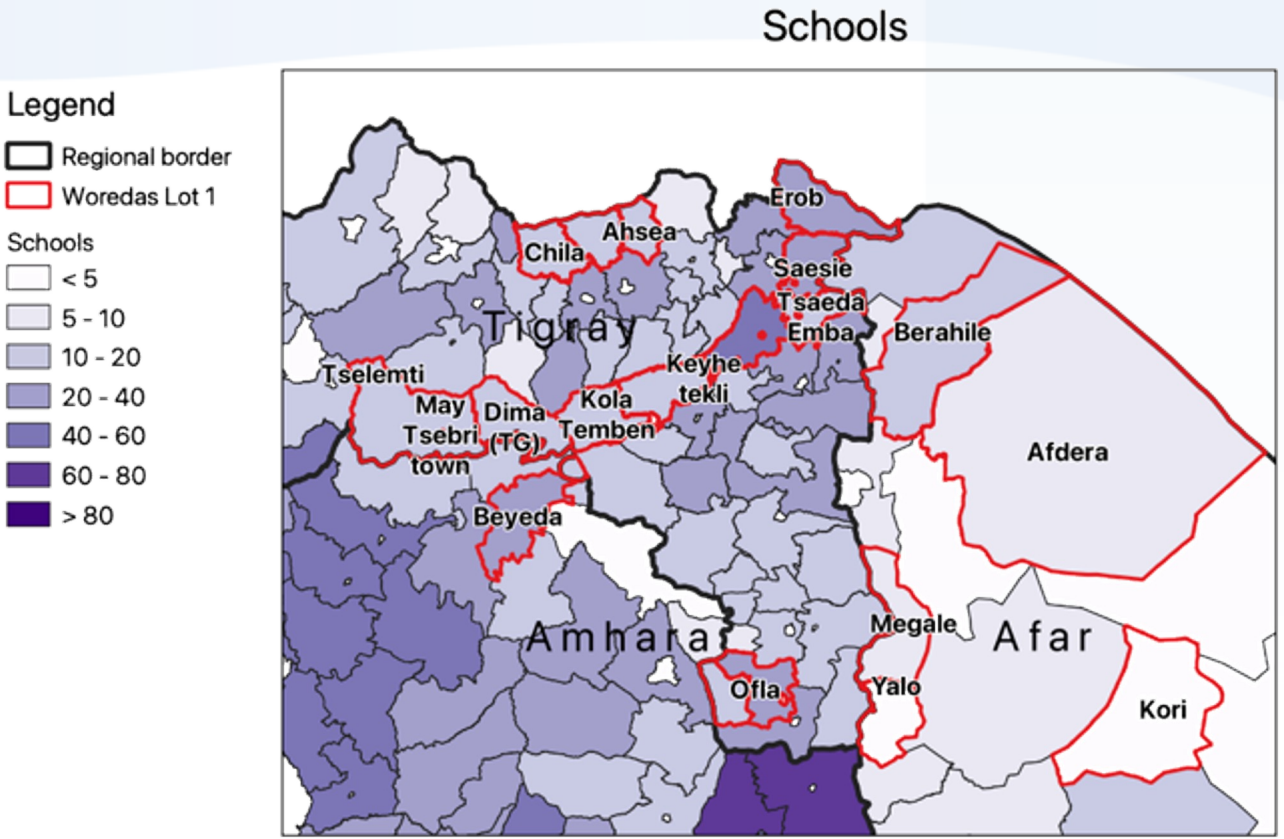
Population density



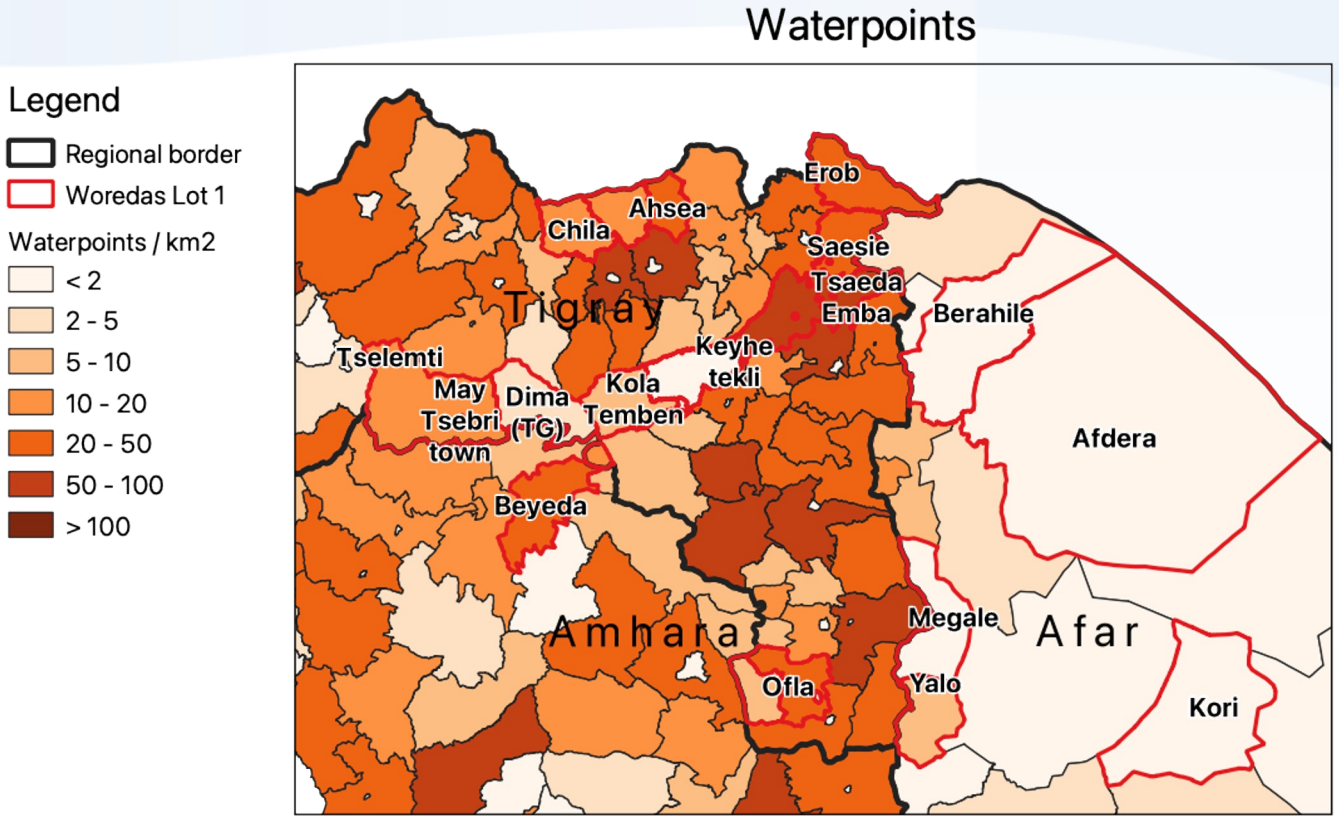
Health facilities



Schools

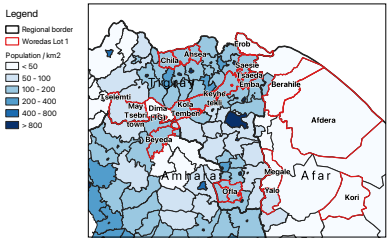

Schools
Legend
Regional border
Woredas Lot 1
Schools
< 5
5 - 10
10 - 20
20 - 40
40 - 60
60 - 80
> 80
Tigray
Amhara
Afar
Erob
Ahsea
Chila
Saesie
Tsaeda
Emba
Berahile
Keyhe
tekli
Tselemti
May
Tsebri
town
Dima
(TG)
Kola
Temben
Afdera
Beyeda
Megale
Yalo
Ofla
Kori

Waterpoints

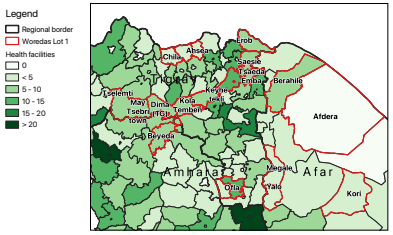


SOCIO-ECONOMIC MAP

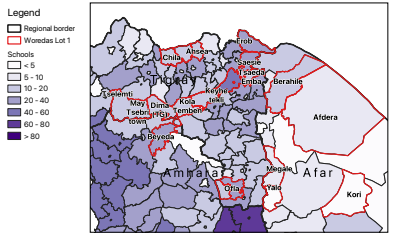
Population



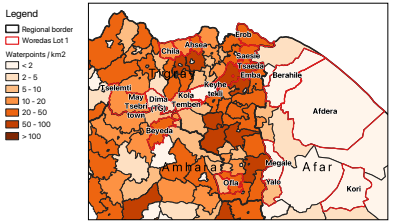
Health facilities

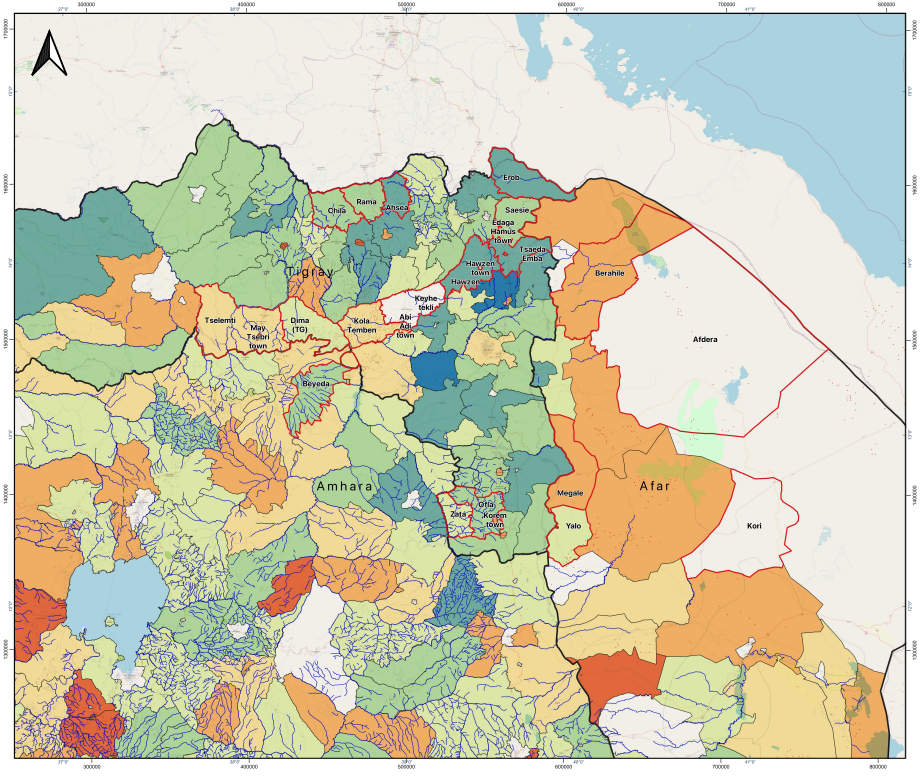


Schools



Waterpoints





Sources:
-Central Statistics Agency (CSA) (2007-2020)
-Regional Bureau of Finance and Economic Development (BoFED) (2020)
-United Nations Office for the Coordination of Humanitarian Affairs office in Ethiopia (OCHA) (2021)
-Openstreetmap (2021)

0 50 100 150 km

1:1,000,000

Horizontal datum: WGS 1984
Map projection: Universal Transverse Mercator, zone 37N

Legend

Regional border
Woredas Lot 1

Roads
primary
secondary
tertiary

Rivers
Intermittent
Permanent

Beneficiaries / waterpoint
< 1000
1000 -2000
2000 - 5000
5000 - 10000
10000 - 20000
20000 - 50000
50000 - 100000
> 100000

Hydrogeological mapping for
Climate Resilient WASH in Ethiopia – LOT 1

BDA/ICB/GW01/2021

Basins Development Authority
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ACACIA WATER

aquacon

Hydrogeological map

Geology

- **Based on:**
  - Geological maps published/unpublished (1:250,000)
  - Fundamental reports describing geology of the area
- **Harmonized and described in two morpho-structural domains:**
  - The western plateau with adjacent escarpment
  - Afar Depression

Hydrogeological map

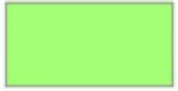
Hydrogeology

- **Based on:**
  - data and hydrogeological and hydrochemical maps at scale 1:250,000 and their explanatory notes published by Geological Survey of Ethiopia
  - data and information collected from different sources
- **Classification:**
  - Qualitative parameters (porous, fissured, karstified, ..)
  - Quantitative parameters (highly/moderate/low productive aquifers, aquitards, aquicludes)

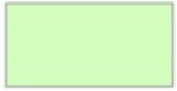
Aquifer classification

Highly productive porous aquifers (T = 10 – 100 m2/d, q = 1 - 10 l/s.m, Q = 5 - 25 l/s for wells and/or springs) or locally extremely productive aquifers

Moderately productive porous aquifers (T = 1 - 10 m2/d, q = 0.01 - 1 l/s.m, Q = 0.5 - 5 l/s for wells and/or springs) or local or discontinuous but highly productive aquifers



Highly productive fissured / karst aquifers (T = 10 - 100 m2/d, q = 1 - 10 l/s.m, Q = 5 - 25 l/s for wells and/or springs) or locally extremely productive aquifers consisting of sedimenta and volcanic rocks



Moderately productive fissured aquifers (T = 1 - 10 m2/d, q = 0.01 - 1 l/s.m, Q = 0.5 - 5 l/s for wells and/or springs) or local or discontinuous but highly productive aquifers consisting of sedimentary and volcanic rocks

Low productive fissured aquifers (T = 0.1 - 1 m2/d,q = 0.001 – 0.01 l/s.m, Q = 0.05 - 0.5 l/s for wells and/or springs) in which flow is mainly developed in irregular system of fissures & weathered mantle of a crystalline rock

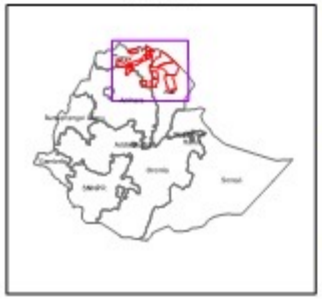
Aquitards minor aquifers with local & limited groundwater resources consisting of sedimentary and volcanic rocks

Aquiclude - formation with essentially no groundwater resources consisting of dome forming phonolite / trachyte & gabbro and metagabbro (aquifuge – solid rocks / blind rocks)

Moderately productive aquifers with alternating layers of fissured and porous permeability (T = 1 - 10 m2/d, q = 0.01 - 1 l/s.m,Q = 0.5 - 5 l/s) for wells and/or springs)consisting of Dalha Formation of basalt flows and layers of lacustrine sediments

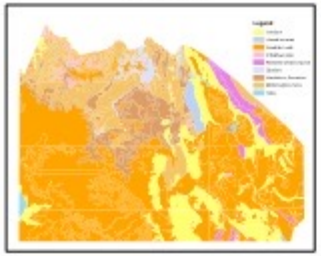
HYDROGEOLOGICAL MAP OF LOT 1

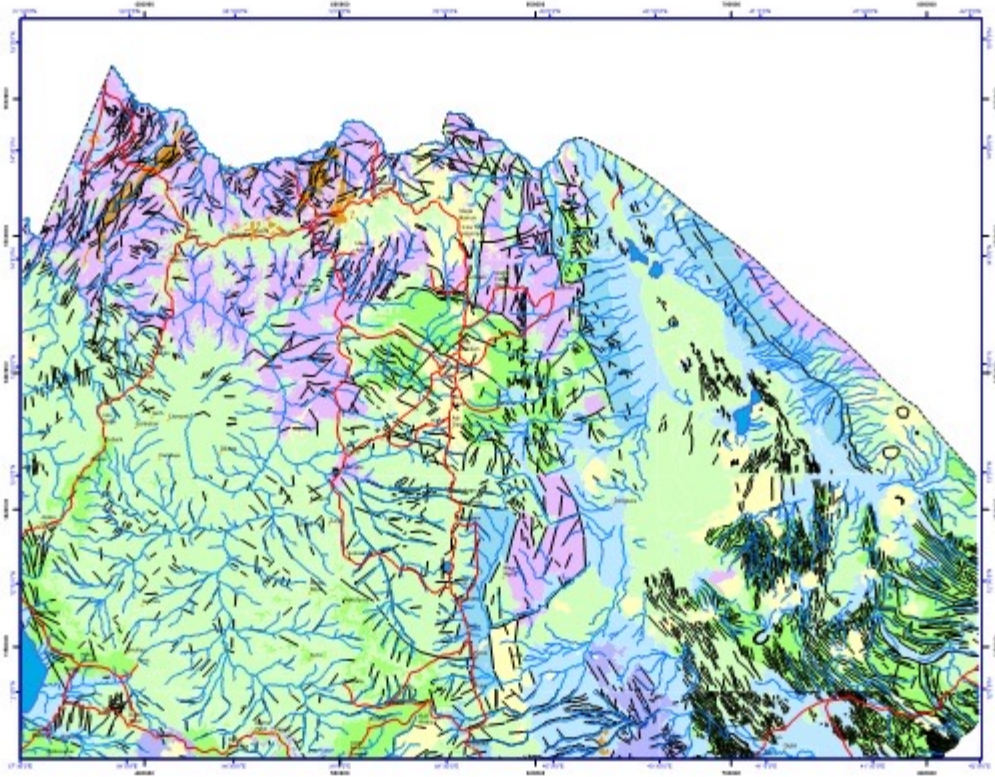
PROJECT AREA



ADMINISTRATIVE BOUNDARY MAP

GEOLOGICAL MAP





LEGEND

Aquifer Classification

Disclaimer:

This document was produced with the financial assistance of The Department for International Development, UK. The boundaries in this map are not authoritative or political.

Geology compiled by Geological Survey of Ethiopia from 1971 to 2015
Hydrogeology compiled by: Jiri Sima, 2021
Digital Cartography: Shiferaw Ayele Mamo, 2021

0 25 50 100Km

1:1,000,000

Horizontal Datum: WGS 1984
Vertical Datum: Mean sea level
Projection: Universal Transverse Mercator, Zone 37N

PROJECT:
HYDROGEOLOGICAL MAPPING FOR CLIMATE RESILIENT WASH IN ETHIOPIA - LOT 1

Phase2: Mapping

For every woreda:

- Prepare base layers
- Determine classes, scores and weights
- Initial overlay
- Ground-truthing, water demand update
- Prepare potential maps
- Prepare water demand maps

Phase2: Target area selection

For every woreda:

- Estimate impact of climate change
- Combine potential and demand
- Propose priority areas
- Select target areas

Inventory formats

Inventory

LOT#	Depth (m)
Unique code	SWL (m)
Region	DWL (m)
Zone	Yield (l/s)
Woreda	Aquifer/formation
Kebele	Site topography
Village	Temperature
Easting	EC (µS/cm)
Northing	TDS (mg/l)
CRS	pH
Elevation	Collected by
Scheme Type	Date
Status	Sample taken
Purpose	Sample nr

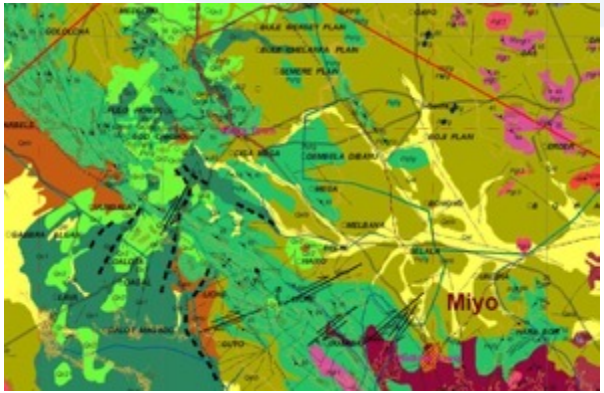
Water quality

General	**Parameters**
Lab No.	Sodium
Client/Project	Potassium
Client ID	Total Iron
Location	Manganese
Reported Date	Ammonia
Client Ref	Total Hardness
Date of Collection	Calcium
Source of Sample	Magnesium
Date received	Alkalinity
pH	Carbonate
Electrical Conductivity (µS/cm)	Bicarbonate
	Chloride
	Sulphate
	Nitrate
	Fluoride

Base layers

- Permeability (primary porosity)
- Lineaments (secondary porosity)
- Recharge
- Slope
- Land use and land cover
- Soil type

Permeability



Source:

geological map

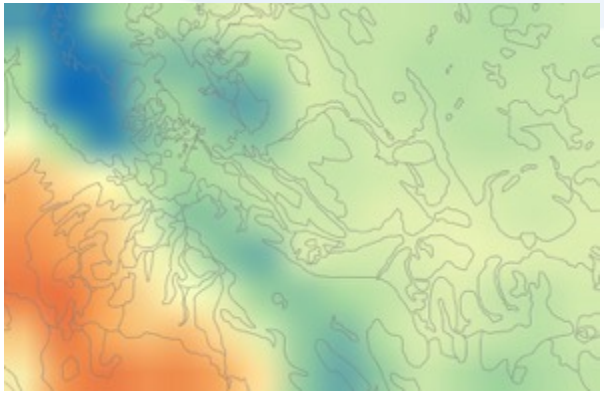
Procedure:

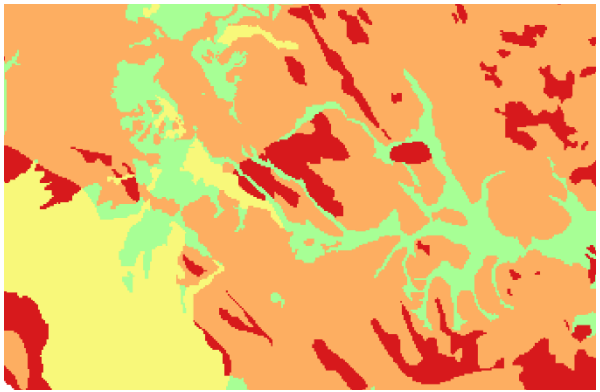
Group lithology by permeability class

Alternative procedure:

Use classes from hydrogeological map

Recharge





Sources:

Precipitation data

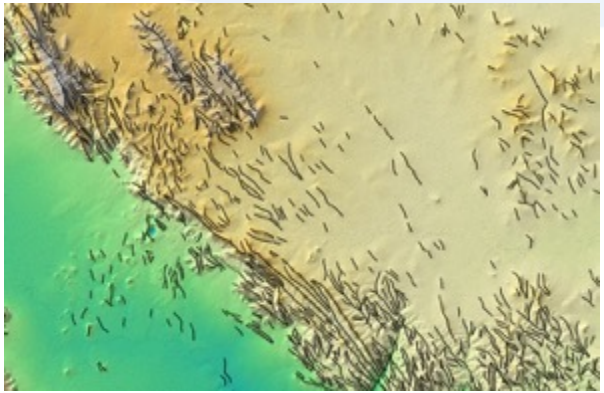
Evapotranspiration data

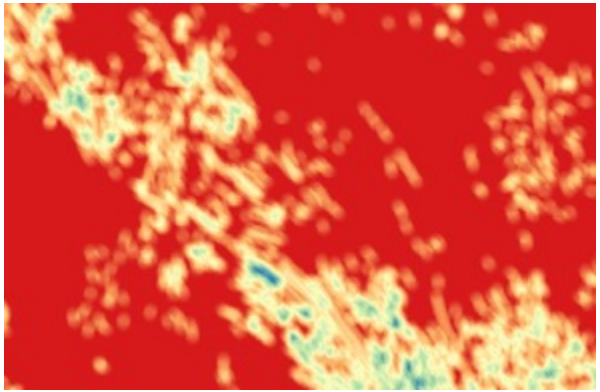
Infiltration coefficient

Procedure:

(P-ET) * IC

Lineament density





Sources:

SRTM

Sentinel-2/Landsat-8

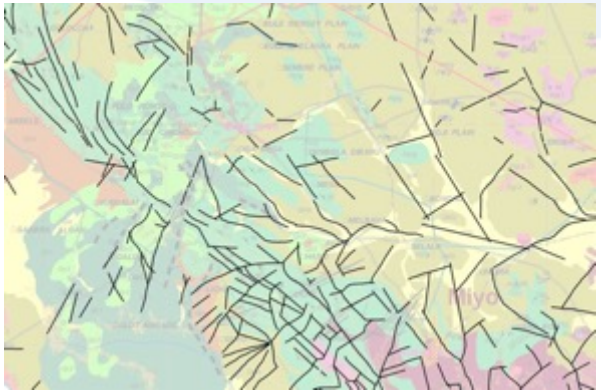
Procedure:

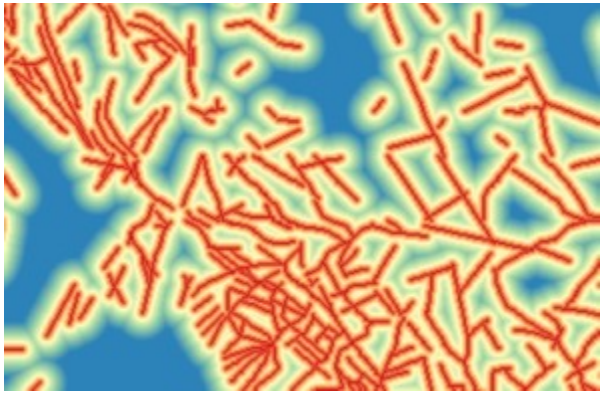
Extraction: LINE module of PCI-Geomatics*

Density (length per cell) in GIS

*Uses on edge detection algorithm (Canny), filtering and extraction

Lineament proximity





Sources:

Geological map

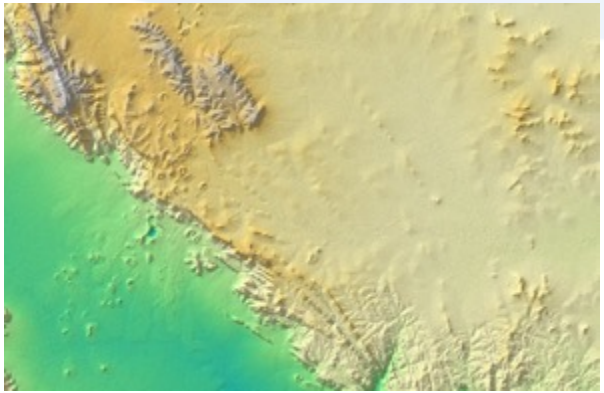
Sentinel-2/Landsat-8/Google Earth

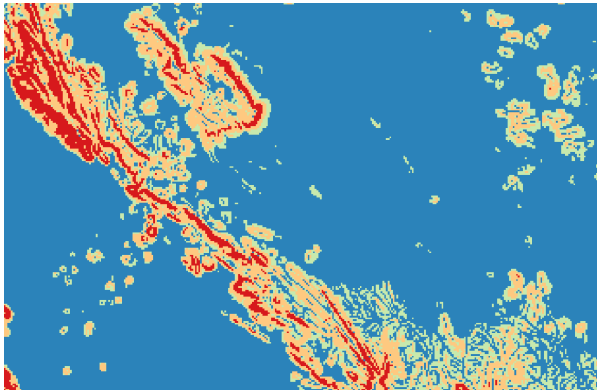
Procedure:

Extraction: manually

Proximity: (distance to line) in GIS

Slope





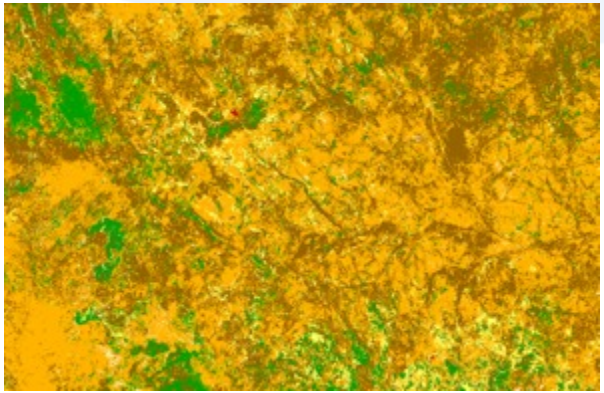
Source:

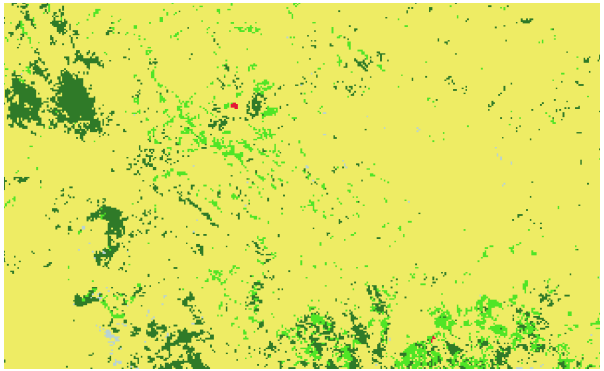
SRTM

Procedure:

Standard GIS algorithm

Land use





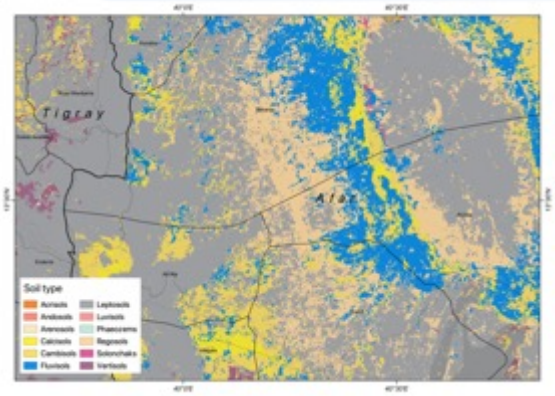
Source:

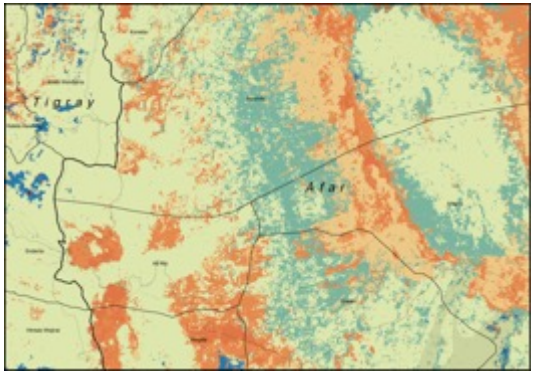
Sentinel-2, ESA

Procedure:

Group land use classes by recharge potential

Soil





Sources:

EthioSIS (ATA)

ISRIC (Wageningen University)

Procedure:

Group soil classes by infiltration capacity

Classes and scores

Slope in degrees	Score
0 – 3	0.6
3 - 5	0.3
5 – 15	0.1
> 15	Not suitable

Lineament proximity in m	Score
0 – 500	0.62
500 – 1000	0.16
1000 – 2000	0.11
2000 – 4000	0.07
> 4000	0.04

Recharge in mm	Score
< 25	0.05
25 – 50	0.11
50 – 100	0.27
> 100	0.57

Landuse	Score
Cropland	0.44
Bush/ range land	0.29
Forest	0.17
Degraded land	0.07
Urban	0.03

Lithology class	Score
Loose quaternary sediments including elluvials and Miocene sediments	0.25
Rift pyroclastics and rift silicics	0.1
Upper Tertiary basalts, Quaternary highland basalts, Rift basalts	0.35
Lower Tertiary basalts	0.15
Limestone, upper sandstone, shale, marls, all other Mesozoic sediments	0.05
Lowgrade basement rocks and Adigrate sandstone	0.08
Highgrade basement rocks	0.03

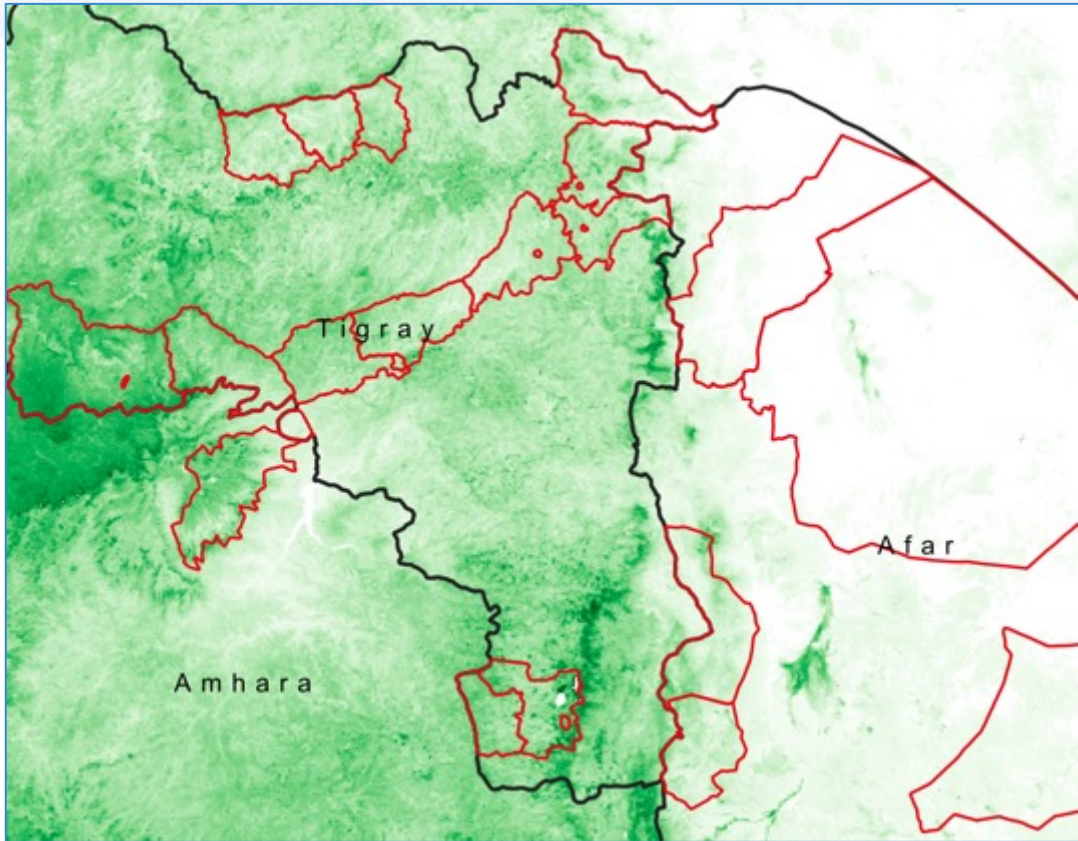
Lineament density in km/km2	Score
< 0.3	0.03
0.3 – 0.6	0.07
0.6 – 0.9	0.15
0.9 – 1.2	0.3
> 1.2	0.45

Weights

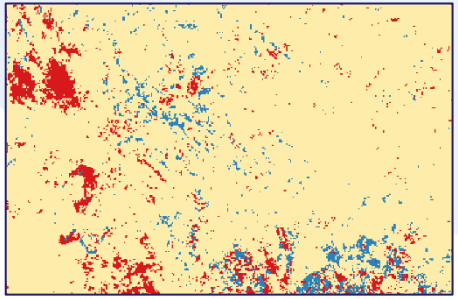
Layer	low	high	average
lithology	0.06	0.53	0.32
density	0.13	0.43	0.24
recharge	0.10	0.57	0.17
slope	0.10	0.21	0.15
proximity	0.03	0.11	0.06
landuse	0.03	0.06	0.05

Secondary layers

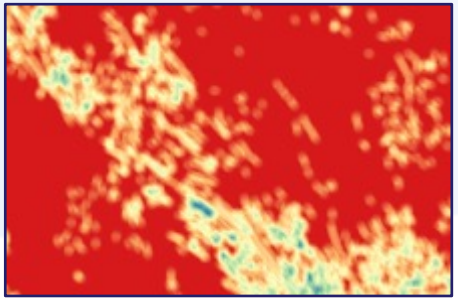
- Normalized Differential Vegetation Index (NDVI)
- Topographic Wetness Index (TWI)
- Drainage density
- Soil moisture



Land use

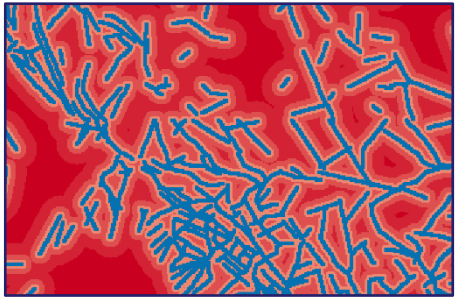


Lineament density

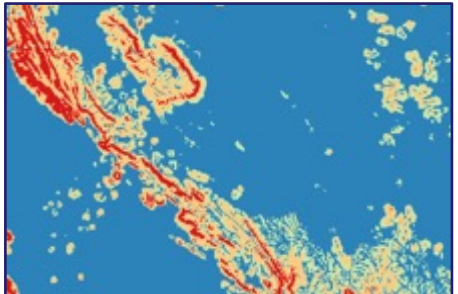


Permeability

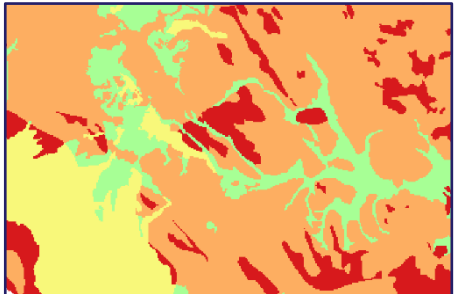
Lineament proximity



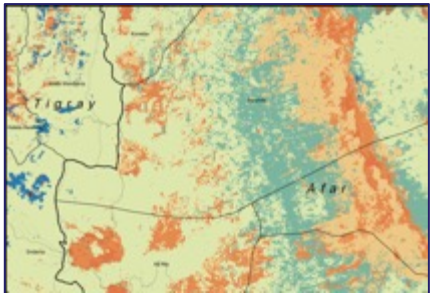
Slope



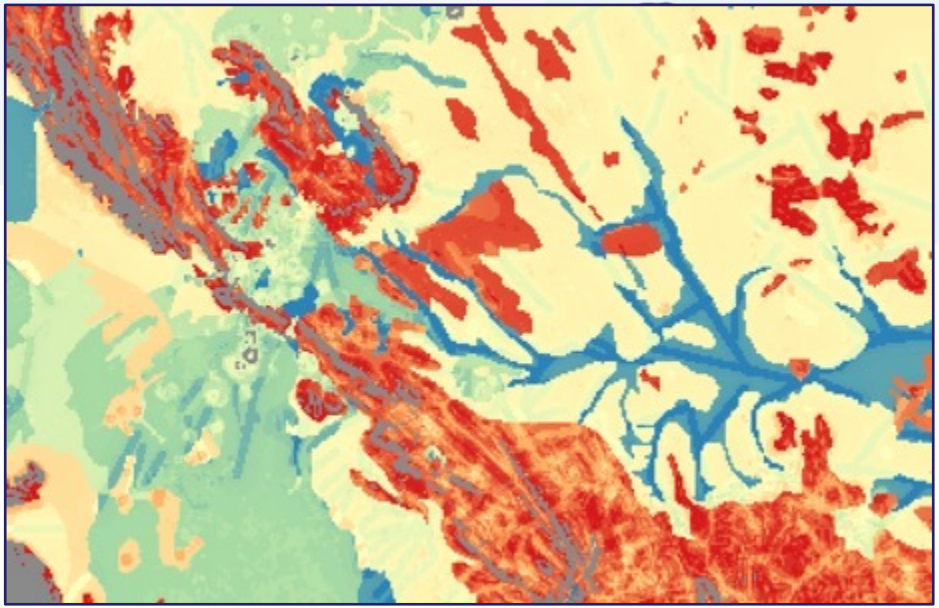
Recharge



Soil



Suitability



Score

Low — High

Phase 3: Siting

For every Target Area:

- Detailed hydrogeological study (fieldwork)
- Detailed demand assessment (fieldwork)
- Geophysical study (fieldwork)
- Hydrogeological conceptual model
- Hydrogeological map (1,50,000)
- Resilience assessment
- Drilling site map (1:5,000)

Points for discussion

- Administrative boundaries
- Population projections
- Water demand criteria
- Layer selection, resolution
- Classes and scores
- Training schedule/alignment
- Dissemination (Lot 5)
- Security issues

Thanks for your attention

July 15th 2021

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