Food and Agriculture Organization of the United Nations

GLOBAL SOIL PARTNERSHIP

Requirements and preparation for national mapping of soil salinity

The following are required for national soil salinity mapping:

1. **Data**: soil, climate, land cover, geology, remote sensing images, altitude, country boundary and other in-country features such as town/urban centres, roads, etc. Table 1 gives a summary of data requirements and suggestion of potential sources of the data. Soil data includes electrical conductivity (EC), pH and Exchangeable Sodium Percent (ESP). Where necessary, Total Soluble Salta (TSS) or soluble ions (ionic composition – Na^{+}, Ca^{++}, Mg^{++}, SO_4^{-2}, CO_3^{-2}, HCO_3^{-}, Cl^{-}, NO_3^{-}) may be included is available

Table 1: Summary minimum data requirements for mapping salinity

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	%			
	*Ionic composition**	*cmol/kg*			
	*TSS**	*g/l*			
Climate (Mean annual)	Rainfall	mm	National data	Worldclim[2]	vector point data
	Min Temperature	°C			
	Max Temperature	°C			
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.

[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. Remote sensing data: Many types of remote sensing data are available. However, the key interest is the availability of multispectral data: 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).

   Any of the following images is a good start depending on the size of the country:

   a. **Landsat Operational Land Imager (OLI)**. Required data includes Band2 (Blue: 0.452-0.512 µm), Band3 (Green: 0.533-0.59 µm), Band4 (Red: 0.636-0.673 µm), Band5 (NIR: 0.851-0.879 µm), Band6 (SWIR1: 1.566-1.651 µm), and Band7 (SWIR2: 2.107-2.294 µm)
   b. **Sentinel 2A**. Required data includes Band2 (Blue: 0.458-0.52 µm), Band3 (Green: 0.543-0.578 µm), Band4 (Red: 0.650-0.680 µm), Band8 (NIR: 0.785-0.899 µm), Band11 (SWIR1: 1.565-1.655 µm), and Band12 (SWIR2: 2.10-2.28 µm)
   c. **MODIS MOD009GA V6**. Required data includes Band3 (Blue: 0.459-0.479 µm), Band4 (Green: 0.545-0.565 µm), Band1 (red: 0.62-0.67 µm), Band2 (NIR: 0.841-0.876 µm), Band6 (SWIR1: 1.628-1.652 µm), and Band7 (SWIR2: 2.105-2.13 µm)

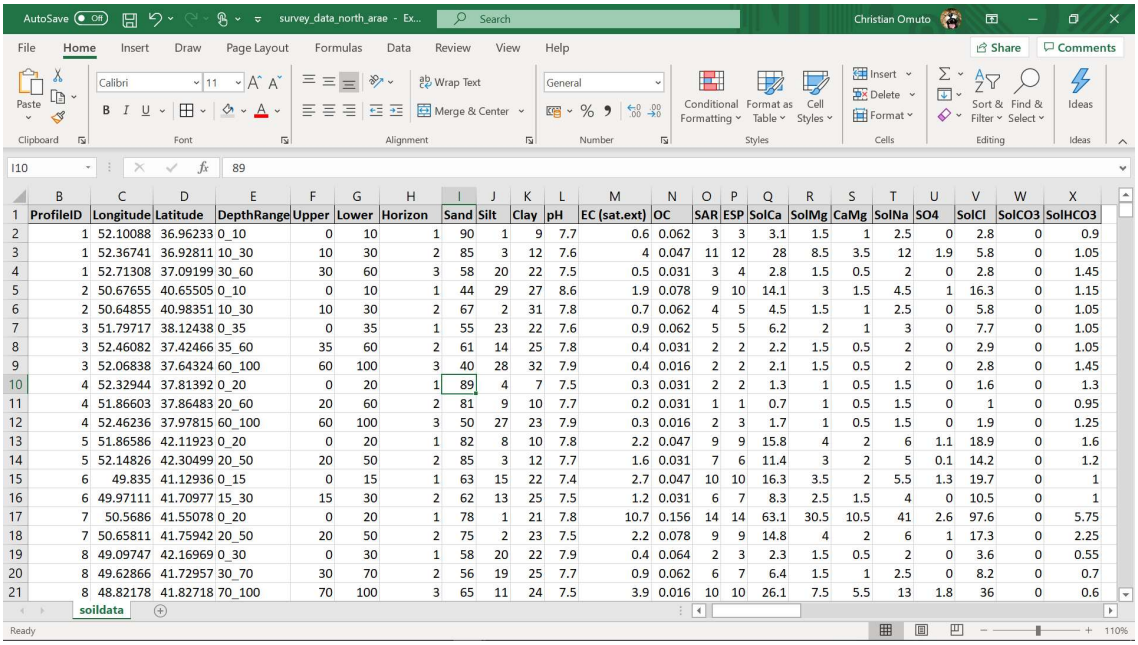
3. **Computer and software**: The following minimum specification of computer requirements is suggested for managing spatial modelling of salinity at the national scale:
   a. At least 8GB RAM and Core I3 (or equivalent)
   b. At least 100 GB storage space
   c. The following installed software of latest 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 also need installation after installing 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

Other resources: In addition to the data and computer needs, mapping soil salinity also requires understanding of soil mapping, soil salinity, and computer applications. Internet connectivity is also a useful resource

A) Organizing soil data

Attempt to collect and organize the soil data in a Spreadsheet (such as Excel) as shown below.



	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	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
2	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
3	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
4	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
5	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
6	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
7	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
8	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
9	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
10	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
11	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
12	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
13	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
14	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
15	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
16	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
17	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
18	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
19	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
20	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
21	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

Ensure the data has at least the following columns (variables):

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

Other additional datasets are necessary such as clay and organic matter content if EC was measured on soil-water mix, salt concentration (TSS) and conversion to EC, and ionic composition (soluble salt contents).

B) Downloading remote sensing images and elevation data

In mapping soil salinity at the national level, preferred remote sensing images are Landsat OLI, Sentinel, and MODIS images. There are many sites for free downloading of these images. This section demonstrates the use of https://earthexplorer.usgs.gov/ to download the images and elevation data. When the site is launched, the following steps lead to data download:

1. Navigate to the area of interest (your country). This is done by pressing and holding left-click of the mouse and sweeping the “hand pan” to your country. It may be necessary to zoom in or out (using + or – navigation signs on the top-right part of the screen) to get clear location of your area/country of interest.
2. Prepare a polygon shapefile that encloses your country shapefile (Appendix 1).
3. Elsewhere in in windows explorer, zip the shapefile of the polygon enclosing your country (making sure to include all file extensions for shapefile such as .dbf, .shp, and .shx) and use it in the next step for delineating the area of interest (Appendix 2).

4. There are four buttons around the top-left corner of the site window: Search Criteria, Data sets, Additional Criteria, and Results (Figure 1). At the active Search Criteria button, you have the option to enter the corners of the polygon bounding the study area or uploading the file (shapefile or kml/kmz). (Appendix 2).

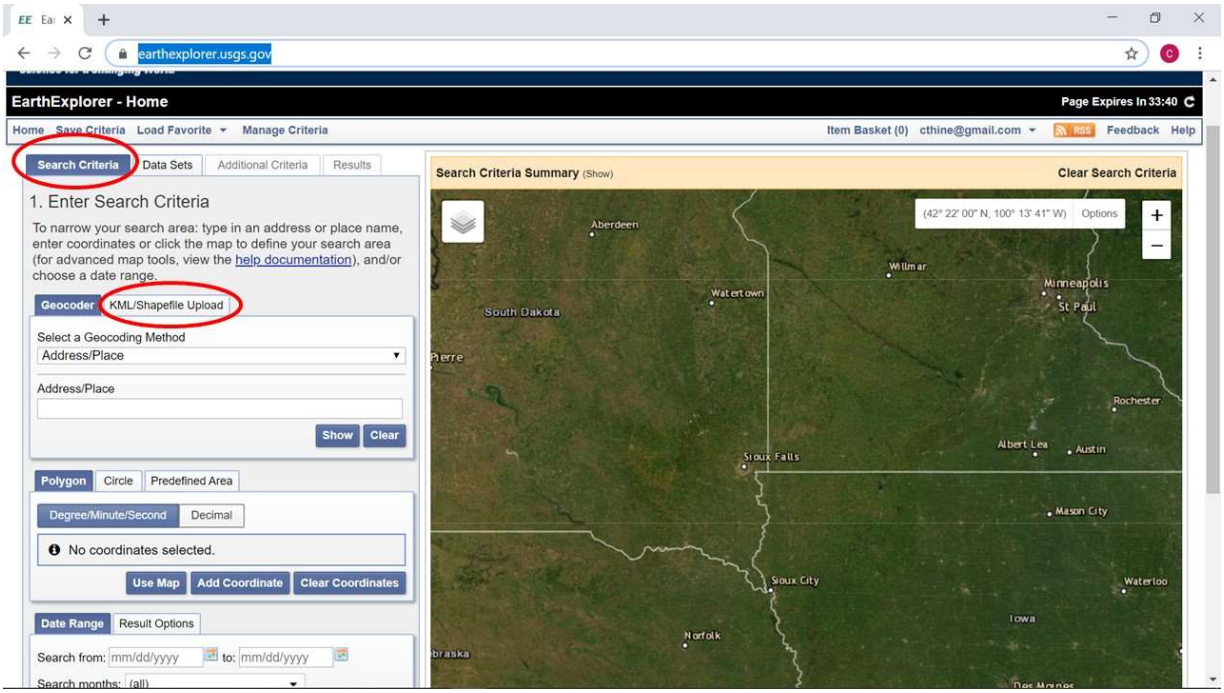


Figure 1: Earth-Explorer interface for data download

5. **Data Sets** selection: After setting the boundaries, activating the Data Sets button navigates to the datasets view. Here, a list of imagery is given by category such as Aerial Imagery, AVHRR, etc (Figure 2). In each category, clicking the *i* – collection Info opens a new website window with data details. For salinity mapping, elevation data (GMTED2010) and images (MOD9A1 V6) are preferred for large-area mapping. For small areas, Landsat OLI/Sentinel and SRTM DEM (30/90 m) are preferred. It's important to note that each data category is selected at a time for easy tracking and download of the available data.
6. **Results view**: Choosing the results button opens a new window in the interactive map view with a list of datasets that are arranged chronologically. Choosing the foot-print symbol (👣) displays the image in the interactive map view. Upon choosing download icon a window for confirming the selection pups up and the data download begins if internet connectivity is available. GMTED2010 has three option 1km (30 arc-second), 500 m (15 arc-second) and 250 m (7.5 arc-second) (Appendix 3)

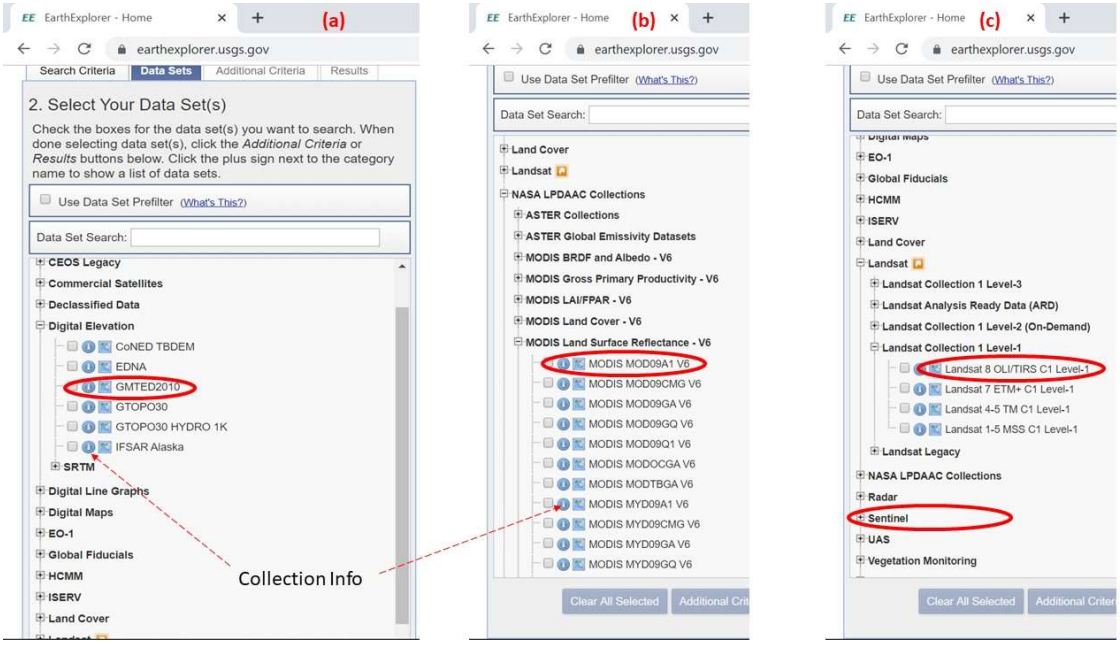


Figure 2: Choosing the dataset: a-elevation, b- MODIS and c-Landsat and Sentinel

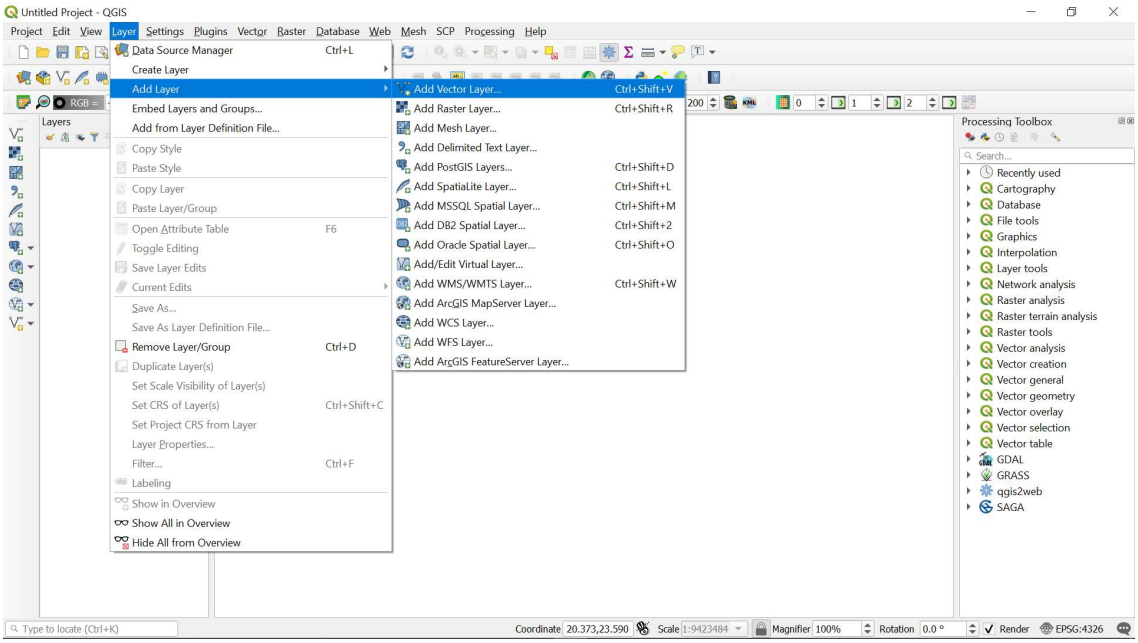
C) Downloading land cover and climate data

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

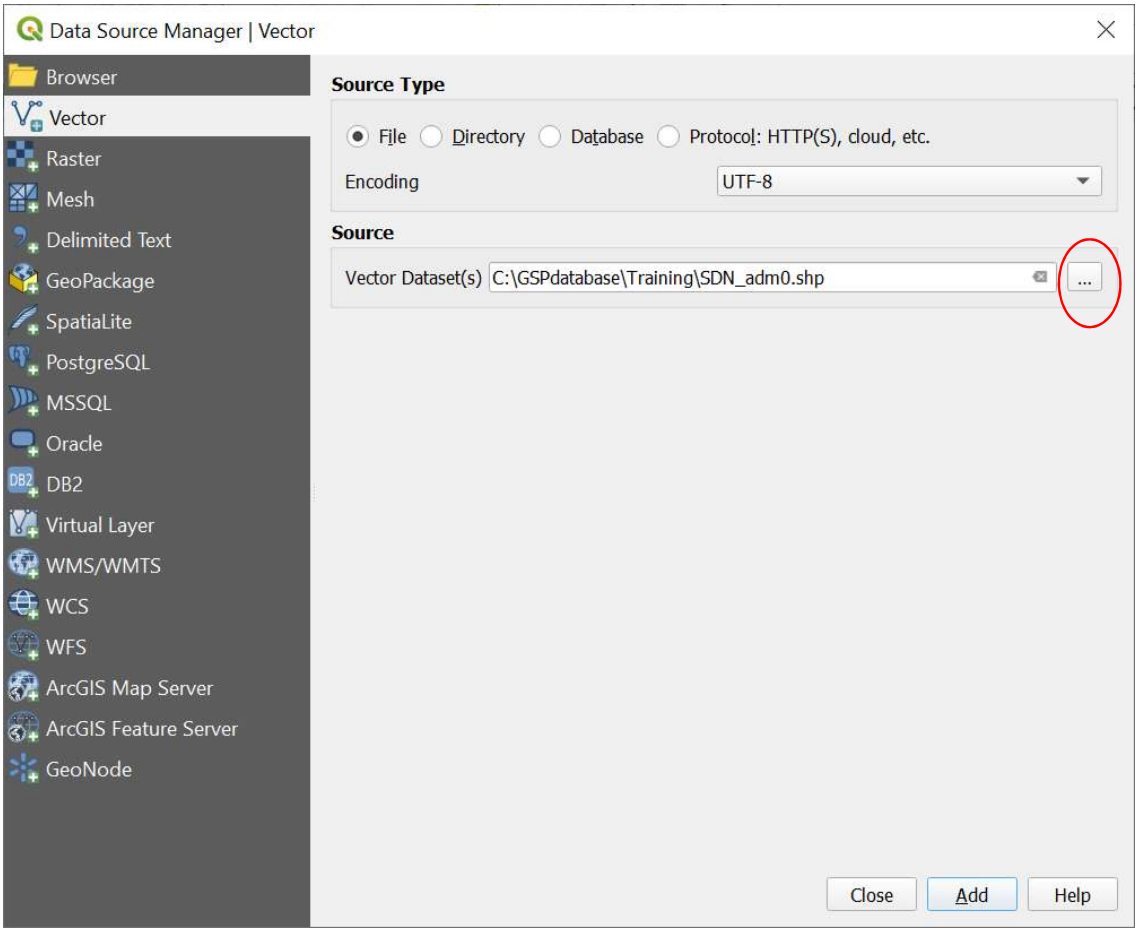
Climate data is downloadable at http://www.worldclim.org/ in GeoTiff files at 1km resolution for the whole world.

Appendix 1: Creating bounding polygon shapefile in QGIS

Step 1: Load the country shapefile into QGIS

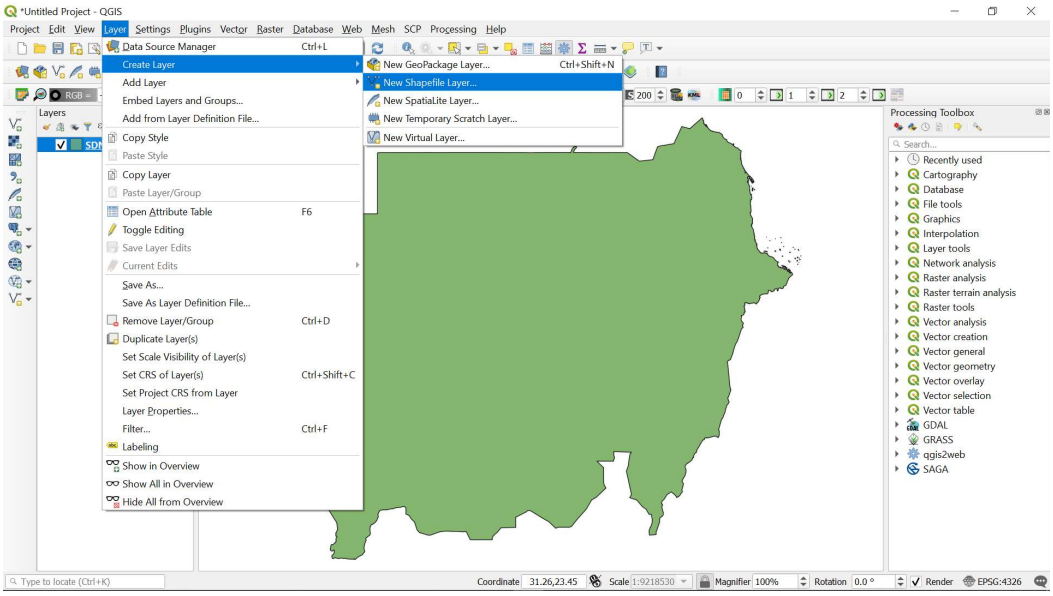


A new window for Adding the vector opens up. Click the three dots and navigate to the folder.

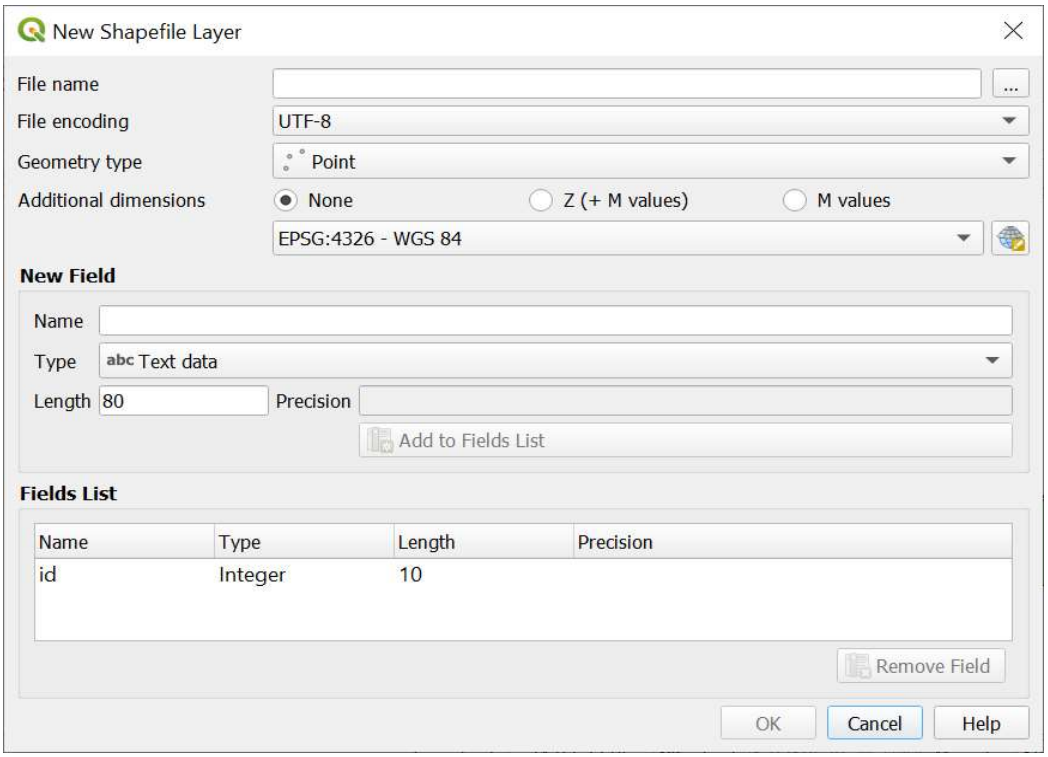


In the folder containing the country shapefile, choose the shapefile then click Add button.

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



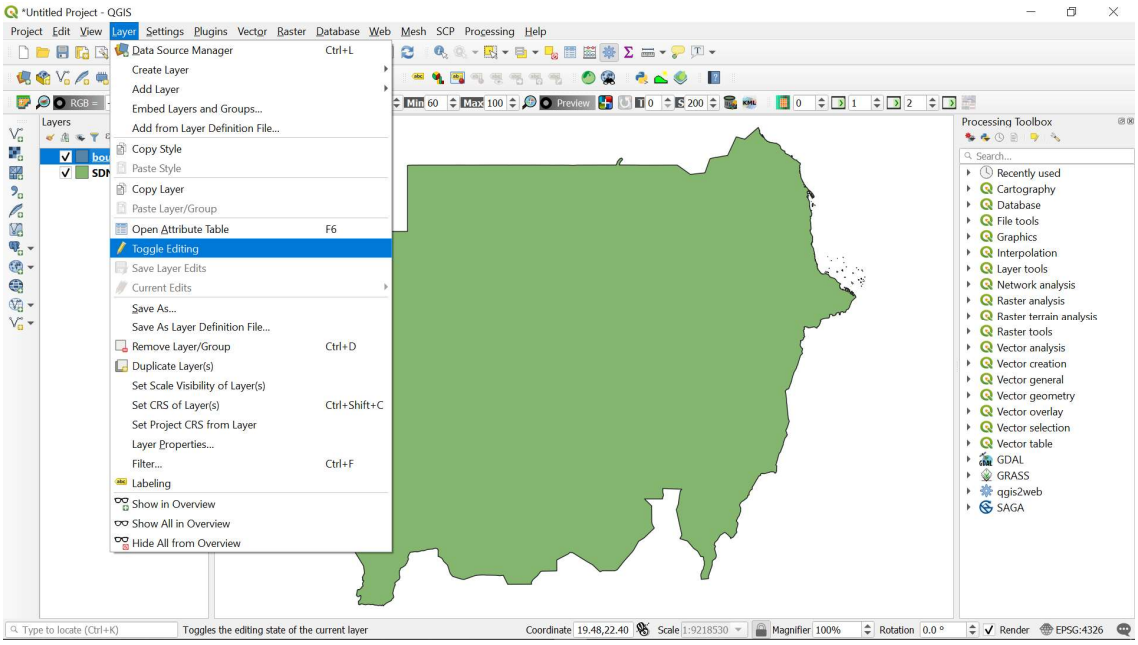
Click the three dots in front of the *File name* to navigate to the output folder where the shapefile will be saved. Give it the name *Boundary* and click save. The window will return to the one below (where you started from)



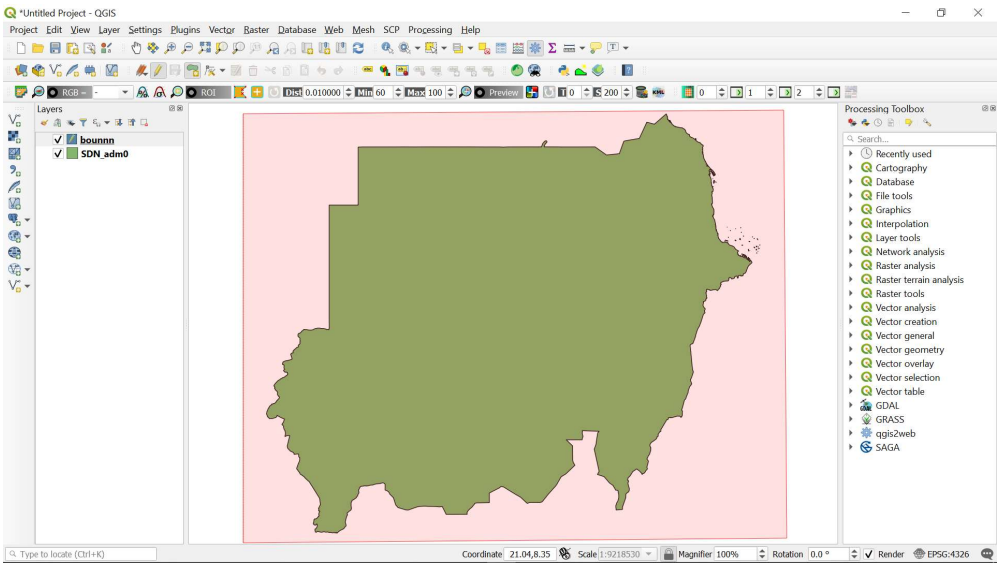
In front of *Geometry Type*, scroll and choose polygon (instead of point). Ensure the EPSG is 4326-WGS 84. Then click OK. The new shapefile will be added as one of the objects in the *Layer Panel*. NB. The shapefile object will not display into the *View* yet.

Step 3: Digitize the bounding polygon

With the newly created layer selected in the *Layer Panel*, go to Layer and choose *Toggle Editing* to begin adding the vertex of the polygon corners. Once selected, the editing mode begins.



Choose *Edit* (Edit button is next to *Project* button among the top buttons). Scroll down to *Add Polygon Features*. This activates the mode for adding the polygon vertex (corners). Choose the first one (top left corner) somewere to provideve the first vertex. Click it and move to the right and choose the second (top right corner). Continue down and pick the third one (bottom right corner) and complete to the last (bottom left corner).

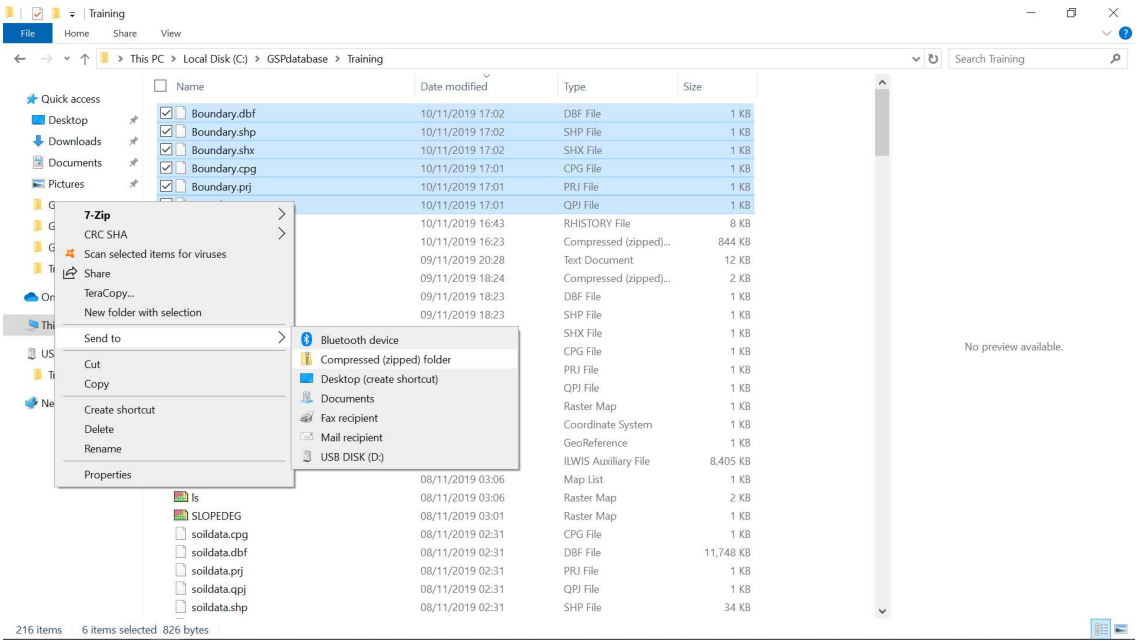


Note that at each corner you should click to create the point before going to the next. After the fourth click right-click to complete the digitization. A window pops up for entering the ID. Enter 1 and click OK. This completes the vertex addition. Go back to *Layer* then *Toggle Editing* and choose the *Toggle Editing* to stop the editing mode. *Stop Editing* window opens. Click save and the new bounding box is created.

Appendix 2: Creating search criteria in Earth Explorer

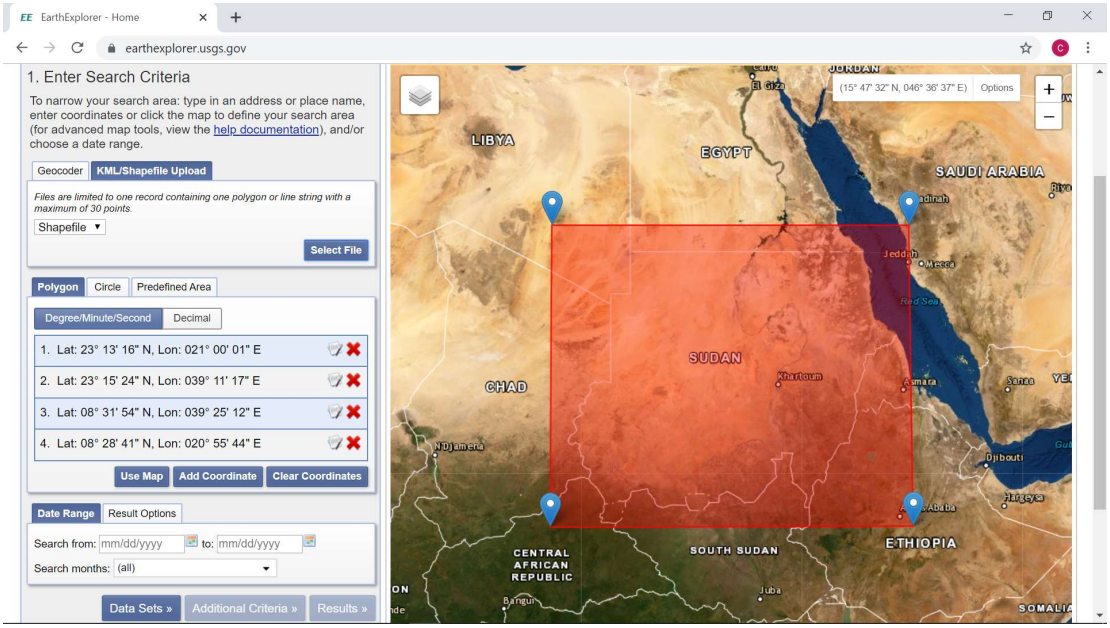
Step 1: Create zipped file of the bounding polygon

Select all file extensions of the Boundary shapefile and zip them. Often, the process will create a zipped file with the name of the shapefile (in this case *Boundary.zip*). Note that it has to be zip and not RAR or any other file compression models.



Step 2: Login (or register) to be able to load the zipped file. Login/register button is at the far-right corner.

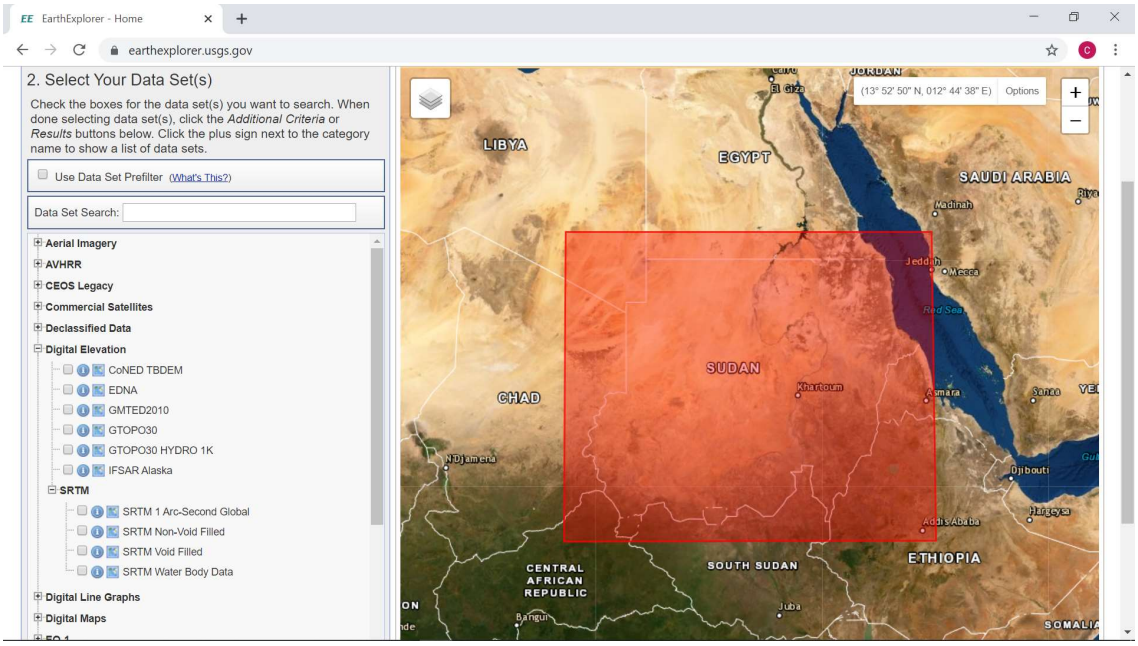
Choose the *Search Criteria* button, then select the button for *KML/Shapefile Upload*. Change the scroll-down from KML/KMZ to Shapefile. Then click *Select File* to navigate to the folder with the *Boundary.zip* and select it. When upload is completed, click close.



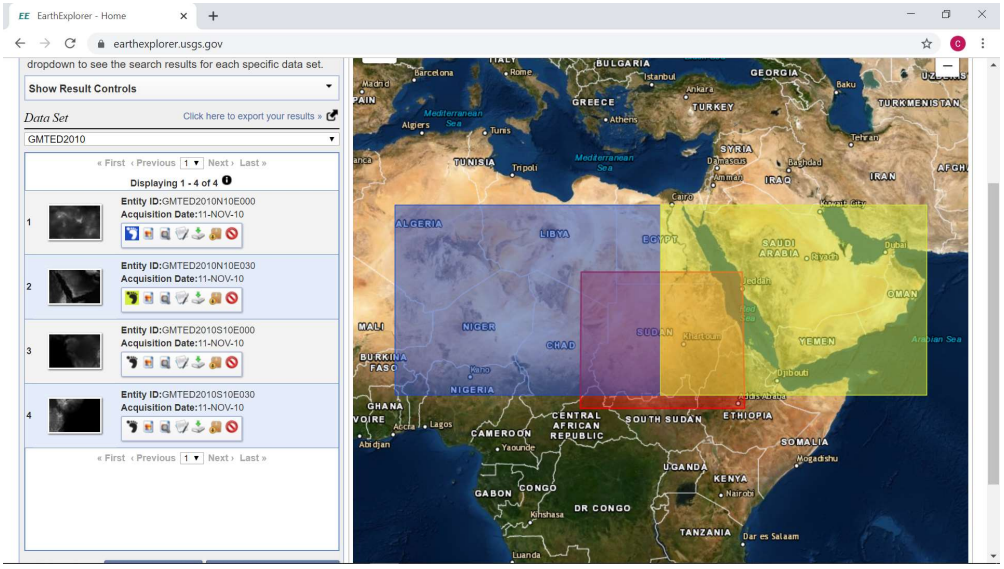
Downloading images from Earth Explorer

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) . Whichever one is chosen (NEVER CHOOSE more than one option to minimize confusion during download)

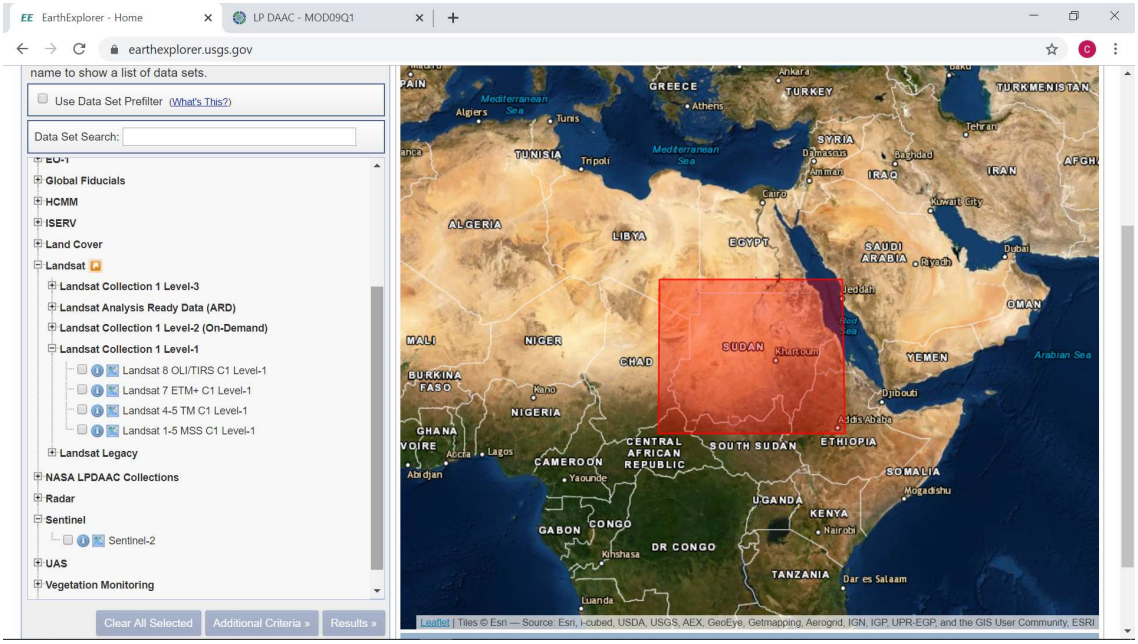


Click the *Results* button to go the window for data selection. Clicking the foot symbol gives transparent view over the study area. You can download the images by clicking download arrow.

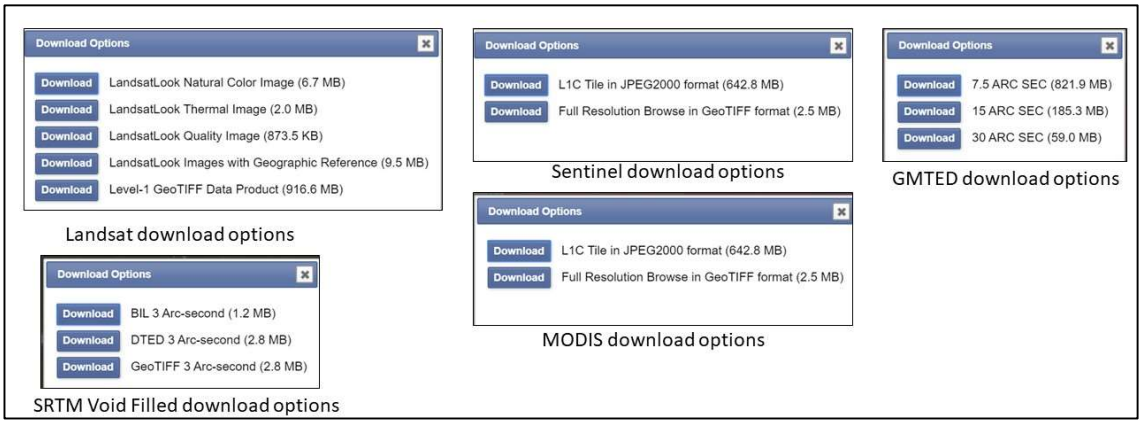


Step 2: Downloading the remote sensing image

For large countries, MODIS image is preferred. For small countries, Landsat OLI or Sentinel can suffice. In the *Data Set* option, NASA LPDAAC Collections section has ASTER and MODIS datasets. In MODIS Land Surface Reflectance – V6 , 8-day composite reflectance is under MODIS MOD09A1 V6 while daily reflectance are under MODIS MOD09GA V6.



Landsat Collection 1 Level-1 has Landsat 8 OLI/TIRS C1 Level-1 while Sentinel has Sentinel-2 images. Clicking *i* before the images takes you to the window with description of the images store under that collection.


Download Options
Download LandsatLook Natural Color Image (6.7 MB)
Download LandsatLook Thermal Image (2.0 MB)
Download LandsatLook Quality Image (873.5 KB)
Download LandsatLook Images with Geographic Reference (9.5 MB)
Download Level-1 GeoTIFF Data Product (916.6 MB)
Landsat download options
Download Options
Download BIL 3 Arc-second (1.2 MB)
Download DTED 3 Arc-second (2.8 MB)
Download GeoTIFF 3 Arc-second (2.8 MB)
SRTM Void Filled download options
Download Options
Download L1C Tile in JPEG2000 format (642.8 MB)
Download Full Resolution Browse in GeoTIFF format (2.5 MB)
Sentinel download options
Download Options
Download L1C Tile in JPEG2000 format (642.8 MB)
Download Full Resolution Browse in GeoTIFF format (2.5 MB)
MODIS download options
Download Options
Download 7.5 ARC SEC (821.9 MB)
Download 15 ARC SEC (185.3 MB)
Download 30 ARC SEC (59.0 MB)
GMTED download options