Proposal to support:

Strengthening Drought Resilience in Arid and Semi-Arid Lands in Ethiopia

Final Report

Support requested by:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

Reference: EOC0012_REP_A_T_v1.0_r0.0
Date: 2020 Dec 18

TABLE OF CONTENTS

AUTHORS

The present document was prepared and coordinated by Patricia Rodríguez Dapena (Program Manager of Aeronautic Division, everis Aeroespacial y Defensa S.L.U. - referred as everis hereinafter) with support from the following contributors:

- Roman Bohovic (CTO from World From Space)
- Gunther Schorcht (Greenspon Gmb)

PURPOSE

This document compiles the objectives and achievements of the Project together with the conclusions and findings. It will present the potential of the methodology applied during the project, but also its limitations, for GIZ and other stakeholders to be aware of the working flow and it's potential, all intended for the future weir construction project activities.

It is also intended for dissemination purposes, and provision of great potential of using EO for identifying most suitable sites dry valleys, for GIZ's projects implementation.

1 DEVELOPMENT CONTEXT AND BACKGROUND

1.1 Introduction

Services based on Earth Observation (EO) are useful tools for providing a wide range of past and present environmental information through the analysis and processing of historical information, present status and analytical data available.

Technology has now achieved the capacity of processing large amounts of data within a time frame and inside an affordable budget.

The particular advantages of EO in this context are the non-intrusive, objective and globally consistent nature of the information and the use of satellite mapping services provides many opportunities for the management and verification of the environmental practices associated with the development projects the banks are helping.

Through unique EO products, it is possible to map agriculture, land use and environment, water quality, energy availability. food security, coastal subsidence and forest state among other equally important data, which EO can gather effectively in areas with little ground information.

ESA's Copernicus programme is aimed to make environmental monitoring a reality, delivering near-real-time data on a global level which can also be used for local and regional needs.

Through its own dedicated Sentinel satellites, various contributing missions and on-ground stations that collects information from in situ systems such as ground stations, which deliver data acquired by a multitude of sensors on the ground, at sea or in the air, Copernicus programme allows us to create value-added information by processing, comparing and analysing data that stretches back for years, and from this monitor changes, create forecasts, analyse patterns and generate maps that identify anomalies and features.

Over this, ESA has been collaborating with Banks and International Financial Institutions for a long time on monitoring development projects and its impact on the environment.

This collaboration has demonstrated the relevance of EO for Development projects, and has proven that it is a valuable tool for make cost effective, quick and incontrovertible assessments, that help to manage urban growth, protect forest, monitor water quality and broadly provides evidence of progress or baselines for remediate actions whenever an environmental transformation occurs as result of a development project.

Although larger initiatives and programmes are currently on execution (like EO4SD, an ESA initiative to support the uptake of EO-derived information in sustainable development), there is a need to cover small-scale and exploratory uses of EO products as a response to short-term, ad-hoc requests from Banks and international institutions. These requests demand an innovative approach and capacity to deliver within a short time frame, a solution that goes beyond standard product generation and that links the EO data with underlying statistical and geographic information in a creative way.

To achieve this, ESA is funding a Framework Contract (named: EO-Clinic) scheme to which this project belongs to.

Under this Framework Contract, several "Request for Proposal" are be issued to the contractors from different end users (banks and International Finance Institutions). These Requests can vary largely on its purposes and will address any or several of the following Thematic Groups: Agriculture, Climate Change, Coastal Zone Management, Disaster Risk Management, Energy and Natural Resources, Forestry, Marine Environment Management, Transport, Urban, Water Resources Management and Non-EO Information and Analytics.

This document is a result from Request for Proposal 12 (RFP012) of the EO-clinic Frame Contract, requested by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH supporting German Government in the fields of international cooperation for sustainable development and education.

1.2 Request for proposal 012: Strengthening Drought Resilience in Arid and Semi-Arid Lands in Ethiopia

This chapter summarises the objectives and approach of the requested EO support dealing referred in the Request for Proposal 12 (RFP002) of the EO-clinic Frame Contract, requested by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

The **main initial objective of this Request for Proposal number 012 (RFP012) is to support GIZ Ethiopia and its partners in the site selection process (site identification and delineation) for future weir construction project activities using EO data, i.e. to conduct a site suitability analysis**.

The results of this study are to be delivered to the GIZ in the form of technical notes and images build upon existing EO datasets and data processing and visualization capabilities.

The project was performed starting by first performing an hydrological analysis in GIS software using available DEM. Also, DEM data provided by GIZ (as mentioned in chapter 3 of the RfP) is also to be analysed where the area covered by DEM data will define a broad area of interest where analyses of potential river beds will be undertaken. In case no high resolution DEM available for the whole expected area of interest, the project expected to perform a global dataset Shuttle Radar Topography Mission (SRTM) will be used.

For this region, preliminary information from global datasets were collected to support the selection of smaller AoI (with cooperation with the GIZ). For this AoI very high resolution data was then obtained and (automatically and manually) analysed in GIS using different tools publicly available.

Cascade Suitability Matrix was first evaluated identifying which factors are obtainable from EO data set. Then scoring of these parameters was undertaken in WP3, finalysing it with a map of combined factors was produced as a comprehensive result based on evaluation of the CSM

1.3 Initial request: Objectives, Work Logic and Expected Outputs

1.3.1 Problems to be Addressed and Geospatial Information Gaps

The overall purpose of this project is to support GIZ Ethiopia and its partners in the site selection process (site identification and delineation) for future weir construction project activities using EO data, i.e. to conduct a site suitability analysis.

In order to identify the most suitable project sites dry valleys for their project, GIZ Ethiopia created a catalogue of site selection criteria called “Cascade Suitability Matrix – GIZ SDR” (a template of this can be found in Annex A). This catalogue includes physical, biological and social location factors that are combined to identify most suitable areas for project implementation.

The factors (information gaps) included in the Cascade Suitability Matrix initially defined by GIZ are as follows:

- Physical aspects
  - Sufficient stones available for construction
  - Sufficient sand available for construction
  - Closest permanent water point
  - Road access (all weather road for motorised vehicles)
- Biological aspects:
  - Predominant soil type (clay or loam, sand, rocky soil)
  - Signs of cultivation (yes, no)
- Social aspects:
  - Proximity of marketplace
  - Presence and maintenance of enclosures
  - Proximity of the next hamlet/village

- Number of hamlets/villages in this area.

1.3.2 Information services to be delivered: Crop Types and Crop Health

The SDR-ASAL programme has defined as target area the AFAR region of Ethiopia (Figure 1). However, the area is very large and the site suitability analysis is expected to require VHR data for at least some factors. It is therefore necessary to limit the AoI to dry river/stream beds.

In the absence of data on dry streambeds, it is expected to develop a limited AoI within the AFAR region by performing a hydrological analysis on an available DEM to identify likely stream beds. The AoI should exclude permanent streams (i.e. streams of the greatest Strahler value). The Contractor shall per-form the above analysis and present/discuss the result, a suitable AoI consisting of a buffer region around likely dry stream beds to the stakeholders prior to the main site suitability analysis. The buffer shall be chosen keeping in mind the distances mentioned in the Cascade Suitability Matrix.

It is acknowledged that not all factors defined in the Cascade Suitability Matrix (physical, biological and social) can be mapped with EO. The Contractor shall identify which factors can be characterised from space, and select satellite imagery with resolutions suitable for the detection of the features described in the matrix (e.g. villages). No general minimum mapping unit or resolution are defined, as these will depend on the solution provided by the Contractor.

Based on EO information, a scoring matrix shall be completed. The data will be used to identify most promising/suitable new project sites for the effective and sustainable rehabilitation and use of degraded land in dry valleys of the Ethiopian lowlands. The most suitable sites will be evaluated for future projects.

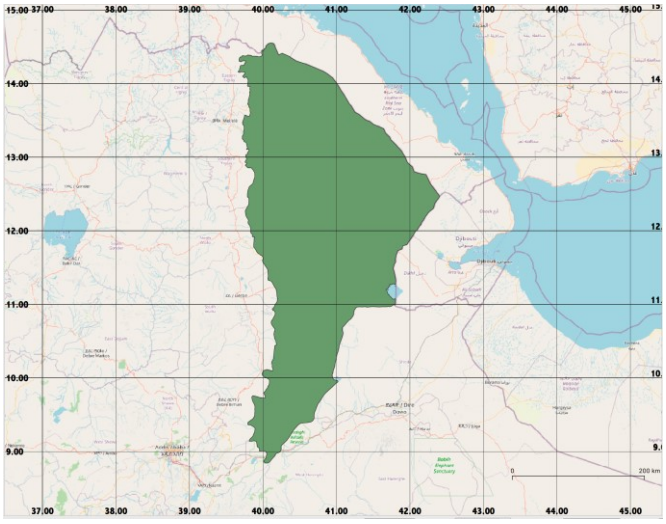

Figure 1 *The AFAR region, i.e. the region of interest for the SDR-ASAL programme.*

The analysis shall be performed for a most recent point in time (i.e. 2020 or 2019 at the earliest).

All Services should be delivered in GIS-ready raster format (GeoTIFF) in the UTM projection suitable for Ethiopia.

Service 1: Factors Identification and Assessment, will outline which of the factors in the Cascade Suitability Matrix can be reliably classified using EO and GIS analysis. It will then perform the classifications of the factors identified, assigning the scores outlined in the matrix. The output is a map per factor containing the applied scores (score layers).

Service 2: Site Suitability Map, will produce a final map with all score layers combined into a site suitability map. The suitability map shall be produced in a single, final instance.

2 WHAT WAS PROPOSED TO BE PERFORMED

2.1 Understanding of the requirements and proposed approach

Our understanding of the situation and expected work was that first hydrological analysis in GIS software was going to be done using available DEM. We expected DEM data was going to be provided by GIZ (as mentioned in chapter 3 of the RfP). The area covered by DEM data was going to define a broad area of interest where analyses of potential river beds will be undertaken. If there is no high resolution DEM available for the whole expected area of interest, and a global dataset Shuttle Radar Topography Mission (SRTM) will be used.

From the DEM analyses, potential river beds were proposed to be identified and buffer zones delineated.

For this region, preliminary information from global datasets was proposed to be collected to support the selection of smaller AoI (with cooperation with the GIZ). For this AoI, very high resolution data was proposed to be acquired and (automatically and manually) analysed in GIS.

The Cascade Suitability Matrix was proposed to be first evaluated to set which factors were going to be obtainable from EO. Then, these parameters were to be scored to finally map of combined factors as a comprehensive result based on evaluation of the CSM.

The RFP requirements are identified here below providing information about how they are implemented.

TABLE 1. *Requirements understanding and proposed approach.*

Requirement	Fulfilment	Comments
Perform hydrological analyses on DEM to identify likely streambeds	Yes	The Shuttle Radar Topographic Mission digital elevation model dataset was used for hydrological analysis in open source GIS software QGIS to identify flow directions, flow accumulation, and likely riverbeds (see Task1.A below).
Present and discuss results of hydrological analyses	Yes	A progress meeting was held on the 14th of October 2020, and a mid-term meeting on the 2nd of November 2020.
Defining buffer zones	Yes	Buffer zones were defined with respect to the information included in the Cascade Suitability Matrix (see Task3.A).
VHR data required	Yes	A GeoEye-1 4-band multispectral image of the selected AoI with 0.5 meter resolution was obtained from Maxar Technologies. The acquisition date of the image is May 6 2020.
Asses which information for CSM can be obtained from EO data	Yes	The usability of a multitude of global, continental and regional datasets was assessed; followed by an assessment of the usability of Sentinel-1 and Sentinel-2 data and VHR data. The CSM factors obtainable from EO data were identified in the process (see WP3)
Complete scoring matrix	Yes	All the factors identified as accessible from global datasets and EO data were evaluated according to the scores defined within the CSM (see WP.3).

GIS-ready format (GeoTIFF, UTM CRS)	Yes	All the data provided to GIZ for further use were projected to the UTM Zone 37N projection and exported in either ESRI shapefile or GeoTiff formats.
support site selection process	Yes	A set of datasets together with layers representing riverbeds scored according to individual factors specified in the CSM were provided to GIZ for further use to ease the future site-selection process.

The main results of the project are:

- technical note (this document), including reports on the
  - hydrological analysis applied to the SRTM DEM dataset
  - global datasets availability and applicability for the site selection process
  - process of pre-selection of a suitable AoI
  - processing of: a) global datasets; b) Sentinel-1 and Sentinel-2 satellite images; c) the VHR satellite image; and d) local datasets
  - CSM factors evaluation and the site suitability map creation
- dataset including
  - the processed SRTM data in the form of a flow direction raster, flow accumulation raster, stream segments raster, stream segments vector layer
  - a vector layer representing riverbed segments with attribute values based on global datasets
  - a vector layer representing the selected AoI
  - vector layers representing objects and areas identified in the VHR image (roads, enclosures, tents and buildings, settlements with household counts, cultivated areas, water points, and a marketplace)
  - vector layers representing riverbed segments located within the selected AoI, evaluated according to the factors specified in the CSM
  - a final vector layer representing riverbed segments located within the selected AoI, attributed with a weighted sum of values assigned to each of the factors specified in the CSM
- final report (this document)
- Fina review/presentation Minutes of meeting.

2.2 The partners

The overall EO-Clinic frame contract consortium is composed by thirteen companies. Twelve EO service providers, expert in a specific thematic group, but also, with expertise in most of them. And the prime contractor, everis aerospace and defense, an entity which primary expertise in management of challenging international development projects. This way, the key of the success lies on a well-structured and collaborative team, which members supporting each other in order to achieve outstanding results.

It is a **well-balanced team** formed by **one (1) multinational entity** leading the consortia, expert in managing international projects, **two (2) research organization** which provides state of the art techniques in term of EO solutions and **ten (10) SMEs** entities highly dynamic and specialized on EO solutions.

The main principles of the consortium are:

- **Highly reactive and dynamic structure** – for accommodating short-term, small and exploratory request from the end user.
- **Deep understanding and expertise on thematic EO products** – providing a wide coverage of range of skills and capabilities in terms of different EO study areas and products generation.
- **Client-oriented solutions** – always keeping in mind the scope and the necessities of the end-users. Their business activity and aiming to provide the best suited EO solutions for them.

- **Time-oriented project** execution – It is essential in this environment to deliver EO information on time against deadlines. This is the only approach for achieving what it is called "rapid-response" capability to the Bank users.
- **High quality assistance for end users** – usually, final users are not familiar EO technologies, even less, when innovative methodologies and techniques are applied. It is essential to provide assistance on final information for its correct exploitation.
- **Expand the knowledge through Europe** – thirteen companies, nine different countries. The consortium aims to promote European missions, generate value-adding services, and take European EO capabilities to the next step.

The complete thematic groups required by ESA for different Request for Proposals are fully addressed by the consortium members.

This project in particular is performed by the following partners providing the best expertise for the specific purpose of the project:

Everis Aerospace and Defense S.L.	Prime Contractor: EO-clinic Frame Contract and project management and technical Coordination
everis is a multinational group that offers to its clients services and solutions that add high value covering all the value chain areas of a company, from defining the strategy, to design, development, integration, implementation and maintenance of technological solutions. **everis Aerospace and Defence**, the **everis** Group's Aerospace and Defence Division, offers global solutions for implementing critical systems in aerospace, defence, security and simulation sectors, integrating reliable and innovative technologies though proprietary development and through the SMEs with which the Group has strategic alliances as leading partners.	
World from Space S.r.o	Subcontractor: Thematic Group 9-Urban Leader
World from Space (WFS) is a start-up company established in September 2017, currently incubated in the South-Moravian Innovation Centre, Brno, Czech Republic. WFS is a company building on experience of its founders in the field of EO and environmental science. The company builds its core business around the interpretation of satellite data for various users. So far, we cooperate especially with cities. Our vision consists of two main product lines of the company - Smart Cities and Smart Agriculture, with ongoing R&D bringing new topics according to customer needs. We want to put stress on transfer of knowledge and know-how from the scientific community to real use. Therefore, we intend to preserve our cooperation with universities and research institutions. The company was awarded the Seal of Excellence under the Horizon 2020 SME instrument in 2018 for the project of vegetation dynamics and drought monitoring. WFS is a winner of ESA BIC Prague EOVation Masters 2018, ESA BIC EOVation Masters Scientific Article 2018 and it won the second place at the ESA BIC Prague City and climate hackathon 2018. We were part of the winning team of the ESA BIC Prague Agricultural hackathon 2017. World From Space (WfS) is an Earth Observation company active in the agricultural sector, urban and land monitoring and management with focus on climate change adaptations. Core of the company's business is DynaCrop service, an API for agricultural software serving monitoring and analytical information based on satellite data. WfS is part of ESA's start-up ecosystem, member of ESA BIC Czech Republic, winner of the Copernicus Masters - Government Challenge 2018 and took part in Copernicus accelerator in 2019. The team of WfS consists of people from multiple domains: remote sensing, geoinformatics, IT, environmental management and smart agriculture. WfS is covering a wide range of skills including satellite data processing and interpretation (optical and radar systems), cloud computing, AI, backend development, GIS that are combined with agricultural, environmental and urban expert knowledge.	

Green Spin GmbH	Subcontractor: Thematic Group 1- Agriculture Leader

GREENSPIN is a spin-off company from the Department of Remote Sensing at the Institute of Geography, University of Würzburg, with close ties to the German Aerospace Agency. The largest part of GREENSPINs team of six consists of remote sensing and data scientists. Over the last 4 years, we specialized in data analytics and service development in digital agriculture. They successfully developed and launched our web-based Agri Analytics application for B2B customers in agriculture in 2017.

GREENSPIN has broad experience in developing agricultural applications based on remote sensing for industrial and institutional customers. They include automated solutions for mapping, monitoring and yield modelling for a wide range of crop types. Their web-based GIS for agricultural applications automatically processes satellite imagery and can, for example, detect crop types on agricultural parcels. GREENSPIN's key personnel for this RFP has long standing experience in working with development organizations and institutional partners in agriculture-related development research projects in Central Asia.

2.3 Work Logic proposed

The work logic of this particular Work Order has been defined to ensure the provision of an efficient service to GIZ and ESA, maximizing added value outputs, delivered on time and in the required format. Indeed, the work for this RFP is organized around five work packages (WP).

- **WP0**: the overall management and the successful implementation of the work as well as the delivery of the results. (Everis)
- **WP1**: Potential riverbed identification (World From Space)
  - WP1.A Hydrological analyses on DEM to identify potential riverbeds
  - WP1.B Pre-analyses of global datasets and assessment for potential AoI with global data-sources
  - WP1.C AoI selection and VHR data
- **WP2**: Data analyses (World From Space)
  - WP2.A Global datasets for large scale assessment (Greenspin, World From Space)
  - WP2.B Copernicus Sentinel-2 data preprocessing
  - WP2.C Very high resolution satellite data processing
  - WP2.D Local data sources processing
- **WP3**: Cascade Suitability Matrix evaluation (World From Space)
  - WP3.A CSM factors identification (Service 1)
  - WP3.B CSM global data classifications and scoring
  - WP3.C CSM Sentinel-2 data classifications and scoring
  - WP3.D CSM VHR data classifications and scoring (Greenspin, World From Space)
  - Site Suitability Map (Service 2)
- **WP4**: This work package contains the final report, recommendations, technical verification and quality assurance of the results of WP 1, 2 and 3. (Everis)

The high level work logic is described in the following Figure 1:

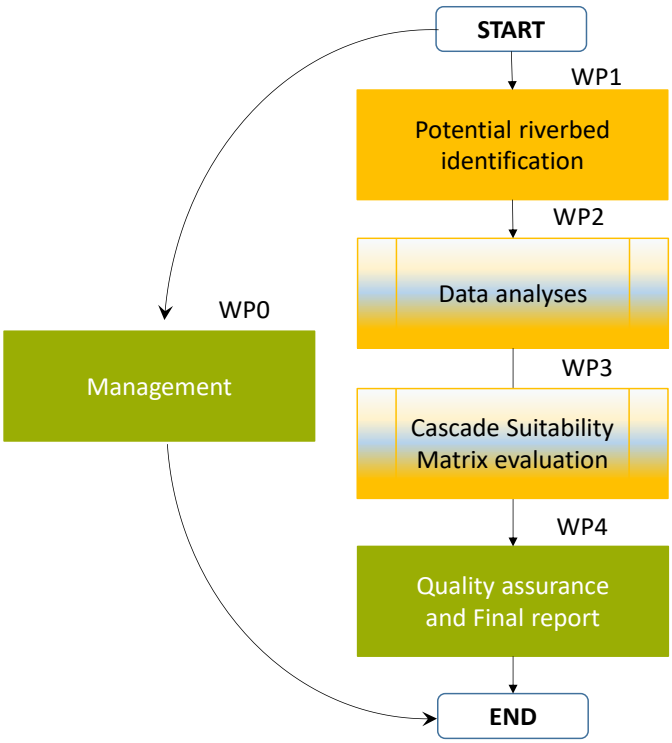

Figure 2 Work Logic of Work Order

2.4 Description of Work packages.

2.4.1 WP0 - Management.

Management activities of this project will be performed by everis. Management processes will follow the ones described in reference Management Proposal. In this proposal, only specific management aspects for this RFP are described. In order to control the progress of the work order with respect to cost, schedule and technical objectives, the following milestones are set up:

TABLE 2. *Milestones management.*

Milestones		Date
Kick-off Meeting (KOM)	Once the Work Order (WO) is launched, a KOM will be held by ESA, GIZ and Everis to review schedule, scope of the work and deliverables.	To
Acceptance Review	A final meeting with ESA, GIZ and Everis will be performed to review and accept the work done along the work order.	To+12w

Other management-related tasks such as cost control procedures, progress reporting, meetings management, actions management and so on will be carried out as stated in Management Proposal. Moreover, the proposal manager will contribute to the final report with the conclusions obtained during the Work Order, and related to the estimation of feasibility, conditions and cost of an extended service.

2.4.2 WP1- Potential riverbed identification

2.4.2.1 Objectives, tasks and methodology

The main objective of Work Package 1 (WP1) is to undertake GIS hydrological analysis on a DEM to identify likely stream beds within the Afar region, evaluate possible options using available datasets and choose specific AoI to undertake scoring using VHR data.

Considering the information and the requests in the RFP, this WP1 has the following tasks:

- Task1.A Hydrological analyses on DEM to identify potential riverbeds
- Task1.B Pre-analyses of global datasets and assessment for potential AoI with global datasources
- Task1.C AoI selection and VHR data

Task 1.A - Hydrological analyses on DEM to identify potential riverbeds:

Hydrological analyses in QGis software will be done using DEM data. As a first step, global DEM SRTM data will be used mostly as a reference for quality check. It will also serve in the case of missing local DEM data for some areas. In the second step, local DEM from the interested stakeholder of this project (GIZ) will be processed. We expect this data will have better resolution and quality.

Shuttle Radar Topography Mission in the last version (SRTMv3) data is in 30 m resolution with vertical and horizontal accuracy of 16 metres and 20 metres, respectively.

QGis tool *fill sinks* will be used to check for local depressions and then *r.watershed* function will be run to obtain stream lines, basins and directions of flow. All potential riverbeds will be identified and buffer zones in 5 and 10 km delineated.

Illustrative DEM data for AFAR region in Ethiopia are depicted in Figure 2.

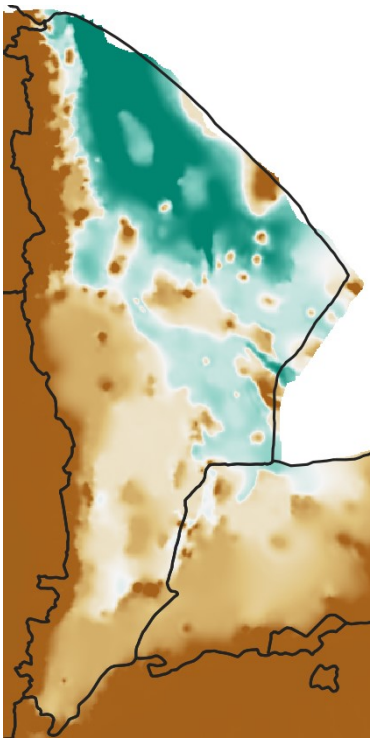

Figure 3 Elevation in AFAR region

Task 1.B - Pre-analyses of global datasets and assessment for potential riverbed buffer zones.

Before the selection of AoI from all potential riverbeds identified in WP1.A, pre-analyses of factors available from global data sources (see table in WP2.A) are done to support the selection process. Dataset of rivers in

Ethiopia is in Figure 3, showing low density of river network in the AFAR region. Moreover it is probable that the available river layer is not updated therefore needs to be taken with caution.

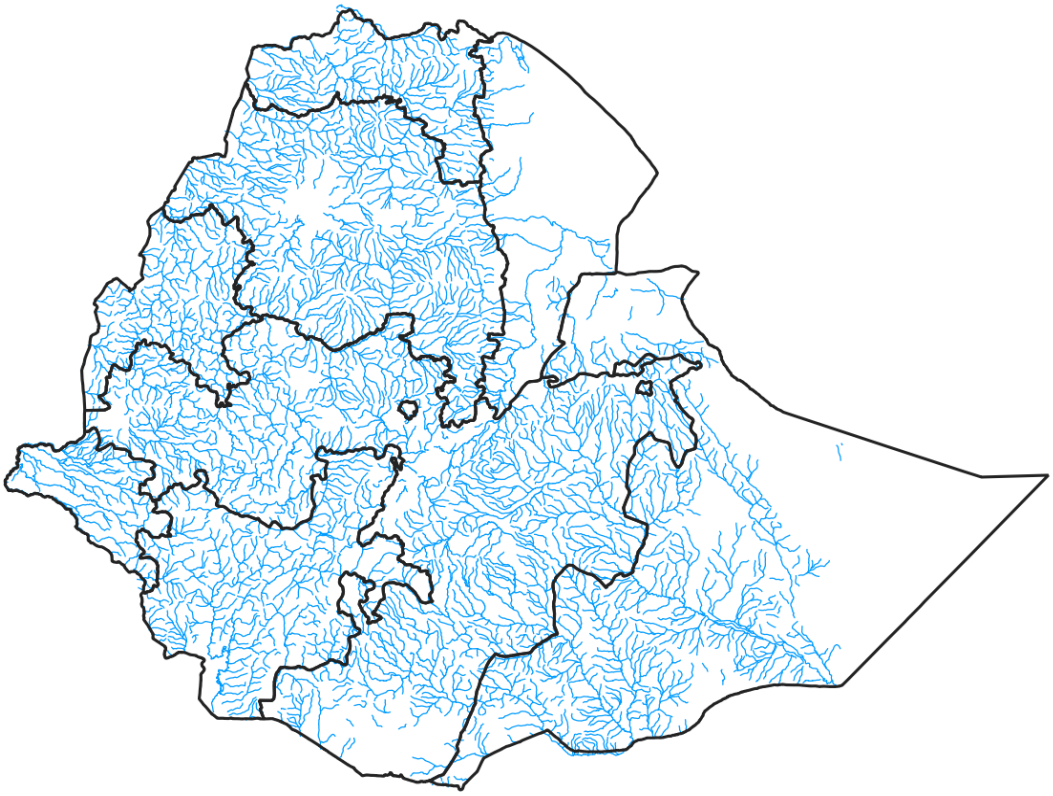

Figure 4 Main water courses in Ethiopia

Task 1.C – AoI selection and VHR data

The objective of this task is the selection of AoI from all potential riverbeds. To perform this selection, several factors will be considered and decisions will be agreed with GIZ during the mid-term review meeting planned to be held in this project. Factors that will be taken in account are:

- Confirmation of availability of VHR data
- suitability of the area based on preliminary analyses
- previous experience and/or preference of GIZ (if any)

Minimum 30000 hectares of VHR data will be obtained. This can include several riverbeds in one area or can be divided into several riverbeds. This AoI may serve as a showcase and test place for scoring of CSM based on EO data.

2.4.2.2 Outputs

The main outputs of this work package will consist of:

1 GIS layer with potential riverbeds in Afar region
2 Attribute values for riverbeds based on global datasets
3 Selection of the specific AoI for VHR data assessment

2.4.3 WP2 – Data analyses

2.4.3.1 Objectives, tasks and methodology.

The main objective of Work Package 2 (WP2) is to process and analyse all data sources that will be used. Focus is taken on WP2.C that is evaluating VHR satellite images that will be conducted only on selected AoI. Rest of

the data will be used for more potential river beds. Some of the tasks are to be performed between Greenspin, World From Space.

The tasks to be performed within this WP2 are:

- Task2.A Global datasets for large scale assessment
- Task2.B Copernicus Sentinel-1 and -2 data pre-processing
- Task2.C Very high resolution satellite data processing
- Task2.D Local data sources processing

Task 2.A – Global datasets for large scale assessment

The focus of Task2.A is to identify data sets suitable to support the site selection process as a whole and the enhancement of the "Cascade Suitability Matrix" specifically. These data sets are globally available or with focus on east Africa or even specifically designed for Ethiopia. Data sets will be obtained, examined and cropped to the AOI's. The following table provides an overview for the data sets to be assessed:

TABLE 3. *Overview for the data sets to be assessed*

Parameter	Sources	Description
Soils	https://soilgrids.org/	Several parameters are available at a grid resolution of 250m: clay/sand silt content, depth to bedrock, wilting point, etc.
	http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/	The Harmonized World Soil Database covers different soil related topics: organic Carbon, pH, water storage capacity, soil depth, etc.
Population	https://data.humdata.org/dataset/ethiopia-population-data-_-admin-level-0-3	Data about population (number, density, development)
	https://www.worldpop.org/geodata/country?iso3=ETH	Gridded data about population density
Infrastructure	https://data.humdata.org/dataset/ethiopia-population-data-_-admin-level-0-3	Data about roads, railways, location of towns, villages
	https://geodata.lib.berkeley.edu/catalog/sde-columbia-global_mapping_ethwater	Vector data covering water courses, roads, railways, settlements, inland waters
	http://geonode.igad.int/layers/geonode:main_livestock_market_igad	Locations of main livestock markets
	http://geonode.igad.int/layers/?limit=20&offset=0	Location of water points in the country
Physical description	http://geonode.igad.int/maps/new?layer=geoportalrcmrdorg:servir:ethiopia_land-cover_2008_scheme_ii&view=True	Gridded map of main land cover types in Ethiopia (2008)
	https://wapor.apps.fao.org/home/WAPOR_2/1	Water related data: gross biomass water productivity, total biomass production, evapotranspiration data, etc

All data sets proven to be useful will be harmonized and converted into a data format suitable for further processing (WP3).

Task 2.B – Copernicus Sentinel-1 and -2 data preprocessing

For the assessment of all potential river beds and selected AoI also high resolution satellite data will be processed and tested. For that Sentinel-1 SAR data and multispectral Sentinel-2 data are ideal and offer possibility for multitemporal comparison. That might be helpful for agricultural activities/land recognition.

We propose to analyse and test using time series analyses of soil moisture index (SMI) from SAR data on riverbed transects. This may in same cases show intra-annual variability in soil water content and serve as a proxy for monitoring of the water flow in rivers/streams. However interesting, this approach is not tested for such use yet.

Vegetation indices from Sentinel-2 and SMI from Sentinel-1 will be obtained from Dynacrop service that is API run by World from Space and can be adapted for this purpose in short time of the proposed activity.

Task 2.C – Very high resolution satellite data processing

Vegetation indices (NDVI, NDRI, NDMI) will be computed from multispectral VHR data. Manual expert inspection will be undertaken to identify objects for scoring the matrix.

Task 2.D – Local data sources processing

Data provided by partner GIZ mentioned in chapter 3 of the RfP will be processed if necessary and reasonable.

2.4.3.2 Outputs

WP2 includes tasks for internal data processing, however as an output VHR image for the AoI will be provided to GIZ for further use.

1. VHR satellite image of AoI
2. Set of data sets to be used in the evaluation of the cascade suitability matrix, gridded into harmonized rasters for all AOI's.

2.4.4 WP3 – Cascade Suitability Matrix evaluation (World From Space)

2.4.4.1 Objectives, tasks and methodology.

During work package 3 factors for Cascade Suitability Matrix will be assessed and evaluated from various data sources:

- Task 3.A CSM factors identification and assessment (Service 1)
- Task 3.B Site Suitability Map (Service 2:)

Task 3.A - CSM factors identification and assessment (Service 1)

Factors comprising CSM will be evaluated and tested. See above Table 1 for a first analysis of the CSM factors with comments how this will be approached.

Global datasets (see Table 3 for list of the data sources) pre-processed in Task2.A and HR data from Sentinel-1 and Sentinel-2 (Task2.B) will be used for scoring of all potential river beds identified in WP1.

Then, very high resolution satellite data processing (Task2.C) and local data sources (processed Task2.D) will be used to score additional factors in AoI.

Data will be evaluated in open source GIS software QGIS and scoring methodology will be set to combine the various datasets. The scoring scheme will follow the procedure of the CSM scoring scheme, organizing different quality aspects of one indicator to a scoring between 1-3 (e.g. sufficient stones available in less than 1km -score 3-, or in less than 5km -score 2- or more than 5km -score 1-).

This task expects also manual and visual inspection of the images and will be done for AoI.

Task 3.B - Site Suitability Map (Service 2)

Multifactor combinations of the factor layers will be done in GIS software and map visualisation will be done.

2.4.4.2 Outputs

There are four deliverables from WP:

1. Report on suitability of EO data and other data sources for Cascade Suitability Matrix scoring
2. Score layers of suitable factors for waterbeds based on large scale datasets
3. Score layers of factors suitable for CSM including VHR images for AoI
4. Final suitability map for AoI

2.4.5 WP4 - Technical Verification, Quality Assurance, and Final Report Creation

2.4.5.1 Objectives and tasks.

Main objectives of WP4 will be dedicated to ensure the overall quality of the service and report findings and conclusions acquired during the WO execution. An independent technical verification will be performed over the generated outputs. Moreover, quality assurance principles such as those described in the management section of the management proposal will be followed. Those procedures will be tailored to fit into the 12-week time frame, and then ensuring that a minimum quality is reached.

The second objective of WP4 will be the creation of a final report. Conclusions and findings will be compiled in this report, and then well support a larger service over other regions, countries and indicators. The potential of the methodology applied during the WO will be described, but also its limitations. Then, GIZ and other stakeholders will be perfectly aware of the working flow and it's potential.

It is also considered to work with GIZ on dissemination activities, and support for determining the viability of using EO for mapping the crop types and their indicators.

To achieve the objectives, following tasks are identified, and will be agreed with ESA and GIZ:

- Task 4.1 - Independent Quality and Verification Check of the output products (according to the RFP requests in what concerns the Countries and crops combination).
- Task 4.2 - Final Report, which includes conclusions and guidelines to an extended project over a larger area.

2.4.5.2 Outputs.

The outputs of this working package will be compiled into the Work Order Final Report. It will include the verification and quality assurance metrics, but also the conclusions and findings of the performed services.

2.5 Input dataset required

Due to organisation of the work, globally available open data sources will be used first to assess potential riverbeds identified in WP1. These data sources comprise free-of-charge Sentinel-1 and Sentinel-2 data sets (https://sentinel.esa.int/web/sentinel/sentinel-data-access). As an output of Task1.C smaller focus area - AoI - will be selected and very high resolution data (VHR) will be obtained.

Due to the price for VHR images and limited time for analyses, not the whole AFAR region can be assessed. AoI will be selected in accordance with preliminary global data evaluated, availability of VHR for area and previous experience and actual priorities of the partner (GIZ). Figure 5 shows available recent (2019, 2020) VHR images covering the focus AFAR area, 67% at the moment.

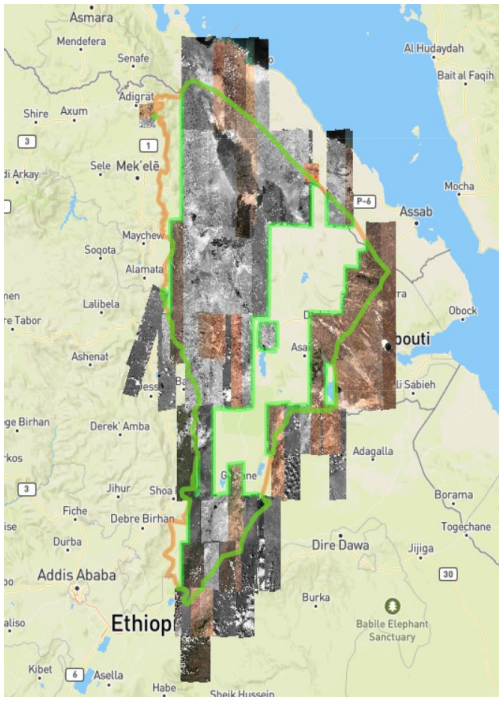

Figure 5 Area of the AFAR region covered by recent VHR images with less than 30% cloud coverage.

Imagery from Worldview-1 (panchromatic, 0.5m resolution) and Worldview-2 (panchromatic 0,46m resolution and 8-band 1,84m resolution) will be obtained covering an area not less tan 30000 hectares. This might serve as a showcase for assessing CSM - GIZ SDR with earth observation data.

Digital Globe's offering to Everis is as follows:

- Price for archive images varies between USD 14 and USD 24 per km2 depending on the type of image, with USD 14 being the price of panchromatic 50 cm and USD 24 for the 8 bands / NIR at 30 cm and there is a minimum order of 25 km2 thus 7kEUR budget is foreseen.
- In the link below 2019 – 2020 coverage for Afar can be found with all sensors and CC < 30%: https://discover.digitalglobe.com/d71268d8-d2f7-11ea-a12e-2ebdcac7d186
- This area is very close to high demand areas. Digital Globe has the most availability on WV01, thus this is the proposed selection including PAN.

2.6 Proposed Schedule

The planned schedule for the delivery of the services, counting from the release of the Work Order is presented below (duration 12 weeks):

WP	Description	Leader	Start	End	Duration
WP0	Managemet and Procurement of Satellite Images	everis	To	To+12	60 days
WP1	Potential riverbed identification	World from Space	To	To+5	10 days
WP1.A	Hydrological analyses on DEM to identify potential rivert	World from Space	To	To+3	15 days
WP1.B	Pre-analyses of global datasets and assessment for poter	World from Space	To + 1	To+5	20 days
WP1.C	AoI selection and VHR data	World from Space	To + 3	To+5	10 days
WP2	Data analyses	WorldfromSpace	To+3	To+11	40 days
WP2.A	Global datasets for large scale assessment		To+3	To+9	30 days
WP2.B	Copernicus Sentinel-2 data preprocessing		To+3	To+9	30 days
WP2.C	Very high resolution satellite data processing		To+5	To+9	20 days
WP2.D	Local data sources processing		To+7	To+11	20 days
WP3	Cascade Suitability Matrix evaluation	World from Space	To+1	To+12	75 days
WP3.A	CSM factors identification (Service 1)	World from Space	To+1	To+10	35 days
WP3.B	Site Suitability Map (Service 2)	World from Space	To+10	To+12	15 days
WP4	Quality Assurance and Final report	everis	To+8	To+12	45 days

3 RESULTS AND CONCLUSIONS

3.1 WP0 – Management Conclusions

The project was managed following the initially planned schedule although some of the initial tasks were not easily performed, delaying the project few days from its initial schedule.

The initial Kick-off meeting plus three bi-weekly progress meetings were held, sending all Minutes of meeting by email to al participants just after the meeting.

A final acceptance review and close out meeting is also held 4 days after the initially planned end of the project.

3.2 WP1 – Crop type maps

The main objective of Work Package 1 (WP1) was to undertake GIS hydrological analysis on a digital elevation model (DEM) to identify potential riverbeds within Ethiopia's Afar region, evaluate possible options using available datasets and choose specific area of interest (AoI) to later undertake scoring using very high resolution (VHR) data.

For the potential riverbeds identification, the global Shuttle Radar Topography Mission (SRTM)[1] elevation dataset, with the spatial resolution of 30 meters and vertical and horizontal accuracy of 16 and 20 meters, respectively, was utilized. The result of this first analysis step was a model potential riverbeds, split based on an 'order' defined, as shown in below figure, used to characterise each individual stream of a certain order dividing it into segments with a maximum length of 1 km.

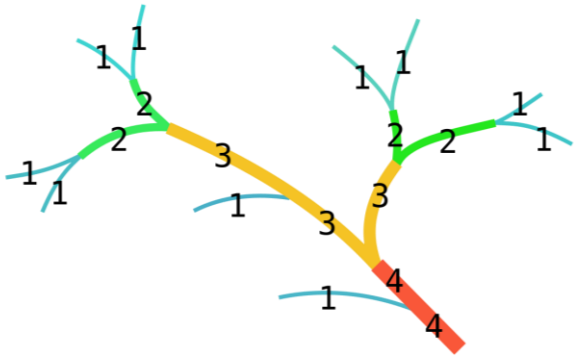

Figure 6 Strahler stream ordering method illustration

Then, the applicability of several - global, regional, and national - datasets for the purpose of preselection of potential AoIs was investigated. The resulting findings from this assessment are summarized in TABLE 4 below.

TABLE 4. *Description of the assessed global, regional and national data and evaluation of their applicability in the presented analysis*

Parameter	Name/URL/Source	Description	Assessment
Population	Ethiopia - Subnational Population Statistics	• 2021 projected population statistics (gender, age, sex, urban/rural population) • spatial coverage: Ethiopia	• applicable at regional level

[1] The Shuttle Radar Topography Mission is an international research effort that obtained digital elevation models on a near-global scale from 56°S to 60°N, to generate the high-resolution digital topographic database of Earth prior to the release of the ASTER GDEM in 2009. https://earthdata.nasa.gov/learn/articles/nasa-shuttle-radar-topography-mission-srtm-version-3-0-global-1-arc-second-data-released-over-asia-and-australia

	https://data.humdata.org/dataset/ethiopia-population-data-_-admin-level-0-3 more information: ETH COD-PS 2020_10_28.pdf	• **levels of detail**: 0 (country), 1 (regions), 2 (zones), 3 (woredas) • **source:** Central Statistics Agency (CSA) • **last update:** October 2020 • **format:** .xlsx, .csv	
Population	Ethiopia: High Resolution Population Density Maps https://data.humdata.org/dataset/ethiopia-high-resolution-population-density-maps-demographic-estimates more information: https://data-forgood.fb.com/tools/population-density-maps/	• gridded population density dataset • **spatial coverage:** global, national • spatial resolution: 30 m • **source:** combination of pattern-recognizing algorithms to identify buildings in VHR satellite images with census data • **author:** FACEBOOK, Center for International Earth Science Information Network (CIESIN) at Columbia University • **last update:** October 2018 • **format:** GeoTiff	• significant false negative in the Afar region • limited applicability
Population	WorldPop Ethiopia Population 2020* https://www.worldpop.org/geodata/summary?id=49635	• gridded population density dataset • spatial coverage: Ethiopia • spatial resolution: 3 arc seconds • **source:** Ethiopian population census of 2007 and projection-based estimates for 2020 in combination with building footprints provided by the Digitize Africa project of Ecopia.AI and Maxar Technologies (2020) and gridded building patterns derived from the datasets produced by Dooley et al. 2020 • **author:** WorldPop, University of Southampton, UK • last update: September 2020 • format: GeoTiff	• quality of the dataset is constrained by the quality of the building footprints detection • calculated density is based on rather old census data • partially applicable
Settlements	Ethiopia - Cities, towns and villages https://data.humdata.org/dataset/ethiopia-settlements	• populated placed • spatial coverage: Ethiopia • **source:** multiple sources; endorsed by the Inter-Cluster Information Management Working group (ICIMWG) • last update: March 2016 • **format:** ESRI Shapefile	• each place represented only by a point • position of places offset compared to satellite images • partially applicable
Settlements	World Settlement Footprint 2015 https://springernature.figshare.com/arti-	• build-up areas • spatial coverage: global • spatial resolution: 10 m • **source:** multitemporal Sentinel-1 and Landsat-8 imagery (2014-2015);	• similar quality to other global settlement datasets, such as Global Human Settlement

	cles/dataset/World_Settlement_Footprint_WSF_2015/10048412 more information: https://www.nature.com/articles/s41597-020-00580-5	methodology developed in the framework of the ESA SAR for urbanisation monitoring (SAR4URBAN) project lead by the German Aerospace Center (DLR) • last update: July 2020 • **format:** GeoTiff	Layer (GHSL)[1] or Global Urban Footprint (GUF)[2] • significant false negative in Afar – only concrete buildings within larger settlements are detected • partially applicable
Settlements	GRID3 Ethiopia Settlement Extents* https://data.humdata.org/dataset/grid3-ethiopia-settlement-extents-version-01-alpha more information: https://grid3.org/	• build-up areas, small settlements, hamlets • spatial coverage: Ethiopia • **source:** Center for International Earth Science Information Network (CIESIN), Columbia University and Novel-T; the building footprint was produced by Ecopia Tech Corporation, and Maxar Technologies, Inc. • last update: July 2020 • **format:** ESRI File Geodatabase • **data used:** extents of build-up areas, small settlements, and hamlets	• generally good detection quality • unlike in other datasets with settlements, tents are detected as well • some false negatives and false positives exist • partially applicable
Infrastructure	Main livestock market IGAD http://geonode.igad.int/layers/geonode:main_livestock_market_igad	• main livestock markets • spatial coverage: IGAD region • **source:** data collated from RISP 2, 2012 consultancy report • **author:** FSNAU, FEWSNET, FAO and ICPALD • last update: January 2016 • **format:** ESRI Shapefile	• no markets within the Afar region • not applicable
Infrastructure	Ethiopia - Roads Network https://data.humdata.org/dataset/roads-network	• roads • spatial coverage: Ethiopia • **source:** compiled from several sources by the World Food Programme (WFP) branch of the UN • last update: May 2016 • **format:** ESRI Shapefile	• does not include all major roads • some features included in the dataset are not visible in VHR satellite images • partially applicable
Infrastructure	Ethiopia Road Network (main roads)* https://data.humdata.org/dataset/wfp-geonode-ethiopia-road-network-main-roads	• roads • spatial coverage: Ethiopia • **source:** OpenStreetMap export following UNSDI-T standards • **author:** WFP; OpenStreetMap contributors	• precise position of roads of higher hierarchy • some features included in the dataset not visible in VHR satellite images • partially applicable

[1] https://ghsl.jrc.ec.europa.eu/index.php
[2] https://datacatalog.worldbank.org/dataset/world-external-geospatial-platforms-population/resource/ff4d2c56-993b-4590-a340-810f80275158

		• last update: January 2020 • **format:** ESRI Shapefile, GeoJSON • **data used:** roads up to tertiary	
Infrastructure	HOTOSM Ethiopia Railways https://data.humdata.org/dataset/hotosm_eth_railways	• railways • spatial coverage: Ethiopia • **source:** OpenStreetMap contributors • **author:** Humanitarian OpenStreetMap Team (HOTOSM) • last update: July 2020 • **format:** ESRI Shapefile	• precise position of railways • applicable
Infrastructure	Dams http://geonode.igad.int/layers/geonode:Damsf	• dams • spatial coverage: IGAD region • **source:** location of dams is obtained from Nile Basin Initiative (NBI) and FAO Web portal[1] • **author:** IGAD Economic Cooperation Division • **last update:** September 2018 • **format:** ESRI Shapefile	• no dams within the Afar region • not applicable
Waterpoints/ rivers/lakes	Ethiopia water points http://geonode.igad.int/layers/geonode:ethiopia_water_points	• water points/hand pumps • spatial coverage: Ethiopia • **source:** Unknown • last update: March 2016 • **format:** ESRI Shapefile	• water points not identifiable in satellite images; however, locations of some of the points are questionable • applicability uncertain
Waterpoints/ rivers/lake	Inland Waters, Ethiopia, 2015 https://geodata.lib.berkeley.edu/catalog/stanford-nr809hb2907	• water bodies (lakes, reservoirs) • a component of the Global Map (scale 1 : 1 000 000) • spatial coverage: Ethiopia • **source:** various sources; authorized by NGIAs of respective countries and regions • **author:** International Steering Committee for Global Mapping and Ya'Ityoṗyā kārtā śerā derejet • last update: 2015 • **format:** ESRI Shapefile, KMZ, GeoJSON	• includes only selected water bodies • low positional accuracy (based on a visual inspection of satellite images) • not applicable
Waterpoints/ rivers/lakes	IGAD Lakes and reservoirs http://geonode.igad.int/layers/geonode:IGAD_Lakes_and_reserviors	• water bodies (lakes, reservoirs) • spatial coverage: IGAD region • **source:** the Digital Chart of the World 1 :1 000 000 (1998) • **author:** IGAD Economic Cooperation Division • **last update:** September 2018	• includes only selected water bodies • partially applicable

[1] www.fao.org/nr/water/aquastat/dams/african_dams.xls)

		• **format:** ESRI Shapefile, GeoJSON	
Waterpoints/ rivers/lakes	IGAD - Lakes and Water Bodies http://geoportal.icpac.net/layers/geonode%3Aigad_water_areas	• water bodies (lakes, reservoirs) • classified by type (Perennial/Permanent, Non-Perennial/Intermittent/Fluctuating) • **source:** OpenStreetMap contributors • **author:** IGAD Climate Prediction and Application Centre (ICPAC); UNITAR's Operational Satellite Applications Programme (UNOSAT) • **last update:** August 2017 • **format:** ESRI Shapefile, KML, GeoJSON	• includes most of the visible permanent and fluctuating water bodies (according to visual inspection of VHR satellite images) • partially applicable
Waterpoints/ rivers/lakes	Global Surface Water 1984-2019 https://global-surface-water.appspot.com/ more information: https://www.nature.com/articles/nature20584	• location and temporal distribution of water surfaces • spatial coverage: global • **source:** multitemporal Landsat imagery (1984 - 2019) • **author:** European Commission's Joint Research Centre • last update: July 2020 • **format:** GeoTiff	• good detection of permanent and fluctuating water bodies (according to visual inspection of VHR satellite images) • rivers mostly undetected • partially applicable
Waterpoints/ rivers/lakes	HOTOSM Ethiopia Waterways https://data.humdata.org/dataset/hotosm_eth_waterways	• waterways • spatial coverage: Ethiopia • **source:** OSM export • **author:** Humanitarian OpenStreetMap Team (HOTOSM); OpenStreetMap contributors • last update: July 2020 • **format:** ESRI Shapefile	• advantage: includes most major rivers • disadvantage: riverbeds not always followed precisely (compared to satellite images)
Physical description	FAO WaPOR 2.1 https://wapor.apps.fao.org/catalog/WAPOR_2/1	• the FAO portal to monitor WAter Productivity through Open access of Remotely sensed derived data • **spatial coverage:** continental (Africa and Near East), national (selected states), subnational (selected river basins) • **spatial resolution:** 250 m (continental), 100 m (national), 30 m (subnational) • **layers:** Gross Biomass Water Productivity, Net biomass Water Productivity, Actual EvapoTranspiration and Interception (annual or Monthly or Dekadal), Quality of Normalized Difference Vegetation Index, Total Biomass Production, Precipitation, Land Cover, ... • **source:** normalized difference vegetation index (NDVI), albedo, and frac-	• continental and national possible for Ethiopia • subnational not possible for the Afar region • login for download

		tion of absorbed photosynthetically active radiation (fAPAR) products from the Proba-V satellite; since 2020, Sentinel-2 data are utilized • **author:** FAO; supported by the Ministry of Foreign Affairs of the Netherlands • last update: 2020 • **format:** GeoTiff	
Physical description	Shuttle Radar Topographic Mission DEM* https://www2.jpl.nasa.gov/srtm/ http://dds.cr.usgs.gov/srtm/ (90m) http://srtm.csi.cgiar.org/srtmdata/ (90m) https://earthexplorer.usgs.gov/ (90m, 30m) https://dwtkns.com/srtm30m/ (30m)	• elevation data • spatial coverage: nearly global • **spatial resolution**: 1 arc-second (~30 m) / 3 arc-seconds (~90 m) • **source:** single-pass synthetic aperture radar (SAR) interferometry • author: NASA • **creation:** February 2020 • **last update:** January 2015 (version 3.0) • **format:** SRTMHGT, GeoTiff • **data used:** SRTM v3.0, resolution 1 arc-second	• 30m version superior to the 90m version • good applicability for hydrological analysis in mountainous parts of Afar • in flat areas, position of some of the modelled river beds differ from their actual positions (according to a visual inspection of VHR imagery)
Physical description	ASTER GDEM https://aster-web.jpl.nasa.gov/gdem.asp	• elevation data • spatial coverage: nearly global • spatial resolution: 30 m • **source:** stereo-pair images collected by the ASTER instrument onboard the Terra satellite • **author:** Ministry of Economy, Trade, and Industry (METI) of Japan and NASA • last update: August 2019 • **format:** GeoTiff	• comparable to or better than the SRTM DEM (30m) in mountainous areas of Afar (based on a comparison between the results of hydrological analysis and VHR satellite imagery) • worse performance than the SRTM DEM in flat areas • contains anomalies and artifacts
Soil	SoilGrids250m 2.0 https://soilgrids.org/ https://maps.isric.org/ (WMS, WCS) https://files.isric.org/soilgrids/latest/data/ (WebDAV) more information: https://www.isric.org/explore/soilgrids/faq-soilgrids	• gridded soil information database • created using machine learning modelling • spatial coverage: global • spatial resolution: 250m / 1km • 6 observation depths (0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100 cm, 100-200 cm) • information included:	• advantages: full coverage; globally harmonized • disadvantage: few soil profiles within the Afar region

	https://soil.copernicus.org/preprints/soil-2020-65/soil-2020-65.pdf	○ **soil groups** (based on the World Reference Base classification[1]) ○ **soil physical properties** (bulk density, clay content, coarse fragments content, sand content, silt content) ○ **soil chemical properties** (cation exchange capacity, nitrogen content, organic carbon content, pH) • **source:** over 230 000 soil profile observations (the WoSIS database[2]) and about 400 environmental covariates • **author:** International Soil Reference and Information Centre (ISRIC) • last update: 2020 • **format:** GeoTiff	
Soil	Africa SoilGrids* https://data.isric.org/geonetwork/srv/eng/catalog.search#/search?resultType=details&sortBy=relevance&any=Africa%20SoilGrids&from=1&to=20 more information: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0125814	• gridded soil information database • created using machine learning modelling • spatial coverage: Africa • spatial resolution: 250 m • **observation depths:** 0-5 cm, 5-15 cm, 15-30 cm, 30-60 cm, 60-100 cm, 100-200 cm • information included: ○ **soil physical properties** (clay content, silt content, sand content, coarse fragments content, bulk density, electrical conductivity, depth to bedrock, drainage classes) ○ **soil chemical properties** (organic carbon concentration, pH in H_2O, cation exchange capacity, total nitrogen, …) ○ **source:** two sets of Africa soil profiles data (Africa Soil Profiles Database v1.2, Sentinel Sites soil database), in combination with the SoilGrids1km product and a series of global and continental covariates • author: ISRIC • **last update:** February 2015 • **format:** GeoTiff • data used: ○ clay content (w%) ○ sand content (w%)	• advantages: soil profiles coverage of Ethiopia quite robust; methodology and covariates adjusted to Africa-specific conditions • disadvantages: few soil profiles within the Afar region; coverage is not complete

[1] http://www.fao.org/soils-portal/data-hub/soil-classification/world-reference-base/en/
[2] https://www.isric.org/explore/wosis/faq-wosis

		○ coarse fragments content (v%)	
Soil	Harmonized World Soil Database v 1.2 http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/	• gridded soil information database • spatial coverage: global • **spatial resolution:** 30 arc-second (approx. 1 km) • information included: ○ soil groups ○ **soil physical properties** (water storage capacity, soil depth, clay fraction, textural class, granulometry) ○ **soil chemical properties** (organic carbon content, pH, cation exchange capacity, total exchangeable nutrients, salinity, ...) ○ **additional (supplementary) data:** terrain slopes, terrain aspects, land use and land cover (for year 2000), soil quality • **source:** combination of existing regional and national soil datasets with the 1:5 000 000 scale FAO-UNESCO Soil Map of the World • **author:** FAO, IIASA, ISRIC, ISSCAS, JRC • last update: 2012 • format: GeoTiff	• advantages: full coverage, globally harmonized • disadvantage: coarse resolution
Land use / land cover	Ethiopia LandCover Scheme II http://geoportal.rcmrd.org/layers/servir%3Aethiopia_landcover_2003_scheme_ii http://geoportal.rcmrd.org/layers/servir%3Aethiopia_landcover_2008_scheme_ii https://nfm.review.fao.org/nfm/catalog/srv/eng/catalog.search#/metadata/05d3f7b5-5e19-4164-b4a1-51c8eca93751	• land cover map • created using supervised classification • 16 categories • available for 2003, 2008 and 2013 • spatial coverage: Ethiopia • spatial resolution: 30 m • **source:** LandSat Imagery (30m resolution); ancillary data provided by Ethiopia Mapping Agency (EMA) • **author:** RCMRD, EMA • last update: 2015 • format: GeoTiff	• the resulting raster is filtered using a 3×3 pixels moving window • overall accuracies[1] - 87.97% (2003), 86.68% (2008), No data for 2013 • advantage: the Scheme II classification is adjusted to Ethiopia-specific conditions • disadvantage: may be outdated in some places

[1] https://www.spiedigitallibrary.org/journals/journal-of-applied-remote-sensing/volume-12/issue-04/041502/Availability-of-global-and-national-scale-land-cover-products-and/10.1117/1.JRS.12.041502.full?SSO=1

Land use / land cover	S2GLC LULC 2016 - Ethiopia http://geoportal.rcmrd.org/layers/servir%3Aethiopia_sentinel2_lulc2016	• land cover map • 9 categories • represents year 2016 • spatial coverage: Ethiopia • spatial resolution: 20 m • **source:** Sentinel-2 images (resolution 10 and 20 m); clipped from the Sentinel-2 Global Land Cover product • author: ESA • **format:** GeoTiff	• overall accuracy (of the full S2GLC product): 82.8 %[1] • advantage: high resolution • disadvantage: classification too broad
Land use / land cover	CCI Land Cover http://2016africalandcover20m.esrin.esa.int/	• prototype land cover map • created using two classification algorithms - the Random Forest (RF) and Machine Learning (ML) • 10 categories • represents year 2016 • spatial coverage: Africa • spatial resolution: 20 m • **source:** Sentinel-2A images from December 2015 to December 2016 • author: ESA • format: Geotiff	• accuracy tested only in Kenya (56%), Gabon (91%), Ivory Coast (47%), and South Africa (44%)[2] • advantage: high resolution • disadvantages: only partially validated; classification too broad
Other	Ethiopia - GIS Dataset https://datacatalog.worldbank.org/dataset/ethiopia-gis-dataset-2016	• GIS database • **layers included:** lakes, flooded areas, rivers, basins, watersheds, meteorological stations, roads, populated places, administrative units, ... • **source:** various sources; provided by the World Bank Group • last update: April 2018 • **format:** ESRI Shapefile	• some layers are not for the Afar region • positional accuracy generally rather low
Precipitation	**SM2RAIN** http://hydrology.irpi.cnr.it/download-area/sm2rain-data-sets/	• Estimated rainfall based on satellite soil moisture data • **temporal archive:** since 2007 • **temporal resolution:** daily • **spatial coverage:** global • **spatial resolution:** 12.5 km • **author:** CNR-IRPI Perugia, Italy	• resolution for the Afar region to low • accuracy given at global scale with rmse of 11.57mm
Precipitation	**TAMSAT** https://www.tamsat.org.uk/	• Estimated rainfall based on satellite data • **temporal archive:** since 1983 • **temporal resolution:** daily • **spatial coverage:** Africa • **spatial resolution:** 4 km • **author:** University of Reading	• accuracy not measured in Ethiopia • rainfall occurrence estimation with higher accuracy than rainfall amount

[1] https://www.spiedigitallibrary.org/journals/journal-of-applied-remote-sensing/volume-12/issue-04/041502/Availability-of-global-and-national-scale-land-cover-products-and/10.1117/1.JRS.12.041502.full?SSO=1
[2] https://eo4society.esa.int/projects/crowdval-using-crowdsourcing-and-innovative-approaches-to-evaluate-and-validate-esas-land-cover-products/

Then, the preprocessing of above mentioned data sets was performed to the extent of the Afar region and their reclassification into several categories based on the criteria described and shown in figures below for altitude, slopes, clay, coarse fragments of soils, population density, roads and watersheds. All the reclassified rasters were then combined together into a common grid. For this purpose, a 30m grid obtained from the SRTM dataset was used. As this dataset was also used in the potential riverbeds modelling process, its usage allowed for a direct evaluation of the previously modelled riverbeds.

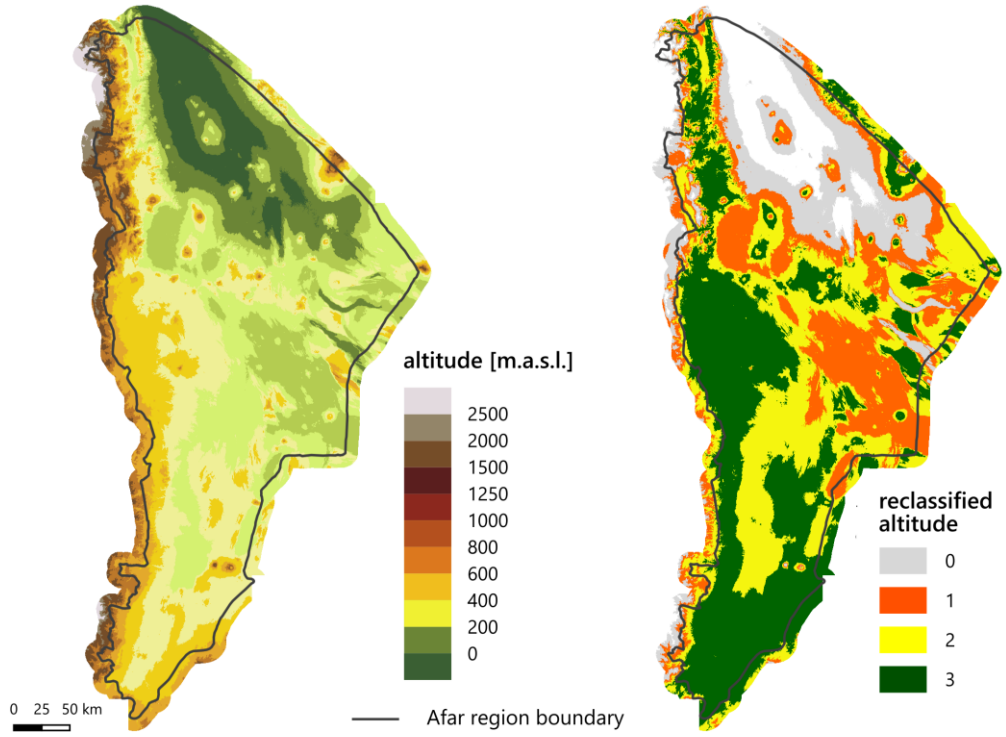

Figure 7 *Terrain altitude in the Afar region (left) and its reclassified version (right) (data source: NASA-SRTM, 2015)*

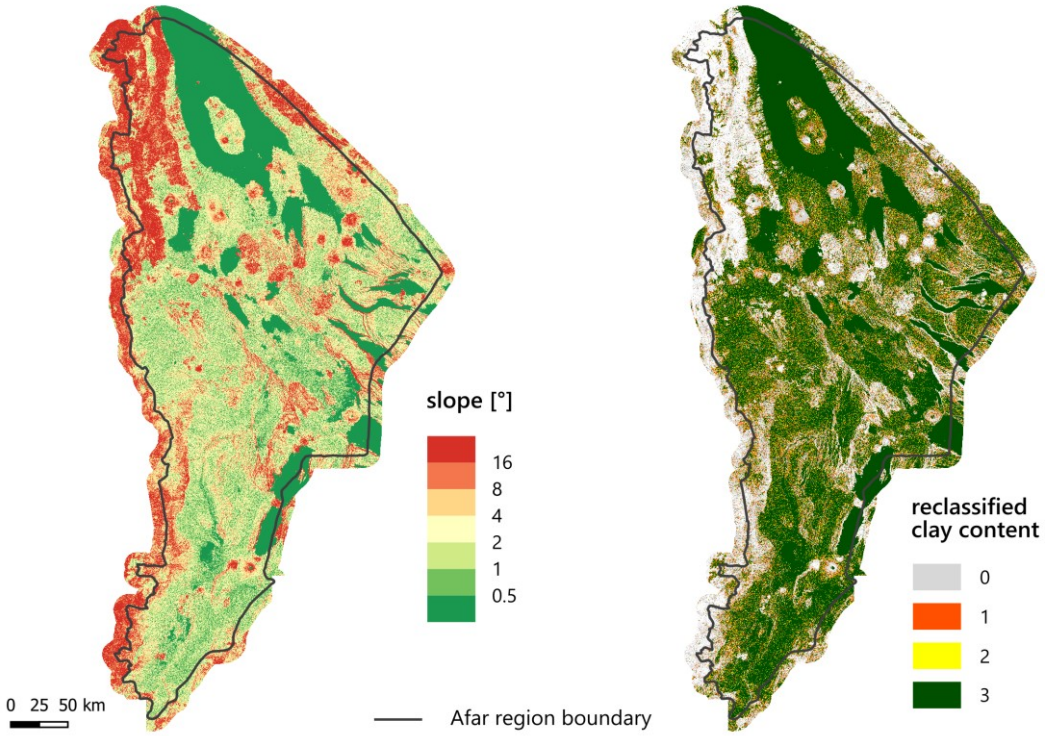

Figure 8 *Terrain slope in the Afar region (left) and its reclassified version (right) (data source: NASA-SRTM, 2015)*

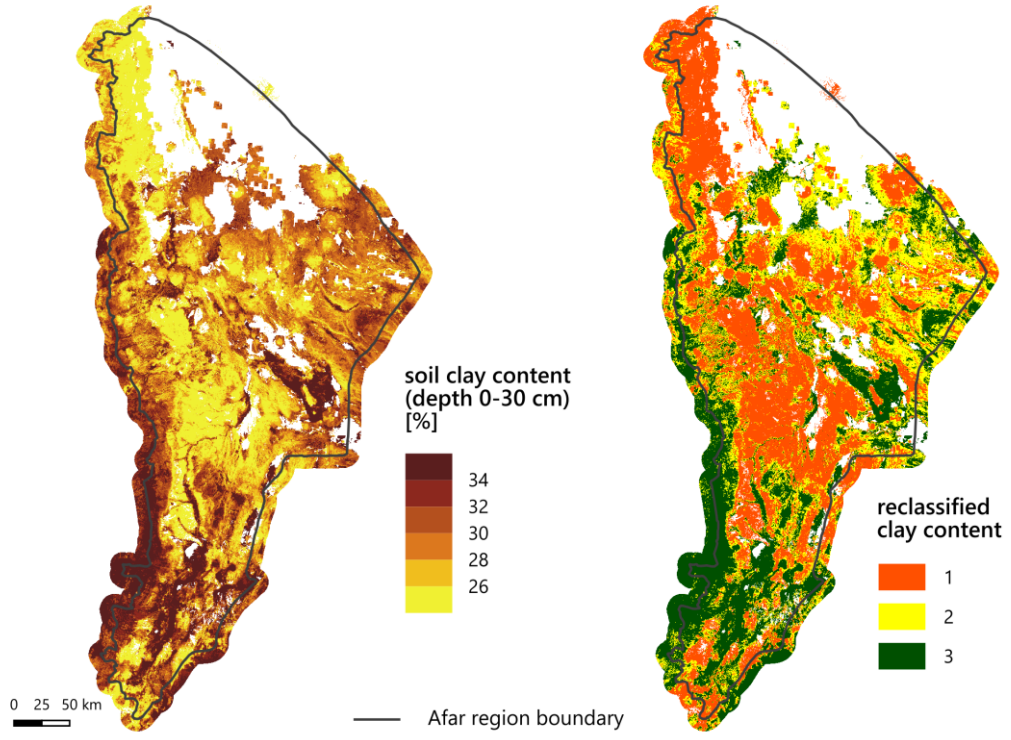

Figure 9 *Clay content of soils in the Afar region (left) and its reclassified version (right) (data source: ISRIC, 2015[1])*

[1] https://www.isric.org/projects/soil-property-maps-africa-250-m-resolution

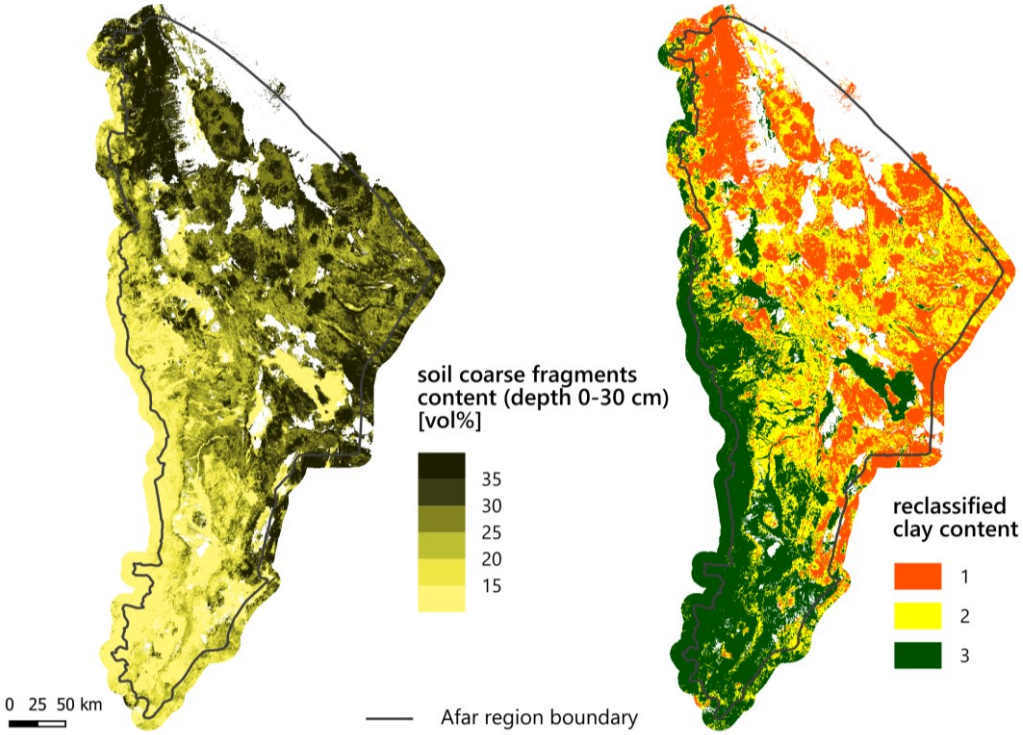

Figure 10 *Coarse fragments content of soils in the Afar region (left) and its reclassified version (right)(data source: ISRIC, 2015[1])*

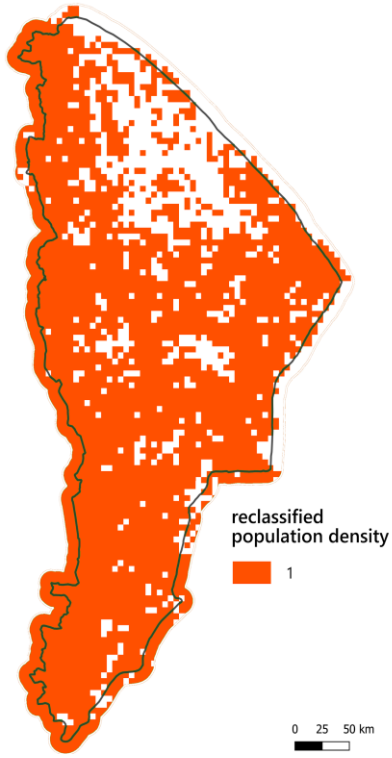

Figure 11 *Reclassified version of a population density map downscaled to 5km resolution (data source: WorldPop, 2020[2])*

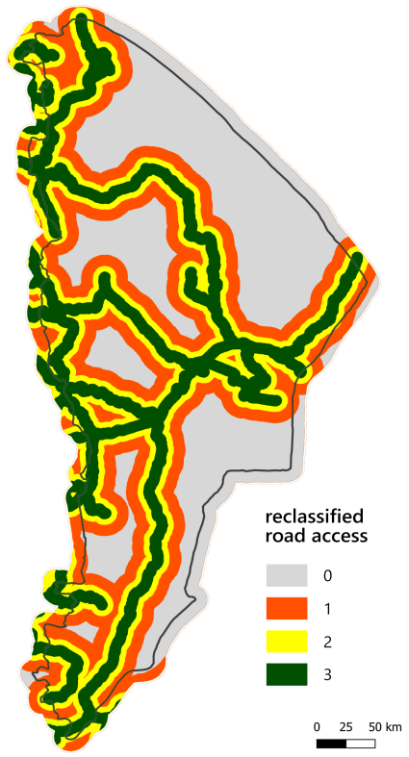

Figure 12 *Major roads in the Afar region and their buffer zones reclassified into three categories (data source: WFP, OpenStreetMap contributors, 2017[3])*

[1] https://www.isric.org/projects/soil-property-maps-africa-250-m-resolution
[2] https://www.worldpop.org/geodata/summary?id=49686
[3] https://www.worldpop.org/geodata/summary?id=49686

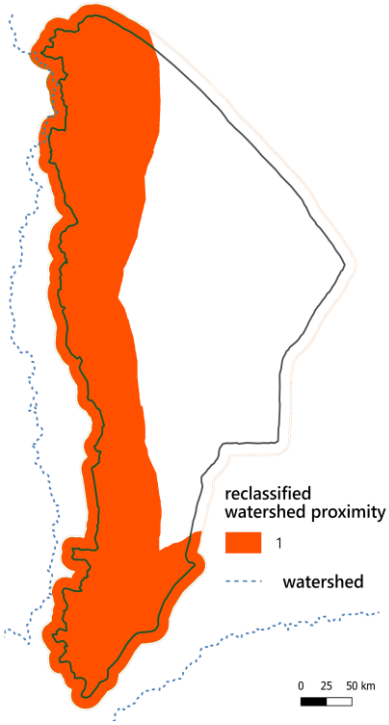

Figure 13 *Main watersheds located outside the western and southern borders of the Afar region and portion of their 100km buffer zones reaching into the region(data source: NASA, 2000;Jarvis et al., 2008[1])*

3.3 WP2 Data analyses

The applicability of global, regional, and national datasets for evaluation of potential riverbeds within the Afar region was briefly assessed in the Task1.B. Selection of these datasets were then used for the preselection of potentially suitable sites for the construction of WSWs within the Task1.C. In WP2 we focus only on those datasets that were further used for the evaluation of the sites selected in the previous steps.

These datasets are described in greater detail in the Task2.A. In case additional processing steps were applied to the datasets, these are described also.

- **Africa SoilGrids:** The soil properties within this dataset (organic carbon, pH, sand, silt and clay fractions, coarse fragments, bulk density, cation-exchange capacity, total nitrogen, exchangeable acidity, exchangeable bases (Ca, Mg, K, Na) and ex-tractable aluminium) for the whole African continent at 250 m spatial resolution at either two or six standard soil depths. In this project two soil properties were used: 1) clay fraction content (%); and 2) sand fraction content (%). The data were aggregated to a depth of 30cm, usually referred to as the topsoil depth. A simple averaging approach of the top three values was applied in the process

- **Geo-referenced Infrastructure and Demographic Data for Development (GRID3) Ethiopia Settlement Extents Version 01**: The settlement extents are derived from the Digitize Africa building footprints. The building footprint lay-er is from Ecopia Landbase Africa powered by Maxar produced by Ecopia Tech Corporation, and Maxar Technologies, Inc. . No ancillary datasets are used. The dataset contained erroneous geometries, which had to be corrected. It was then clipped to the Afar region and the separate classes of settlement files were merged into a single dataset.

[1] https://www.researchgate.net/publication/225091458_Hole-filled_seamless_SRTM_data_V4_Tech_rep_International_Centre_for_Tropical_Agriculture_CIAT

The Task2.B then includes a description of the processing steps applied to the Copernicus Sentinel-1 and Sentinel-2 satellite data. These include standard pre-processing and calculation of vegetation and soil moisture indices.

- **Sentinel-1**: 111 C-band Sentinel-1 SAR products were analysed and preprocessed mainly using the the Sentinel application platform (SNAP) tool. This data was used to obtain soil moisture values from SAR data. This is complicated by the fact that beside soil moisture the resulting reflectance from a particular area on the Earth's surface is largely affected by surface roughness and sometimes also by vegetation cover. Thanks to the sparsely vegetated character of the selected AoI, vegetation cover is not much of an issue in our analysis. On the other hand, the effect of surface roughness still needs to be compensated for but this project it was calculated and compensated using proposed formulas (as per he details provided in the Technical Note resulting from this project).

- **Sentinel 2**: The Sentinel-2 satellite mission images used in this project were used to calculate:
    - The normalized difference vegetation index (NDVI) being the most common and best-known vegetation index.
    - The normalized difference moisture index (NDMI), also known as normalized difference water index , us-es near-infrared (NIR) and short-wave infrared (SWIR) bands to display vegetation moisture level.

Within Task2.C basic information about the VHR datasets used for this study are given, followed by a description of the processing steps applied. The main results from VHR data are presented in figures below for the several objects and areas needed to be identified in the images including:

- roads
- tents and buildings
- enclosures
- settlements
- agricultural areas
- water points

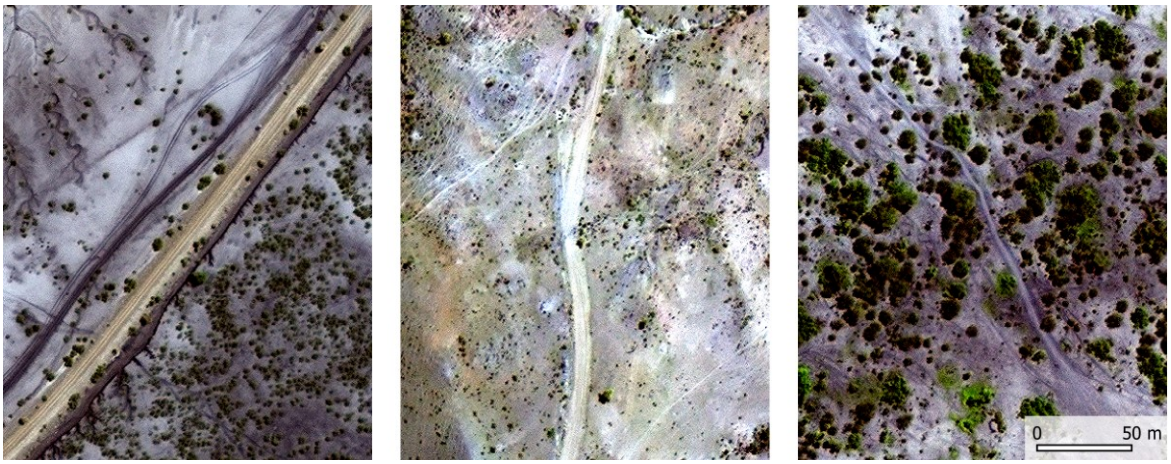

Figure 14 Roads identified in the VHR image and marked as: a) class I for paved road (left); b) class II potentially all-weather road (middle); and c) class III a road or path identifiable in the image but without a clear separation from its surroundings (right) (data source: Maxar Technologies, 2020)

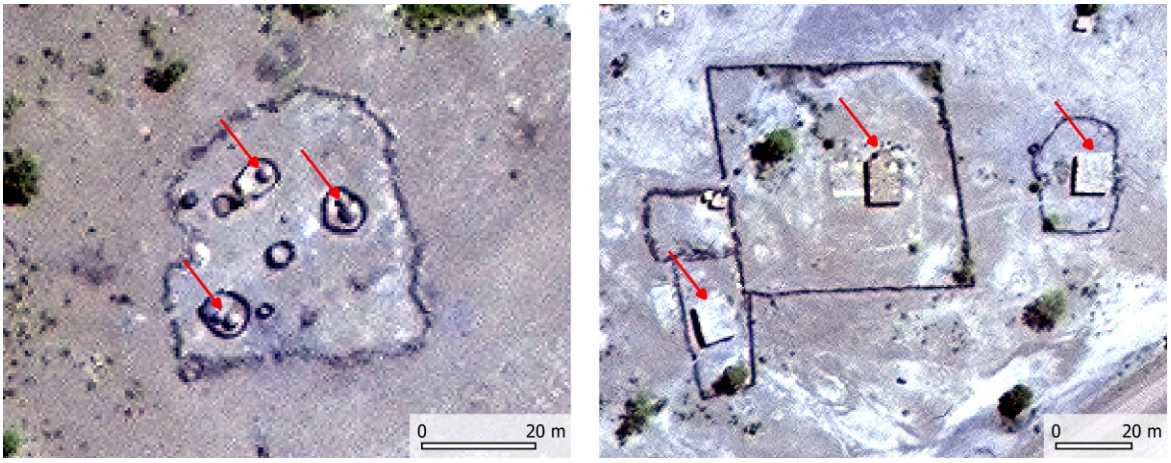

Figure 15 *Tents (left) and buildings (right) identified in the VHR satellite image (data source: Maxar Technologies, 2020)*

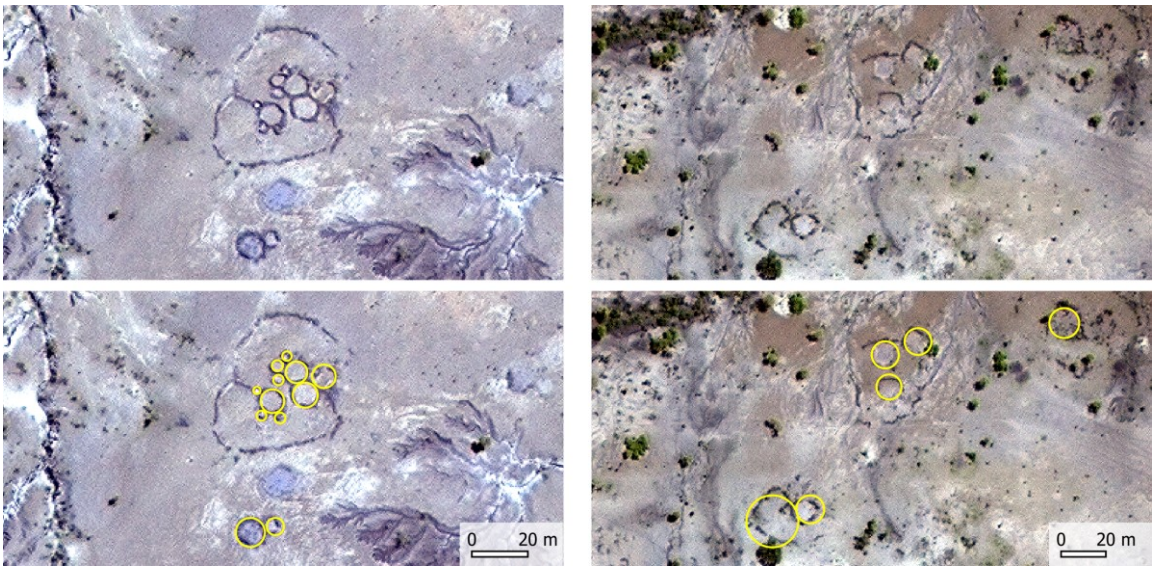

Figure 16 *14:enclosures identified in the VHR satellite image as maintained (left) and not maintained (right) (data source: Maxar Technologies, 2020)*

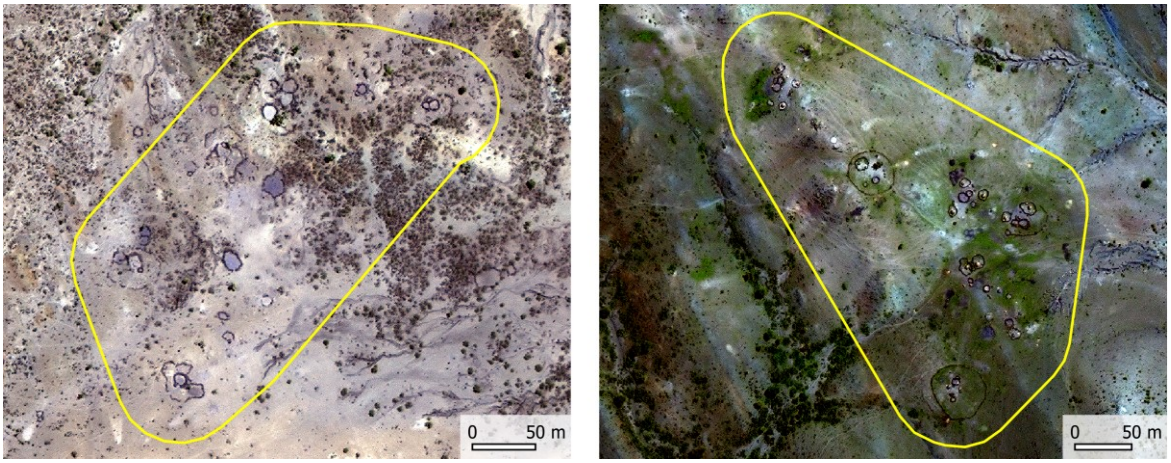

Figure 17 *Potentially semi-permanent (left) and (semi-)permanent settlements identified in the VHR satellite image (data source: Maxar Technologies, 2020)*

Figure 18 Signs of cultivation identified in the VHR satellite image (data source: Maxar Technologies, 2020)

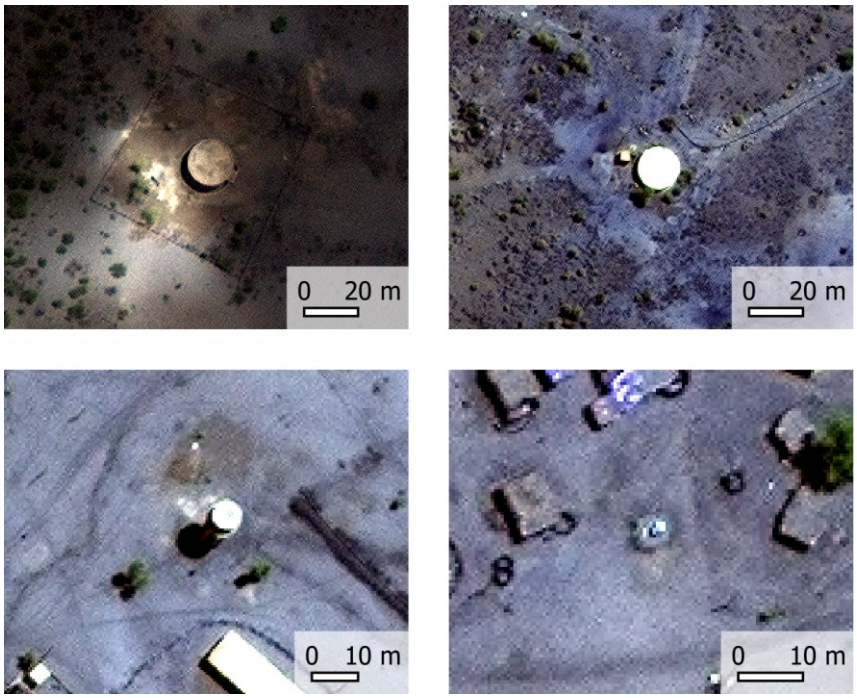

Figure 19 Potential water points identified in the VHR satellite image (data source: Maxar Technologies, 2020)

Task2.D about the Local data sources processing, deducted that the most useful of the provided datasets was the vector layer of other WSW. For each WSW included, in the dataset the average altitude and slope were obtained from the SRTM DEM dataset, which were further used for preselection of potentially suitable sites for the construction of WSWs.

Further, as noted in the previous section, some of the information included in the tabular dataset on water points was used in their later identification. The most valuable were photos of individual water storages and water access points (mostly hand pumps).

3.4 WP3 Cascade Suitability Matrix evaluation

In this chapter the riverbeds located within the selected AoI are evaluated on the basis of the factors outlined in the Cascade Suitability Matrix (CSM) provided by GIZ, using global datasets together with statistical information obtained from the VHR data. As many factors as possible were assessed in this analysis, including:

1) Predominant soil type;

2) Closest permanent water point;
3) Road access (all weather road for motorized vehicles/trucks);
4) Signs of cultivation (e.g. maize, sorghum, grasses);
5) Proximity of market place;
6) Presence and maintenance of enclosures;
7) Proximity of the next (semi-)permanent hamlet/village;
8) Number of hamlets/villages in this area (meaning in the area predefined via drone pictures); and
9) Average number of households per hamlet/village.

As the proposed CSM was initially considered it is improvable in relation to its use with EO data. This chapter also includes some recommendations for the use of such data in the site-selection process.

3.4.1 Task3.A CSM factors identification and assessment (Service 1)

3.4.1.1 Datasets

Global data sets in general

Available global data sets (e.g. climate data, soil data, land use data, crop extents) typically show a low spatial resolution. The application of global data sets in a small region must therefore be viewed with caution. Especially in a dry, low populated and low productive area these data sets tend to be either not verified or show higher errors than in surrounding areas. However, during the last years, new data sets based on satellite observations have been produced, sometimes including focus regions like Africa (e.g. the Africa SoilGrid). The use of regional data sources with special focus on the given climate and ecological frames is to be preferred.

Precipitation

Both precipitation data sets, TAMSAT and SM2RAIN were evaluated in order to identify any impact on a suitability matrix. In the time frame of the given data archive, no significant impact on the AOI was found. Therefore, no precipitation was included in the further matrix evaluation.

Land cover

Given the frame of the suitability matrix, no additional valuable information could be generated based on the land cover data sets.

The **Africa SoilGrids dataset** was used to assess the *Predominant soil type* factor included in the Biological aspects table provided by GIZ.

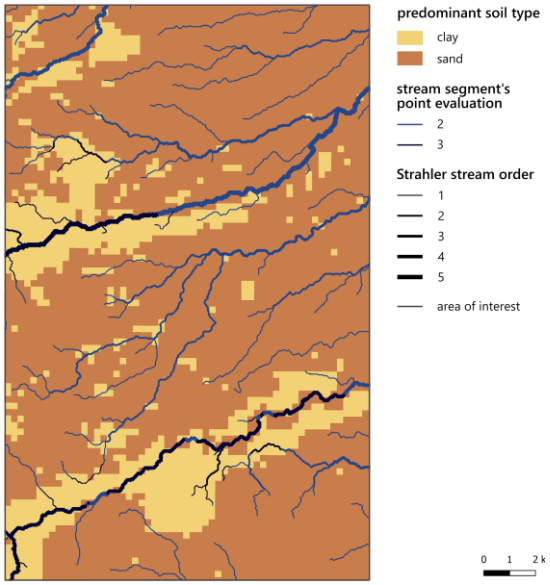

Figure 20 Predominant soil type within each 250×250m grid cell and the respective evaluation of riverbed segments (data source: NASA-SRTM DEM, 2015; ISRIC, 2015)

GRID3: To ease the process of a manual identification of hamlets and other settlements within the selected AoI the Hamlets and Small settlement area layers included in the GRID3 Ethiopia dataset were used. This approach has proven to be particularly effective in areas affected by clouds in the used VHR image. However, the GRID3 dataset was published in early 2020 and can be assumed to capture the states in 2019 or earlier. For this reason, the position of hamlets included in the dataset is not always in line with the position of hamlets delimited as part of our analysis.

Sentinel-1 and Sentinel-2 data are not used directly in the CSM evaluation process. Nevertheless, the following paragraphs present the possibilities of incorporating this type of data in the site evaluation process. More specifically, the data is considered useful for the: 1) potential riverbeds identification; 2) identification of agricultural areas; and 3) preselection of potentially suitable sites for WSW construction at local level.

In Figure 21, the results of NDVI, NDMI, and SMI zonations within the selected AoI are presented, overlaid by the riverbeds modelled using the SRTM DEM data and classified according to their Strahler order.

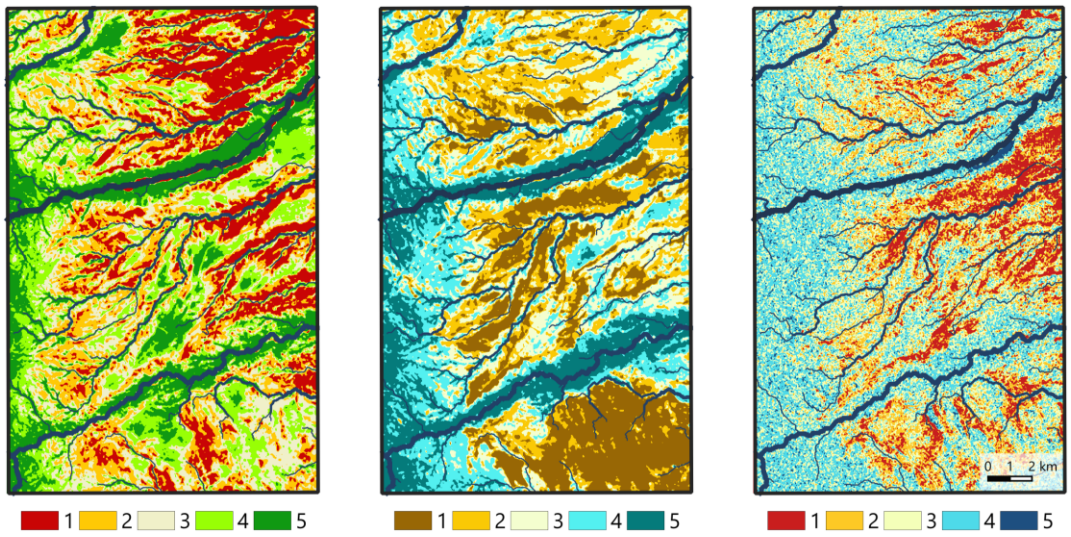

Figure 21 *Zonations of NDVI (left), NDMI (middle) and SMI (right) within the selected AoI (source: Contains modified Copernicus Sentinel data [2017-2020])*

Figure 22(left) displays a satellite image of the selected area within the AoI.

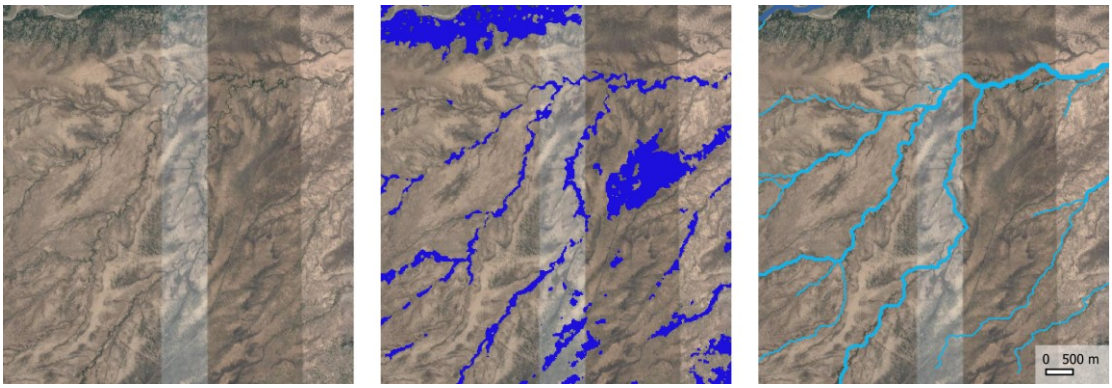

Figure 22 *Satellite image of a selected area within the AoI (left); the same image overlaid by a raster layer with pixels falling into categories 4 or 5 in NDMI and SMI zonation displayed in blue (middle); and the same image overlaid by a vector layer with riverbeds modelled from the SRTM DEM dataset displayed in cyan (right) (basemap: Google Hybrid; data sources: Contains modified Copernicus Sentinel data [2017-2020]; NASA-SRTM, 2015)*

Figure 23 displays standard deviation of SMI values within the studied area.

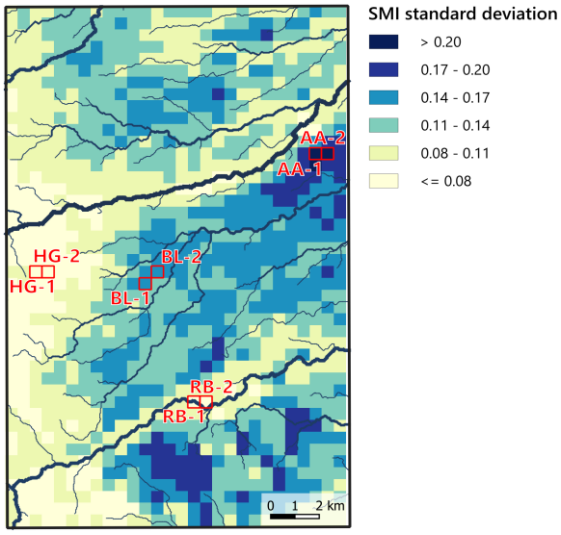

Figure 23 *Zonations of NDVI (left), NDMI (middle) and SMI (right) within the selected AoI (source: Contains modified Copernicus Sentinel data (2017-2020) to be used*

Time series of NDVI, NDMI and SMI for the selected pixels (AA-1, AA-2, HG-1, HG-2, BL-1, BL-2, RB-1, RB-2) are displayed in Figure 24, Figure 25 and Figure 26, respectively, where clear seasonality of the observed values can be seen, with the highest values of all the indices usually reached in August or September, except for the season of 2019. These observations suggest that time series of the proposed indices could be used to identify agriculturally exploited areas or to locate suitable sites for certain crop growing regimes. In this case we present the results for pixels of a size 500×500 m; nevertheless, the resolution of such analysis could be upscaled up to 10 meters if needed.

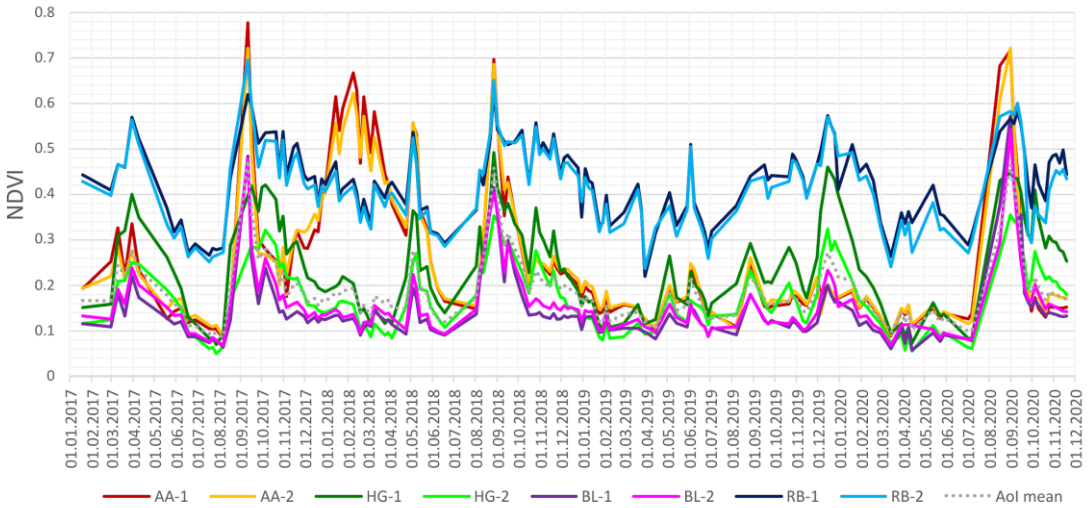

Figure 24 *Time series of NDVI values for the selected pixels (source: Contains modified Copernicus Sentinel data (2017-2020)*

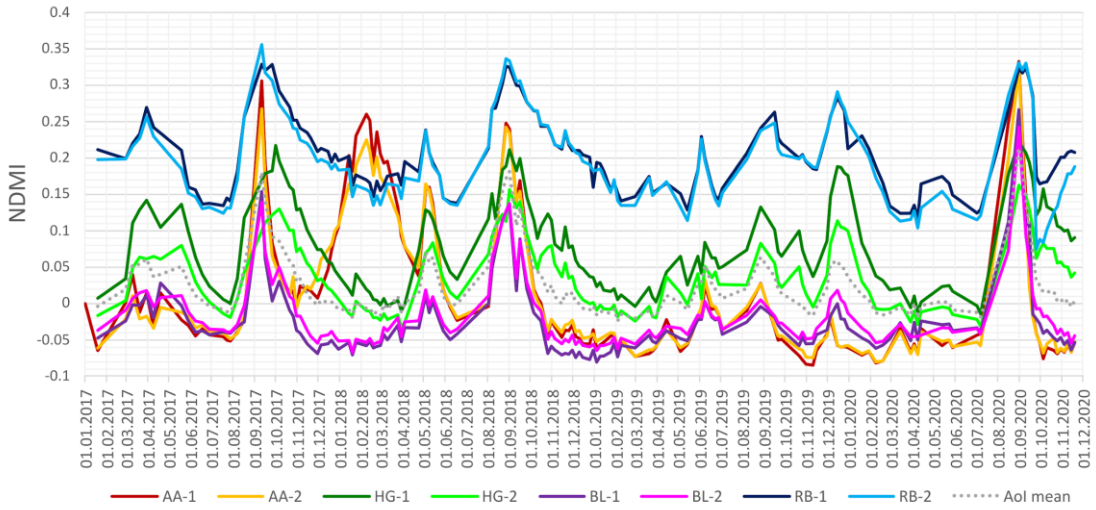

Figure 25 *Time series of NDMI values for the selected pixels (source: Contains modified Copernicus Sentinel data (2017-2020)*

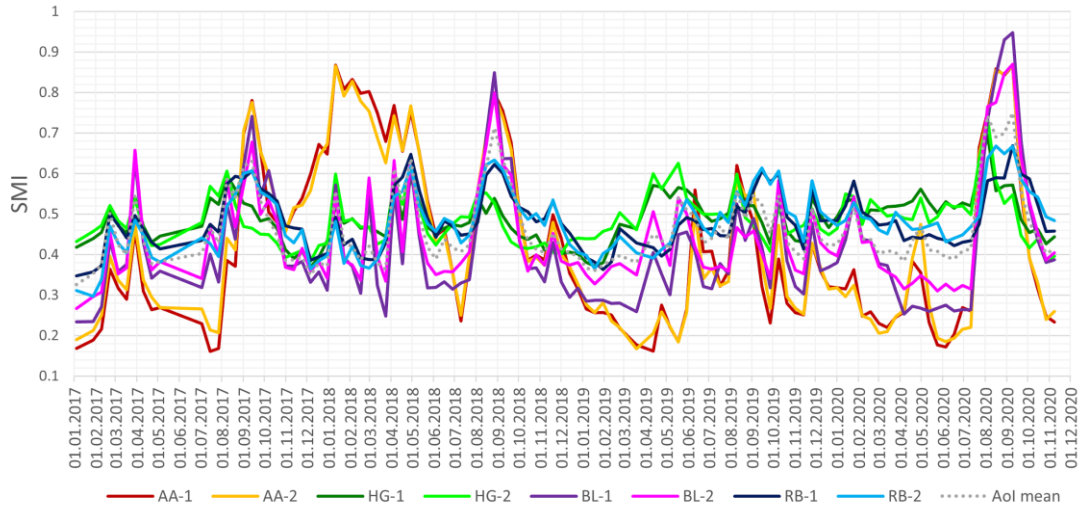

Figure 26 *Time series of SMI values for the selected pixels (source: Contains modified Copernicus Sentinel data (2017-2020)*

VHR data analysis resulted in the analysis and identification of different objects/group of objects is presented together with the respective network of evaluated riverbed segments.

TABLE 5. *Statistical summary of objects and areas identified within the selected AoI (data source: Maxar Technologies, 2020)*

Object/area	type	quantity
tent		1802
building		732
enclosure	maintained	2652
	not maintained	4324
settlement	(semi-)permanent	109
	potentially semi-permanent	32
road	class I	33.64 km

	class II	29.15 km
	class III	252.61 km
water point		4
market place		1
cultivated land		365 ha

3.4.1.2 CSM factors identification and assessment

For the evaluation of the CSM matrix elements, each river of a certain Strahler stream order was divided into segments of a maximum length of 100 meters. For each of the created segments buffer zones with certain distances (mostly 1 and 5 kilometres) were produced, according to the distance parameters described within the CSM proposed by GIZ. In case a distance is not specified explicitly (e.g. in the case of the *'Number of hamlets/villages in this area (meaning in the area predefined via drone pictures)'* factor) a distance of 1 kilometre was used.

For the created buffer zones appropriate statistics were calculated (e.g., a simple presence of a road within a buffer zone, or several hamlets within the zone). According to the results of the analysis, each segment was assigned a score, following the scoring approach included in the CSM.

The following figures present some of these results obtained for different CSM factors.

Physical aspects: Two out of five factors from the Physical aspects table proposed by GIZ (in the Request for Proposal) were possible to be assessed: 1) *Closest permanent water point*; and 2) *Road access (all weather road for motorized vehicles/trucks)*.

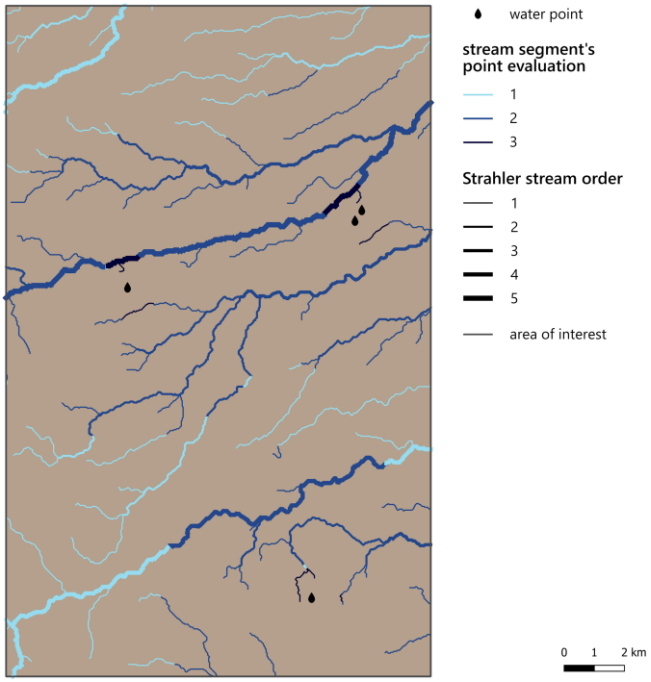

Figure 27 Locations of water points identified within the selected AoI and the respective evaluation of riverbed segments (data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

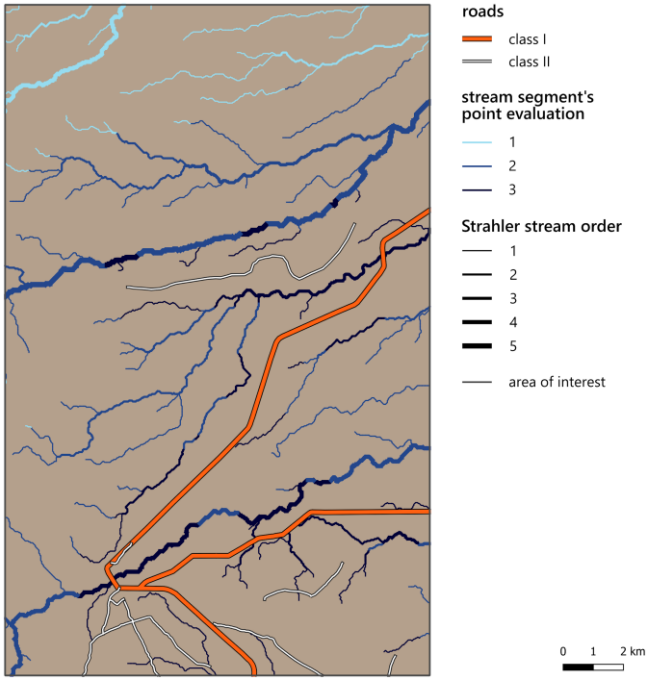

Figure 28 Roads marked as class I and class II identified within the selected AoI and the respective evaluation of riverbed segments(data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

Biological aspects: Two out of 5 factors included in the Biological aspects table proposed by GIZ were possible to be assessed: 1) *Predominant soil type*; and 2) *Signs of cultivation (e.g. maize, sorghum, grasses)*.

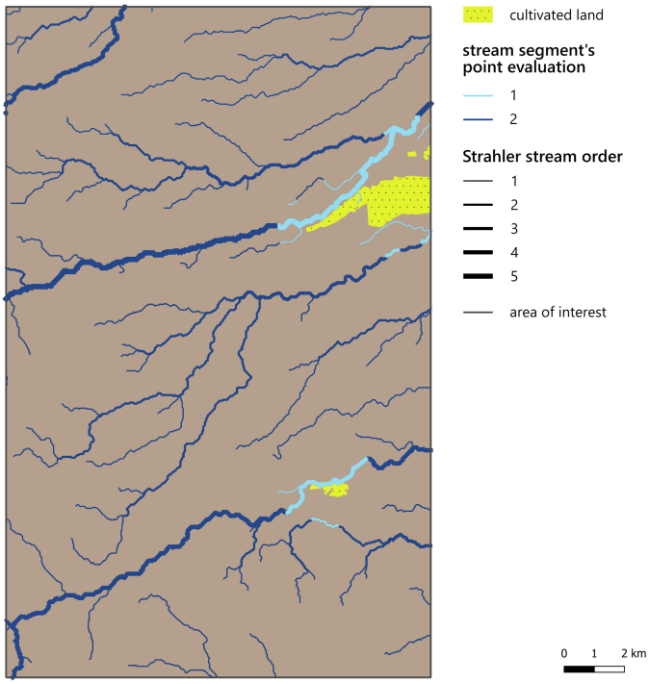

Figure 29 Cultivated areas identified within the selected AoI and the respective evaluation of riverbed segments (data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

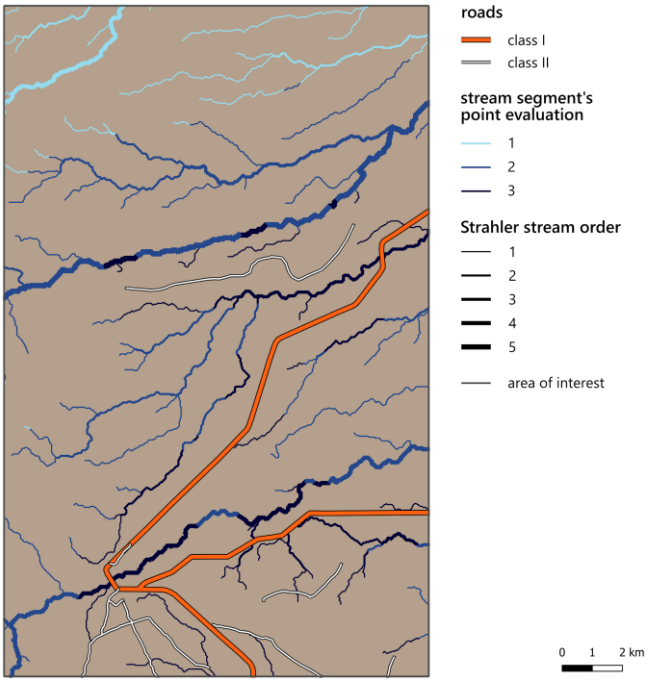

Figure 30 Roads marked as class I and class II identified within the selected AoI and the respective evaluation of riverbed segments(data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

Social aspects: All 5 factors included within the Social aspects table provided by GIZ were assessed. These include the following: 1) *Proximity of market place*; 2) *Presence and maintenance of enclosures*; 3) *Proximity of the next (semi-)permanent hamlet/village*; 4) *Number of hamlets/villages in this area*; and 5) *Average number of households per hamlet/village*.

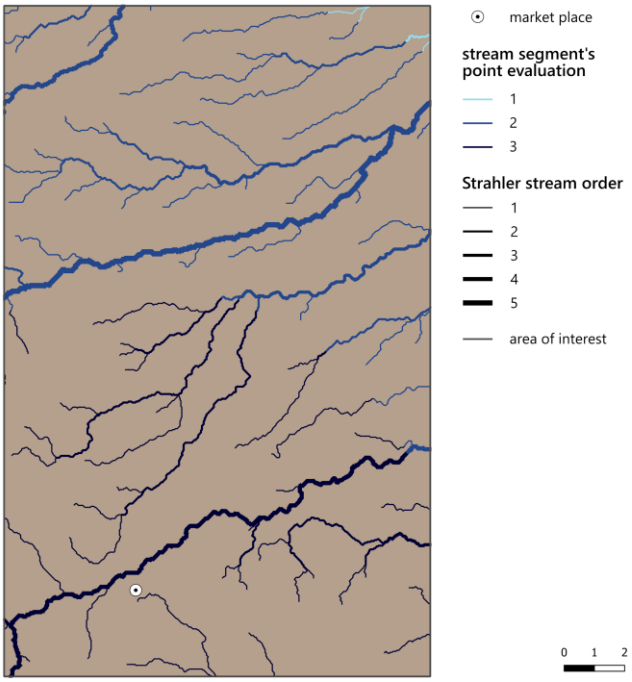

Figure 31 Assumed position of a water point located within the selected AoI and the respective evaluation of riverbed segments(data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

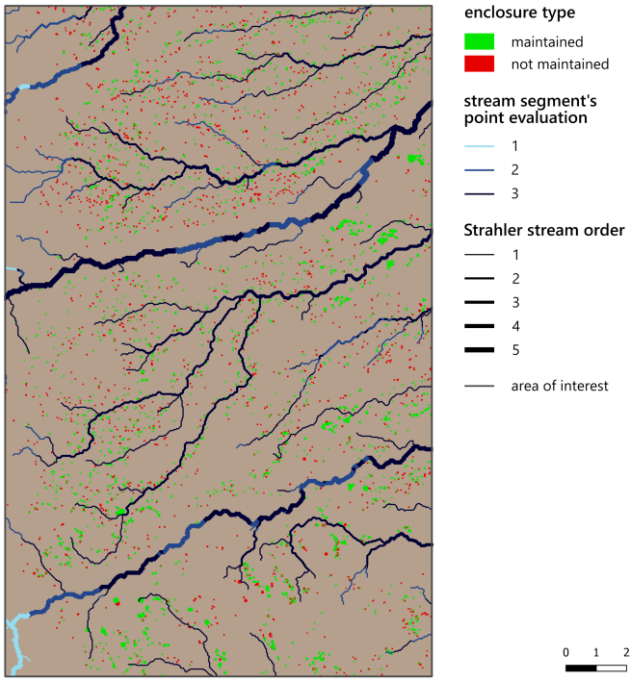

Figure 32 Maintained and not maintained enclosures identified within the selected AoI and the respective evaluation of riverbed segments (data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

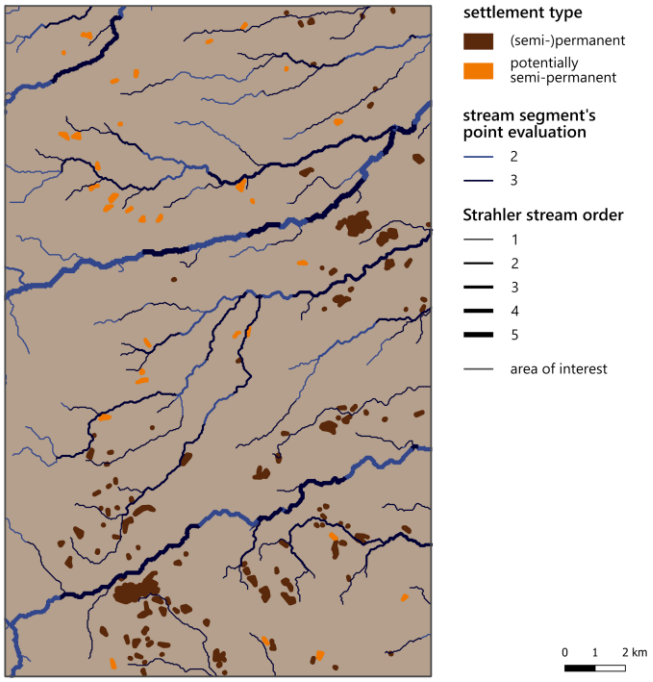

Figure 33 (Semi-)permanent and potentially semi-permanent settlements identified within the selected AoI and the respective evaluation of riverbed segments according to the proximity of the nearest settlement (data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

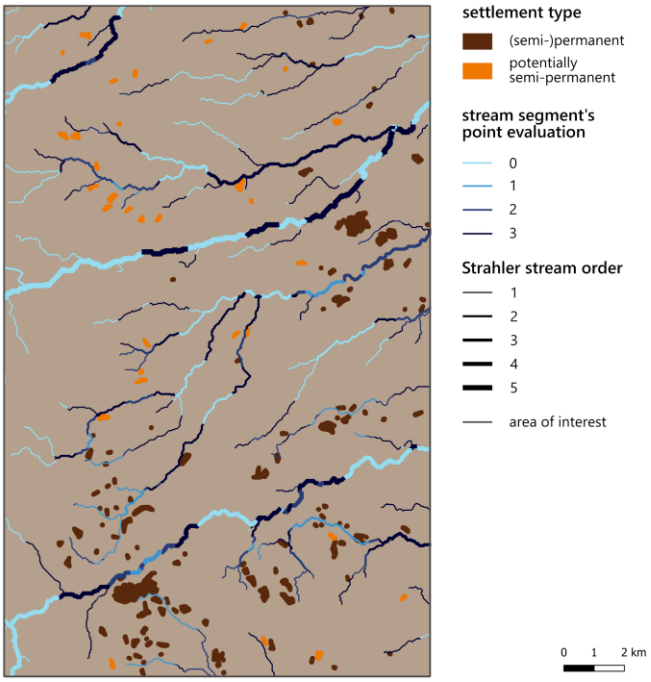

Figure 34 (Semi-)permanent and potentially semi-permanent settlements identified within the selected AoI and the respective evaluation of riverbed segments according to the number of settlements within the 1km buffer zone of each segment (data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

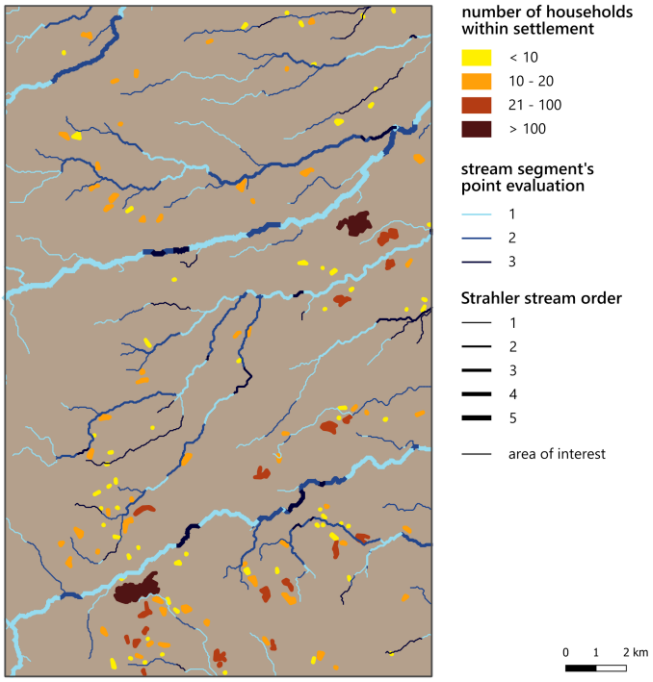

Figure 35 Number of households within each settlement identified within the selected AoI and the respective evaluation of riverbed segments according to the average number of households in settlements located within the 1km buffer zone of each segment (data source: NASA-SRTM DEM, 2015; Maxar Technologies, 2020)

3.4.2 Task3.B Site Suitability Map (Service 2)

The resultant site suitability map is displayed in Figure 36.

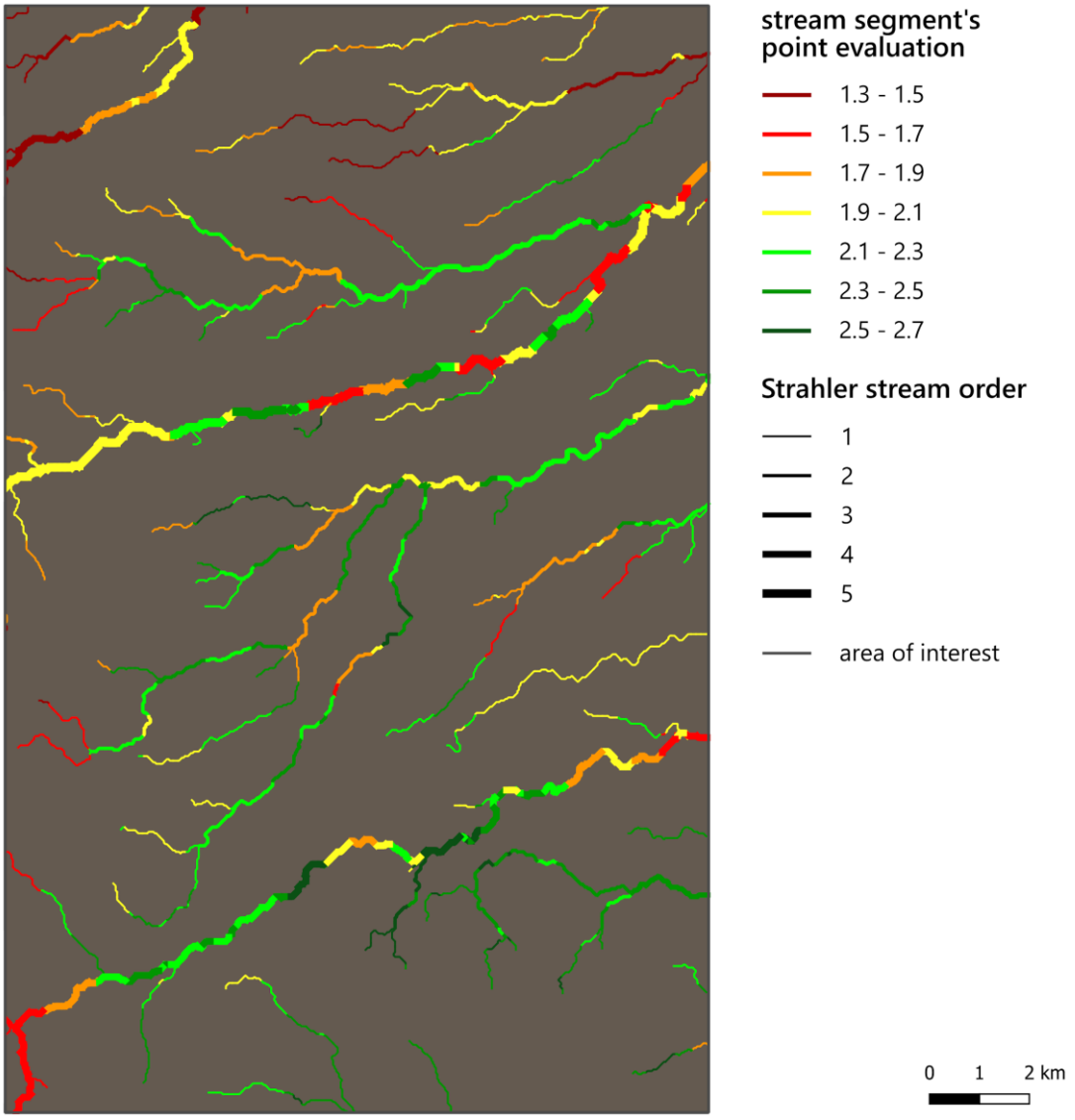

Figure 36 *Site suitability map with riverbed segments of a length of 100 meters evaluated using 9 physical, biological, and social factors assessable from global datasets and EO data (data source: NASA-SRTM DEM, 2015; ISRIC, 2015; Maxar Technologies, 2020)*

3.5 GIZ Matrix coverage analysis

The fulfilment of the evaluation of each of the factors defined in the Cascade Suitability Matrix from GIZ is summarized and commented here below. TABLE 6 considers only the information included in the CSM and its assessment using global dataset and VHR satellite images.

TABLE 6. *Factors identified in the CSM proposed by GIZ and the fulfilment of their evaluation*

Factor of CSM	Fulfilment	Comments
Sufficient stones available for construction	No	Resolution of VHR images available for the Afar region is not sufficient to identify individual stones. Coarse fragments content of soil contained in the Africa SoilGrids dataset may be indicative, but it cannot be guaranteed without in situ validation.
Sufficient sand available for construction	Partialy	Information about sand content of soil contained in the Africa SoilGrids dataset may be indicative but it cannot be guaranteed without in situ validation.
Closest permanent water point	Partially	Only larger water storage objects (e.g., water tanks, water towers) may be identified in VHR satellite images. Presence of a water point not identifiable through soil moisture or vegetation water content state.
Road access (all weather road for motorised vehicles)	Yes	Visual inspection of VHR data (see Task3.A).
Predominant soil type (clay or loam, sand, rocky soil)	Yes	Using information about clay content, sand content and coarse fragments content contained in the Africa SoilGrids dataset (see Task1.C and Task3.A)
Signs of cultivation (yes, no)	Yes	Visual inspection of VHR data (see Task2.C). Also identifiable from the time series of NDVI and NDMI values obtained from the Sentinel-2 images.
Proximity of marketplace	Partly	Available global dataset does not include any market located within the Afar region. No market place was identified in the used VHR satellite image. Nevertheless, existence of a market place was inferred to be located in the largest of the settlements identified within the selected AoI (see Task2.C).
Presence and maintenance of enclosures	Yes	Visual inspection of VHR data (see Task2.C).
Proximity of the next hamlet/village	Yes	Visual inspection of VHR data. For a hamlet delimitation a clustering method was applied to the tents and buildings identified within the selected AoI (see Task2.C).
Number of hamlets/villages in this area	Yes	Visual inspection of VHR data, clustering of the identified tents and buildings, and calculation of a number of hamlets within 1km radius from a modelled riverbed segment of a length of 100 m (see Task2.C and Task3.A)
Average number of households per hamlet/village	Yes	Visual inspection of VHR data, clustering of the identified tents and buildings to delimitate hamlets/villages, and calculation of an average number of households within each hamlet/village in 1km radius from a modelled riverbed segment (see Task2.C and Task3.A)

4 SUMMARY. RECOMMENDATIONS AND FUTURE WORK

Data outputs of the Request for Proposal are delivered and shared in standard GIS formats. The methodological approach used is described in this Technical Note. This chapter presents recommendations for potential further use of Earth Observation data for the the ultimate purposes of GIZ and better exploit EO data.

Recommendations/notes to elevation model/riverbeds modelling:

Use SRTM DEM is recommended:

- It provided the best results among global DEM datasets
- as being created February 2000 it may be outdated in areas undergoing frequent terrain changes
- but with possible problems in very rugged terrain (radar shadow, foreshortening, layover)
- for riverbed identification information about soil moisture (SMI) and moisture content in vegetation (NDMI) can be used as proxy to improve precision on a local level

Recommendations for use of VHR data

This project has shown that VHR data can be effectively used for detection of roads, tents and buildings, enclosures, and agriculturally exploited areas, but:

- VHR data are not being acquired regularly -
    - possible problem with timeliness (impact on identification of semi-permanent settlements, maintained/not maintained enclosures)
    - time of acquisition during a year needs to be taken into account due to the nomadic way of life of the majority of Afar people
- clouds may represent a major problem
- coverage of VHR data (with resolution better than 1 meter) is not global (only parts of the Afar region are available) - acquisition for the whole region would have to be ordered
- water points identification - storage tanks may be identifiable, access points mostly not
- 4-band (R,G, B,NIR) multispectral data are of a limited use
- more expensive than panchromatic data
- NDVI values and spatial trends similar to Sentinel-2 data, which offers multitemporal observation

Recommendations for use of Sentinel-1 and Sentinel-2 data

- for time series of vegetation indices from Sentinel-2 - good usability for identification of cultivated land;
- for time series of NDVI, NDMI and SMI suit well to identify rain seasons and soil regime in different parts a selected area of interest → may be used to locate suitable sites for certain crop growing regimes;
- radar reflectance may be used to identify land prone to floods (approach already presented for use in Afar[1])

Recommendations for global datasets usage:

- Africa SoilGrids
    - comprehensive information about soil properties - coverage of Ethiopia with soil profiles quite robust, however, no profiles in Afar → accuracy needs to be verified.
- GRID3
    - for settlements extent
    - high resolution, tents are detected also
    - published at the beginning of 2020, so 2019 data at most

[1] https://www.cambridge.org/core/journals/renewable-agriculture-and-food-systems/article/assessing-potential-locations-for-floodbased-farming-using-satellite-imagery-a-case-study-of-afar-region-ethiopia/75275C5A1D3C14E1C5D39301B246E847

    - results in some places differ from those obtained in this project - probably caused by using images from different season and different methodology for delimitation of hamlets.
- TAMSAT / SM2RAIN (precipitation)
    - spatial resolution too coarse
    - no specific impact on the suitability matrix since low rainfall values during a season
- ESA CCI Land Cover / Ethiopia Land Cover / FAO Wapor Land Cover
    - differentiation between different land cover types only possible for tree/no tree coverage
    - quality not uniformly, especially cropland often misclassified
    - results might be useful as a proxy if a configuration of land cover classes fits into a specific rule set (e.g. tree coverage together with nearby (open) shrubland as a proxy for the existence of building material

Recommendations for use of EO data for use in the Afar region:

- EO data bring just limited added value concerning matrix (as designed now), however the use of EO data could be better exploited if the matrix is modified.
- A three-step approach for identification (1) of regions first and (2) of specific places afterwards for building water spreading weirs, is presented here below:
    - large areas (and relatively easily the whole Afar region) can be assessed with the use of global datasets and open satellite data (Copernicus) to identify focus regions
    - focus regions can be further assessed with VHR data mainly to identify population patterns and roads (this can serve to some extent as an alternative to drones) to identify optimal riverbeds parts
    - local investigation needs to be done in context of the occurrence invasive plant species, building material accessibility and river accumulation micro-topography
- for the better use of the EO and GIS in the methodology, several recommendations are suggested here below:
    - explicit setting of the distances (rather than “surrounding”) - riverbed transect length, buffer distance for settlements, distance between tents to consider it as a settlement
    - addressing rules for assessing population - what time in year, how many tents form a hamlet, etc.

After the successful finalization of this RFP, it will be very easy to apply the developed methodology to additional sites in other locations. Due to the nature of the used data -satellite information paired with available local sources- the whole process can be easily adapted to further environmental locations and purposes (e.g. locate suitable sites for certain crop growing regimes). This ensures GIZ and other development agencies a huge potential for future activities, for which selecting a suitable location for certain implementations is a crucial point-of-start. The combination of existing data sets of several sources with up-to-date VHR satellite information will bridge the gap between general available information and local assessment when ground observations are lacking.

APPENDIX A: LIST OF ACRONYMS

Acronym	Meaning
AoI	Area of interest
CCI	Climate Change Initiative
CIESIN	Center for International Earth Science Information Network
CSM	Cascade Suitability Matrix
CSA	Central Statistics Agency
DBSCAN	Density-based spatial clustering of applications with noise
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt e. V.
EMA	Ethiopia Mapping Agency
EO	Earth Observation
ESA	European Space Agency
FAO	Food and Agriculture Organization
fAPAR	fraction of absorbed photosynthetically active radiation
FEWSNET	Famine Early Warning Systems Network
FSNAU	Food Security and Nutrition Analysis Unit
GDEM	Global Digital Elevation Model
GHSL	Global Human Settlement Footprint
GIZ	Gesellschaft für Internationale Zusammenarbeit
GRID3	Geo-Referenced Infrastructure and Demographic Data for Development
GUF	Global Urban Footprint
HOTOSM	Humanitarian OpenStreetMap Team
ICIMWG	Inter-Cluster Information Management Working group
ICPAC	IGAD Climate Prediction and Application Centre
ICPALD	Igad Centre For Pastoral Areas and Livestock Development
IGAD	Intergovernmental Authority on Development
IIASA	International Institute for Applied Systems Analysis
ISRIC	International Soil Reference and Information Centre
ISS-CAS	Institute of Soil Science - Chinese Academy of Sciences
JRC	Joint Research Center
LULC	land use land cover
ML	machine learning
NASA	National Aeronautics and Space Administration
NBI	Nile Basin Initiative
NDVI	Normalized Difference Vegetation Index
NDMI	Normalized Difference Moisture Index

NDRE	Normalized Difference Red-Edge Index
NDWI	Normalized Difference Water Index
NGIA	National Geospatial-Intelligence Agency
OSM	OpenStreetMap
RCMRD	Regional Centre For Mapping Of Resources For Development
RF	random forest
RfP	Request for Proposal
S2GLC	Sentinel-2 Global Land Cover
SAR	synthetic aperture radar
SAR4URBAN	SAR for urbanisation monitoring
SFD	Single Flow Direction
SRTM	Shuttle Radar Topographic Mission
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNITAR	United Nations Institute for Training and Research
UNOSAT	UNITAR's Operational Satellite Applications Programme
UNSDI-T	United Nations Spatial Data Infrastructure for Transport database schema
VHR	very high resolution
WCS	web coverage service
WebDAV	Web-based Distributed Authoring and Versioning
WFP	World Food Programme
WMS	web map service
WO	Work Order
WOR	Work Order Report
WoSIS	World Soil Information Service
WP	Work Package
WSW	water spreading weir

--- END OF DOCUMENT ---