Food and Agriculture Organization of the United Nations

Global Soil Salinity Map (GSS map)

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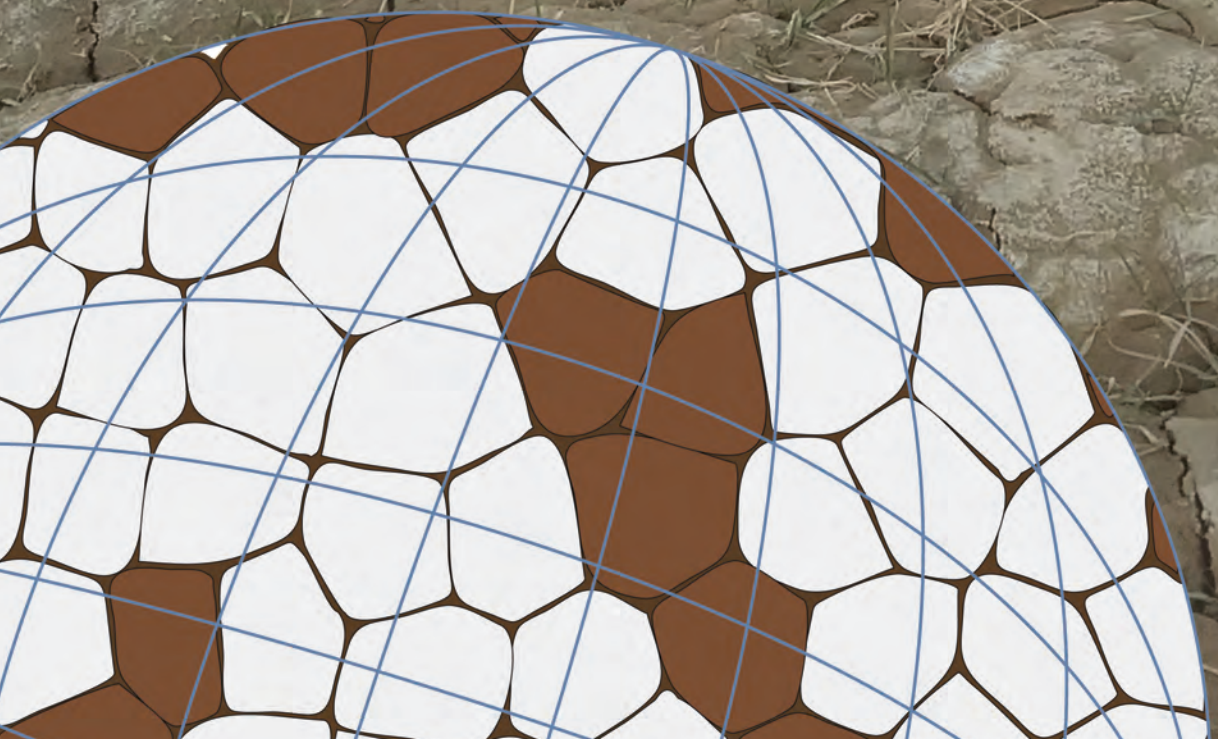

GLOBAL SOIL PARTNERSHIP

Global Soil Salinity Map (GSS map), Lesson 1 - Requirements and preparation for national mapping of salt-affected soils

Capacity building program is part of the country-driven framework for updating national and global level information of salt-affected soils. It aims at mobilizing country-level resources and expertise to assess the status of salt-affected soils and build foundation for future monitoring and management of these soils. The program is a systematic procedure to strengthen national capacities as well as harmonize global approaches for building information of salt-affected soils. This document illustrates the first lesson of the capacity-building program and focuses on the requirements and necessary preparation for implementing the program.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 2020

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Recommended citation:

Omuto, C.T., Vargas, R., Viatkin, K., Yigini, Y., 2020. Global Soil Salinity Map (GSS map) - Capacity building for national assessment of salt-affected soils: Lesson 1 - Requirements and preparation for national mapping of salt-affected soils. Rome

Summary

This Lesson is the first step of the capacity-building program, which is designed to build national capacities as well as harmonize procedures for developing information of salt-affected soils at the national and global levels. The overall goal of this Lesion is to support participants in preparing input data and computing requirements for assessing salt-affected soils at the national level. At the end of the lesson, the participants are expected to have well-developed operational database and tools for mapping salt-affected soils in their countries.

Summary requirements for developing national information of salt-affected soils

Item	Description		Timeline
Data	**Georeferenced soil profile data (between 0-100 cm)**		One week
	Electrical Conductivity	dS/m	
	pH	-	
	Exchangeable Sodium percent	-	
	Climate		
	Temperature (Minimum/Maximum)	^{o}C	
	Precipitation	mm	
	Other spatial data		
	Land cover map	Hydrogeology map	
	Geology map	Soil map	
	Remote sensing images	DEM	
	Country boundary shapefile		
Computer	At least 8GB RAM, Core I3, and 100GB storage		-
Software	QGIS, R, ILWIS, Spreadsheet software		One day

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1 Introduction

1.1 Overview

Salt-affected soils are groups of soils with high content of soluble salts and/or high amounts of sodium ions. The type and concentration of these salts and their drivers are important characteristics and the basis for mapping salt-affected soils. This Lesson targets data on these characteristics and sets the stage for systematic harmonized mapping of salt-affected soils from the country to the global level. The Lesson puts emphasis on identification of sources of required input data and eventual development of a database for national mapping of salt-affected soils. It targets national experts with knowledge of and access to indicators of salt-affected soils in their countries. Its outputs are expected to form the database and tools for national assessment of salt problems.

1.2 Objective

The overall objective of this Lesson is to establish a harmonized database and tools for national assessment of salt-affected soils in each member country.

1.3 Expected outcomes

By the end of this Lesson, the participants are expected to:

i. Understand the requirements for national assessment of salt-affected soils
ii. Identify sources of input data for assessing salt-affected soils
iii. Establish a database for national mapping salt-affected soils
iv. Document input data in the database for mapping salt-affected soils

2 Requirements for assessing salt-affected soils

2.1 Data requirements

Global Soil partnership (GSP) approach for assessing salt-affected soils at the country level uses measured soil indicators and spatial predictors of salt-problems in the soils as primary input data. Consequently, when assessing input data requirements for soil mapping, the focus is on measured soil data (or their equivalent) and spatial predictors of salt-affected soils.

The required data are:

- Soil data
- Spatial covariates such as climate, land cover, geology, remote sensing images, altitude
- Other data such as country boundary, town/urban centers, roads, etc.

A summary of data requirements and suggestion for their potential sources is given in Table 1. The soil data includes electrical conductivity (EC), pH and Exchangeable Sodium Percent (ESP). Total Soluble Salts (TSS) or soluble ions (Na^{+}, Ca^{2+}, Mg^{2+}, $S0_4^{-2}$, $C0_3^{-2}$, $HC0_3^{-}$, Cl^{-}, $N0_3^{-}$) may be included if the data is available. TSS-EC conversion models may be necessary in case TSS is available without the corresponding EC values

Remote sensing data: Many types of remote sensing data are available for mapping salt-affected soils. This lesson puts emphasis on multispectral data, which includes visible band (with wavelength

between 0.40 – 0.70 micrometre (µm)), near infrared band (0.75 - 0.88 µm), and shortwave infrared band (1.55 – 2.30 µm). Examples are given in Table 2.

Table 1: Summary of minimum data requirements for mapping salt-affected soils

Data type	Variables	Units	Main data source	Other sources	
				Name	Format
Georeferenced soil data (between 0-100 cm)	EC	dS/m	National data	WOSIS[1]	vector point data
	pH	-			
	ESP	%			
	*Soluble ions**	*cmol/kg*			
	*TSS**	*g/l*			
Climate (Mean annual)	Rainfall	mm	National data	Worldclim[2]	vector point data
	Min Temperature	ºC			
	Max Temperature	ºC			
Land use/cover	cover/use types	-	National data	ESA[3]	raster image (300 m)
soil map	soil types	-		WOSIS	vector polygon
DEM	Elevation	m	National contour map	USGS[4]	Raster image (15, 30, 90 m, etc.)
Remote sensing land surface reflectance	Visible (RGB) reflectance	-	National data	USGS	MODIS (500 m) Landsat OLI (30 m) Sentinel2A (10-20 m) ASTER images
	IR reflectance	-			
	SWIR reflectance	-			
Geology	Lithology types	-	National data		
Hydrogeology*	Groundwater level	m	National data		

*Optional data.

Table 2: Remote sensing images for mapping salt-affected soils

Image	Spectral bands	
Landsat (OLI)	Band 2	Blue: 0.452-0.512 µm
	Band 3	Green: 0.533-0.59 µm
	Band 4	Red: 0.636-0.673 µm
	Band 5	NIR: 0.851-0.879 µm
	Band 6	SWIR1: 1.566-1.651 µm
	Band 7	SWIR2: 2.107-2.294 µm
Sentinel 2A	Band 2	Blue: 0.458-0.52 µm
	Band 3	Green: 0.543-0.578 µm
	Band 4	Red: 0.650-0.680 µm
	Band 8	NIR: 0.785-0.899 µm
	Band 11	SWIR1: 1.565-1.655 µm
	Band 12	SWIR2: 2.10-2.28 µm
MODIS MOD009GA V6	Band 3	Blue: 0.459-0.479 µm
	Band 4	Green: 0.545-0.565 µm
	Band 1	Red: 0.62-0.67 µm
	Band 2	NIR: 0.841-0.876 µm
	Band 6	SWIR1: 1.628-1.652 µm
	Band 7	SWIR2: 2.105-2.13 µm

[1] WOSIS: https://www.isric.org/explore/wosis
[2] WorldClim: https://www.worldclim.org/
[3] ESA: https://www.esa-landcover-cci.org/
[4] USGS: https://earthexplorer.usgs.gov/

2.2 Computer and software requirements

The following minimum computer requirements is suggested for mapping salt-affected soils at the national scale:

a. At least 8GB RAM and Core I3 (or equivalent)
b. At least 100 GB storage space
c. The following installed software of latest version
   i. R (https://www.r-project.org/)
   ii. QGIS (https://qgis.org/en/site/forusers/download.html)
   iii. RStudio (https://rstudio.com/products/rstudio/download/#download)
   iv. ILWIS (https://www.itc.nl/ilwis/download/ilwis33/)
   v. Spreadsheet software (Excel, Access) and document software (Word, Notepad)

The following R packages are also needed for spatial modelling with R: *soilassessment, sp, foreign, rgdal, car, carData, spacetime, gstat, automap, randomForest, e1071, caret, raster, soiltexture, GSIF, aqp, plyr, Hmisc, corrplot, factoextra, spup, purrr, lattice, ncf, ranger*. They should be downloaded and installed alongside R software.

3 Resources

The following resources are useful for implementing the activities during data collection:

- References
  - Technical guidelines and cookbook for mapping salt-affected soils (GSP-Secretariat@fao.org)
  - Country guidelines and specifications for global mapping of salt-affected soils
- Data sources
  - Soil data:
    - WOSIS: https://www.isric.org/explore/wosis
    - FAO Soils Portal (http://www.fao.org/soils-portal/en/)
    - EU Soil data (https://esdac.jrc.ec.europa.eu/resource-type/national-soil-maps-eudasm)
  - Climate: (WorldClim) https://www.worldclim.org/
  - Land cover:
    - ESA: https://www.esa-landcover-cci.org/
  - Remote sensing images
    - USGS: https://earthexplorer.usgs.gov/

4 Activities

4.1 Collecting soil data

Table 1 outlines potential sources of soil data for salt-affected soils. These sources should be explored to facilitate data collection where necessary. It's important to document all collected data. The following should be noted when documenting data: 1) Previous attempts/methods for mapping salt-affected soils, 2) prevalence of drivers/causes of salt problems in the soil, 3) policy implementation and management of salt-affected soil, 4) available relevant publications, 5) any conversion models for

soil indicators. A two-column textfile/notepad is adequate for summary documentation of identified data. The documentation should include:

- Title (short description data type – point or spatial GIS layer)
- Data type, date of data generation, number of profiles/augers
- Salinity/sodicity indicator
- Type of measurement (field or laboratory) and units of measurement
- Type of soil-water solution (saturated extract or soil-water ratio, etc.)
- GPS coordinate system
- Reference publication/contact address

An example of such metafile is given below:

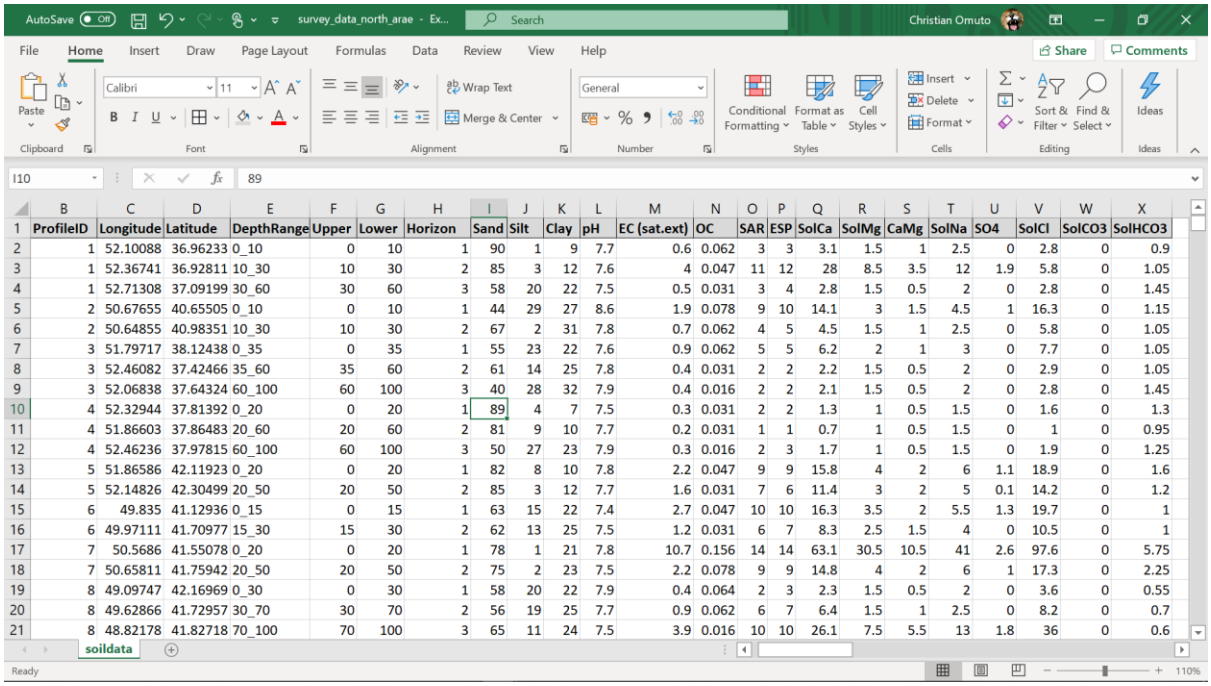
Title:	Soil salinity measurements of North Sudan in 2018
Data type:	Point-data of soil profiles
Data date:	From January – June 2018
Profiles:	1065 auger holes (0 - 35 cm) and 897 pits (0- 200 cm)
Attributes:	EC (dS/m), pH(H_2O), ESP
Type measurements:	Laboratory (all measurements carried on saturated paste extract)
GPS co-ordinates:	WGS84 (Geographic)
Reference:	Mohamed Nuha (nuha75n@gmail.com; Ministry of Agriculture, Agriculture Research Centre, P.O. Box 126 Wad Medani, Sudan)

Figure 1: Example documentation of input data

The database of collected soil data should, at least, contain:

1. Profile ID
2. Latitude and Longitude
3. Depth Range (start and end of each Horizon)
4. EC
5. ESP
6. pH (water)

Other additional variables may be necessary if EC was not measured on saturated soil paste extract. They include soil textural components and organic matter content. In addition, calibration models between EC (or any of the above soil indicators) of soil paste extract and any other EC determination method should be clearly stated where they are used. Figure 2 is an example of database organization for the above soil variables.



ProfileID	Longitude	Latitude	DepthRange	Upper	Lower	Horizon	Sand	Silt	Clay	pH	EC (sat.ext)	OC	SAR	ESP	SolCa	SolMg	CaMg	SolNa	SO4	SolCl	SolCO3	SolHCO3
1	52.10088	36.96233	0_10	0	10	1	90	1	9	7.7	0.6	0.062	3	3	3.1	1.5	1	2.5	0	2.8	0	0.9
1	52.36741	36.92811	10_30	10	30	2	85	3	12	7.6	4	0.047	11	12	28	8.5	3.5	12	1.9	5.8	0	1.05
1	52.71308	37.09199	30_60	30	60	3	58	20	22	7.5	0.5	0.031	3	4	2.8	1.5	0.5	2	0	2.8	0	1.45
2	50.67655	40.65505	0_10	0	10	1	44	29	27	8.6	1.9	0.078	9	10	14.1	3	1.5	4.5	1	16.3	0	1.15
2	50.64855	40.98351	10_30	10	30	2	67	2	31	7.8	0.7	0.062	4	5	4.5	1.5	1	2.5	0	5.8	0	1.05
3	51.79717	38.12438	0_35	0	35	1	55	23	22	7.6	0.9	0.062	5	5	6.2	2	1	3	0	7.7	0	1.05
3	52.46082	37.42466	35_60	35	60	2	61	14	25	7.8	0.4	0.031	2	2	2.2	1.5	0.5	2	0	2.9	0	1.05
3	52.06838	37.64324	60_100	60	100	3	40	28	32	7.9	0.4	0.016	2	2	2.1	1.5	0.5	2	0	2.8	0	1.45
4	52.32944	37.81392	0_20	0	20	1	89	4	7	7.5	0.3	0.031	2	2	1.3	1	0.5	1.5	0	1.6	0	1.3
4	51.86603	37.86483	20_60	20	60	2	81	9	10	7.7	0.2	0.031	1	1	0.7	1	0.5	1.5	0	1	0	0.95
4	52.46236	37.97815	60_100	60	100	3	50	27	23	7.9	0.3	0.016	2	3	1.7	1	0.5	1.5	0	1.9	0	1.25
5	51.86586	42.11923	0_20	0	20	1	82	8	10	7.8	2.2	0.047	9	9	15.8	4	2	6	1.1	18.9	0	1.6
5	52.14826	42.30499	20_50	20	50	2	85	3	12	7.7	1.6	0.031	7	6	11.4	3	2	5	0.1	14.2	0	1.2
6	49.835	41.12936	0_15	0	15	1	63	15	22	7.4	2.7	0.047	10	10	16.3	3.5	2	5.5	1.3	19.7	0	1
6	49.97111	41.70977	15_30	15	30	2	62	13	25	7.5	1.2	0.031	6	7	8.3	2.5	1.5	4	0	10.5	0	1
7	50.5686	41.55078	0_20	0	20	1	78	1	21	7.8	10.7	0.156	14	14	63.1	30.5	10.5	41	2.6	97.6	0	5.75
7	50.65811	41.75942	20_50	20	50	2	75	2	23	7.5	2.2	0.078	9	9	14.8	4	2	6	1	17.3	0	2.25
8	49.09747	42.16969	0_30	0	30	1	58	20	22	7.9	0.4	0.064	2	3	2.3	1.5	0.5	2	0	3.6	0	0.55
8	49.62866	41.72957	30_70	30	70	2	56	19	25	7.7	0.9	0.062	6	7	6.4	1.5	1	2.5	0	8.2	0	0.7
8	48.82178	41.82718	70_100	70	100	3	65	11	24	7.5	3.9	0.016	10	10	26.1	7.5	5.5	13	1.8	36	0	0.6

Figure 2: Structure of the soil data

4.2 Downloading online spatial data

Remote sensing data: Any of the remote sensing images in Table 2 can be used for mapping salt-affected soils at the national level. These images are freely downloadable from many online sites such as https://earthexplorer.usgs.gov/. Sections 4.4 describes the steps for downloading remote sensing images from at https://earthexplorer.usgs.gov/ (Accessed on 20 January 2020).

The https://earthexplorer.usgs.gov/ has four buttons at the top-left corner for navigation and data search in the database. They are *Search Criteria*, *Data Sets*, *Additional Criteria*, and *Results* (Figure 3). *Search Criteria* allows input of spatial parameters for data search. *Data Sets* button is used for searching data of interest within the database. *Additional Criteria* provides opportunity for refining the search criteria. The outputs for the search criteria are given in the *Results* button.

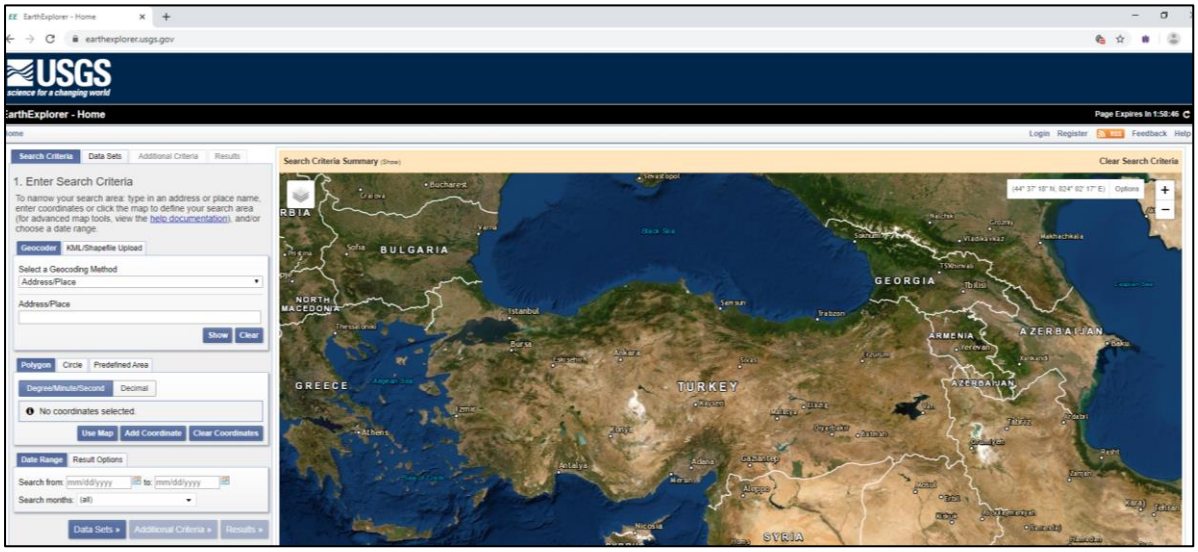


Figure 3: Current https://earthexplorer.usgs.gov/ architecture (20 January 2020)

Downloading data from online sites begins with setting a search criterion. At the website https://earthexplorer.usgs.gov/, the search criteria is either manually digitized or imported from a boundary file (shapefile or kml/kmz) (Figure 4).

(a) Digitizing option: In this case, the corners of a polygon bounding the area of interest (country) are manually digitized on the screen. The procedure is to first select the *Geocorder* button and then digitizing the corners of the bounding box by pressing and holding left-click of the mouse and moving the "hand pan" over the area (country) of interest. Zooming signs (using + or – navigation signs at the top-right part of the screen) may be used for precise location of the corners.

(b) Uploading a boundary shape file: In this case, a zipped shapefile is uploaded. The file should contain a maximum of 30 vertices. Section 4.3 describes the creation of the zipped shapefile for downloading the images. Select *KML/Shapefile Upload* button and navigate to the zipped shapefile of the bounding box (Figure 4).

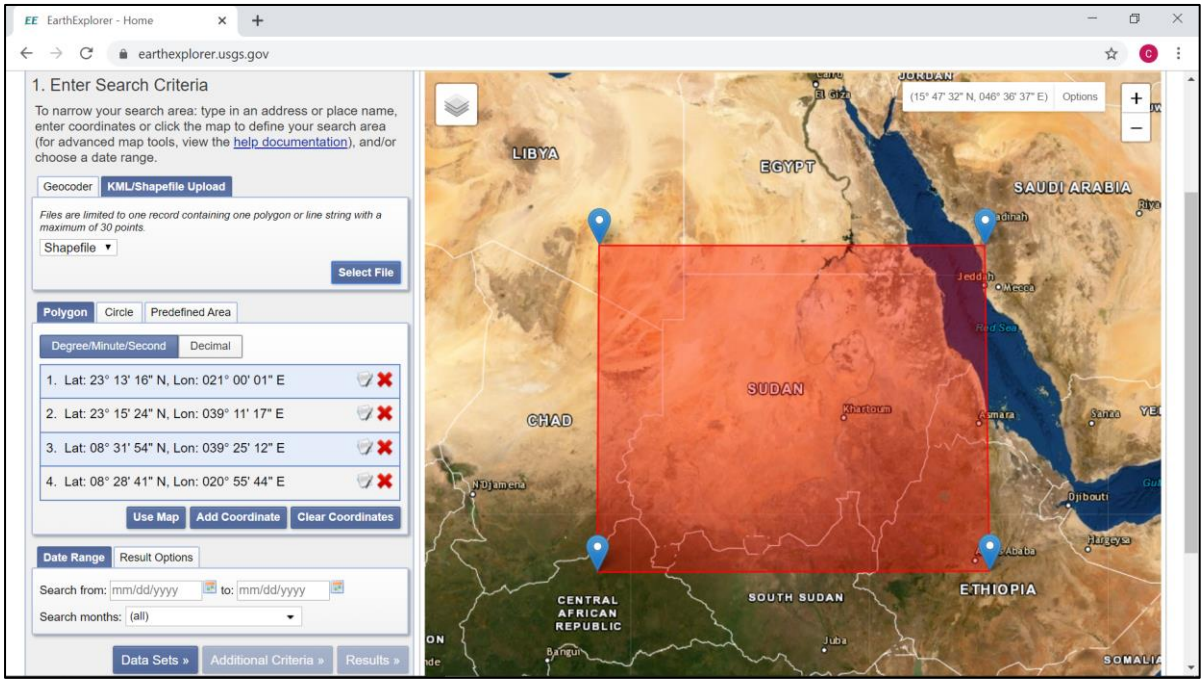


Figure 4: Earth-Explorer interface for data download

Online sites are digital repositories with arrays of different datasets. These datasets are grouped by category such as Digital Elevation, Aerial Imagery, Classified maps such as land cover, etc. At https://earthexplorer.usgs.gov/, the datasets are accessed by activating *Data Sets* button (Figure 3) and a new window opens with a list of images in different categories (Figure 5). Each category has an expandable (+) for accessing more information on the available dataset in the group. The data of interest is selected by clicking the white square boxes next to the data. Furthermore, choosing ⓘ symbol opens a new website window with metadata details for the dataset. The following guidelines are necessary for national mapping of salt-affected soils: elevation data (GMTED2010) and images (MOD9A1 V6) for large-area mapping and Landsat OLI/Sentinel and SRTM DEM (30/90 m) for mapping of salt-affected soils in smaller areas. It is important to select each data category at a time for easy tracking and data download.

The outputs of data search are given in the *Results* button. Selecting this button opens a new interactive window with the available data for the selected data category. The data is chronologically listed. Choosing the footprint symbol (👣) displays the image in the interactive map-view. A window for confirming the selection pups-up and the data download begins after choosing the download icon. Adequate internet connectivity should be available at this point. GMTED2010 contains elevation data in three options: 1km (30 arc-second), 500 m (15 arc-second) and 250 m (7.5 arc-second) (Figure 5).

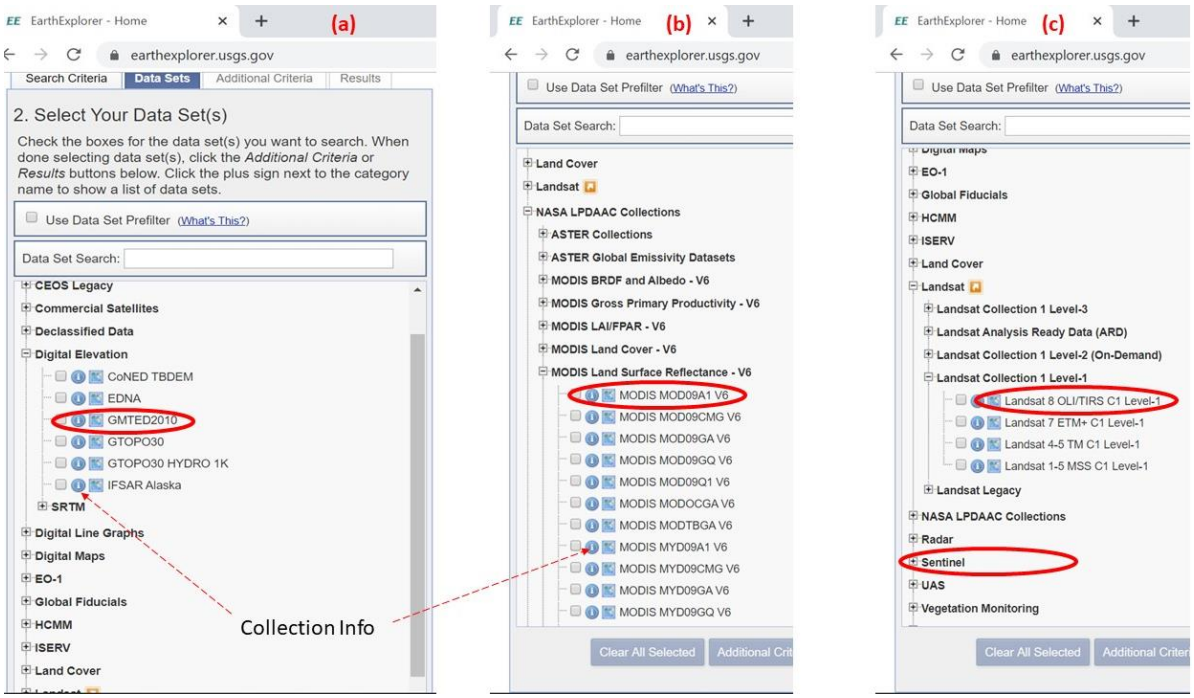


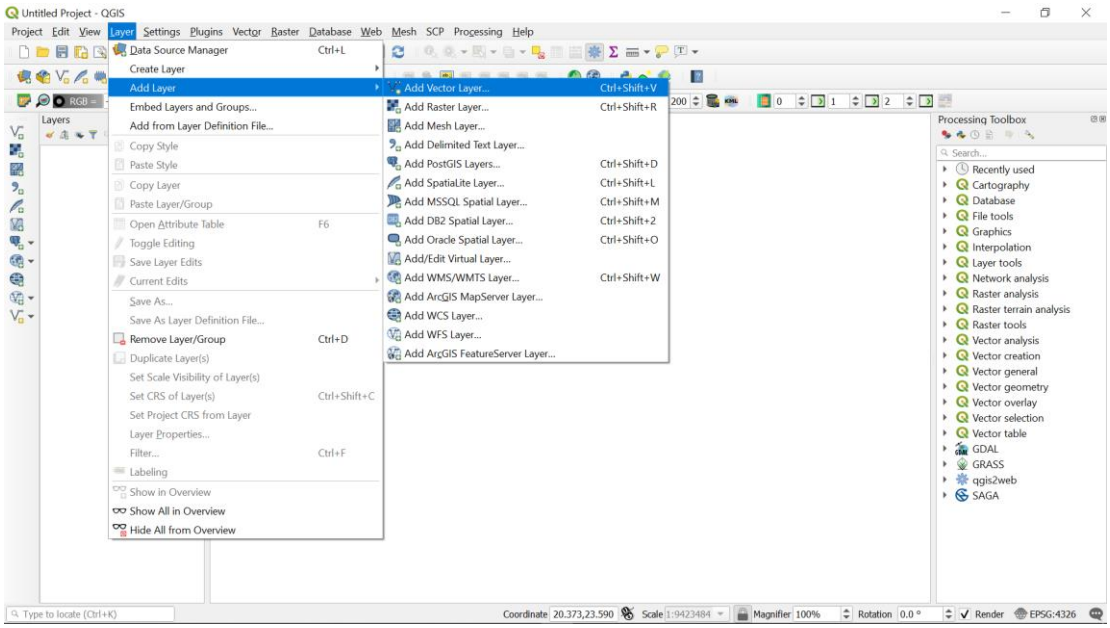
Figure 5: Choosing the dataset: a-elevation, b- MODIS and c-Landsat and Sentinel

Land cover data: Global land cover data is available at the European Space Agency (ESA) http://maps.elie.ucl.ac.be/CCI/viewer/download.php. The data is available for the whole world between 2000 and 2015 at 300-m resolution. The site also has a user-tool for sub-setting and other functionalities. First time use may require registration before data download. Nonetheless, further navigation opens the download data window. The data comes with legend and symbology for ArcGIS and QGIS software.

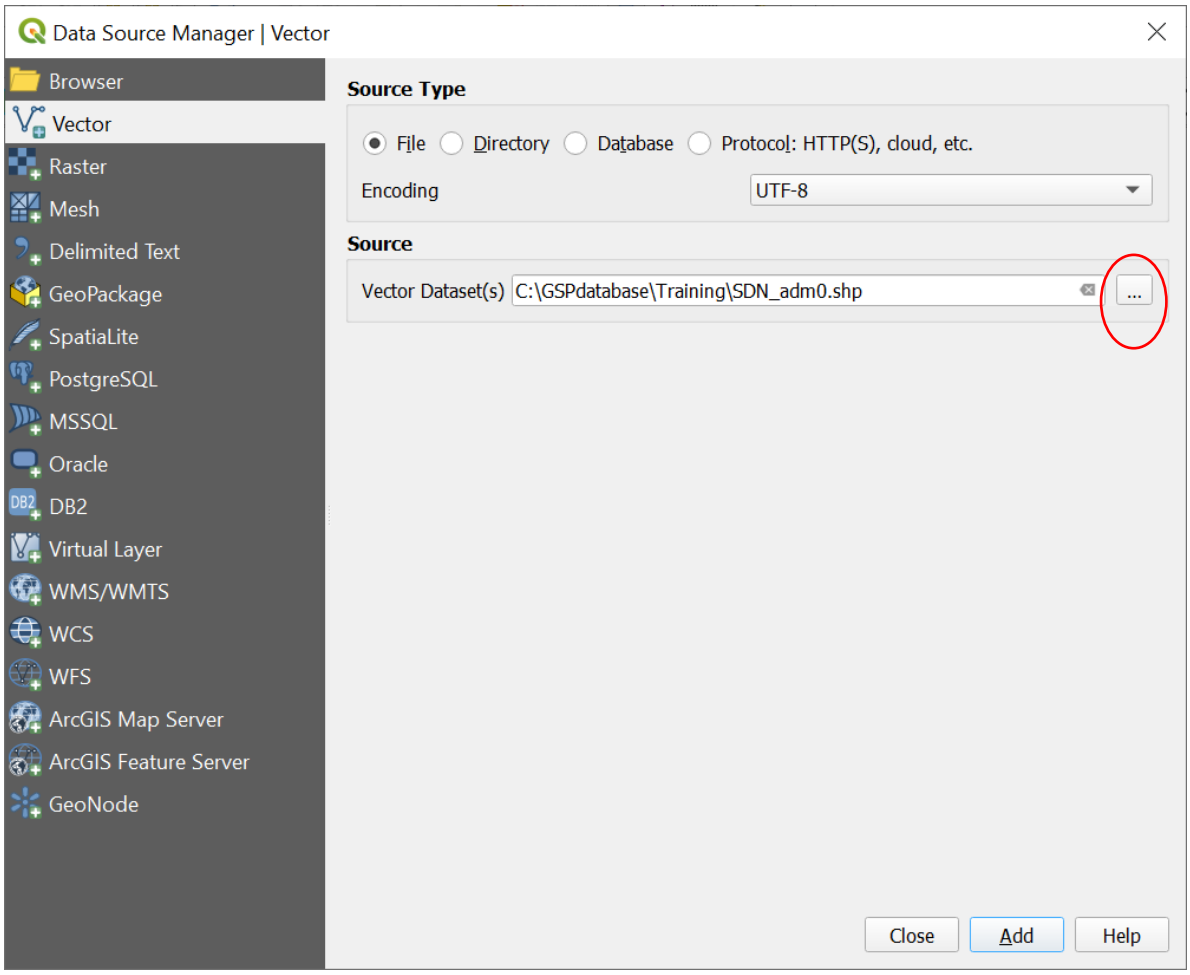
Climate data is downloadable at http://www.worldclim.org/ in GeoTiff files at 1km resolution for the whole world.

4.3 Creating bounding polygon shapefile in QGIS

Step 1: Load the country shapefile into QGIS

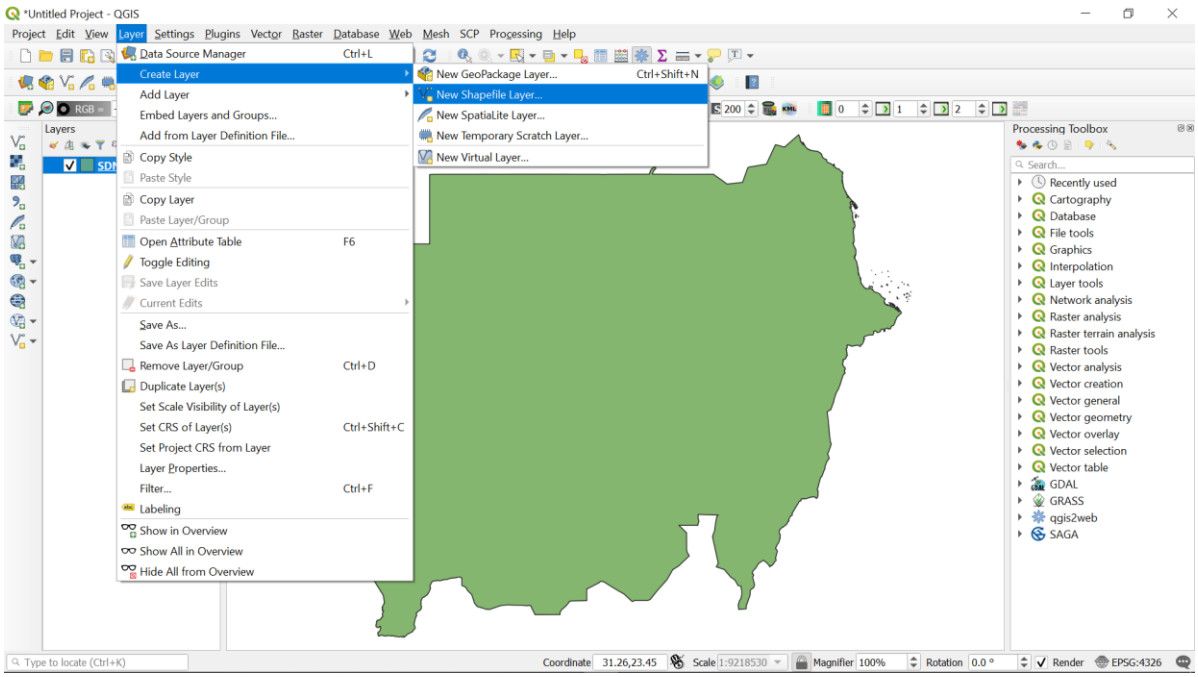


A new window for adding the vector opens up. Click the three dots and navigate to the folder.

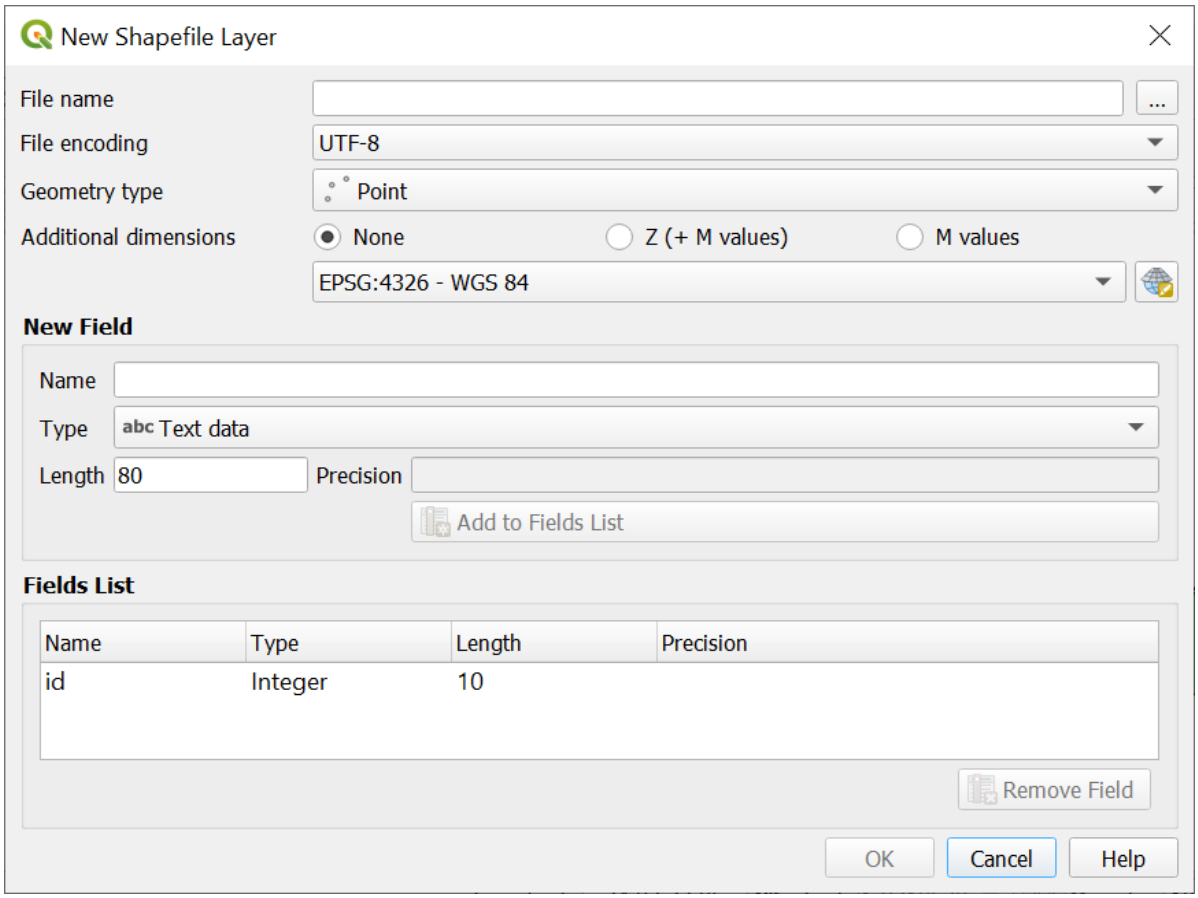


In the folder containing the country shapefile, choose the shapefile then click Add button.

Step 2: Create a new shapefile of the bounding polygon covering the country



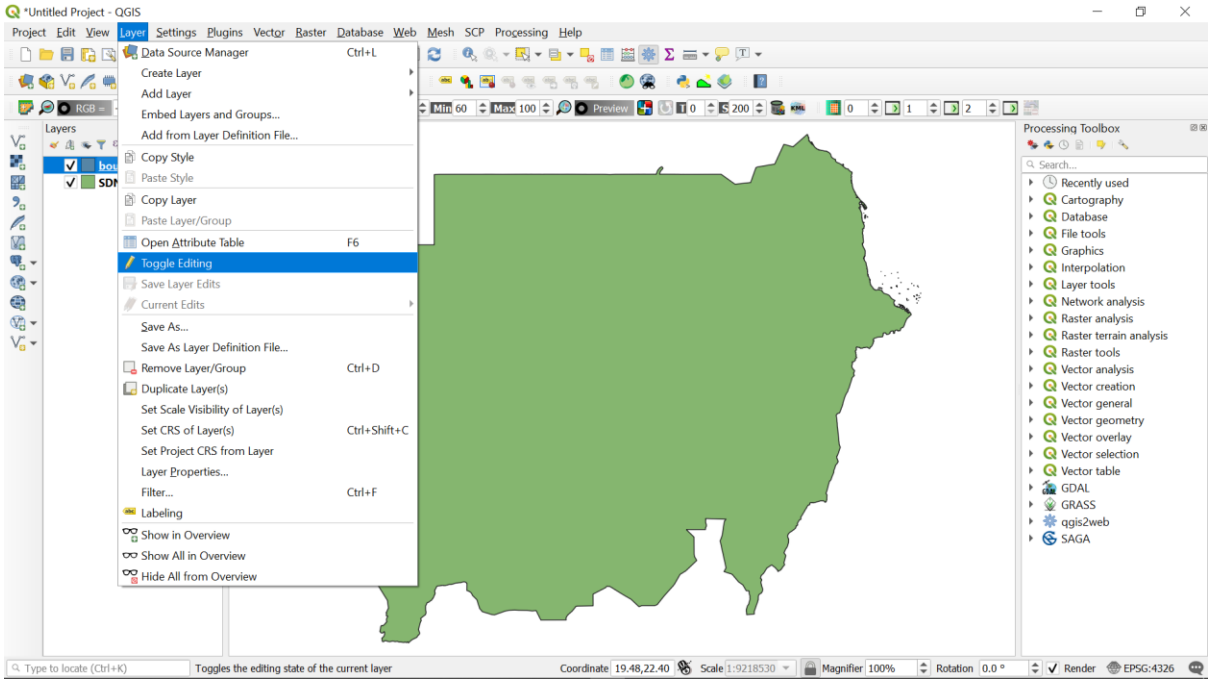
Click the three dots in front of the *File name* to navigate to the output folder where the shapefile will be saved. Give it the name *Boundary* and save. The window will return to the one below (where you started from)



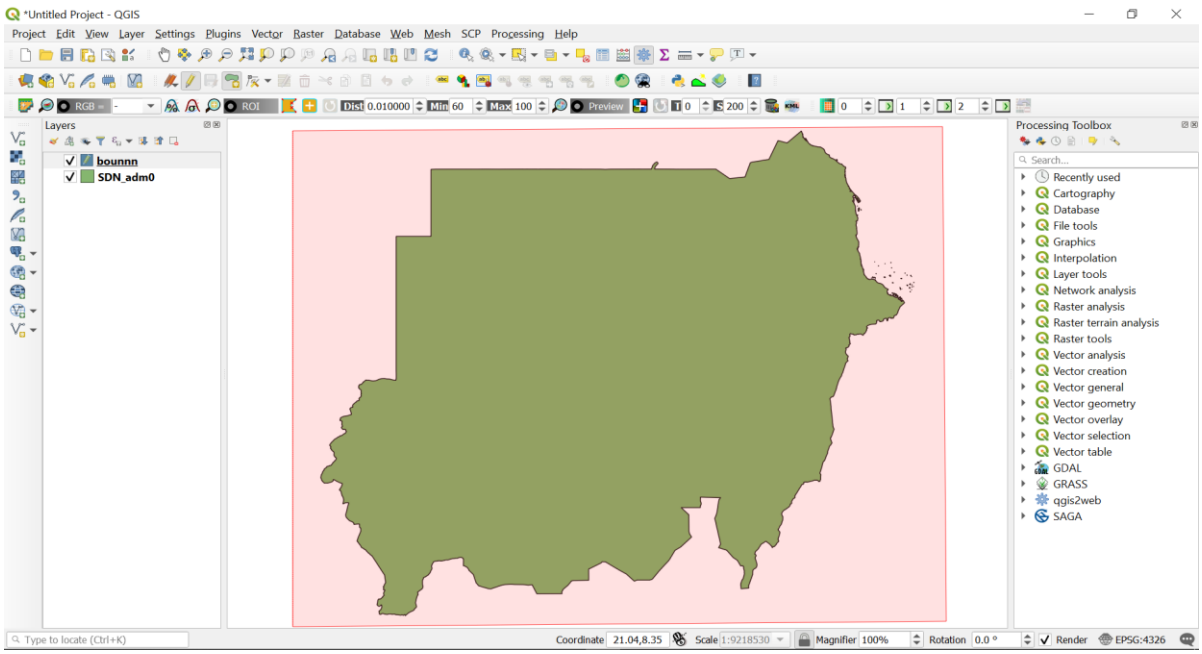
In front of *Geometry Type*, scroll and choose polygon (instead of point). Ensure the EPSG is 4326-WGS 84. Then click OK. The new shapefile will be added as one of the objects in the *Layer Panel*. NB. The shapefile object will not display into the *View* yet.

Step 3: Digitize the bounding polygon

With the newly created layer selected in the *Layer Panel*, go to Layer and choose *Toggle Editing* to start digitizing the polygon corners (i.e. adding the vertex). The editing mode is activated after selecting the *Toggle Editing* icon.



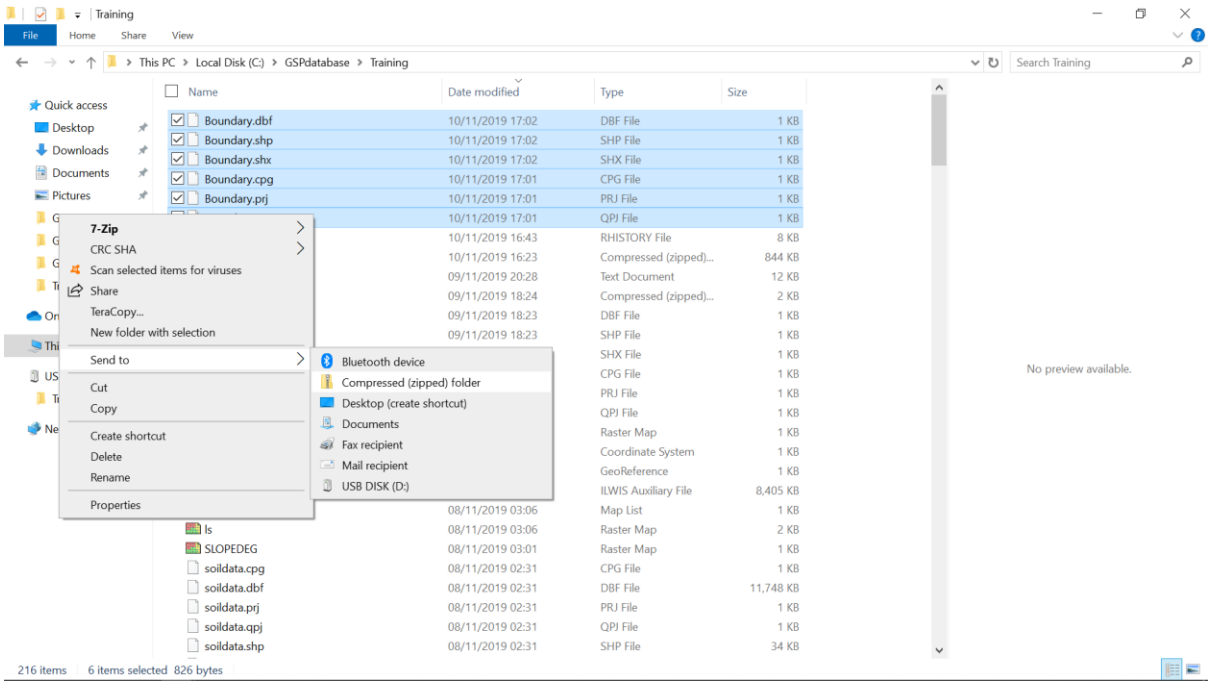
Choose *Edit* panel (the 3rd panel after *Project* among the top row of panels). Scroll down to *Add Polygon Features*. This activates the mode for adding polygon vertex (corners). Digitize at least four corners of the bounding box (from top left corner clockwise to the bottom left corner).



Note that at each corner you should click to create the point before going to the next. After the last corner (say fourth), right-click to complete the digitization. A window will open for entering the polygon ID. Enter 1 and choose OK. This completes the vertex addition. Go back to *Layer* panel then scroll down to *Toggle Editing* and choose it to stop the editing mode. A *Stop Editing* window opens. Click *Save* to complete digitizing the new bounding box.

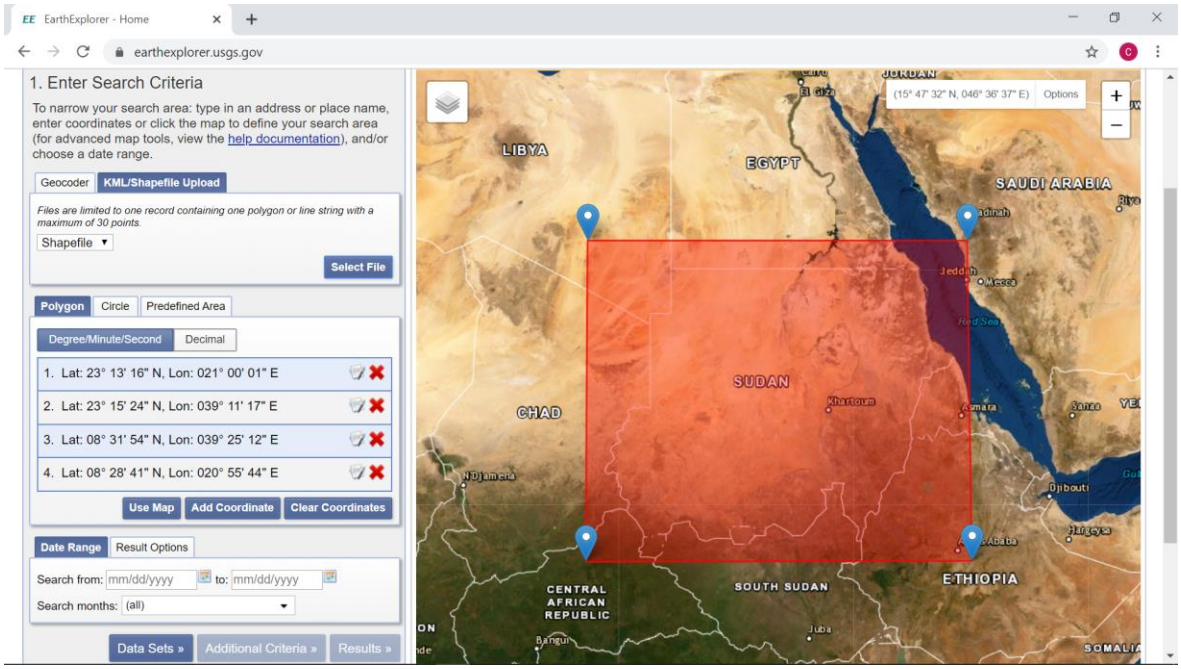
Step 4: Creating search criteria in Earth Explorer

Open Windows Explorer and select all file extensions of the Boundary shapefile. Right-click the mouse and zip them. The process will create a zipped file with the name of the shapefile (in this case *Boundary.zip*). It is important to note zip extension is preferred (Do not use RAR or any other file compression models).



Login (or registration) is necessary at https://earthexplorer.usgs.gov/ to be able to load the zipped file. The icon Login/registration is located at the far-right corner of the website. New users will be required to provide some details by the site.

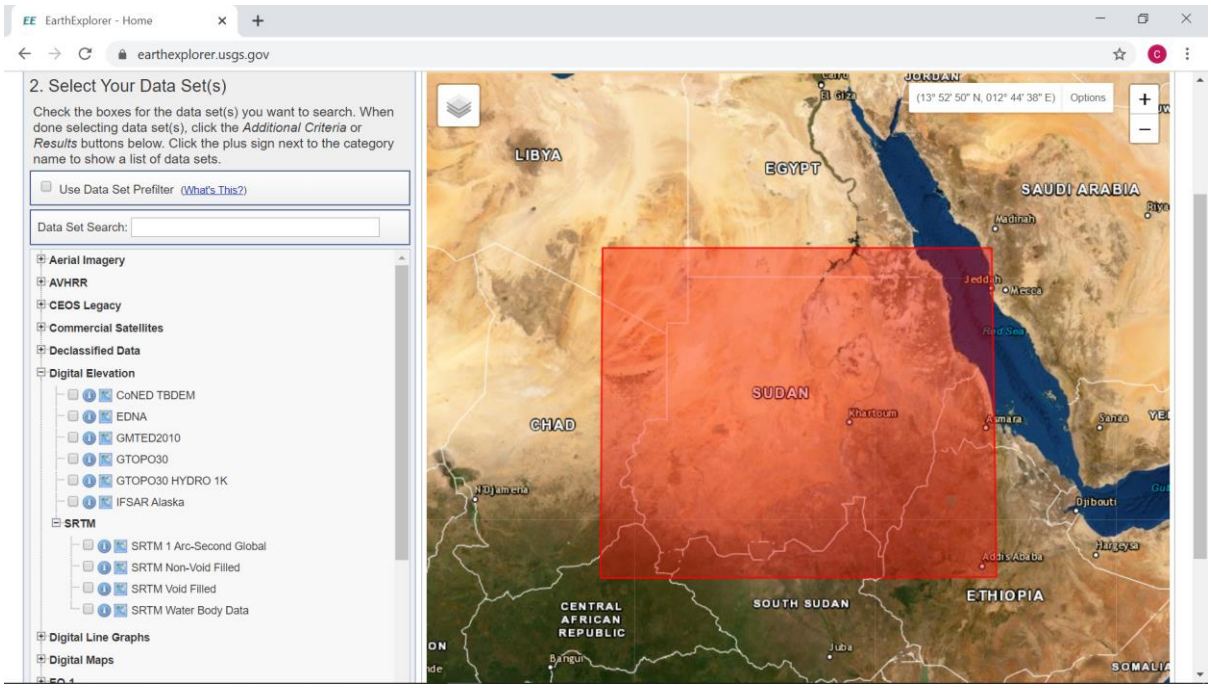
In order to load the zipped shapefile, choose the *Search Criteria* button, then select the button for *KML/Shapefile Upload*. Change the scroll-down from KML/KMZ to Shapefile. Then click *Select File* and navigate to the folder with the *Boundary.zip*. Close the window when upload is completed



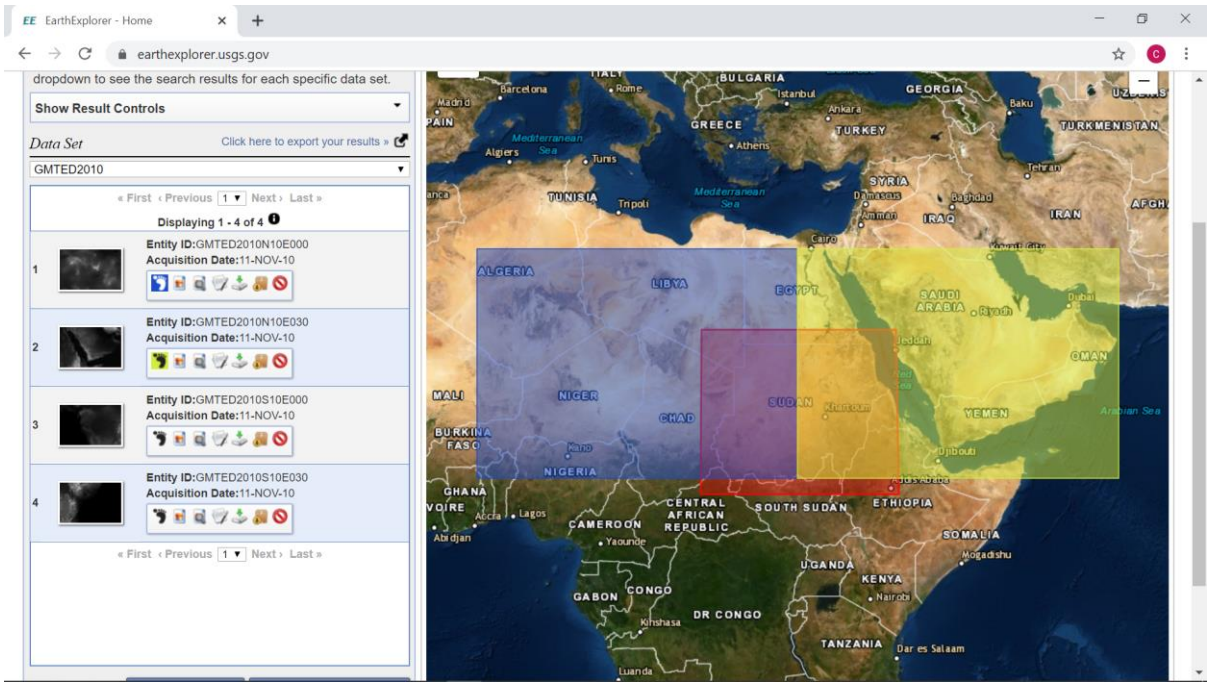
4.4 Downloading images from Earth Explorer

Step 1: Downloading Elevation data

After selecting the *Data Sets* option in Earth Explorer, a panel with list of available data is shown. Expanding the part for *Digital Elevation* shows the available elevation data. GMTED2010 has Elevation data at 1km, 500m, and 250 m resolutions in decimal degrees (30-, 15-, and 7.5 -arc seconds respectively). SRTM Void Filled has 90m resolution (and in some places 30m resolution). Do not select more than one option to avoid download mix-up.

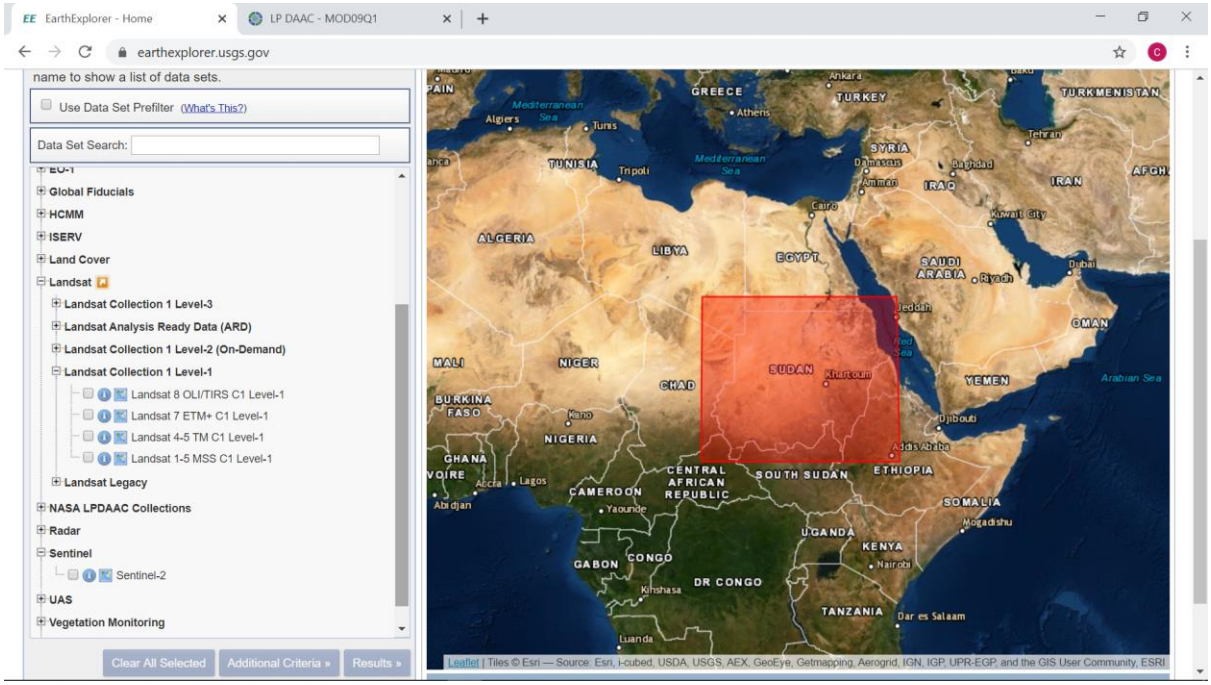


Click the *Results* button to go the window for data selection. The foot symbol gives a transparent view of the image location in the study area. Suitable images download by activating the download icon.

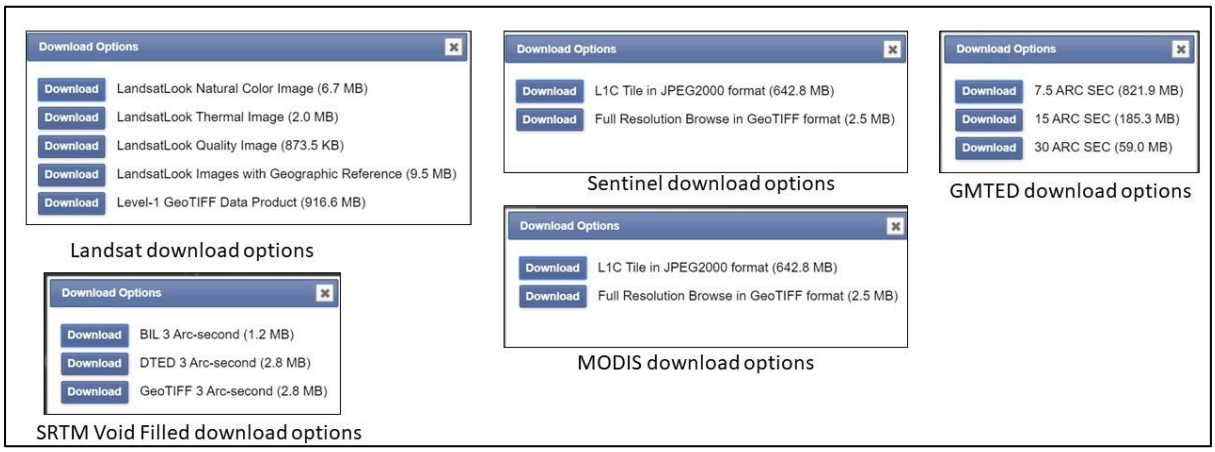


Step 2: Downloading the remote sensing image

MODIS images are recommended for extensive countries while small countries can use Landsat OLI or Sentinel images. In the *Data Set* option, NASA LPDAAC Collections section has ASTER and MODIS datasets. 8-day composite MODIS images are found in the MODIS MOD09A1 V6 sub-category while daily images are MODIS MOD09GA V6 sub-category in the MODIS Land Surface Reflectance – V6 category.



The category of *Landsat Collection 1 Level-1* has Landsat 8 OLI/TIRS C1 Level-1 while *Sentinel* category has Sentinel-2 images.



5 Outputs

Each participant is expected to produce the following at the end of this lesson:

1. Database of soil indicators of salt-affected soils 9EC, pH, ESP, soluble ions)
2. Database of spatial predictors (land cover, climate, geology, images, DEM, soil map, etc.)
3. Computer and software for mapping salt-affected soils
4. Documentation of available data in the database

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Thanks to the financial support of

Rural Development Administration

AFACI
Asian Food & Agriculture Cooperation Initiative