

# In-Country Technical Training on Hazard Assessment Using Earth Observation and GIS for Eritrea

25 – 30 November 2019

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# **Module 1: Introduction to Geographic Information System (GIS)**

# 1 Module 1: Introduction to Geospatial Information System (GIS)

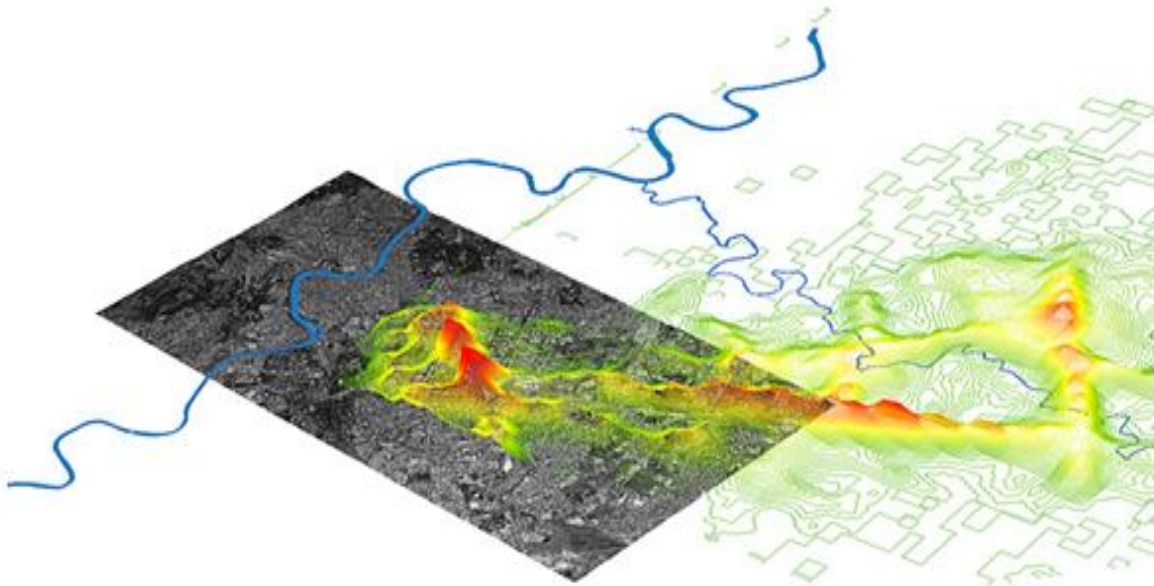
## 1.1 Theories and Concepts of GIS

**Learning Objectives:** At the end of this module you will be able to;

- Understand the theory and concepts of GIS
- Get familiar with ARCGIS software along with geoprocessing tools and spatial analysis
- Identify main open GIS data sources that can be used for Disaster Risk Management(DRM)
- Baseline data analysis and information extraction in ARCGIS

### 1.1.1 Introduction

Geographic Information System (GIS) helps to manage spatial and non-spatial information in a very efficient way. Properly managed data and information helps in better territorial planning and decision making. In GIS, data about real-world objects is drawn quickly and can be displayed using the different attribute fields stored in GIS databases. A typical GIS data is shown in the Figure below.



*Source: Senseable City Laboratory, MIT*

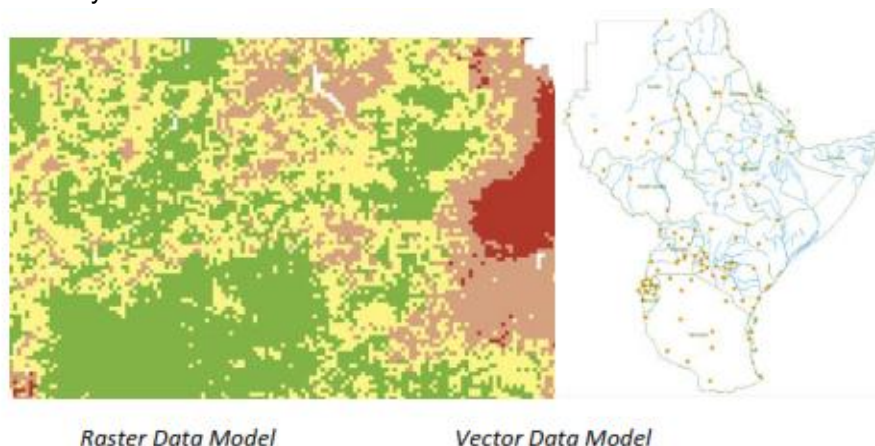
### 1.1.2 Source and Nature of Spatial Data

The sources for spatial data can be from different sources including Field observation/measurement, GPS based data collection, Remote sensing and software based derivations like map digitization. Now days Satellite based data acquisition is providing continues image products for almost all areas of the world at different spatial resolutions. The field based data collection also remain important in providing ground based accurate measurements which often helps to calibrate space based products.



### 1.1.3 GIS Data Models and Coordinate Geometry

The nature of the spatial data can be of vector or raster format. Vector data formats are used to represent discrete type of data and often represented by point, line and/or polygon. Raster data types are used to represent continuous data types like rainfall, temperature, topography...etc. The smallest entity of a vector is a point whereas for raster it is a pixel. The type of data modeling depends on the nature of the data, the scale of the map, and our preference for the analysis that follows. However, it is good to remember that conversion of raster to vector or vice-versa is always possible although it might compromise the quality/form of the original data. For example, if you convert a raster to vector the edge may be generalized and may not follow the exact boundaries. It is highly recommended to avoid back and forth conversion of your data between vector and raster unless you are required to do so. It is also worth to remind you the many raster file formats which sometimes creates obstacles to data processing as all data formats are not compatible to the software's we may choose to use.

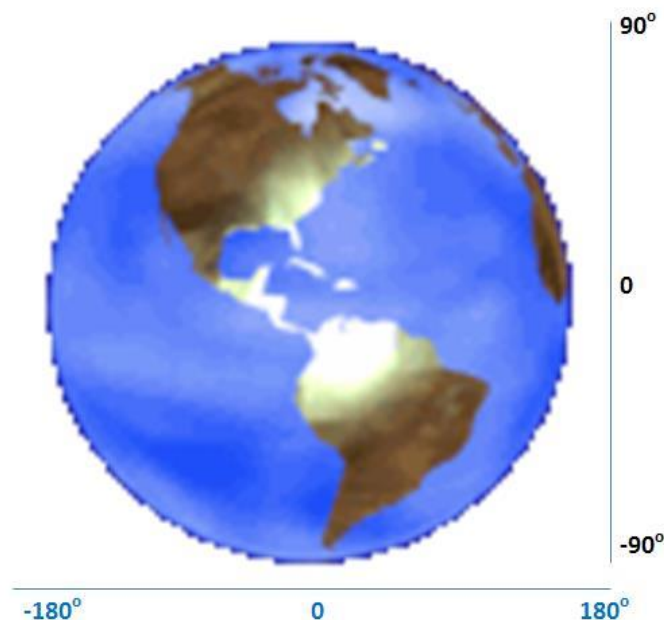


Attributes shows characteristics of a feature; any additional information that are associated with each vector features such as land cover class or area or administrative division. So every field (column) in an attribute table refers to the attributes. Raster consists only of a cell value associated with that pixel.

**Coordinate systems:** Any data that represent the location/position is called spatial data. The most common ways of representing spatial data is through the use of X and Y or longitude and latitudes which are obtained through the system called coordinate system. There are two categories of coordinate systems and these are Geographic coordinate systems (uses degrees minutes and seconds) and projected coordinate systems (uses meter as a unit of measurement often with six/seven digit numbers).

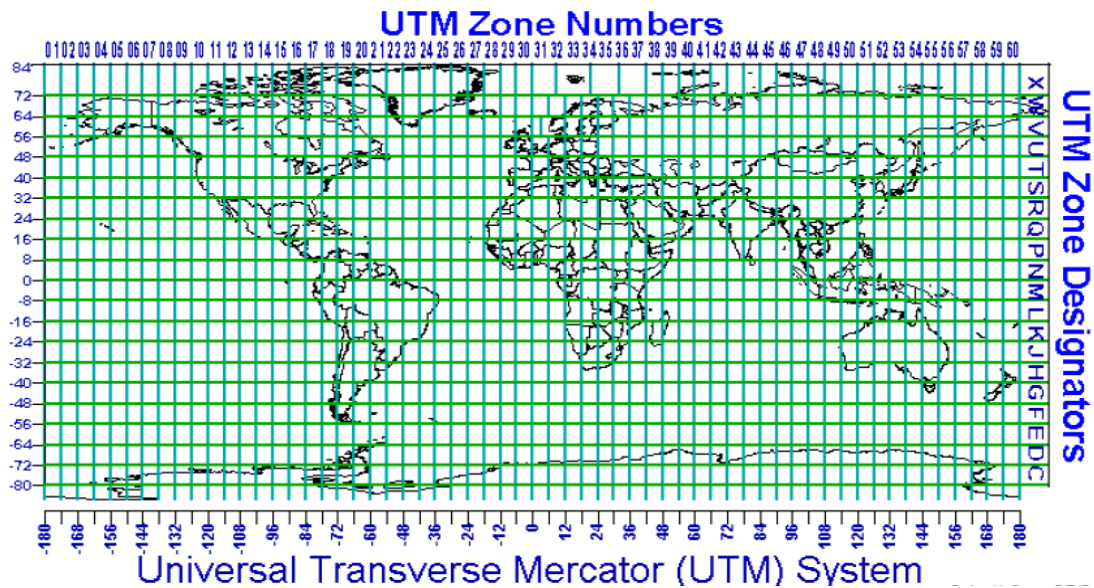
#### a) Geographic Coordinate Systems

It uses Latitudes (0-90°N-S) and Longitudes (0-180°E-W) and the Latitudes are measuring the distance from the equator (Y-dimension) and Longitudes are measuring distance from Greenwich (X dimension) either be positive on the north hemisphere or negative on the south Side of the equator are measured using degrees, minutes and seconds (° , ' , ").



#### b) Projected Coordinate Systems

This system by Mercator divides the globe in to 60 grids called zones and uses meter as a unit of measurement.



## 1.2 Introduction to ARCGIS

### 1.2.1 Brief Introduction to Geospatial Technology

Geospatial refers to a technology/advancement made in the areas of spatial data capture, processing, store, visualize, present and sharing using both hardware, software and methods. The advances made in space technology opened the way for spatial data capture which revolutionizes the geospatial world. Recent advances in space borne and airborne (including drones) technologies make the way for high resolution data capture in near real time.

GIS helps to manage spatial and non-spatial information in a very efficient way. Properly managed data and information helps in better territorial planning and decision making. In a GIS, data about real-world objects is drawn quickly and can be displayed using the different attribute fields stored in GIS databases. ArcMap is one of the main components of ESRI's ArcGIS Desktop software package, and it is used primarily to view, edit, create and analyze geospatial data. ArcMap allows the user to explore and analyze data from different datasets, symbolize features accordingly, and create maps.

### 1.2.2 Learning Objectives

By going through this exercise you will become familiarized with some basic tools and functionalities of ArcMap and you will be able to:

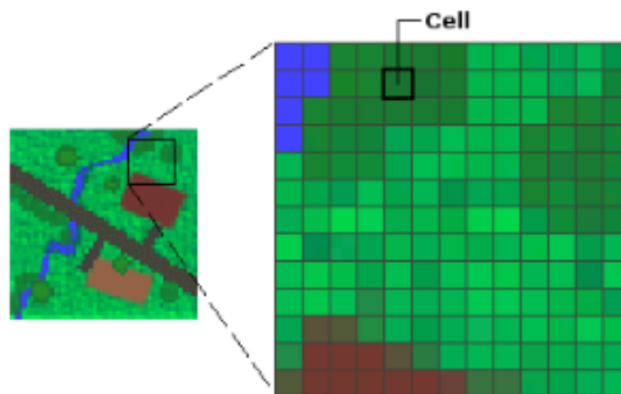
- Recognize ArcMap interface and toolbars
- Add, Manipulate data layers and attribute tables
- Download baseline data.
- Label features, create spatial bookmarks and save a map using relative path
- Create an Area Of Interest known as AOI.
- Clipping baseline data to AOI.
-



## 1.3 Glossary

**Geographic Information System (GIS):** A system for capturing, storing, checking and displaying data related to positions on the Earth's surface. GIS can handle data as several layers, in two predominant data models.

**Raster** consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.



Source: ESRI

**Vector** consists of geographic features such as point, line and polygon.




Source: ESRI

**Attributes** shows characteristics of a feature; any additional information that are associated with each vector features such as land cover class or area or administrative division. So every field (column) in an attribute table refers to the attributes. Rasters consists only of a cell value associated with that pixel.

**Layer Files** (layer\_name.lyr) saves all of the symbolization (colors, symbols etc) and labelling that you have defined for that layer. Layer files do not contain the actual datasets.

## 1.4 Basic Geoprocessing and Spatial Analysis

### 1.4.1 Getting Familiar with ArcMap

- **Start** ArcMap by double-clicking on the ArcMap icon on your desktop . If an icon is not present, you can use the Start Menu: *Programs > ArcGIS > ArcMap*.



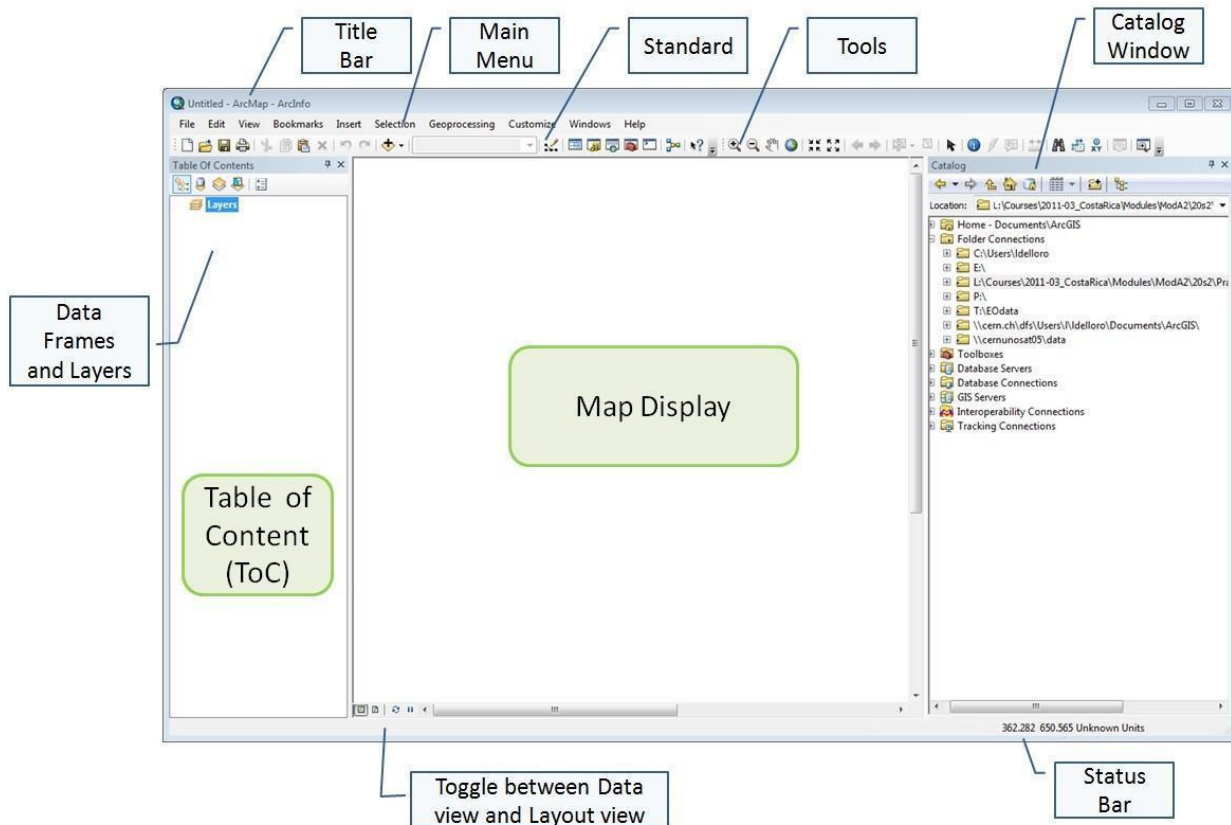
- You can specify whether or not to start with a new empty map, a template or an existing map

We will start this exercise by opening an empty map document:

- **Select** Blank Map and **click** OK.

### 1.4.2 ArcMap Interface and its main Elements

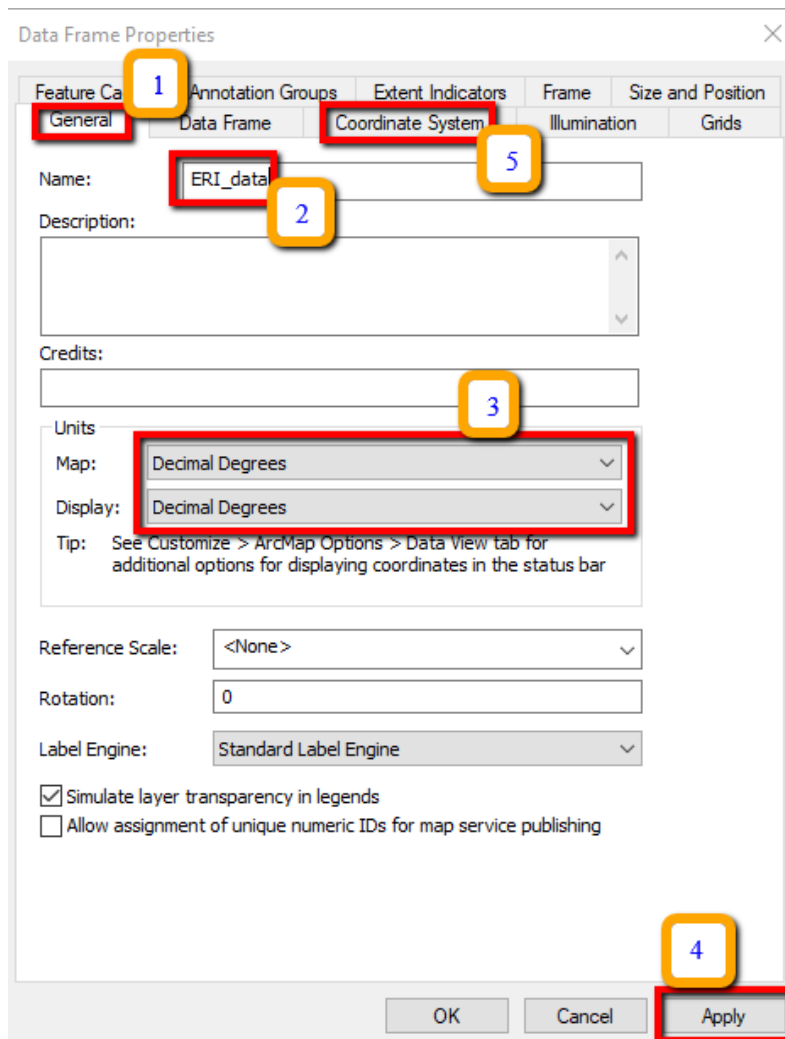
Your ArcMap window should look similar to the one shown below. Do not worry if the interface displayed on your screen looks different. The toolbar will probably have a different layout but it may be easily customized according to your needs.



### 1.4.3 Set Data Frame Properties

From the *Data Frame Properties* dialog box, you can set the reference scale of your map, map units, coordinate system and assign a name to the data frame.

- From the table of contents, **right click** on the data frame name "*Layers*"
- **Select** *Properties* > *General* tab
- In the *Name* section, **type** "*ERI\_data*"
- In the *Units* section, **select** *Decimal Degrees* for both *Map* and *Display Units* and **click** *Apply*




- **Select** the *Coordinate System* tab and notice that no projection is selected
- **Expand** the *Geographic Coordinate Systems > World > WGS 1984*
- **Click** *Add to Favorites* (so it will be easy to find next time) and **click** *Apply* > then *OK*




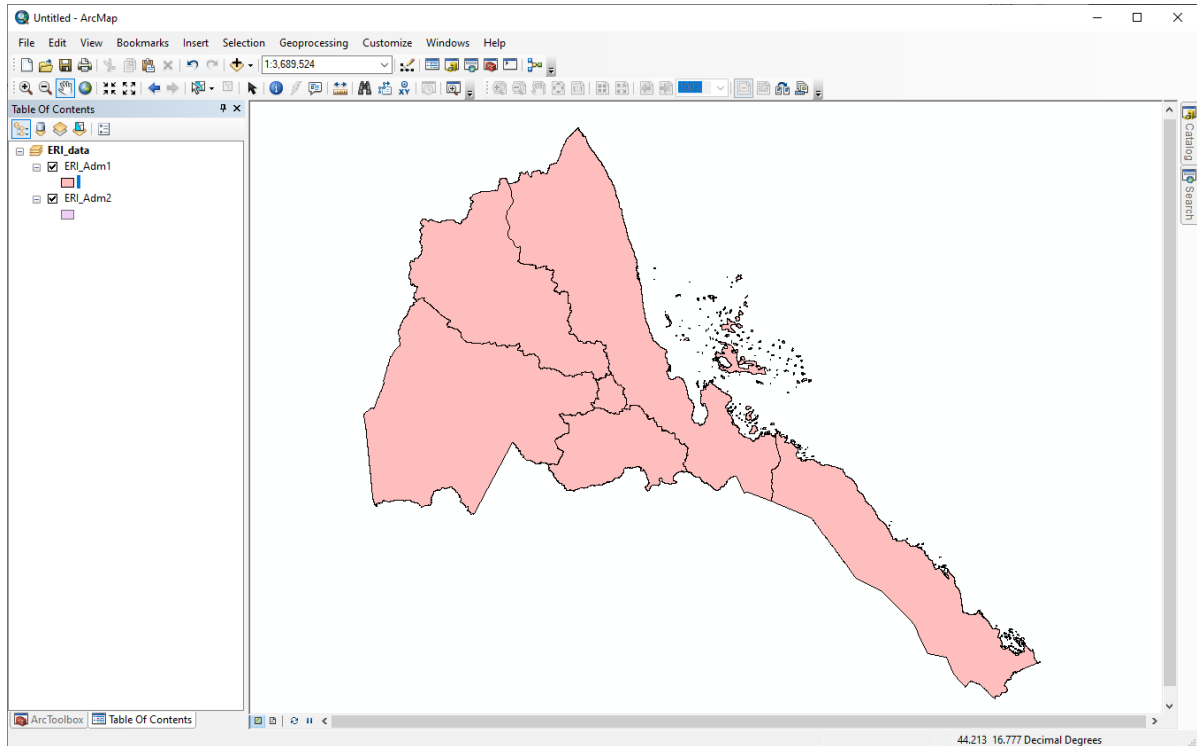
**Note:** To display data correctly, each data frame uses a coordinate system which determines the map projection. The data frame coordinate system might be different from your layers coordinate system. ArcMap can project your data on the fly, but it can take longer to draw.

*When ArcMap is started with a new, empty map, the coordinate system for the default data frame is not defined.*

#### 1.4.4 Add data into ArcMap

- From the standard toolbar, **click** the *Add Data* button 
- Browse to: **X:\ERI\_data\Module1\Admin**

- You might need to connect to the data folder for this exercise by **clicking** the *Connect to Folder* button in the *Add Data* dialog box 
- From Admin Folder, select *ERI\_adm1.shp* and *ERI\_adm2.shp*. You can select multiple files by **pressing** “Ctrl” key while selecting the files.



The selected layers are added to the *Table of Contents* and displayed (*if checked*) in the *Data View*. Layers are displayed with random colors and can always be changed.

### 1.4.5 Change Layer Color

The layer's symbol is the point, line or rectangle displayed below the layer name in the *Table of Contents*. To change the color or the size of a layer:

- **Double click** on the symbol(s) below the layer name.
- From the dialog box that appears, **select** your preferred color.
- You can also **edit** an existing symbol and **save** it.



### 1.4.6 Arrange the Table of Content

Data layers are drawn in the order they appear in the *Table of Contents*. Layers at the bottom are drawn first and layers at the top are drawn on the top of the map. If a layer on top is hiding a layer underneath you may not be able to see the lower layer.

In the *Table of Contents*, you can move a layer up or down by dragging it to the desired position.

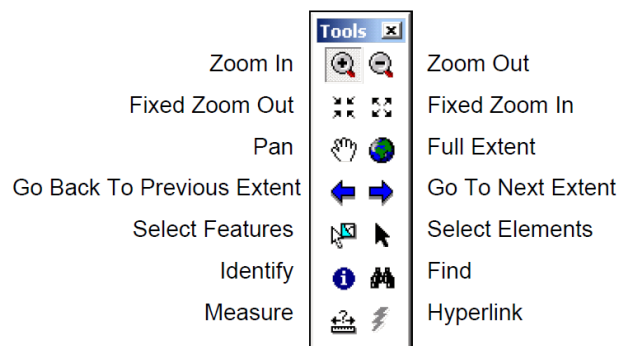
### 1.4.7 Creating a Group Layer

To improve the organization of the different data layers, you can create Group Layers to sort your data by category. A Group Layer behaves similar to other layers in the Table of Contents. To create a Group Layer:

- **Right click** on the *Data Frame > New Group Layer*
- **Right click** on the new group layer and select *Properties*
- **Enter** “*Administrative Boundaries*” as Layer Name. You can change the name of the new group layer by single left click
- **Select** “*Show layer at all scales*” and **Click OK**
- **Drag** the displayed layers into the “*Administrative Boundaries*” Group Layer.

### 1.4.8 Zoom and Pan

Use the ArcMap toolbar to zoom in, zoom out and pan over a region of interest within the data view.

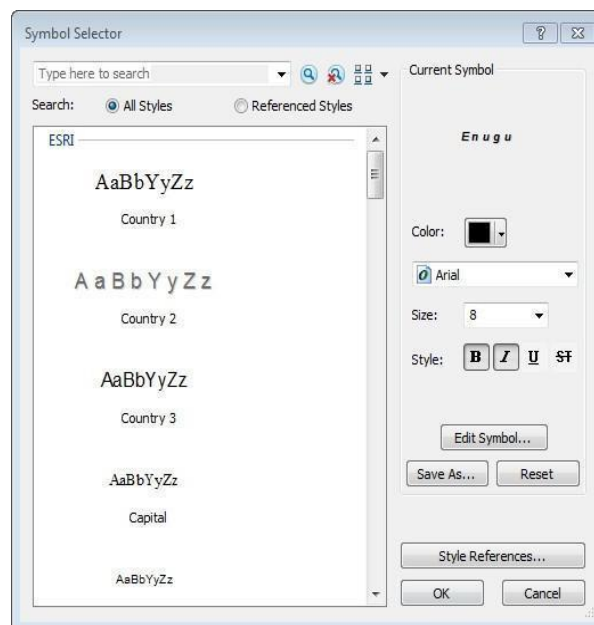


**Notice** that as you move the cursor around the map, the cursor position displayed at the bottom left of ArcMap window changes respectively.

### 1.4.9 Labeling Features

Labels are text items on the map that are dynamically placed and whose text values are defined from one or more feature attributes.

- **Right click** on one of the *Admin* layers > *Properties* and **choose** *Labels* tab
- **Check** ☒ *Label features in this layer*
- **Select** “*Label all the features the same way*”
- **Select** label field that is the most appropriate.
- **Click** *Symbol...*
- **Select** from the *Symbol Selector* dialog box one of the predefined text labels
- You can always modify your text labels by changing color, size and style. **Click** *OK*
- **Click** *Apply* and *OK*



- **Right click** on any layer, check or uncheck label *features* to have it on or off

Layer Properties

General Source Selection Display Symbology Fields Definition Query **Labels** Properties & Relations Time HTML Popup

☒ Label features in this layer

Method: **2** Label all the features the same way.

All features will be labeled using the options specified.

Text String

Label Field: **3** NAME\_1 Expression...

Text Symbol

Font: Tw Cen MT 8

Color: Black Bold Italic Underline **4** Symbol...

Other Options

Placement Properties... Scale Range...

Pre-defined Label Style


Label Styles...

**5** OK Cancel Apply




### 1.4.10 Creating Spatial Bookmarks

To save a specific extent of the map, you can use Spatial Bookmarks. Once saved, you can click the *Bookmark* button from ArcMap main menu bar, point to the saved bookmark and the map display will automatically zoom to that extent.

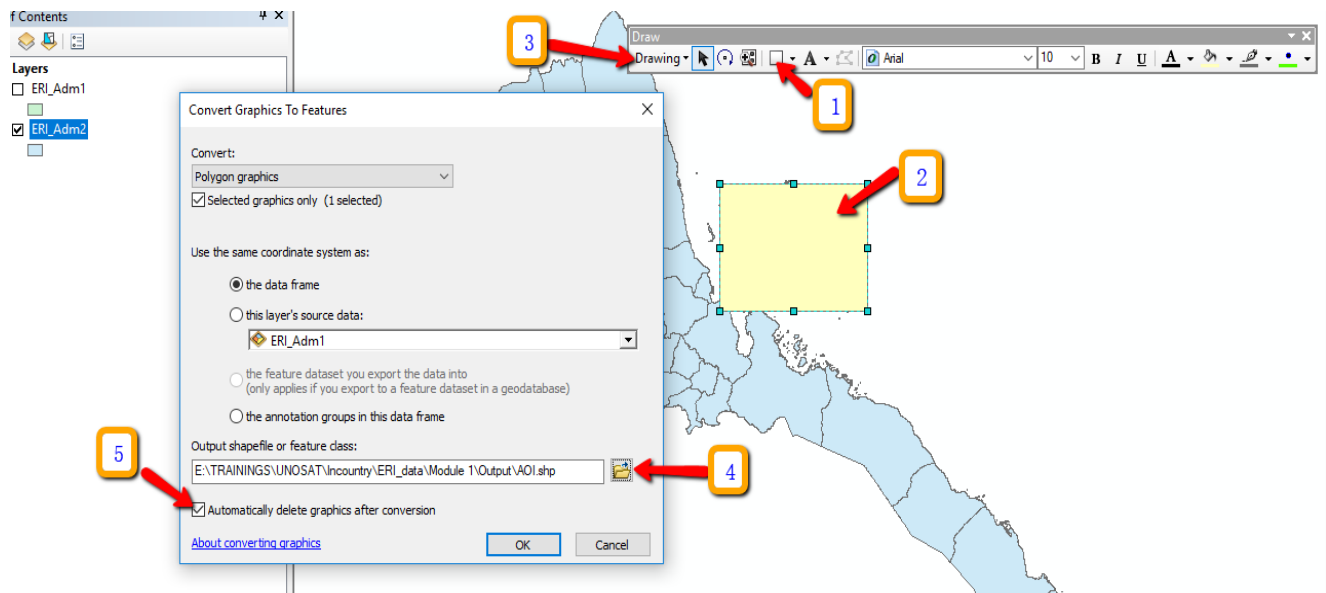
- **Zoom to** one place of interest (**choose** any region(s) from *ERI\_adm2.shp*)
- From the main menu toolbar, **click** *Bookmarks > Create*
- In the *Spatial Bookmarks* dialog box, **type** the name of the place you have chosen
- Zoom to full extent  and then **click** *Bookmarks > "placename"*

### 1.4.11 Create an Area of Interest (AOI)

One of the key steps in managing and analysing geospatial data is to identify one or more areas of interest (AOI) which allows you to focus and limit your search over a specific area.

- **Click** on *Customize menu > Toolbars > Make sure Draw tool is checked*
- By using the drawing tool, **Click** on  and **draw** a new rectangle that covers your areas of interest (**Click** on the top-left vertex and **drag** to the vertex in bottom-right corner)
- From the *Drawing* toolbar **click** *Drawing > Convert Graphics to Features*, **activate** "Automatically delete graphics after conversion". Name the output layer as "AOI.shp" and save it on:

*X:\ERI\_data\Module1\Output*



- **Click** Yes in the next dialog box to export the layer.
- From the table of contents, **double click** on the icon of the layer you just created and **change** the layer style to *hollow* and *outline* red.




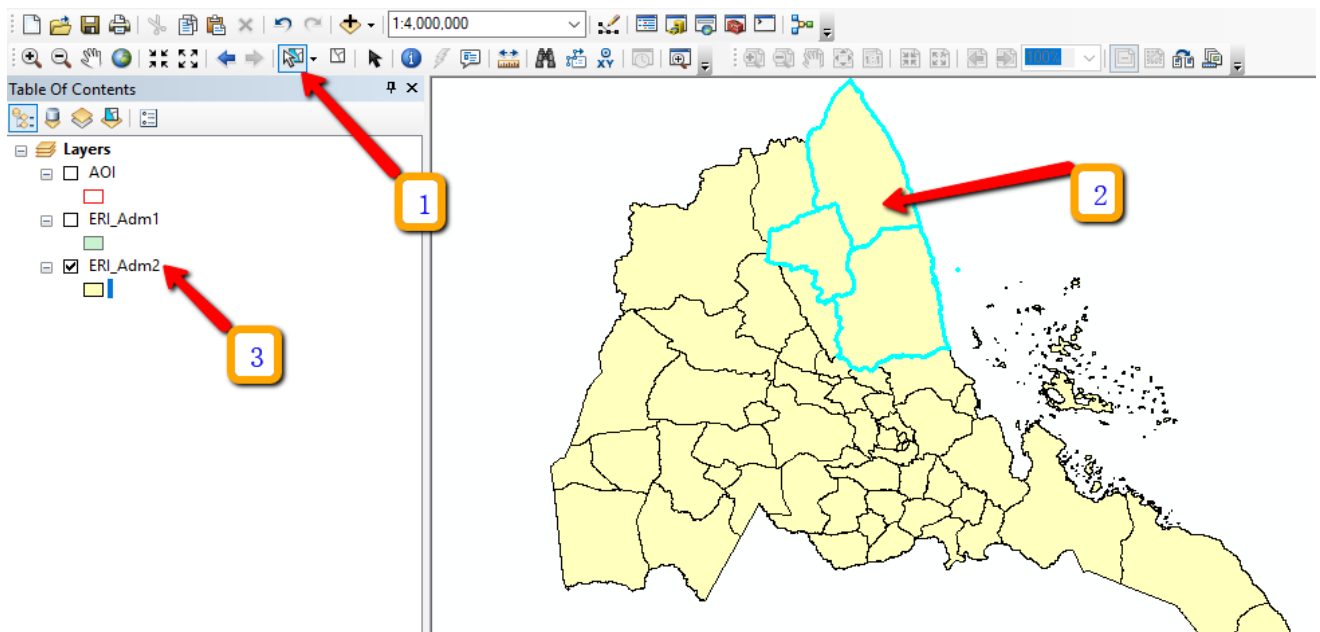
## What is the purpose of creating an AOI layer?

### 1.4.12 Select Features

This tool lets you select the features on which you want to perform certain operations (e.g. move, delete, edit, copy, etc.). You have multiple options for selecting features (i.e. by rectangle, circle, polygon, etc).


**NOTE:** In order to make the layer of interest to be the only layer that could be selected, **right click** on the layer > *Selection > Make this the only selectable layer*.

- From the ArcMap toolbar, **click** on the *Select Features* button 
- **Hold down** the shift key on your keyboard and **select** few features in any layer by **clicking** on them.
- From the *Table of Contents*, **right click** on the feature of interest
- **Go to** *Selection > Create a Layer from Selected Features*



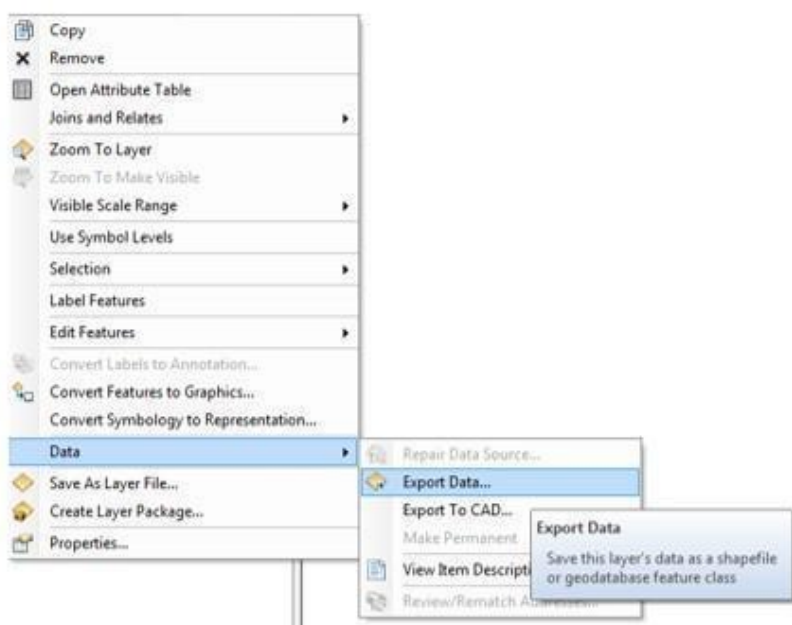
At this stage you cannot edit the selected features (you will learn later how to edit features later), but you can perform some basic operations such as zoom and pan, clear and switch selection and create new layers from selected features.



- **Click** on the *Clear Selection* button 
- **Uncheck** the *Administrative Boundaries* group layer
- **Right click** on the layer created from selection
- **Click** on *Zoom to layer*

**NB:** The layer you have created is stored by ArcMap as a temporary file. If you want to create a new dataset from the selection you need to export the layer:

- **Right click** on the layer > *Data > Export Data...*



- In the dialog box, under the title, '*Use the same coordinate system as*' **choose** "*this layer's source data*"
- **Save** the file in the following location: **X:\ERI\_data\Module1\Output**
- **Name** the feature class to export as "*Practice\_Selection*"
- **Save as type** "*shapefile*" and **click** save then **click** *OK*

A prompt window will ask you if you want to add the exported data to the map as layer

- **Click** Yes and **explore** the newly created dataset (zoom in, pan and identify features).

When you are done, **remove** the two data layers that were created from the selected features

- **Right click** on the layer > *Remove*

**Check/activate** ☒ the *Administrative Boundaries* group layer **Right click** > *Zoom to layer*

#### 1.4.14 Working with Attribute Tables

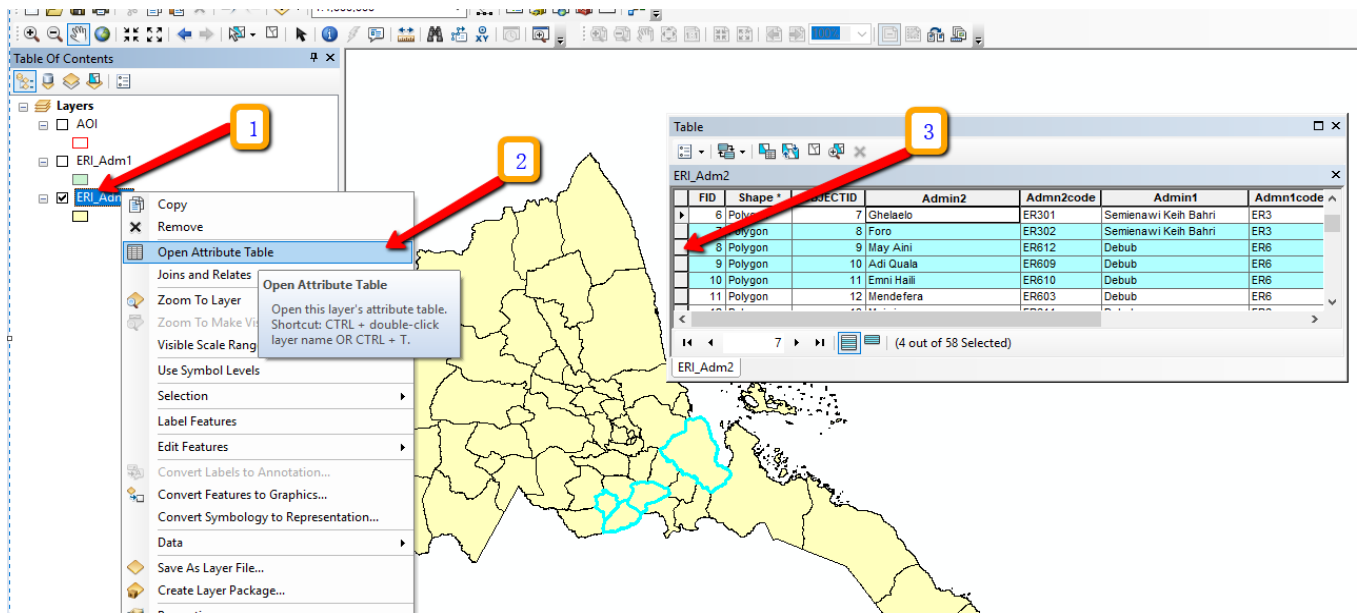
In GIS, a feature on a map may be associated with a lot of information (attribute values) stored in a table. A layer's attribute table contains a row (or record) for each feature and a column (or field) for each attribute or category (attribute field).

To explore the attribute of a layer, **open** its attribute table to select and find features with a particular value.

- **Right click** on "ERI\_adm2" administrative layer
- **Click** *Open Attribute table*

The table opens, containing one record for each division. The FID field contains a unique identification number for every record (or every feature in the map). The intersection of a record and a field is a cell. A cell contains an attribute value. The total number of records stored in the table is displayed at the bottom of the attribute table.

With the selection tool, **select** one or more records/features from either the *Attribute Table* or the *Data View* (from the map).



Notice that when a record is highlighted in the table, its corresponding feature is highlighted on the map (and vice versa).

- **Right click** on the selected record from the table

- **Click** on *Zoom to selected* or Click on this icon



To sort attribute values stored in the table:

- **Right click** on a field name and **click** *Sort Ascending*

By clicking on the *Options* menu on the top of the attribute table, you can perform more operations such as *Find and Replace*, *Select by Attributes*, *Clear Selection*, *Switch Selection*, *Add Data*, and so on.

#### 1.4.15 Advance Selection

The **Select by Attributes** dialog box allows you to select features on a given layer using a SQL expression.

- From the Main Menu Toolbar, **click** *Selection > Select by Attributes*

The Select by Attributes dialog box appears

- **Select** "ERI\_adm2" under *Layer*
- **Select** *Create a new selection*
- **Select** the attribute field "Admin2" and
- **Double click** on "Admin2", **click** "=" and **click** on *Get Unique Values*.

A list with all the values will appear. **Double click** on an area of interest from the right. **Scroll down** to find your area of interest e.g. Afabet.

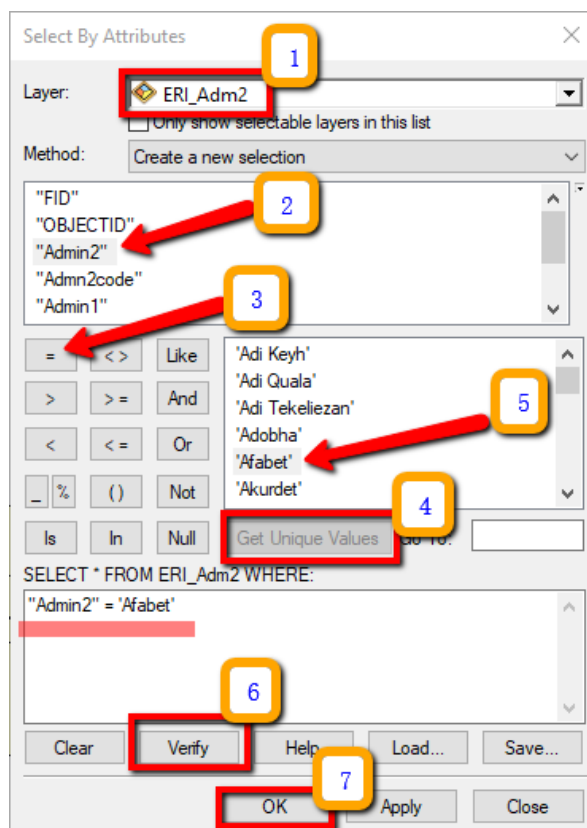
In the dialog box below, the expression should appear as follows: "Admin2" = 'Afabet' (**Choose** a region of your interest, Ex: 'Akurdet').

- **Click** *Verify* and then **click** *OK*
- **Click** *Apply*
- From the *Main Menu* toolbar, **click** *Selection > Zoom to Selected Features*.
- **Click** *Clear Selection* and then *Full Extent*.

NOTE: You can select more than one region using the *IN* function as shown below:

"Admin2" IN( 'Adi Keyh' , 'Adi Quala' , 'Adi Tekeliezan' )

The **Select by Location** dialog box lets you select features based on their location relative to other features. You can use a variety of selection methods to select the point, line, or polygon features in one layer that are near, or overlap the features in the same or another layer.



### 1.4.16 Joining Tables

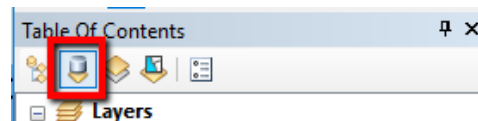
Attribute tables contain predefined fields that hold data on geometry and the object ID. We can also add excel table into ArcGIS workspace and view the table. This table can be joined with existing layer or converted into a shapefile.

In this exercise you will be joining the NDVI anomaly mean for Feb 2018 data to the level 2 (*ERI\_adm2*) administration boundary polygons.

- Add “*ERI\_adm2.shp*” and “*Mean\_NDVI\_anom\_Feb2018.txt*” data to ArcMap from this location;

**X:\ERI\_data\Module1\Baseline\_data**

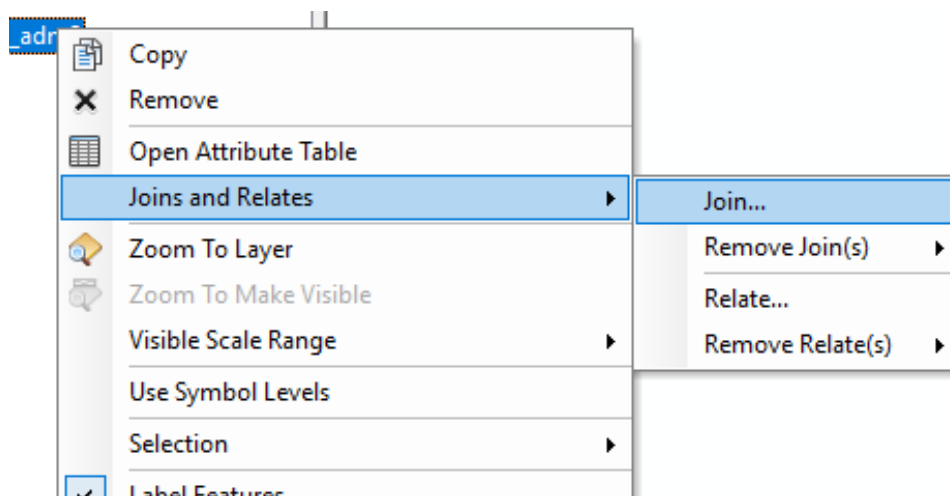
Attribute tables for feature layers are automatically loaded when the layer is added to the map. Tables without associated features only show up on the Source tab of the ArcMap table of contents.



Join the attributes of the “*Mean\_NDVI\_anom\_Feb2018*” table to the Attribute table of “*ERI\_adm2*”.

- **Right-click** the layer or table you want to join (*ERI\_adm2*), **point** to *Joins and Relates* > **click**

*Join.*



- **Click** the first drop-down arrow and **click** *Join attributes from a table*.
- **Click** the second drop-down arrow and **click** the field name in the layer “*Admin2*” on which the join will be based.
- **Click** the third drop-down arrow to **choose** the table to join to the layer “*Mean\_NDVI\_anom\_Feb2018.txt*”.

- **Click** the fourth drop-down arrow and **click** the field in the table on which to base the join

*“Admin2”*.

- **Click** OK

Open the attribute table of *“Admin2”*. The attributes of the table are appended to the layer's attribute table.

Table

ERI\_Adm2

Admin0code	OBJECTID	Admin2	ZONE_CODE	COUNT	AREA	MEAN
ER	1	Tesseney	1	18216	0.092218	-0.987319
ER	2	Asseb	2	6234	0.03156	0.847449
ER	3	Araeta	3	114433	0.579317	-0.628682
ER	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
ER	4	Debub Deb.Keih Bahri	5	160961	0.814865	0.606402
ER	5	Maekel Deb.Keih Bahri	6	68791	0.348254	-0.036066
ER	6	Ghelaelo	7	110982	0.561846	-1.262033
ER	7	Foro	8	44837	0.226987	-4.012913
ER	8	May Aini	9	13067	0.066152	0.278335
ER	9	Adi Quala	10	11787	0.059672	-0.73598
ER	10	Emni Haili	11	6793	0.03439	-0.643015
ER	11	Mendefera	12	10391	0.052604	0.829757

(0 out of 58 Selected)

ERI\_Adm2

- To sort values in an attribute field **right-click** the selected field's heading and **click** Sort Ascending or Sort Descending.

Table

ERI\_Adm2

Admin0code	OBJECTID	Admin2	ZONE_CODE	COUNT	AREA	MEAN
ER	47	Segeneity	48	12067	0.061089	2.183061
ER	46	Adi Keyh	47	10009	0.050671	1.983819
ER	35	Dekemhare	36	11622	0.058836	1.955774
ER	45	Massawa	46	5457	0.027626	1.47462
ER	36	Dbarwa	37	15916	0.080575	0.984607
ER	42	Galaneffi	43	6442	0.032613	0.968333
ER	2	Asseb	2	6234	0.03156	0.847449
ER	11	Mendefera	12	10391	0.052604	0.829757
ER	53	Senafe	54	16814	0.085121	0.67872
ER	4	Debub Deb.Keih Bahri	5	160961	0.814865	0.606402
ER	8	May Aini	9	13067	0.066152	0.278335
ER	52	Tsorona	53	10725	0.054295	0.269744

(0 out of 58 Selected)

ERI\_Adm2

Sort Ascending  
Sort Descending  
Advanced Sorting...  
Summarize...  
Statistics...  
Field Calculator...  
Calculate Geometry...  
Turn Field Off  
Freeze/Unfreeze Column  
Delete Field  
Properties...



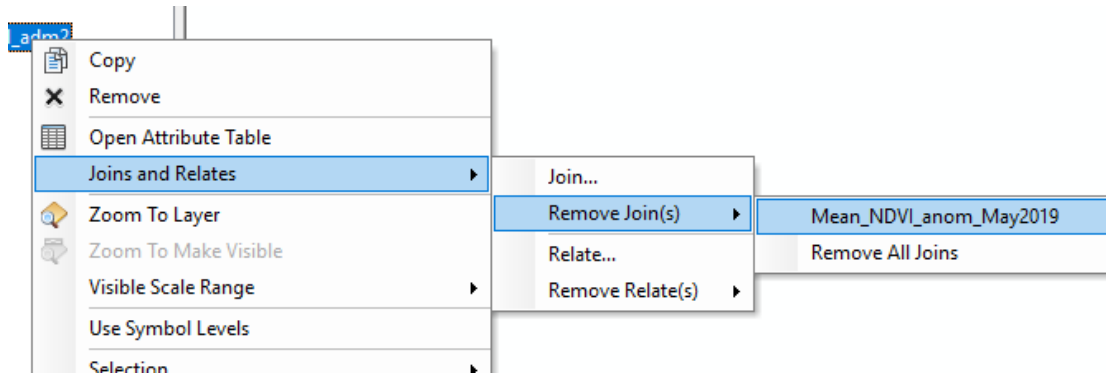
Which district has the highest mean of NDVI anomaly in Feb? \_\_\_\_\_

Which district has the least mean of NDVI anomaly in Feb? \_\_\_\_\_

**NOTE:** You may want to remove the current join from “*ERI\_adm2*” to do so, here is the procedure;

- **Right-click** the layer containing a join you want to remove and point to *Joins and Relates*.
- **Point** to *Remove Join(s)* and **click** the join you want to remove

“*Mean\_NDVI\_anom\_Feb2018.txt*”.



## 1.5 Basic Geoprocessing and Spatial Analysis

**Rational:** The main rationale for using geoprocessing tools and spatial analysis is to try to answer some spatial questions which are necessary to get more information out of your data to make an informed decision.

**Geoprocessing:** refers to an activity or set of activities in GIS used to manipulate spatial data. A typical geoprocessing operation takes an input dataset, performs an operation on that dataset, and returns the result of the operation as an output dataset. All data preparation and manipulation can be called Geoprocessing. We will see some of the most important tools under this topic which really helps you answer spatial questions. There are hundreds of tools in ArcGIS to handle the various chores of day to day GIS activities.

### 1.5.1 Spatial Analysis

The rationale for spatial analysis science is to understand the spatial distribution, variation, interaction and relationships of features or phenomena. According to Carleton College definition spatial analysis is a set of techniques for analyzing spatial data. The results of the spatial analysis are dependent on the locations of the objects being analyzed. Software that implements spatial analysis techniques requires access to both the locations of objects and their attributes. The other description is from ESRI “Spatial analysis is how we understand our world—mapping where things are, how they relate, what it all means, and what actions to take. From the computational analysis of geographic patterns to finding optimum routes, site selection, and advanced predictive modeling, spatial analysis is at the very heart of Geographic Information System (GIS) technology.”



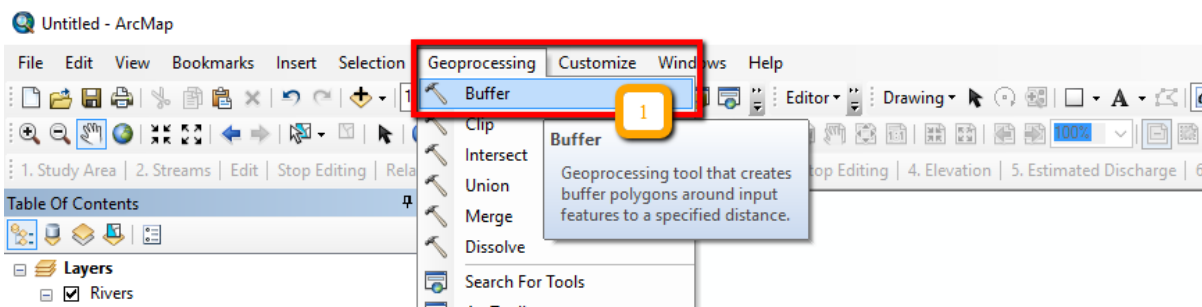
The goal of the spatial analysis is to answer spatial questions which might be related to location, pattern, change, scenarios and others. GIS software's are designed to provide a state of the art tools to process data and answer such complex space based questions.

There are hundreds of tools under the ARCGIS toolbox to help you carry out spatial analysis, however, it is very important to first design a methodology or a model which needs to be supported with scientific methods to reach a conclusion.

### 1.5.2 Buffer Analysis

Buffer analysis is one of the most important **Geoprocessing** tools that help to identify proximity of places from a reference layer. For instance, if you wish to identify road networks within 300 m of rivers you can easily identify them. Let's create a buffer of 300 m from a **rivers** and see how much road length is existing close to the river.

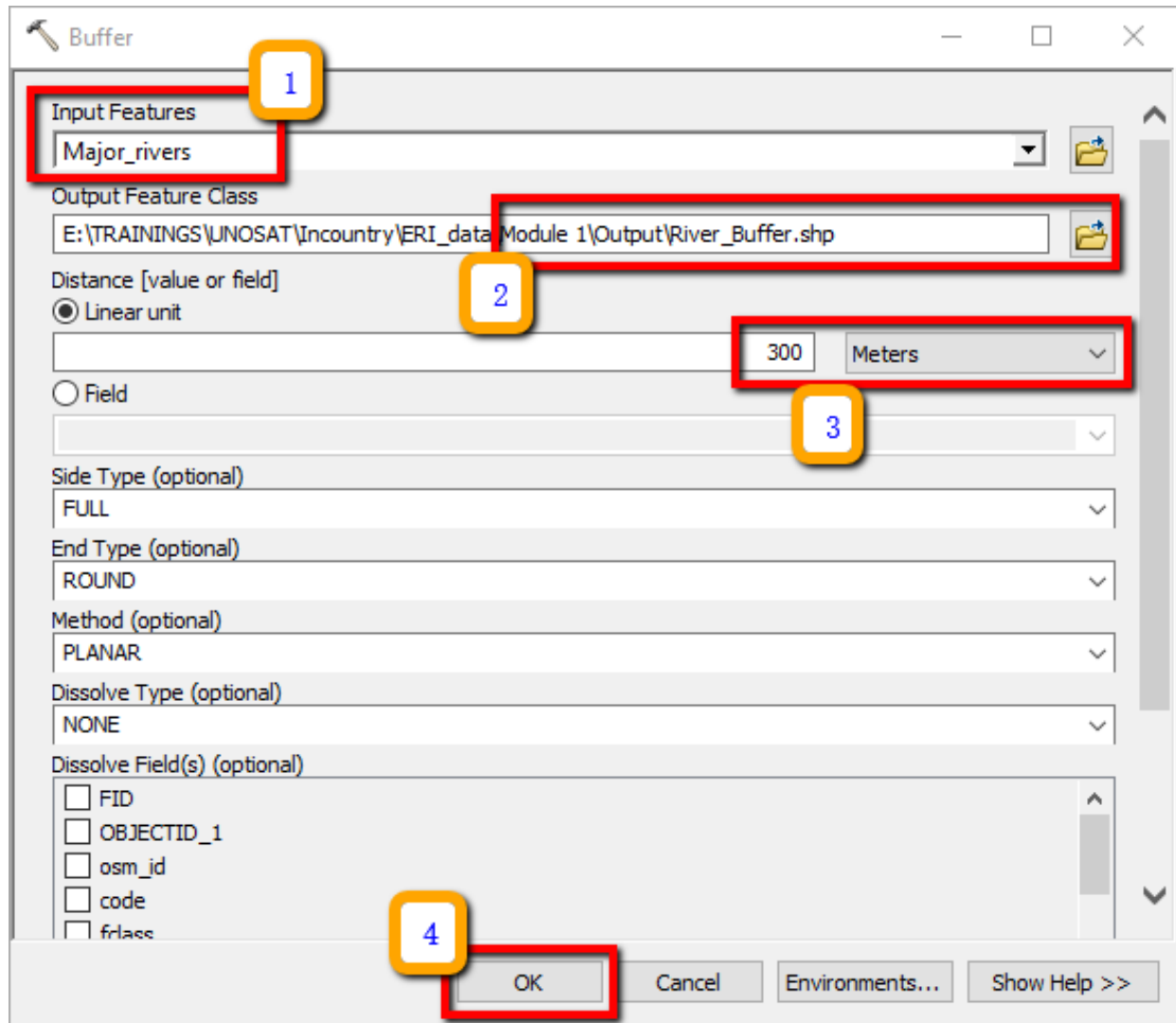
- **Open ArcMap and add the layer for Rivers** from **X:\ERI\_data\Module1\Baseline** folder
- **Click on Geoprocessing** from the Menu Bar > then **Click on Buffer**



- Under **Input Features** **select "Major\_rivers.shp"**
- **Save Output Feature Class** as '**River\_Buffer.shp**' at **X:\ERI\_data\Module1\Output\**
- **Linear Unit** **should be '300 meters'**.
- **Click OK**



- **Zoom in** to one river line to see the buffer area of 300m.



What are the different applications this can be used? \_\_\_\_\_



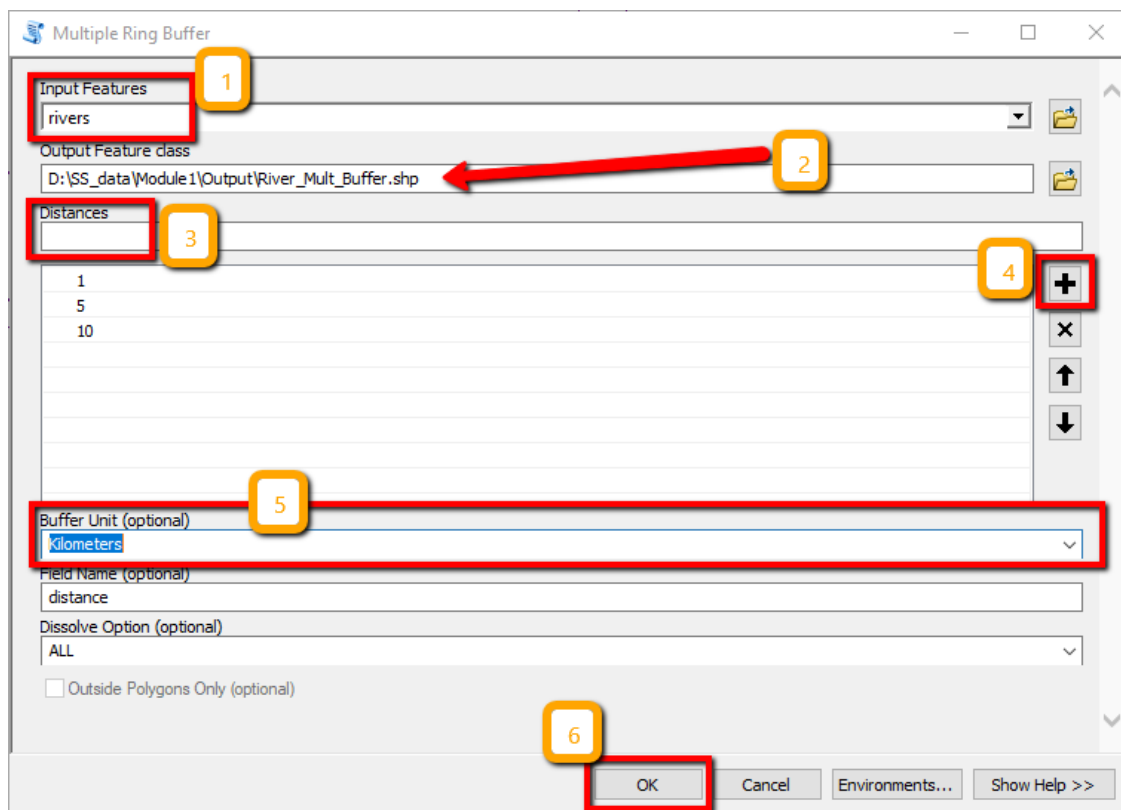
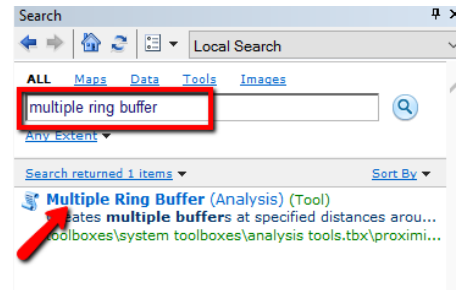
What if we want different buffer distance like 1km, 5km, 10km to show from most to least areas at risk of flood hazard?

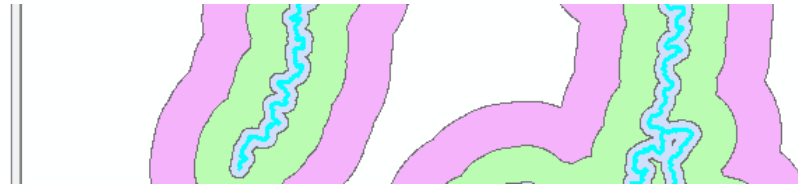
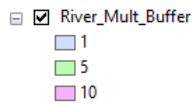
\_\_\_\_\_

### 1.5.3 Multiple Ring Buffer

Multiple Ring Buffer allows us to create multiple buffers at specified distances around the input features. The different levels of buffer distances can be used to define different elements at risk.

- Click on 'Search tool' and type 'Multiple Ring Buffer'.
- Click on the 'Multiple Ring Buffer (Analysis)' tool.
- Under Input **Select** "River\_Buffer.shp"
- **Save** the Output as "River\_Mult\_Buffer.shp" at **X:\ERI\_data\Module1\Output\**
- Under 'Distances' **give** the following three levels, 1, 5, and 10. **Type** each number once and **click** on the *plus button* (+).
- **Change** the 'Buffer Unit' option to **Kilometers**.
- **Click OK**
- Now **Zoom in** to 'River\_Mult\_Buffer.shp' and see the different levels of Buffer distances.





### 1.5.4 Intersect

This is an important geoprocessing tool to find the intersection between two or more layers. It has a practical application, for instance if you wish to calculate the length of roads existing in different countys (admin 2) of Djibouti, you can intersect roads layer with admin2 layer. Steps to carry out this is given below.

#### Steps

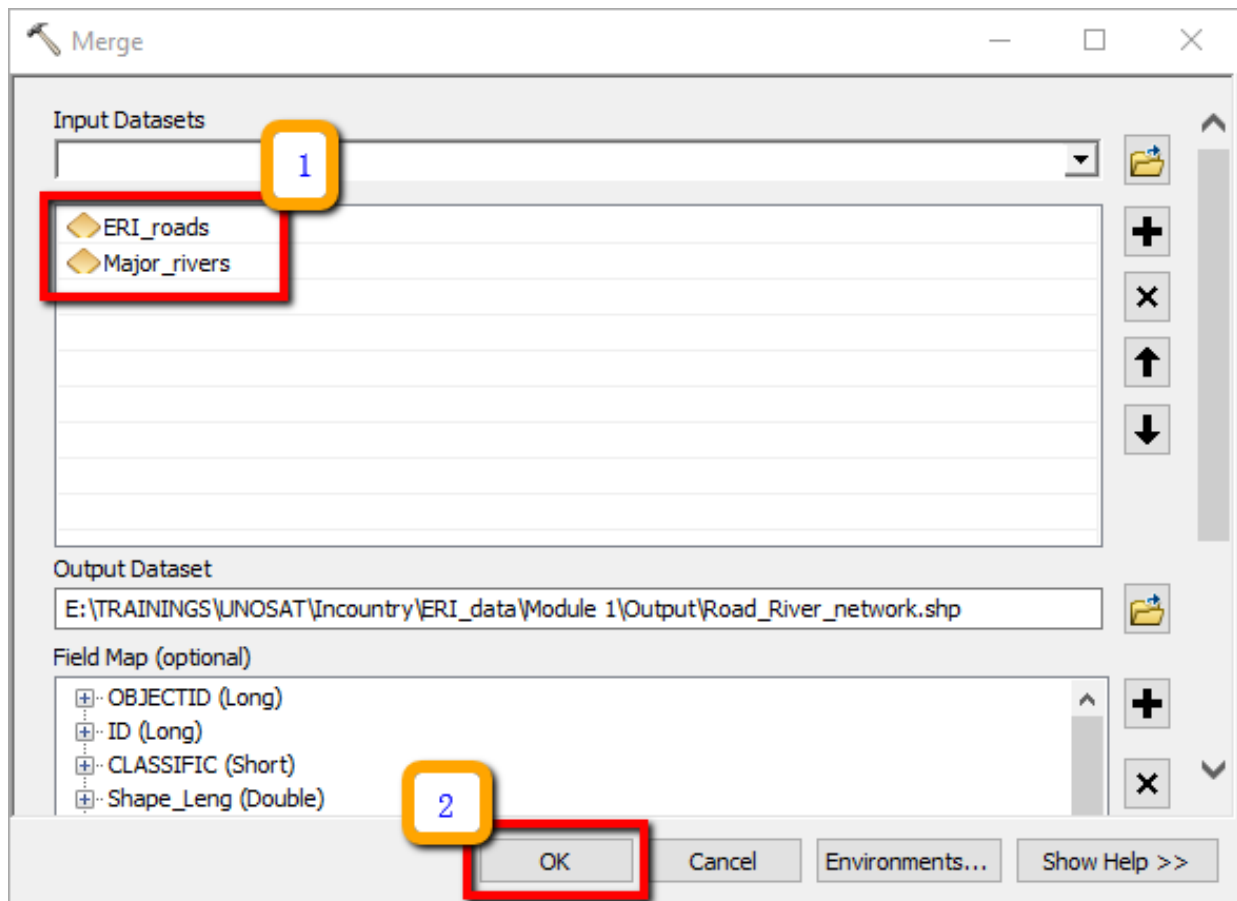
- Open ArcMap and add 'ERI\_roads.shp' layer from X:\ERI\_data\Module1\Baseline\ and 'ERI\_Adm2.shp' from X:\ERI\_data\Module1\Admin\ folders respectively to Table of Contents.
- Now go to **Windows** in ArcMap main menu and **click** on *Search*. **Key** in *Intersect* and **search** and then open the '*Intersect (analysis) tool*'
- Now give 'ERI\_roads.shp' and 'ERI\_Adm2.shp' as features to intersect
- **Save** the Output feature class to X:\ERI\_data\Module1\Output\ folder with the name **Roads\_Admin2.shp** and **click** *Ok*.
- Now you can open the attribute table of the **Roads\_Admin2.shp** to see that the district names are attached to the *roads* attribute table. This means that you can also calculate the length of roads in each of the counties (*admin 2*).
- Right click on '**Admin2**' field in the attribute table of **Roads\_Admin2.shp** and select '*Summarize*' option.
- Click on '**Length**' field and select '**sum**' and give an output name for the table as '**Road\_sum\_Adm2**' and select 'Save as Type' as '*dbase*'. Click *OK* for the option 'Do you want to add result table to the map'.
- Click on the table '**Road\_sum\_Adm2**' in Table of contents and select open option.
- Observe the table and try to understand the result.

### 1.5.5 Merge

Merge is another important tool for combining two or more layers of the same feature types. This tool provides an opportunity to compile data of similar nature. Take for instance, you can merge **ERI\_roads.shp** and **Major\_rivers.shp** polyline layers, which can be used for assessing the combined transport network in Eritrea.

Let's merge the **ERI\_roads.shp** and **Major\_rivers.shp** layers in Eritrea for further analysis.

- Add the **ERI\_roads.shp** and **Major\_rivers.shp** layers from **X:\ERI\_data\Module1\Baseline\**
- Search for a tool **Merge** and **open**. Set the **ERI\_roads.shp** and **Major\_rivers.shp** layers as inputs layers
- Save the *Output feature class* to **X:\ERI\_data\Module1\Output\** folder with the name **Road\_River\_network.shp** and click **OK**.
- If you open the layer, you will notice that the two layers and their attribute tables are combined.



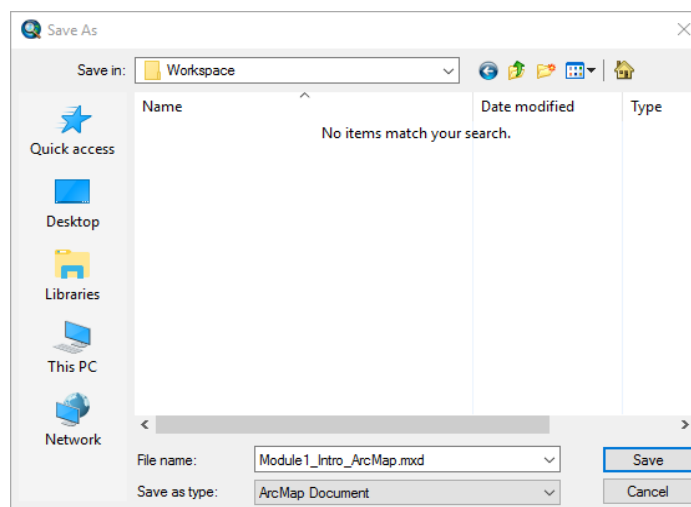
### 1.5.6 Saving Your Workspace

After you finish working on a map, you can save it and exit ArcMap. ArcMap saves your map as a project document (.mxd). The *Home* folder available in the Catalog window is used by default in ArcMap to save

results, store new datasets, and to access file-based information. In addition, each map document has a default geodatabase, which is the home location for the spatial content of your map. This location is used for adding datasets and for saving resulting datasets created by various editing and geoprocessing operations.

If you haven't saved the map project before and you want to save it into a desired folder location:

- **Click** *File > Save As*.
- **Enter** the name “*Module1\_Intro\_ArcMap.mxd*” and **save** it on: *X:\ERI\_data\Module1\Output\*



## 1.6 Open GIS data Sources

In the aftermath of a disaster it is very important to collect and review disaster related information from media reports, OCHA situation reports, reports from government and local authorities. This would enable you to get an understanding about the type and magnitude of the disaster event which is very useful before doing any kind of geospatial analysis. When a first review of available disaster- related information is completed, you can start searching and gathering relevant geo-data (i.e. pre and post disaster satellite imagery and GIS baseline data) to be used for GIS analysis and mapping.

### 1.6.1 Baseline Geospatial Data for Disaster Risk Assessment

This section presents a list of free and commercial spatial available for download. Explore and download some GIS and EO data by browsing different geospatial data portals, which provide access to useful data sets for emergency response mapping.

Web Portal	Web Link	Data Description	Data Type
ICPAC-Geoportal	<a href="http://geoportal.icpac.net/">http://geoportal.icpac.net/</a>	Free regional data	Vector/Raster

ArcGIS Online	<a href="http://www.esri.com/software/arcgis/arcgisonline">http://www.esri.com/software/arcgis/arcgisonline</a>	Free online imagery, relief, topography, road networks	Web map, not editable, only visual
Giovanni	<a href="http://giovanni.gsfc.nasa.gov/giovanni/">http://giovanni.gsfc.nasa.gov/giovanni/</a>	Free Precipitation data (TRMM, GPM)	TIFF
MODIS Rapid Response System	<a href="http://earthdata.nasa.gov/lance/rapid-response">http://earthdata.nasa.gov/lance/rapid-response</a>	Free imagery from the MODIS sensor	Multiband raster
Digital Globe	<a href="http://www.digitalglobe.com">http://www.digitalglobe.com</a>	Commercial satellite very high resolution imagery	Preview imagery can be downloaded
USGS earthexplorer	<a href="http://earthexplorer.usgs.gov">http://earthexplorer.usgs.gov</a>	Free Landsat, ASTER, SRTM, MODIS	Raster
OpenStreetMap OSM	<a href="http://extract.bbbike.org/">http://extract.bbbike.org/</a>	Free Baseline data	Vector
Humanitarian Data Exchange	<a href="https://data.hdx.rwlab.org/">https://data.hdx.rwlab.org/</a>	Free Baseline data	Vector/Raster
Sentinel Scientific Hub	<a href="https://scihub.copernicus.eu/dhus">https://scihub.copernicus.eu/dhus</a>	Free RADAR and high resolution OPTICAL data	Raster
WorldPop	<a href="http://www.worldpop.org.uk/">http://www.worldpop.org.uk/</a>	Free Population data	Raster

Flood monitoring portal

<https://realearth.ssec.wisc.edu/?products=RIVER-FLDglobal-composite.75&center=10,0&zoom=3&basemap=satellite&labels=-&timestep=1d>

## **Module 2: Vegetation and Land Cover/Land Use Monitoring**

## 2 Module 2: Vegetation and Land Cover/Land Use Monitoring

In this module we will cover vegetation and land cover monitoring using satellite data and remote sensing technologies. One of the most important opportunities presented by advancements in remote sensing through earth observation satellites is the ability to monitor phenomenon on or around the Earth's surface at near-real time over the entire planet. Earth observation satellites have enabled large scale monitoring of remote inaccessible regions such as the Amazon or the icebergs at the poles.

Vegetation indices derived from Earth observation satellites are important for a wide range of applications such as vegetation monitoring, drought studies, agricultural activities, climate and hydrologic modeling. Vegetation monitoring plays an important role in drought early warning systems, which help to anticipate the risk of food crises at local and global scale. Land Cover analysis is important in monitoring changes on the land which is useful in identifying deforestation activities, forest degradation, human encroachment into protected areas and so on.

This module is divided into two sections: 1) Vegetation Monitoring and 2) Land Cover/Use monitoring. We will use the **eStation software** to monitor vegetation variables over time and over space in Eritrea. Using maps and graphs we will identify trends and patterns over time and compare current conditions to past conditions. In the second section of this module we will use **IMPACT toolbox** to perform land cover/use mapping and land cover change analysis to understand how the land is changing and thus the impact of such changes. **IMPACT** offers a toolbox for high resolution satellite imagery processing, classification and statistics generation.

- ❖ Vegetation Monitoring
  - ✓ Vegetation Indices
  - ✓ Introduction to the eStation
  - ✓ Rainfall and NDVI maps
  - ✓ Rainfall and NDVI Anomaly maps
- ❖ Land Use Land Cover Analysis

### 2.1 Vegetation Monitoring

**Learning Objectives:** By the end of this module you will be able to:

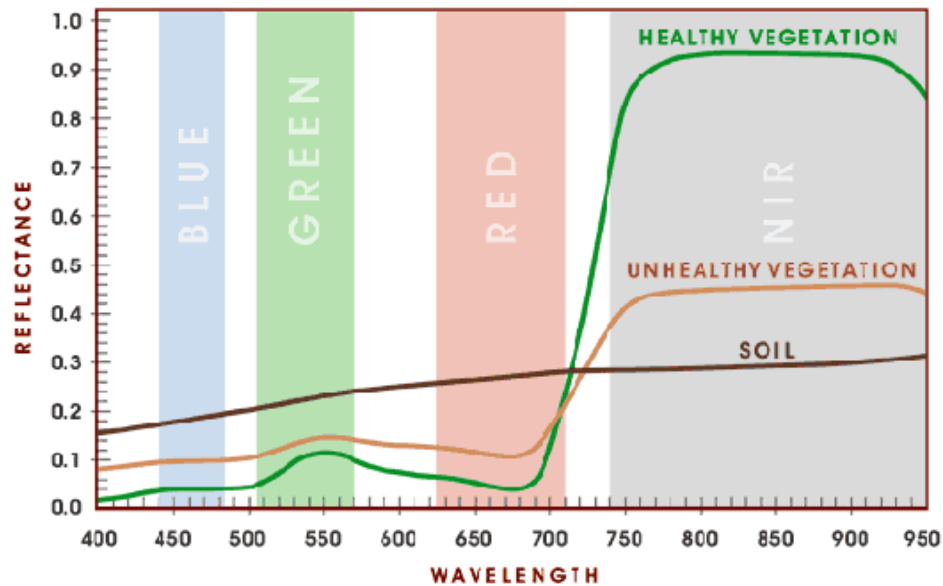
- Monitor vegetation condition using satellite derived data (Earth Observation data)
- Create and interpret maps and graphs of vegetation and rainfall conditions from EO data
- Understand how to analyze vegetation condition using the eStation system.
- Identify geographically areas of dry spells and vegetation stress at specific times

#### 2.1.1 Vegetation Indices

Vegetation indices are derived from multispectral or hyperspectral remotely sensed images to enhance the properties of vegetation thus helping to distinguish vegetation from the other features in the image. A Vegetation Index is a single unitless value calculated by combining different spectral bands of a satellite image using various algorithms to accentuate vegetation signal. Depending on the transformation algorithm and the spectral bands used, the resulting vegetation index will highlight different aspects of the vegetation in the image such as percentage of vegetation cover, amount of chlorophyll content, leaf area index and green biomass among others. Vegetation Indices (VI) exploit the differences in the amount of differing reflected radiation from plants across the electromagnetic spectrum. The reflection of radiation by



vegetation shows low values in the blue and red band, slightly higher values in the green band, very high values in the near infrared band, and low to high values in the shortwave infrared bands (depending on the wavelength). Very characteristic for the vegetation spectrum is the steep increase of reflectance from red to near infrared, the so called “red edge”.

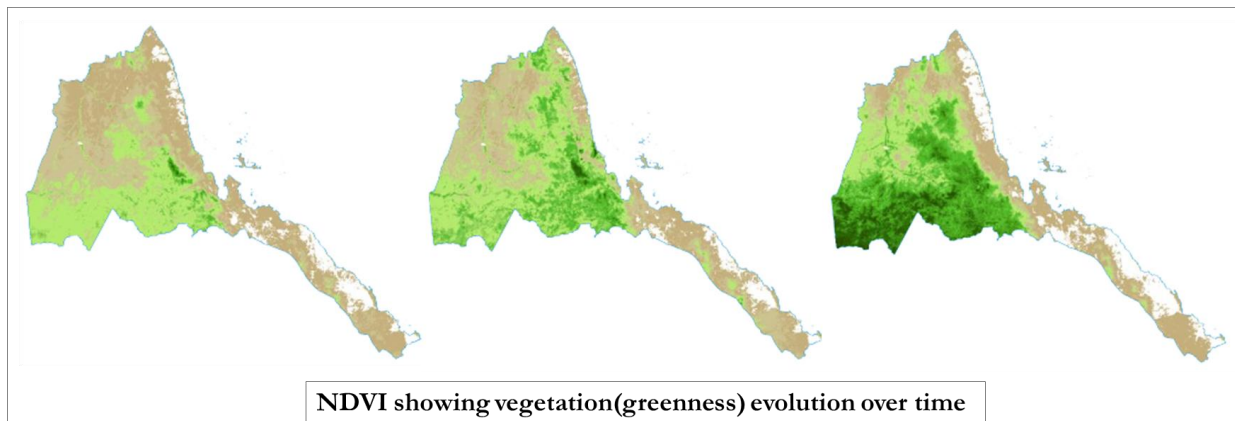


One of the most common vegetation indices is Normalized Difference Vegetation Index (NDVI) that exploits the “red edge”. NDVI is calculated from NIR and RED reflectance and NDWI from NIR and SWIR.

$$NDVI = \frac{(NIR - RED)}{NIR + RED}$$

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR}$$

Other common vegetation indicators include: Enhanced Vegetation Index (EVI), Soil Adjusted Vegetation Index (SAVI), and Vegetation Condition Index (VCI).



The eStation provides access to several vegetation indices among other products such as rainfall estimates, fire and temperature EO data. Vegetation Indices available on the eStation include:

- **NDVI** – Normalised Difference Vegetation Index, is an index of plant “greenness” or photosynthetic activity.
- **LAI** – Leaf Area Index is the total one-sided area of leaf tissue per unit ground surface area. LAI directly quantifies canopy structure, and can be used to predict primary productivity and crop growth
- **Fcover** - Fraction of green Vegetation Cover, corresponds to the fraction of ground covered by green vegetation. It quantifies the spatial extent of the vegetation. It is also a good indicator of the start of the growing season, and the time series can be used for year to year comparison of vegetation status for applications in agriculture and forestry among others.
- **fAPAR** - Fraction of Absorbed Photosynthetically Active Radiation. The FAPAR quantifies the fraction of the solar radiation absorbed by live leaves for the photosynthesis activity. Then, it refers only to the green and alive elements of the canopy.
- **VCI** - The Vegetation Condition Index (VCI) compares the current NDVI to the range of values observed in the same period in previous years. The VCI is expressed in % and gives an idea where the observed value is situated between the extreme values (minimum and maximum) in the previous years. Lower and higher values indicate bad and good vegetation state conditions, respectively.
- **DMP** – Dry matter Productivity (DMP) represents the overall growth rate or dry biomass increase of the vegetation and is directly related to ecosystem Net Primary Productivity (NPP), however with units customized for agro-statistical purposes (kg/ha/day).

Vegetation Indices are also available for download from the Copernicus website:

<https://land.copernicus.eu/global/themes/vegetation>

### Introduction to eStation 2.0

By the end of this section you will be able to:

- Install and set-up eStation on windows computer
- Get familiar with the eStation user interface
- Create rainfall, vegetation and fire maps on the eStation and download these maps for integration into reports or presentations
- Create rainfall, vegetation and fire analysis graphs on the eStation and download graphs in .PNG picture format for integration into reports or presentations.
- Download rainfall, vegetation and/or fire data of an area of interest in excel format for further analysis
- Interpret rainfall and vegetation maps to monitor the environment

The **eStation 2.0** is an Earth Observation processing system developed by the Joint Research Center (JRC) since the year 2009. The **eStation 2.0** is designed to automatically deal with acquisition, processing, visualization and analysis of key environmental parameters derived from remotely sensed data. The

measurements are, among others, obtained from the SPOT/PROBAV, SEVIRI/MSG, TERRA-AQUA/MODIS and Copernicus Sentinel 2 and 3 Earth Observation satellites.

The eStation has been distributed to the Regional and National Centers in all sub-Saharan African countries involved in the MESA project and is being further developed and customized for the beneficiaries of the GMES & Africa support program.

In addition to the MESA stations, eStation is now available in two other formats:

- eStation for Windows – that can be installed on any computer running Windows Operating System
- Online eStation available at <https://estation.jrc.ec.europa.eu/eStation2/>

In this training we will use the windows version. The eStation 2.0 for Windows Operating System can be downloaded at <https://estation.jrc.ec.europa.eu/webclients>. The installation manual is also available on the same page.

To proceed with the exercises on this workshop you need the following

- i) eStationSetup-Full-2.1.2.exe
- ii) eStation 2.0 Installation Manual Windows
- iii) Earth Observation data available on the disk distributed during the workshop.

#### Downloading the eStation 2.0

eStation 2.0 can be downloaded from the JRC website at <https://estation.jrc.ec.europa.eu/webclients>. On this website page, there are two options of the software: i) full version with *vector* layers ii) light version without *vector*. Vector layers are shapefiles (GIS files) of various boundaries such as country, province, district, protected area etc.

- Download one of the versions it is recommended to download the *full version*
- Download the *installation manual*

#### Installing the eStation 2.0

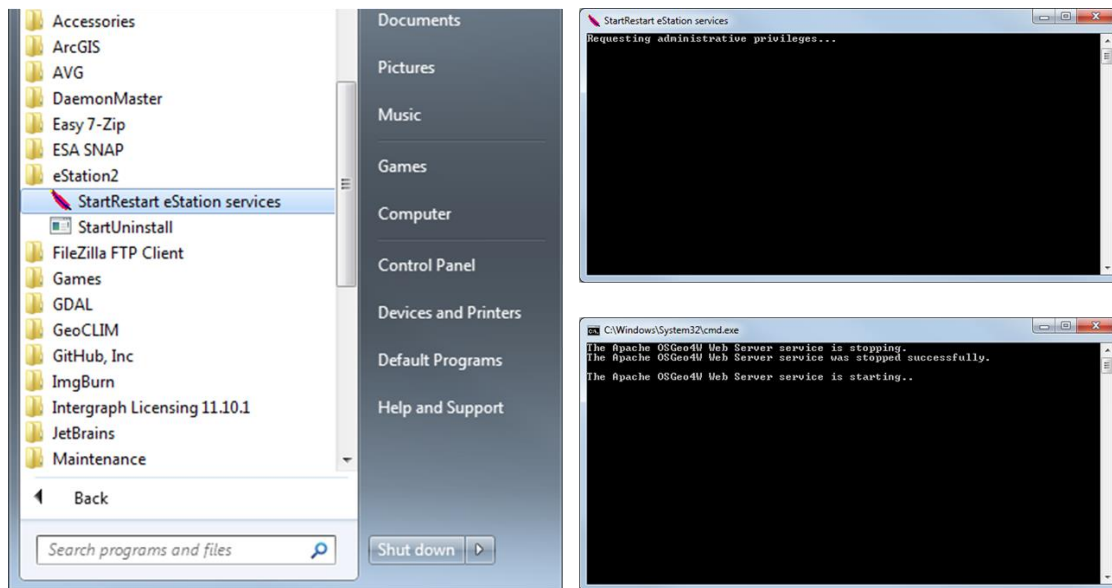
Copy the eStationSetup-Full-2.1.2.exe onto your computer

Follow the instructions in the installation manual (also available as an Annex in this document)

#### 2.1.2 Launching eStation 2.0

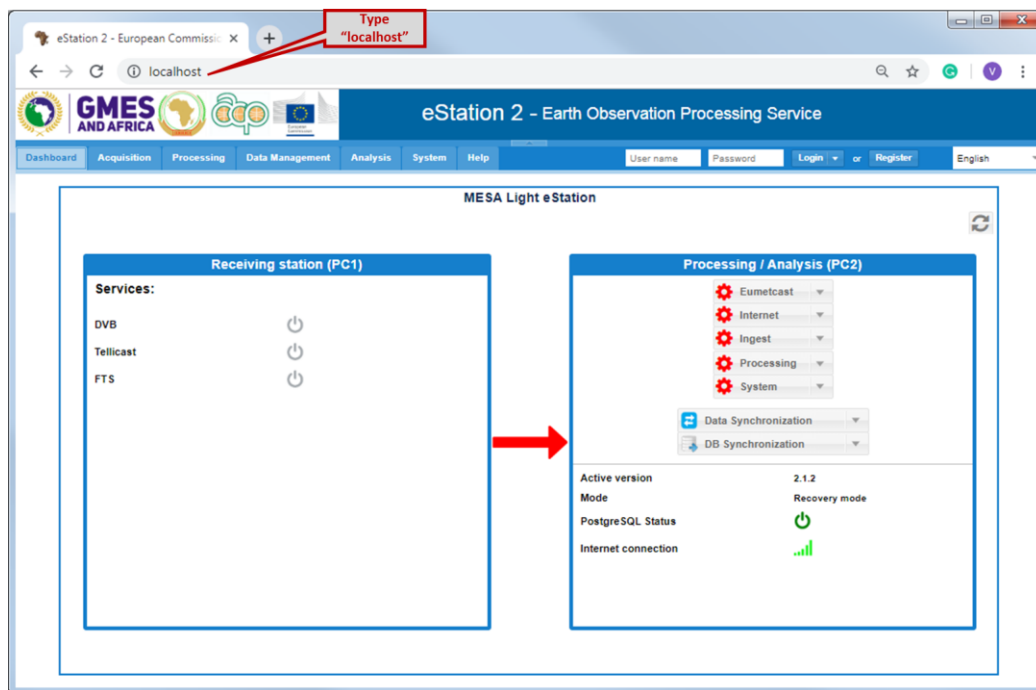
To start the eStation 2.0 after a successful installation.

- Go to *Start > All Programs > eStation2 >*
- Click *StartRestart eStation Services* to start the eStation services

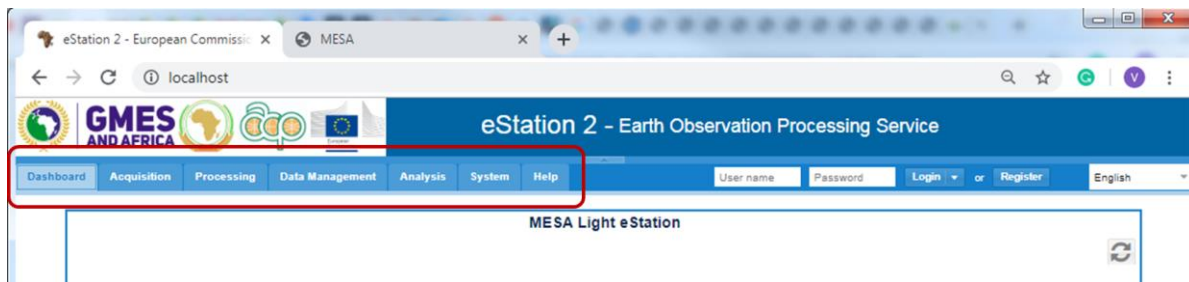


A screen with command prompt as shown on the upper right will appear

- **Click** Yes on the pop-up screen asking if you would like to allow the program to make changes to your computer, the second command prompt window on the lower right will appear, it will stop and restart Apache.
- Open a browser (firefox or chrome) and in the url bar type *localhost*, this will start the eStation interface like below



The eStation 2.0 interface on localhost has 7 tabs as below:

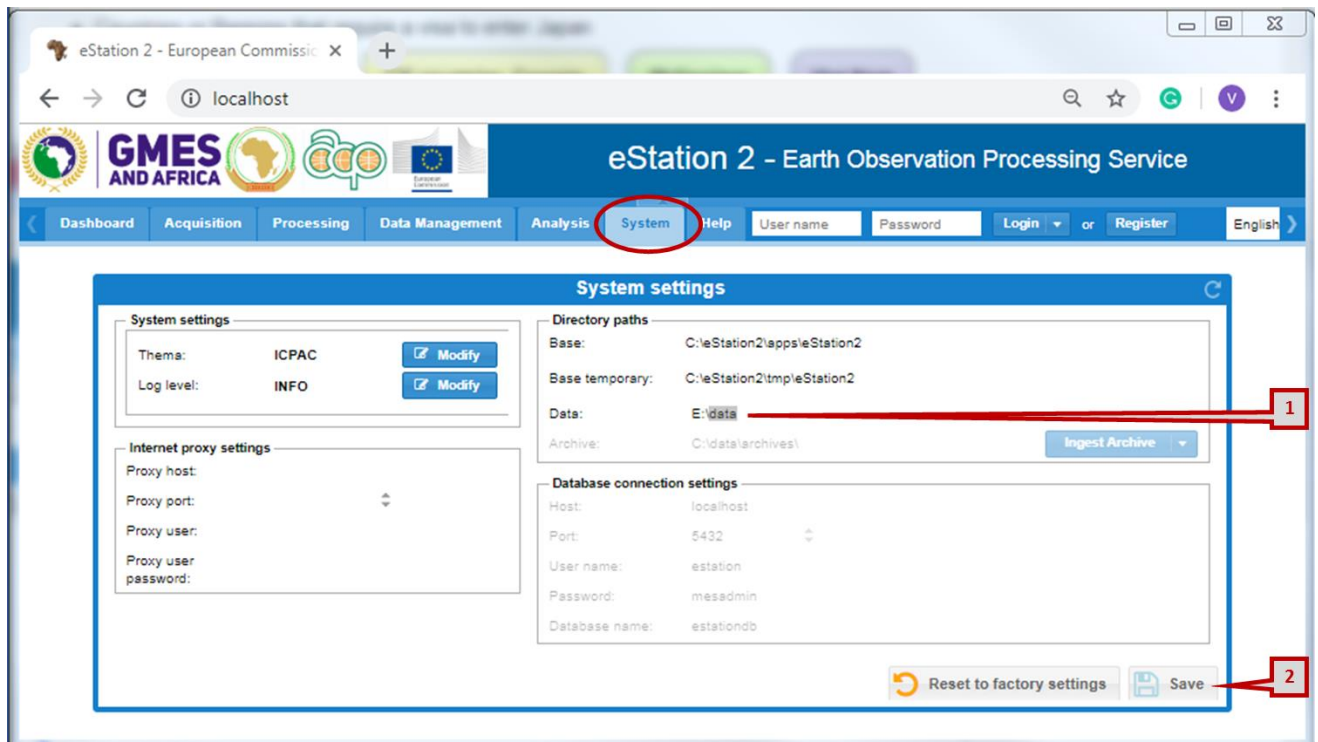


- **Dashboard:** Presents the overall status of the MESA Station, and allows user to control all the enabled services.
- **Acquisition:** To view and control the status of the services for retrieving and ingesting the EO data.
- **Processing:** to start and stop the processing of new products, e.g. to control the 'Processing' Service.
- **Data Management:** lists available data sets, both those acquired and processed by the eStation 2, allows user to generate list of missing data and to download the missing data to ensure completeness of the time series.
- **Analysis:** to perform the data analysis and generate maps and graphs for bulletins/reports.
- **System:** to control the application settings (Thema region, log level, and working directories paths), and to generate system reports.
- **Help:** allows the user to download the help files in pdf and to access reference web sites. Currently four pdf files are available: i) User Manual ii) Administration Manual iii) Installation Manual iv) Product report that lists and describes all the data available in the MESA station.

### 2.1.3 Set directory path of the data

**Important:** Before starting work on the eStation for windows version you have to set the path to the folder containing the data. This is done on the *Systems tab*

- Go to *Systems tab* >
- Change the path of Data to reflect the path to where you copied you data. **NB:** It is recommended to keep the directory name as "data" and to maintain the directory structure of the data.
- Then Click *Save* to save the new settings



### 2.1.3.1 Register and Login

It is recommended to register and then to work while logged in. These allows you to save your work as a workspace, this way if you stop working on the eStation you can continue from where you left.

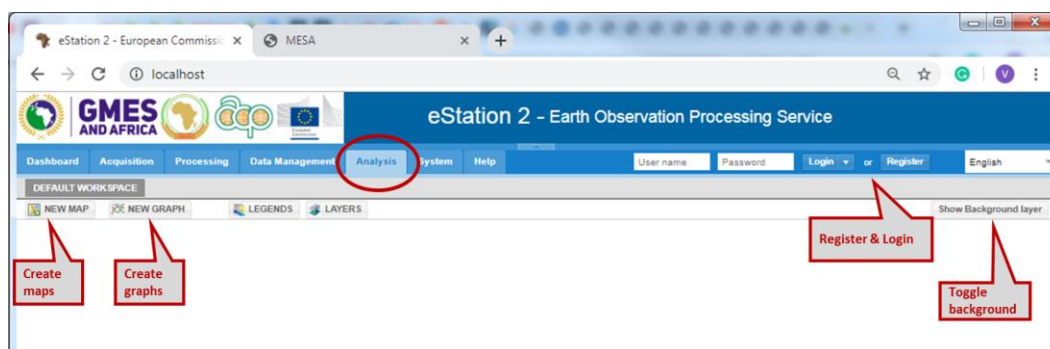
- Click *Register*
- Enter *full name*, *username* and *password* and click *Submit*
- Once you have successfully registered, use your username and password to *Login*

Note: It is possible to create maps and graphs without logging in however, once you shut down the eStation you will not be able to save your work

### 2.1.4 Create maps and graphs of vegetation and rainfall

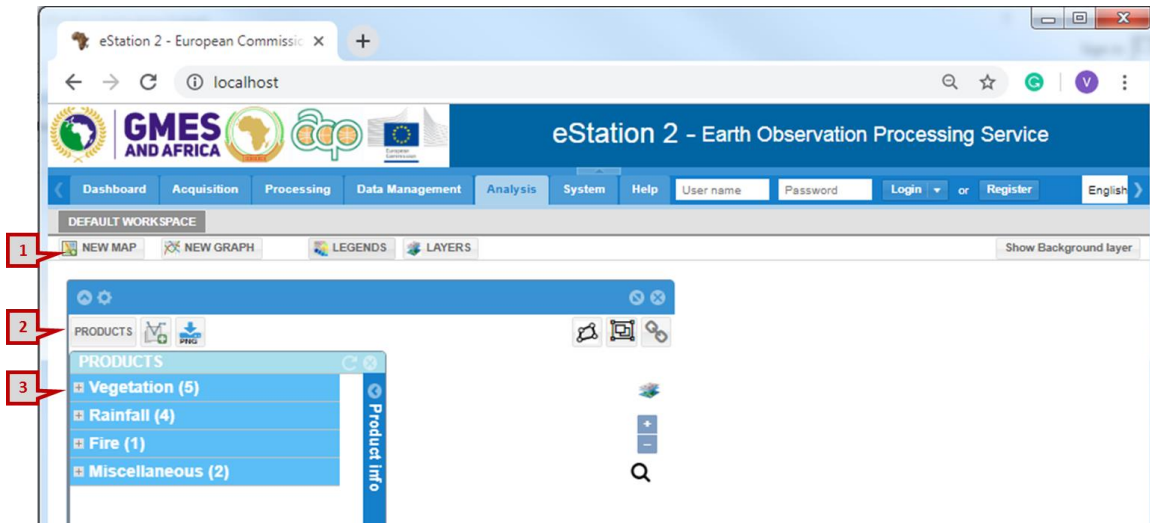
The eStation 2.0 has 7 tabs. To visualize the data as maps or graphs, we use the **Analysis** tab.

Overview of **Analysis** tab



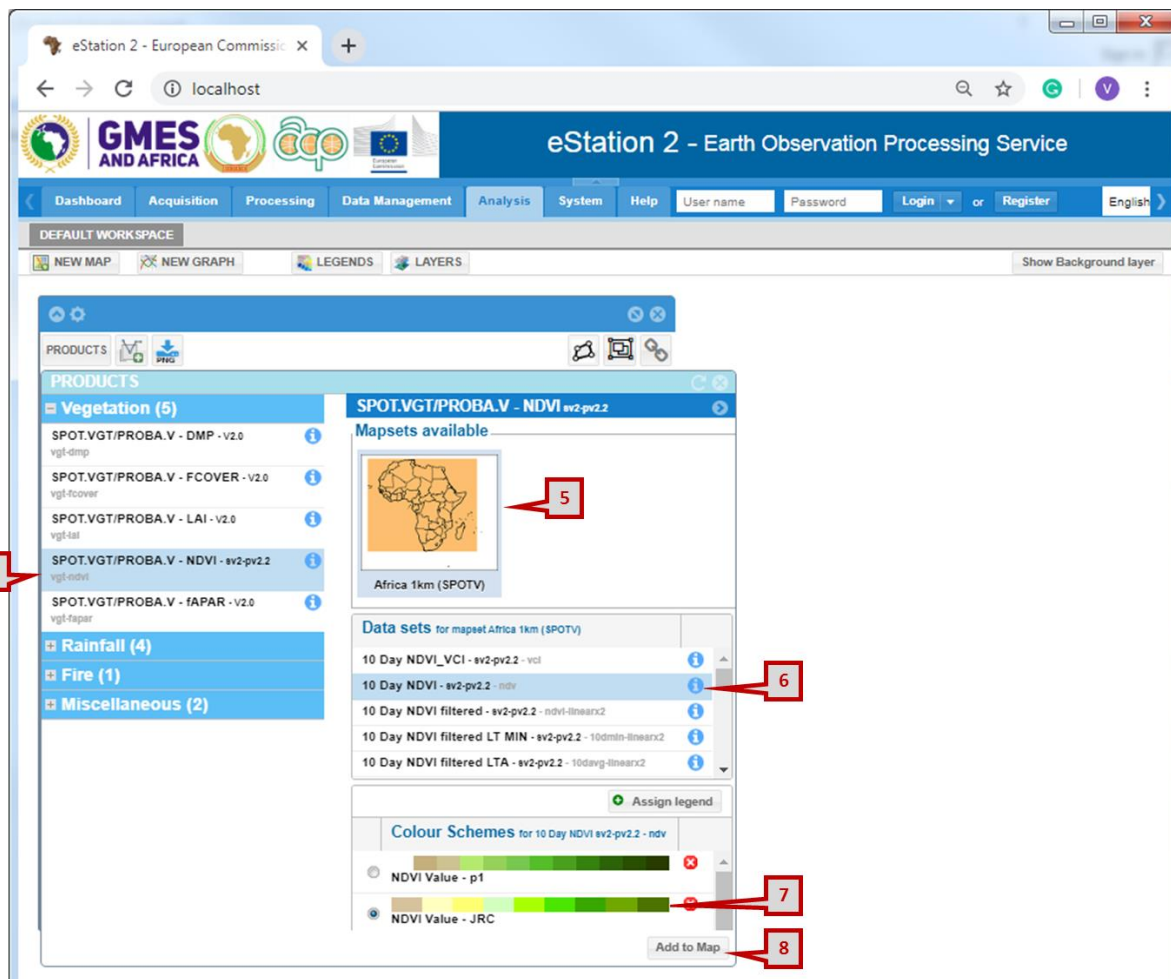
### 2.1.5 Create NDVI Maps

1. **Click** *New Map*
2. **Click** *Products*: this displays the list of data available on the eStation grouped by categories i.e. vegetation, rainfall, fire and miscellaneous NB: if the product list is empty, it means the path to the data is not set. Check under *Systems* tab that the directory path for *Data* is correct i.e. points to the location of the data and that the top directory is named *data/*
3. **Click** on *Vegetation* to expand the list and show the list of available vegetation products; DMP, FCOVER, LAI, NDVI and fAPAR



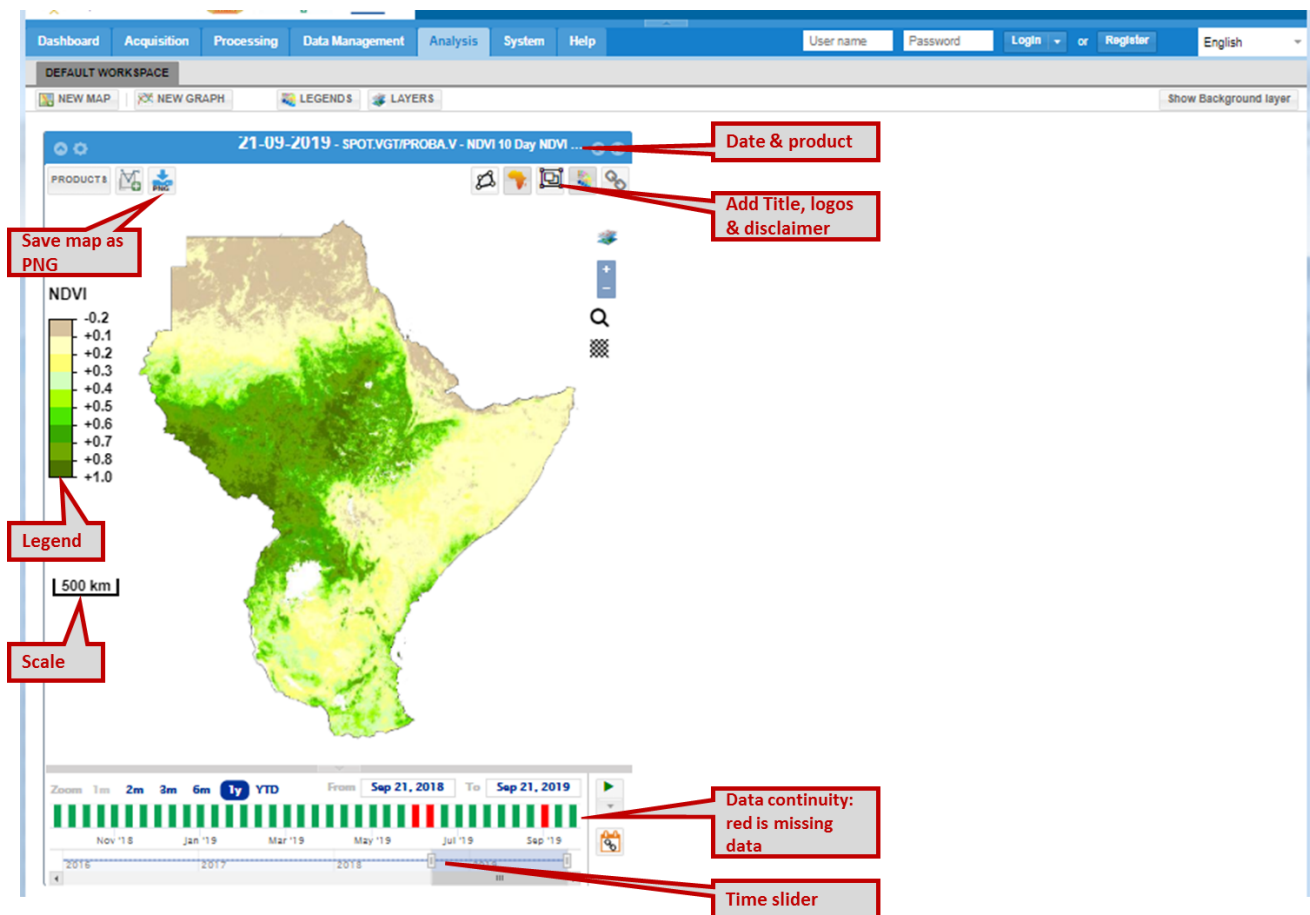
4. **Select** *NDVI*
5. **Select** a *Mapset* on the right this will open the list of sub-products
6. **Select** *10 Day ndvi*
7. **Select** the *legend* to apply, go with the default ndvi value JRC
8. **Click** *Add Map*





The NDVI map will display in the map area as below





### 2.1.5.1 Download map as picture image

eStation 2.0 allows users to download the maps as .png to be used in reports or presentations.

To download the NDVI map as a .png:


- **Click** on the button written *PNG* on the top left of the map viewer labelled as “save map as PNG”
- **Select** the *folder* to save the png. In this case save in flash\_disk:/eStation/outputs/
- It's optional to change the name of the file, it is recommended to use the default file name especially if you will be saving several images as the default naming takes into account the region, data type and date.
- **Click** *Save*

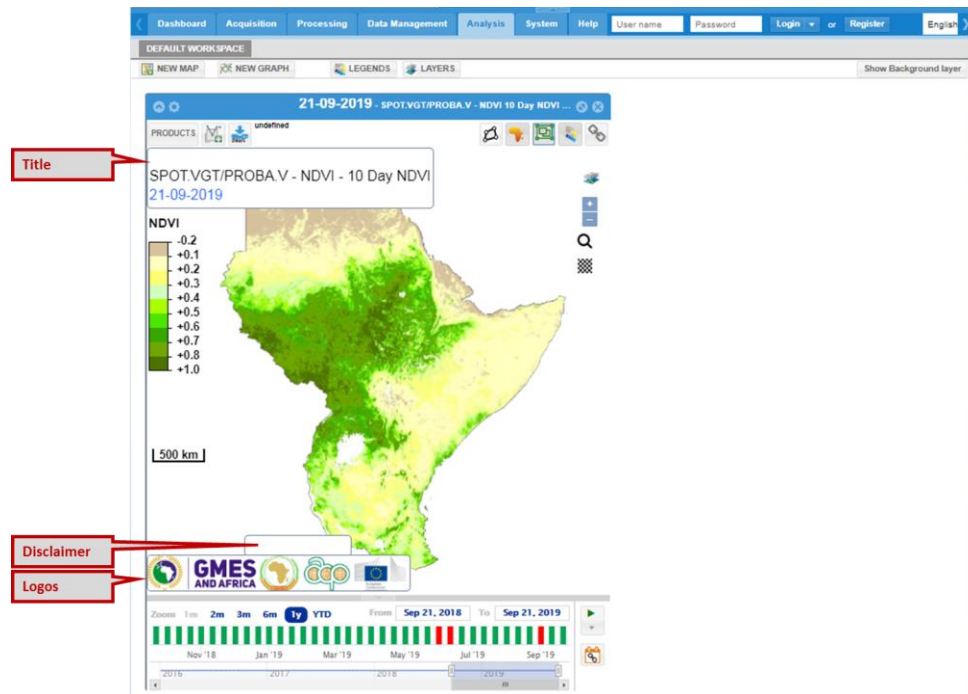
Navigate to the folder where you just saved the image. You should find the file:

*10 Day NDVI sv2-pv2.2 SPOTV-Africa-1km 20190921.png*

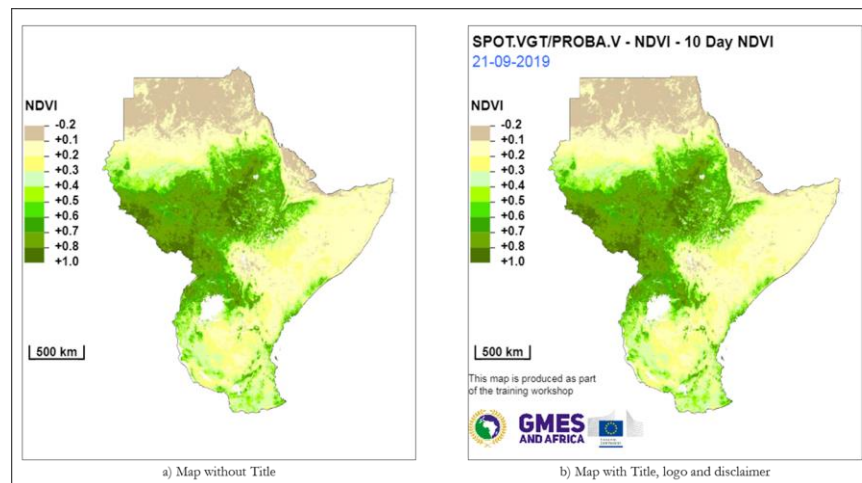
### 2.1.5.2 Add Title and Logo to Map

To make the map more understandable to users you can add a Title, relevant logos and a disclaimer.

- Click the add title button  on the top right of the map viewer as shown on the figure



- To move the position of either of the three items; title, logo or disclaimer Click and Drag to new position
- To edit any of the three items, double click on one at a time to enter edit mode




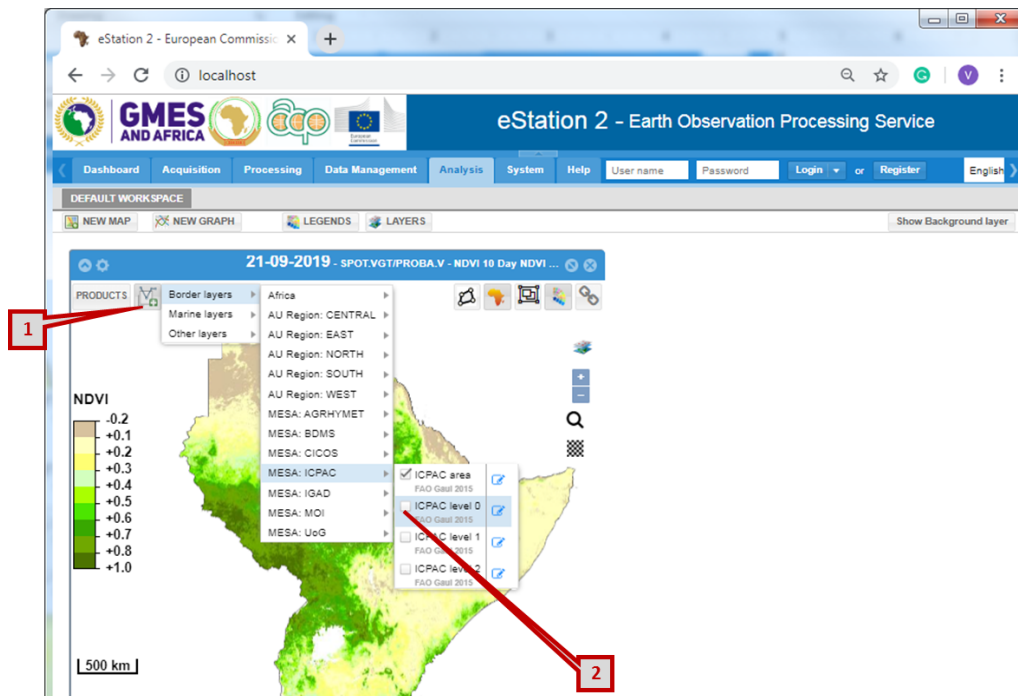
### 2.1.5.3 Add Country Boundary

**eStation 2.0** comes pre-loaded with several boundary data referred to as *Layers*. The Layers are divided into categories i) Borders Layer, ii) Marine Layers and iii) Other Layers.


The Administrative boundaries layers are from FAO-GAUL (Global Administrative Units Level) dataset. The first level corresponds to a region i.e. East, West, North Africa etc. Level-0 data corresponds to Country boundaries, Level -1 corresponds to Province or Region in a Country, and Level-2 corresponds to smaller administrative units like Districts. For Eritrea, Level-1 correspond to Zoba boundaries and Level-2 corresponds to sub-Zoba boundaries.

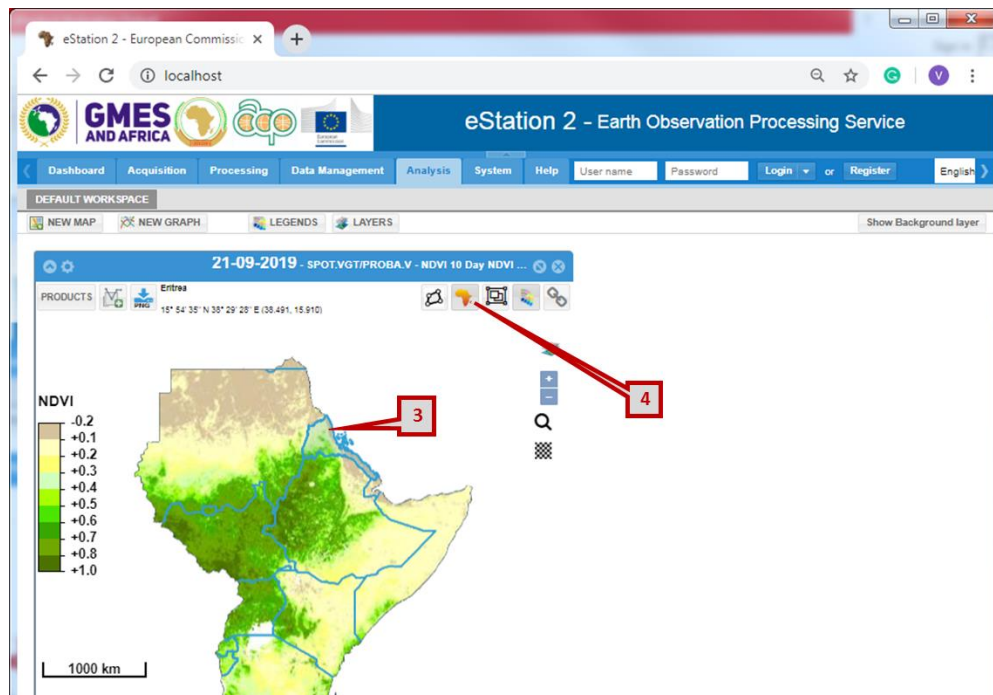
To add any boundary as an overlay on the map:

1. Click on the *Open a Vector Layer* icon  on the top left of the map viewer window
2. Select *Border Layers > AU-Region: EAST > Click ICPAC level-0* to select it and add the boundary of ICPAC to the map

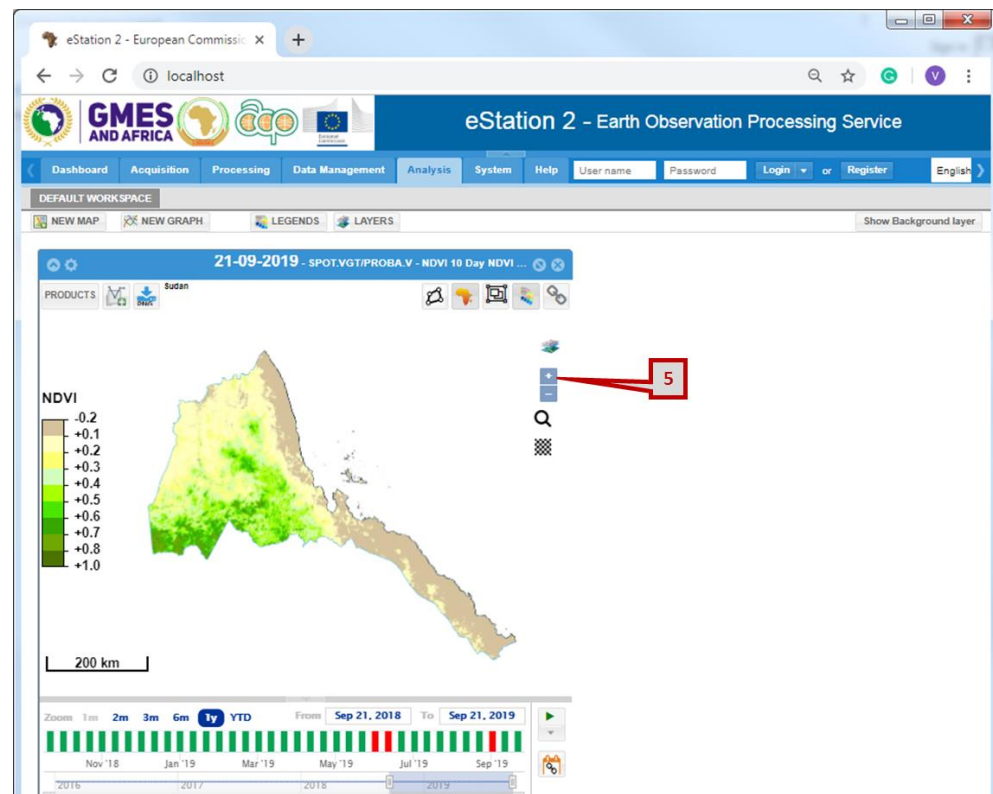


The map shows data for either the whole of Africa or ICPAC region based on the *Mapset* selected when creating the map. It is possible to zoom to a specific region (polygon) and through the outmask process mask out the areas that are not of interest. To show only the map of Eritrea

3. On the map, click anywhere within Eritrea to select the boundary of Eritrea
4. To show only data for Eritrea, we will use the *Outmask* button. Click the *Outmask* button  on the top right of the map-viewer window

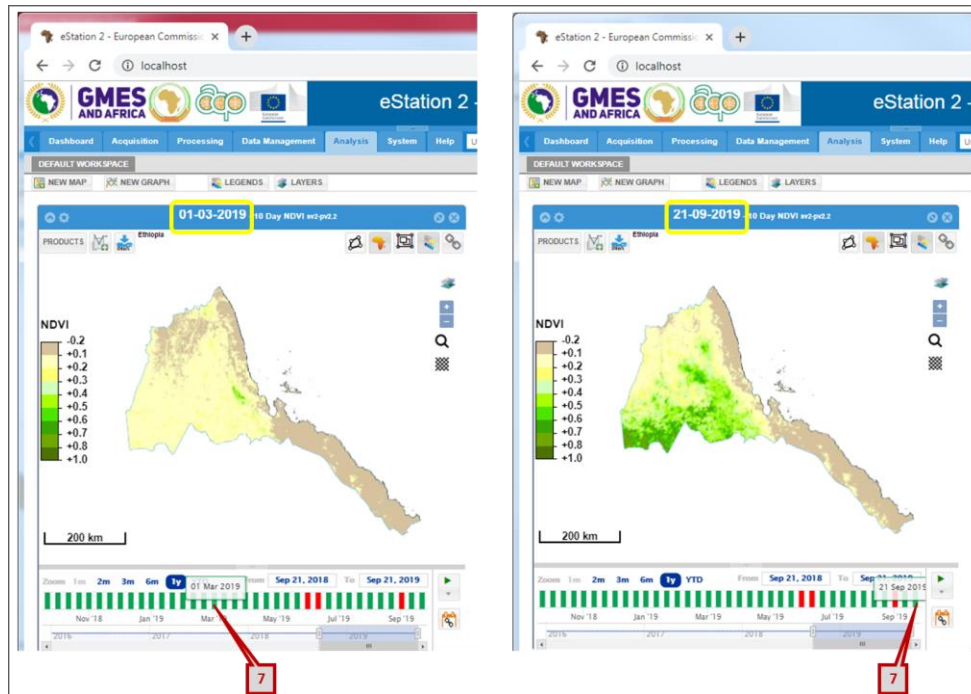


5. **Click** the **Zoom in** button to zoom into the map
6. To **Center** the map over Eritrea, **click** inside Eritrea hold and move the map to the center.



By default the map displays the latest data available, in this case the latest NDVI data available is of the last dekad of September 2019 (21-09-2019). **eStation 2.0** allows you to navigate the available time series using the time bar at the bottom of the map viewer.

- To display the map of a different date use the “time bar” at the bottom of the map viewer; Placing the cursor on the green bars, a pop up displays the date, clicking on the green bar will change the map to display the NDVI of the selected date.



### Exercise 1:

- Create monthly NDVI maps of Eritrea for the past 12 months to show the evolution of NDVI over time. Organise these maps into a powerpoint slide.
- Following the above steps, create monthly rainfall estimate maps of Eritrea for the past 12 months. Use Chirps rainfall data, organise the maps into a powerpoint slide to show evolution.
- Create a monthly rainfall map for Debub Zoba for September 2018. The map should include a title, and relevant set of logos, sub-Zoba boundaries

### 2.1.6 Create Graphs

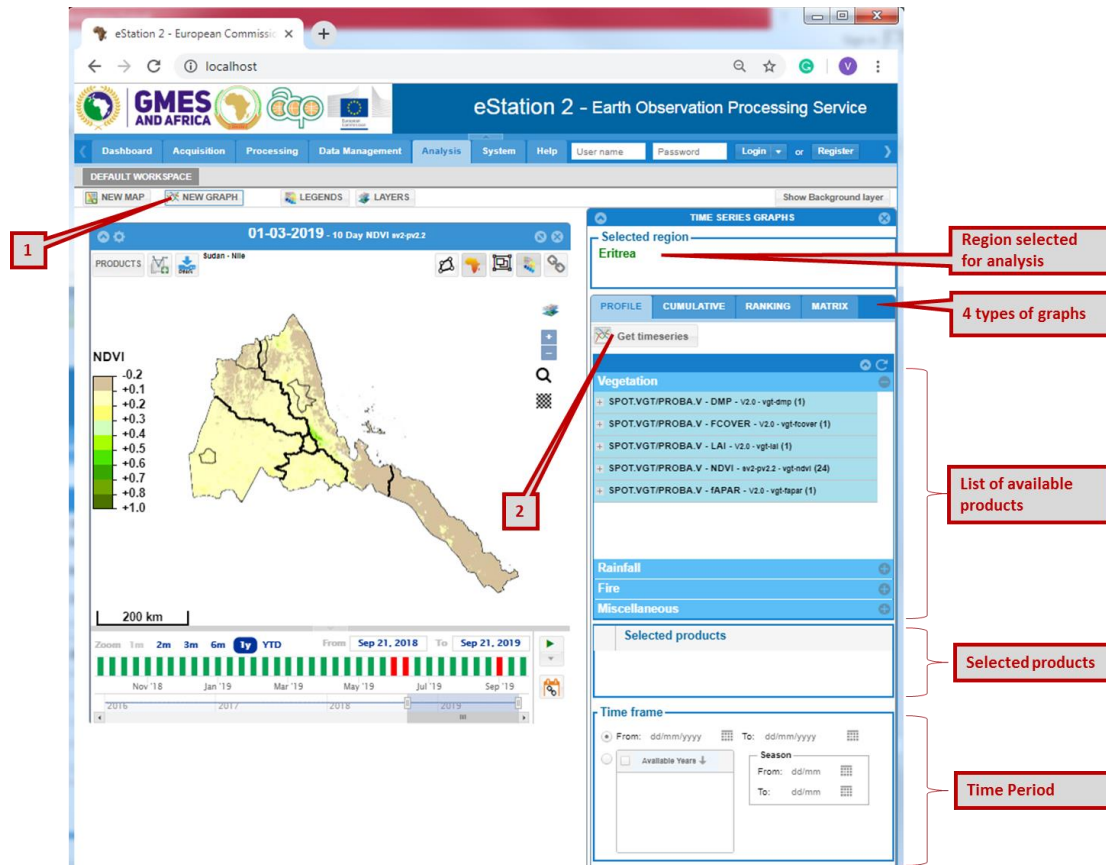
Graphs are important in understanding trends over time. **eStation 2.0** provides 4 different types of graphs.

**eStation 2.0** creates graphs by aggregating pixel values over a region i.e. on a polygon. Below are the four types of graphs available in eStation 2.0.

- Profile
- Cumulative
- Ranking
- Matrix

There are five steps for creating any of the above graphs

- Step 1: Select the area/region to perform the analysis
- Step 2: Select the type of graph (profile, cumulative, ranking, matrix)
- Step 3: Select the data products you want to analyse
- Step 4: Select the time period
- Step 5: Generate the time series graph

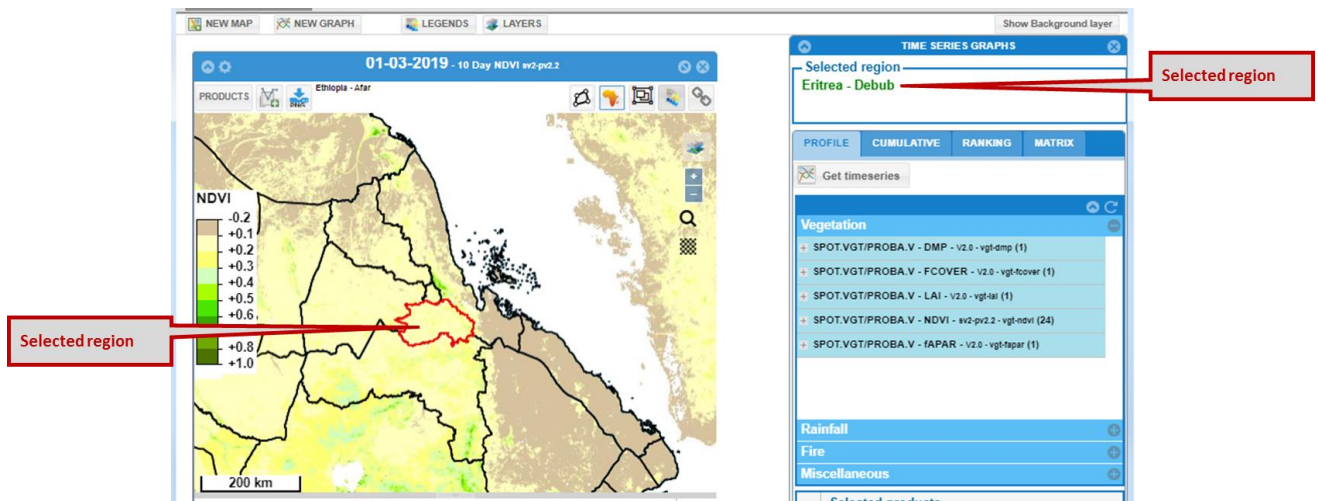


### 2.1.7 Create a rainfall and NDVI graph (profile graph)

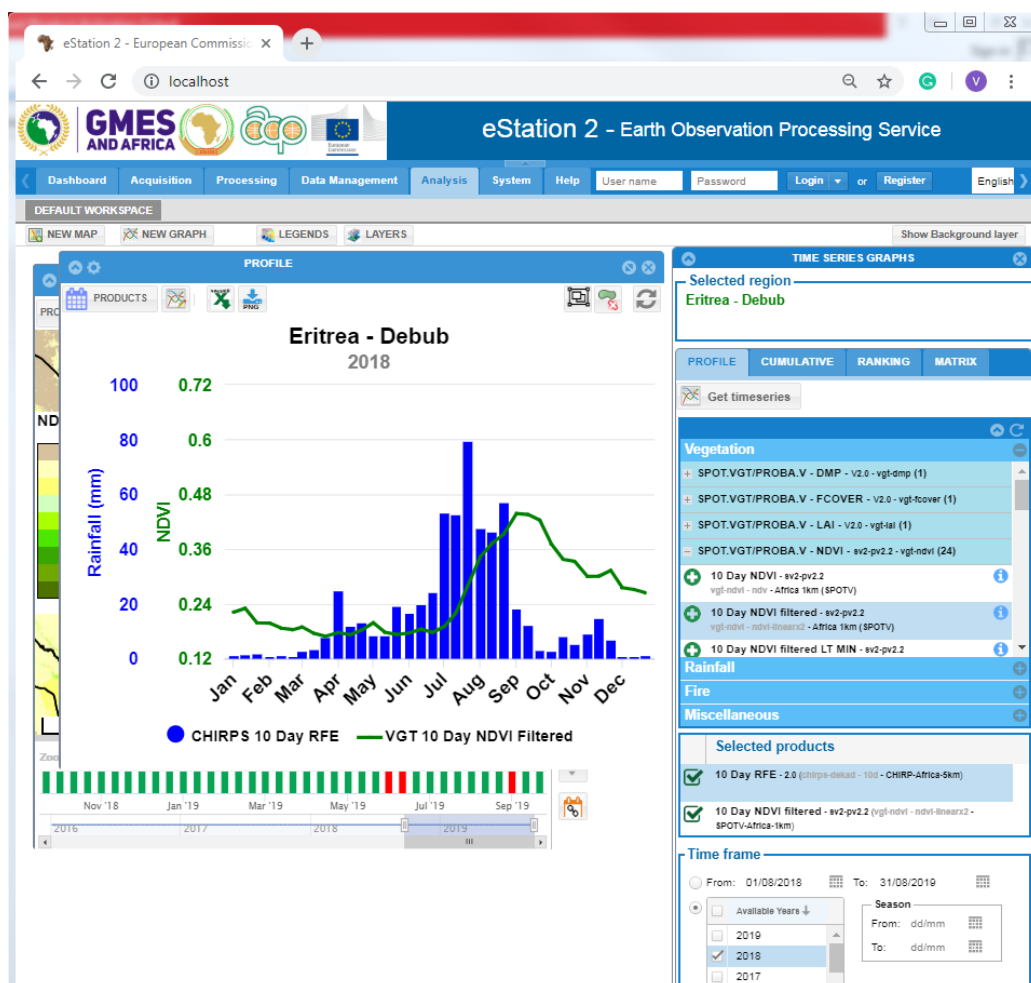
Profile graphs are temporal graphs showing how rainfall or NDVI behave during a specific season or over time. Graphs combining rainfall and NDVI are particularly useful for early warning purposes. Combined graphs show possible stress situations and indicate whether evidence from both independent data sources regarding such situations converges. To create a graph:

- **Click NEW GRAPH** button to open the graph window
- Select the area of interest in this case Debub Zoba; to select the place you map over *Debub Zoba* and click to select
- The selected region is highlighted in red on the map and shown on the graph window as below

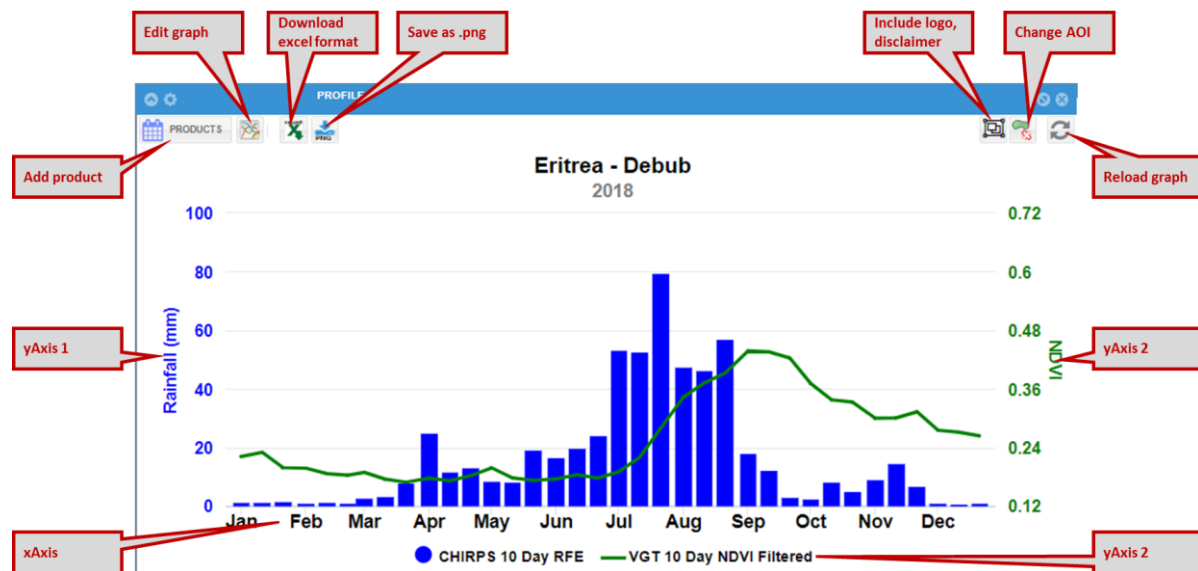




- Select rainfall data (Chirps 10 day RFE) and NDVI data (10 day filtered NDVI) from the product list (The order of selecting the products affects the position of the graph elements for example if you select NDVI first the NDVI line graph will appear behind the bar)
- Select the time as 2018
- Click *Get Timeseries* to generate the graph



## Overview of the graph viewer interface



### 2.1.7.1 Edit Graph Properties

To edit the graph properties for example change the color of the bars/lines, the minimum and maximum values of the Y-axis, use the Edit graph properties.

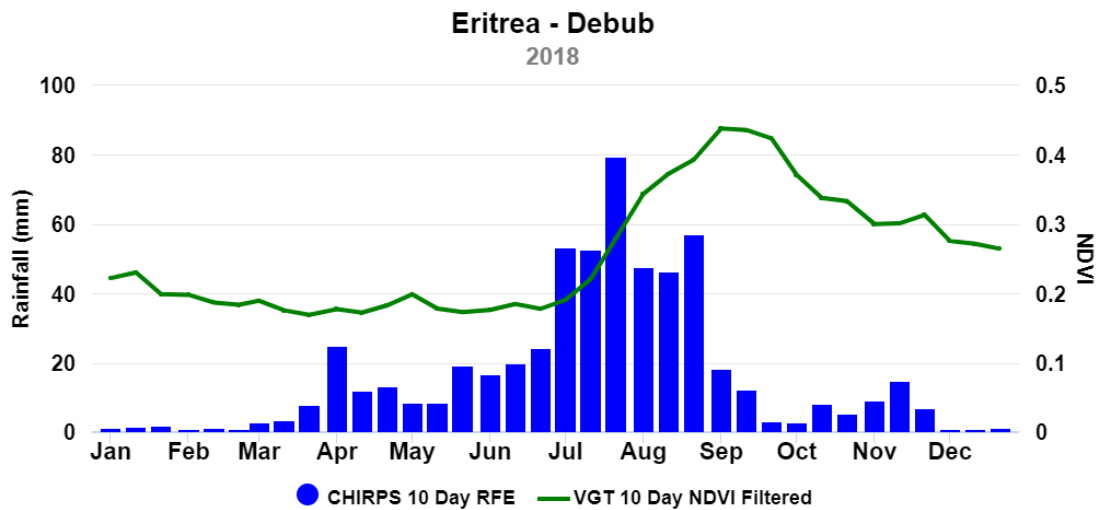
- Click the *Edit graph properties*  on the top left of the graph viewer.



- On the graph the two axes for NDVI and Rainfall both appear on the left side. To move one of the axes to the right, edit the property *yAxis Opposite* = false change it to True
- Edit the minimum and maximum value of NDVI axes by changing the following properties in the graph properties editor
  - yAxis 1 min = 0




- yAxe 1 max = 0.5
- Save the graph as **.png** in the folder output directory



#### 2.1.7.2 Download data for a region in tabular format (excel format)

Once you have created the graph it is possible to download the data in excel format

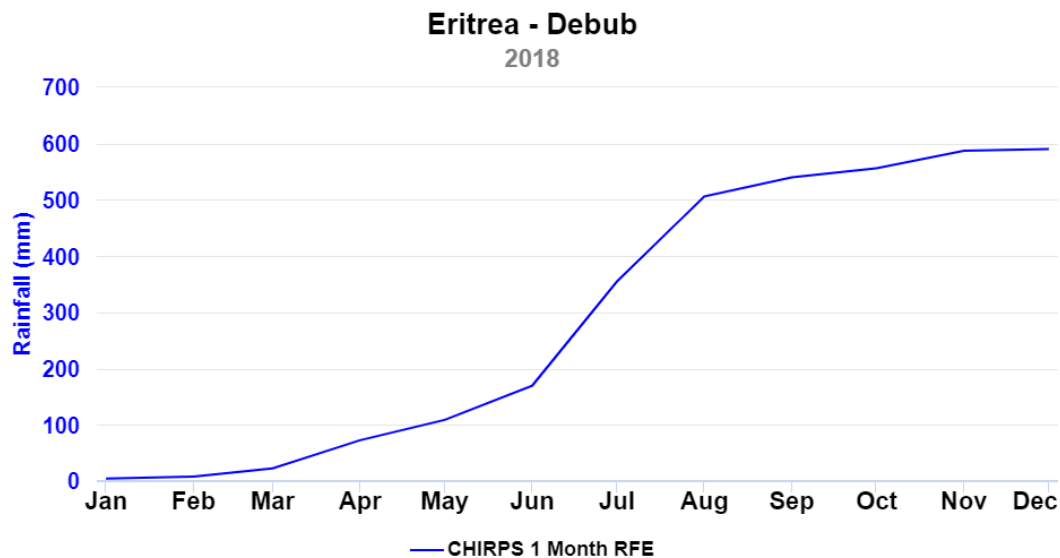
- **Click** the *Download Time Series*  on the top left of the graph viewer
- Select the folder to save the tabular data
- **Click** Save
- The file is saved in .xls, open the file using excel
- The file will contain a column for the date and columns for the selected data i.e. for the graph above it will contain date, Chirp rainfall and NDVI.

NDVI\_Rainfall\_PRC

	A	B	C	D	E
1	DateTime	CHIRPS 10 Day RFE	VGT 10 Day NDVI Filtered		
2	1/1/2018 0:00	1.37	0.22		
3	1/11/2018 0:00	1.46	0.23		
4	1/21/2018 0:00	1.79	0.20		
5	2/1/2018 0:00	1.08	0.20		
6	2/11/2018 0:00	1.35	0.19		
7	2/21/2018 0:00	1.07	0.18		
8	3/1/2018 0:00	2.76	0.19		
9	3/11/2018 0:00	3.60	0.18		
10	3/21/2018 0:00	8.03	0.17		
11	4/1/2018 0:00	25.05	0.18		
12	4/11/2018 0:00	11.89	0.17		
13	4/21/2018 0:00	13.21	0.18		
14	5/1/2018 0:00	8.51	0.20		
15	5/11/2018 0:00	8.37	0.18		
16	5/21/2018 0:00	19.38	0.17		
17	6/1/2018 0:00	16.62	0.18		
18	6/11/2018 0:00	19.77	0.18		
19	6/21/2018 0:00	24.17	0.18		

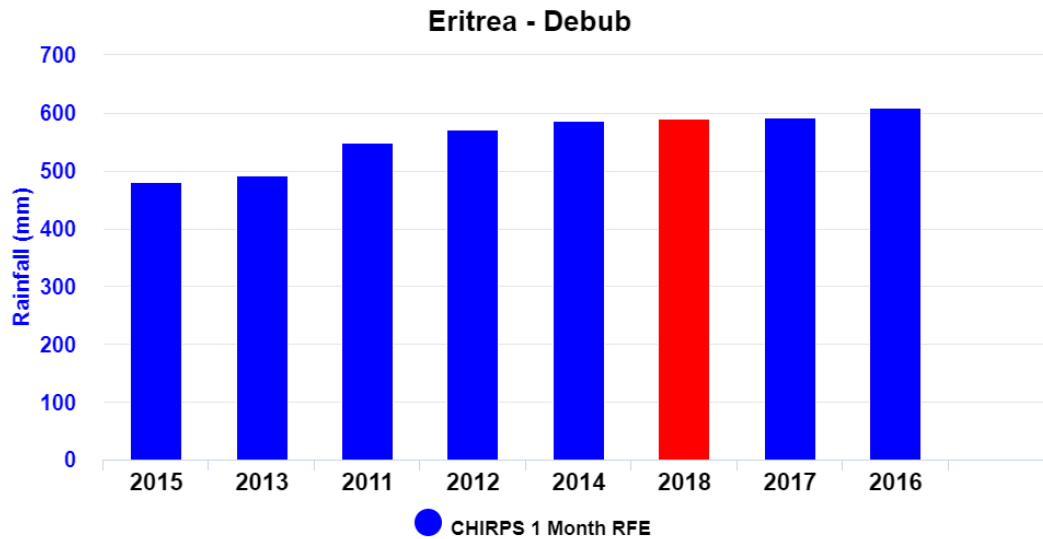
### 2.1.8 Create a cumulative graph

The Cumulative Graph computes for the selected region the cumulative amount of rainfall (or NDVI) over time



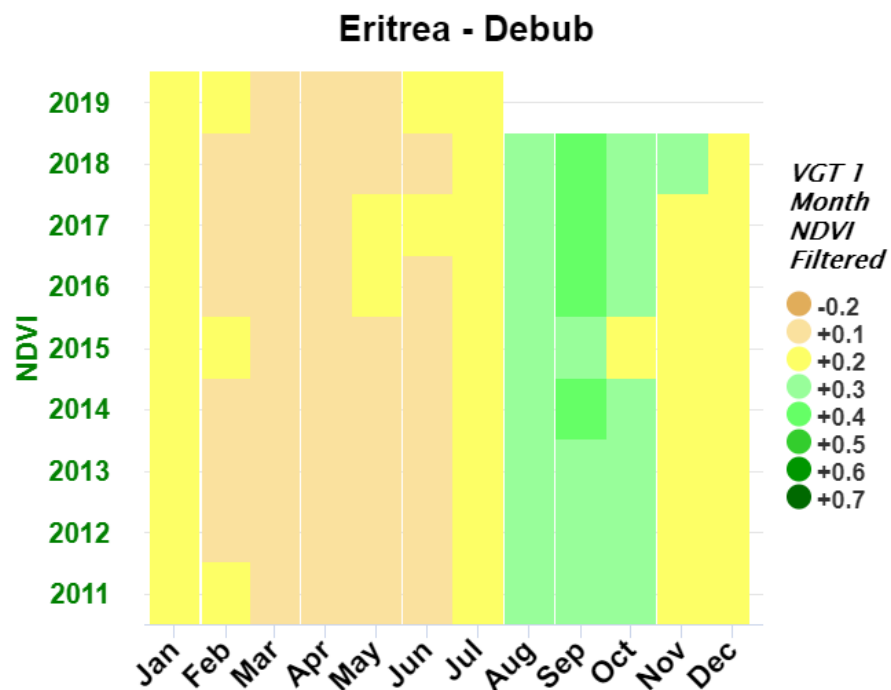
### 2.1.9 Create a ranking graph of rainfall

The ranking graph calculates the total of the indicator (rainfall, ndvi, dmp) per year for the years selected and ranks years from the least to the highest as below.



### 2.1.10 Matrix Graph

The matrix graph shows spatial visual representation of an indicator over selected years. The graph is useful in identifying patterns over time.



#### Exercise 2:

- Create a profile graph of Rainfall and DMP over Anseba for the year 2018
  - Identify the rainy season from the graph
- Create a cumulative graph of DMP over Anseba Zoba for the year 2016.

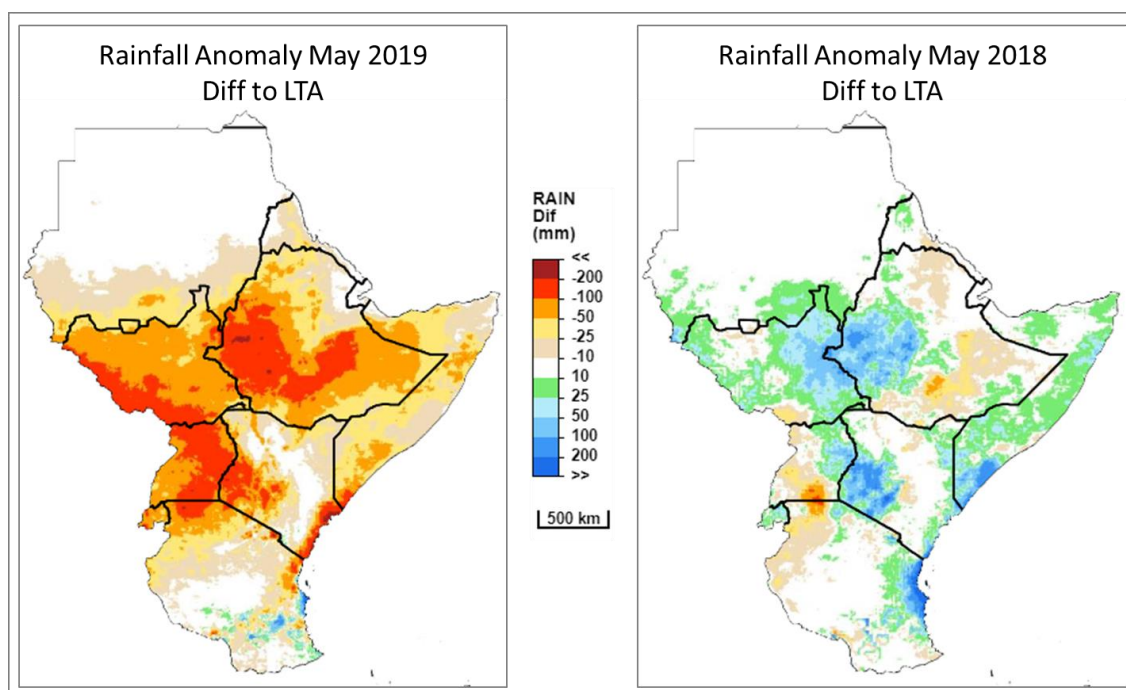
- Create a Ranking graph of Rainfall over Anseba Zoba for the period 2014 – 2018
  - Identify the year with the least amount of rainfall and the year with most amount of rainfall

### 2.1.11 Rainfall and Vegetation Anomalies

**An Anomaly** is a deviation from normal behavior. Rainfall and NDVI anomalies can be represented in maps, which identify how and where rainfall and vegetation development are different from normal. The current conditions can be below or above normal conditions:

- **Below-normal** conditions relate to drought (water stress) conditions. These may have implications for crop yields and pasture availability, potentially affecting human lives and livelihoods.
- **Above-normal** conditions could imply good vegetation development, but in the case of rainfall could also relate to problems like flooding. Therefore it is good to look at more indicators, i.e. not only at rainfall. Rainfall is a necessary condition for crop development, while vegetation indices observe actual vegetation growth.

The following maps show the rainfall anomaly maps of the same period (May) in 2018 and in 2019, from the maps, the rainfall estimates in May 2019 were below normal for most of the Eastern Africa region while for the same period the previous year (May 2018), the rainfall estimates were above-normal for most of the region



The **MESA stations** contains the following statistics for the various data i.e. for vegetation, rainfall and temperature.

- Long term average (**LTA**):- for each pixel multi-years average of the available time series
- Long term minimum:- for each pixel multi-years minimum value of the available time series

- Long term maximum:- for each pixel multi-years maximum value of the available time series data

The station has anomalies computed as relative and absolute differences for each data i.e. vegetation, rainfall, temperature. The anomalies are available at two timescales; dekadal (10ddiff), monthly(1mondiff).

- Absolute:- simple difference between current and long term average
  - dekad anomaly **10ddiff**= (10d – 10davg) and
  - monthly anomaly **1mondiff**=(1monndvi – 1monavg)
- Relative:- the difference between current and long term average is expressed as a percentage of the long term average
  - dekad anomaly in percentage = (10d-10davg)/10davg
  - monthly anomaly **1mondiff**=(1monndvi – 1monavg)/1monavg

In this section we will use NDVI and Rainfall anomaly maps and graphs to identify geographic locations of dry spells and vegetation stress at specific times during the crop season.

### 2.1.12 Create Rainfall and NDVI anomaly map over Eritrea

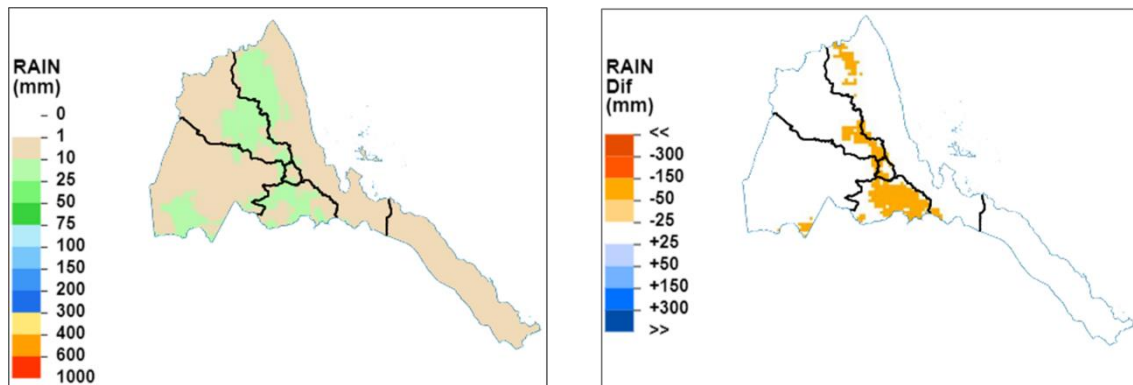
The process to create an anomaly map is similar to the process explained above except for selecting the right anomaly data.

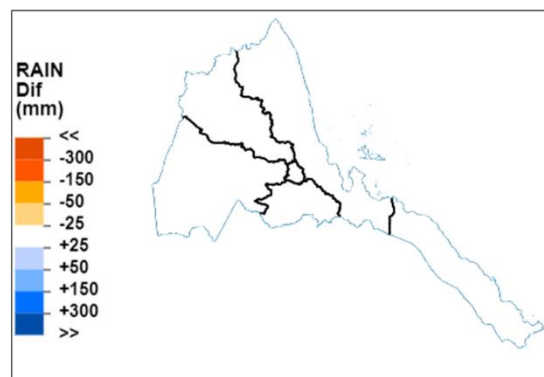
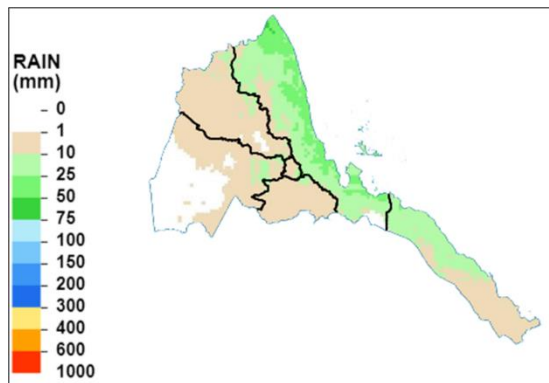
To create rainfall anomaly map:

- **Click New Map**
- **Click PRODUCTS > Rainfall > Chirps RFE >**
- **Select 1 Mon Diff to LTA**
- **Outmask** to show only Eritrea
- Add the following **Vector Layers**; Country Boundary and Zoba boundary

The maps below show the monthly rainfall for 1<sup>st</sup> dekad of May 2019 (left) and the monthly rainfall anomaly map of the same period 1<sup>st</sup> dekad of May 2019 (right).

NB: While there was rainfall recorded for May 2019, compared to the normal, for most of the areas with rainfall the rainfall recorded was between 50 -100mm **below normal**. However, for 1<sup>st</sup> Dekad of January 2019, the amount of rainfall received is similar to the normal and therefore the anomaly map does not show any areas either below or above the normal.





To create NDVI anomaly maps

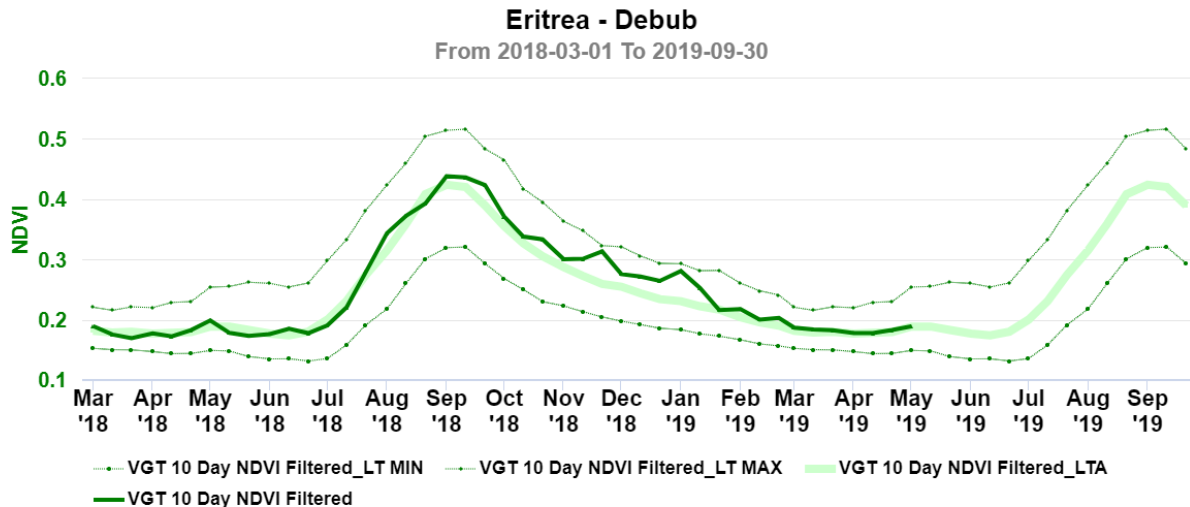
- **Click** *New Map*
- **Click** *PRODUCTS > Vegetation > NDVI >*
- **Select** *1 Mon Diff to LTA*
- **Outmask** to show only Eritrea
- Add the following *Vector Layers*; Country Boundary and Zoba boundary

### 2.1.13 Create graphs comparing current vs Long Term Statistics

To understand how a certain period (say current year) compares to historic periods, we create profile graphs including the long term statistics. The graph will include the long term average,

To create comparison graphs:

- **Click** *New Graph*
- **Select** the region as *Debub Zoba*
- **Select** type of graph as *Profile graph*
- **Select** the following data (in the specific order)
  - 10d NDVI-Min
  - 10d NDVI-LTA
  - 10d NDVI-Max
  - 10d NDVI-10-Day filtered
- **Select** Period as *Sep 2018 to Sep 2019*
- **Click** *Generate graph*



The NDVI graph above shows **above-normal** vegetation starting from August 2018 to February 2019, while NDVI was slightly **below normal** at the start of 2018.

### Exercise 3:

- Create monthly rainfall anomaly maps for Eritrea for 2019. Use PowerPoint slide to organize the maps showing evolution over time
- Create a ranking graph for rainfall anomaly for Eritrea and for Debub Zoba. Identify the year that received the least amount of rainfall compared to the normal and the year that received the most amount of rainfall compared to the normal.

## 2.2 Impact Tool for land cover Analysis (Landsat and sentinel 2 data)

### 2.2.1 Introduction

IMPACT toolbox was designed for analyzing and assessing forest degradation using satellite imagery. Processing satellite imagery requires many technical operations: IMPACT toolbox proposes a series of module simplifying those tasks, as many intermediate steps are wrapped in unique functions.

### Installing IMPACT and Review of IMPACT Functions

- ✓ Installing the IMPACT software
  - Downloading and launching Impact







Impact runs on Microsoft Windows 64bit (Xp, Vista, Win7, Win8, Win10). You can download the self-extracting package (.exe) or the compressed one (.zip) from our server <http://forobs.jrc.ec.europa.eu/products/software/>: save it on your disk and run it.

Choose a place on your hard drive to extract and save the software. Once the extraction is done, you will find a directory named IMPACT (default), which has the following directories inside:

- DATA folder: contains user's vector and raster data (for further details see the "getting data section" below);
- GUI folder: contains the graphical user interface, dependencies and map editing functions;
- LIBS folder: contains the engine and other software such as Apache, Python, GDAL, Openlayers, Mapserver, GeoExt, Javascript and HTML;
- TOOLS folder: contains a dedicated folder for each processing module or external library/package used within the tool such as a portable version of Firefox under "Browser", python scripts for image classification, segmentation, clipping etc;
- START\_Impact.bat: Impact launching command.

To start Impact, double click on "START\_Impact.bat". You have two windows: a shell window (a black windows showing only text) and the Impact graphic user interface, showing a map, and different icons. Note that the shell windows should not be close, else Impact would not work properly.

To close Impact, close the shell windows. If you accidentally close the Graphic User Interface, close the shell window and then restart Impact tool.

Name	Date modified	Type	Size
 DATA	9/10/2015 2:51 PM	File folder	
 Gui	9/18/2015 4:51 PM	File folder	
 OSGeo4W	9/18/2015 4:21 PM	File folder	
 Tools	9/18/2015 4:20 PM	File folder	
 license	8/6/2015 12:45 PM	Text Document	36 KB
 START_Impact	9/18/2015 4:03 PM	Windows Batch File	2 KB

### 2.2.2 Updates

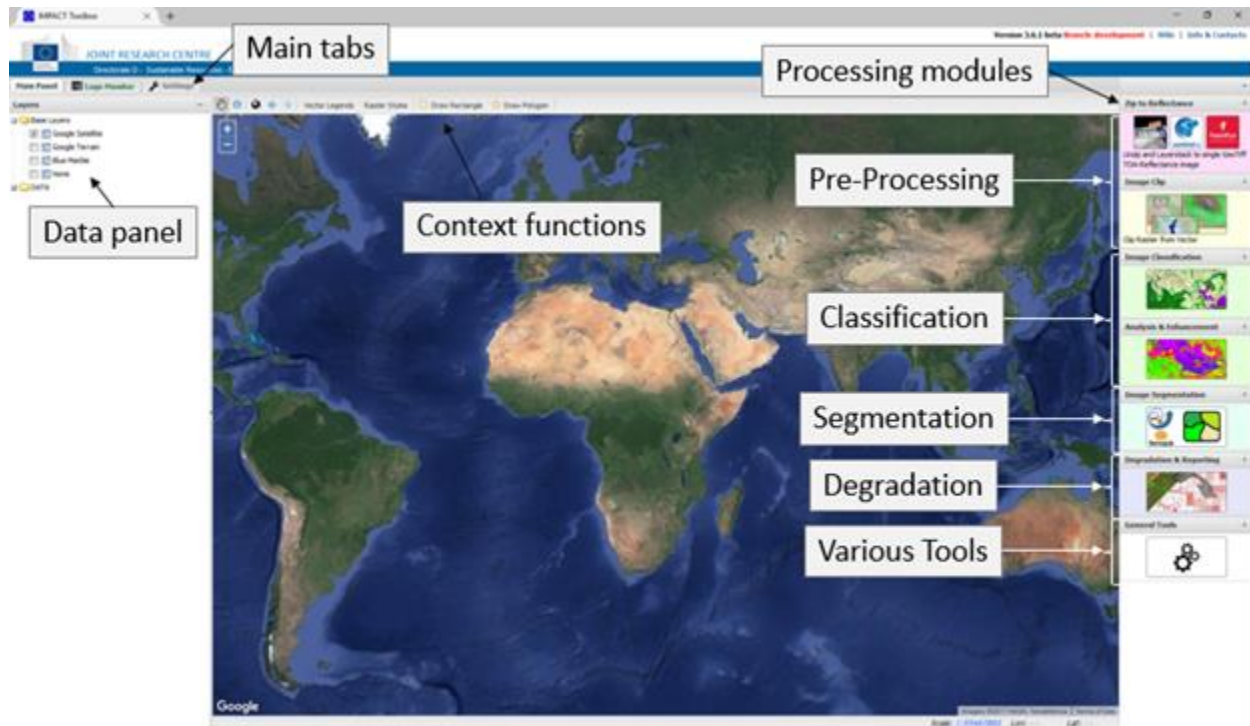
When you launch Impact, it checks the JRC server through your internet connection. If a newer version is found, it will propose you to update your own version. Simply accept the update and follow the instructions on screen.



### 2.2.3 Overview of the IMPACT interface

#### The interface is divided into three panels – Data; Display and Processing

Background: blank, Blue Marble map, JRC Sentinel2 2015-2017 and 2018 cloud-free composite, Google Satellite and Streets maps, which is the default and automatically selected if internet connection is available.

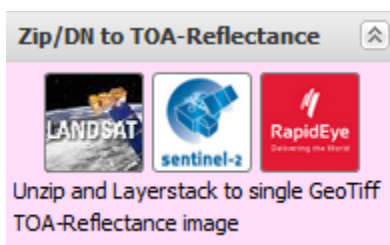


DATA: any vector (.shp) or raster (.tif) layers in DATA and subfolders will be visible under this group;

### 2.2.4 Practical Session 1: IMPACT functions

#### 2.2.4.1 Pre-processing

#### Zip/DN to TOA reflectance



By executing this module, Landsat/Sentinel-2/RapidEye zipped (.tar.gz or .tar.bz) archives can be selected from your PC, network drive or external sources; processing consists of

1) Conversion of selected/default bands into single Geo Tiff file, and 2) conversion into top-of-atmosphere (TOA) reflectance (if raw DN values)

### Processing options and calibrations coefficients:

#### Landsat

**Landsat (Zip) to Reflectance GeoTiff**

**Input RAW images**

Input RAW images:

+ Select inputs

**Processing options**

Only B,G,R,NIR,SWIR1,SWIR2 bands are processed

Processing Type:

- ☐ Keep DN values (e.g Surface Reflectance input)
- ☒ DN to TOA Reflectance Byte rescaled [0-255]
- ☐ DN to TOA Reflectance Float [0-1]

Output date format:

- ☐ YYYYMMDD
- ☒ DDMMYYYY

Overwrite Output: ☐ Yes ☒ No

Run Close

Landsat satellite data products provided by space agencies consist of quantized and calibrated scaled Digital Numbers (DN) representing multispectral image data. The products are generally delivered in 8/16-bit unsigned integer format and can be rescaled to the Top Of Atmosphere (TOA) reflectance and/or radiance using radiometric rescaling coefficients provided in the product metadata file, as briefly described below.

#### Geo Tiff conversion

Only (R,G,B,NIR,SWIR1,SWIR2)<sup>#</sup> bands are extracted, renamed and layer stacked; thermal and panchromatic bands are zipped and stored within the same folder. The output directory contains the resulting files with the following naming convention:

Multispectral GeoTiff file: [sensor]\_[path]\_[row]\_[ddmmyyyy].tif

Multispectral quick look : [sensor]\_[path]\_[row]\_[ddmmyyyy].gif

Metadata file: [sensor]\_[path]\_[row]\_[ddmmyyyy].met

Zipped files for archive:

[sensor]\_[path]\_[row]\_[ddmmyyyy]\_[band{1\*,61,62,8,9,10,11,BQA}].tif.gz

Projection and spatial resolution: as derived from the source data.

# Landsat 4/5/7 : bands 1,2,3,4,5,7      Landsat 8 : bands 2,3,4,5,6,7

\* Landsat 8 pre-blue band 1.

TOA Reflectance Conversion

NOTE: only applicable for Landsat raw DN type; if Surface Reflectance products, select "Keep DN value to skip TOA conversion"

By converting the raw digital number (DN) values to top-of-atmosphere (TOA) reflectance data from different sensors/platforms are calibrated to a common radiometric scale, minimizing spectral differences caused by acquisition time, sun elevation, and sun–earth distance.

8bit (or 12bit for Oli) DN to TOA correction formula is as follows:

$$\rho_{\lambda} = \pi * L_{\lambda} * d^2 / ESUN_{\lambda}$$

where

$\rho_{\lambda}$  = TOA reflectance for band  $\lambda$

$L_{\lambda}$  = Radiance for band  $\lambda$  =  $M_{\lambda} * Q_{cal} + A_{\lambda}$

$M_{\lambda}$  = Band-specific multiplicative rescaling factor

$A_{\lambda}$  = Band-specific additive rescaling factor

$Q_{cal}$  = Quantized and calibrated standard product pixel values

$d = (1 - 0.01672 * \cos(0.01745 * (0.9856 * (\text{Julian Day Image} - 4))))$

$\theta_{sz}$  = Local solar zenith angle

$Tm ESUN = [1957.0, 1826.0, 1554.0, 1036.0, 215.0, 80.67]$

Etm ESUN = [1969.0,1840.0,1551.0,1044.0,225.70,82.07]

Oli ESUN = [2067.0,1893.0,1603.0,972.6,245.0,79.72]

Multiplicative and additive rescaling factors are extracted from the metadata file. In order to reduce the size of the calibrated data, 32bit Float reflectance values [0-1] are then rescaled to 8bit Byte [0-255] with a linear multiplication factor of 255.

## RapidEye

Data are usually provided as 5 band layer stacked Geo-Tiff files. To convert 16bit Digital Number (DN) to radiance it is necessary to multiply by the radiometric scale factor, as follows:

$$L_{\lambda} = DN_{\lambda} * ScaleFactor(\lambda)$$

where  $ScaleFactor(\lambda) = 0.01$

The resulting value is the at sensor radiance of that pixel in watts per steradian per square meter ( $W/m^2 \text{ sr } \mu m$ ). The TOA correction formula for RapidEye data is as follows:

$$\rho_{\lambda} = \pi * L_{\lambda} * d^2 / ESUN_{\lambda} * \cos \theta_{sz}$$

where

- $\rho_{\lambda}$  = TOA reflectance for band  $\lambda$
- $L_{\lambda}$  = Radiance for band  $\lambda$
- $\theta_{sz}$  = Local solar zenith angle
- $d = (1 - 0.01672 * \cos(0.01745 * (0.9856 * (\text{Julian Day Image} - 4))))$
- $ESUN = [1997.8, 1863.5, 1560.4, 1395.0, 1124.4]$

32bit Float reflectance values [0-1] are then rescaled to 16bit Unsigned Integer [0-10000] with a linear multiplication factor of 10000. Formulas and parameter are derived from [\[1\]](#).

## Sentinel2

The Copernicus Sentinel-2 mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) will

support monitoring of Earth's surface changes. The coverage limits are from between latitudes 56° south and 84° north.

How to get Sentinel2 data: [Copernicus Open Access Hub](#) or [JRC Sentinel2 explorer](#) (including server-side pre-processing for lighter download) are only few example. See chapter "How to download Sentinel2 data" for further info.

Once downloaded \*SAFE.zip files can be selected from any location (local or remote disks) and processed by choosing configuration parameters from the interface hereafter

**Sentinel2 (Zip) to Reflectance GeoTiff**

**Input RAW images**

Input RAW images:

Select inputs

**Processing options**

**Bands:** B01 B02 B03 B04 B05 B06 B07 B08 B8A B09 B10 B11 B12

☐ ☒ ☒ ☒ ☐ ☐ ☐ ☒ ☐ ☐ ☐ ☒ ☒

**Projection:** UTM (most frequent)

**Resolution:** highest

**Output type:** Byte (0-255)

**AOI:**

**Output name:** Original

\* Short = [ID]\_[ProcTime]\_[Row]\_[AcqTimeStart].tif  
e.g. S2A\_MSIL1C\_20160222T155750\_R018\_V20160219T034145.tif

**Overwrite Output:** ☐ Yes ☒ No

Run Close

While importing raw .zip files, only selected \*.JP2 bands will be processed and eventually rescaled , reprojected and subset according to selected parameters.

#### Notes:

- default bands (2,3,4,8,11,12 ) have been selected to match Landsat specs, giving the possibility of applying built-in automatic Classification, Forest Normalization, Spectral Unmixing

- by selecting a vector file as Area Of Interest (AOI) from the one available in Layers section, only intersecting images and/or part of them are processed, reducing processing time and image size
- in case of ingestion of pre-processed (GeoTiff multiband file) Sentinel2 data downloaded from [JRC Sentinel2 explorer](#) IMPACT will simply extract the file while raising a warning message
- Processed bands name are saved in the GeoTiff metadata tag "Impact\_bands"

## 2.2.5 Sentinel-2 naming conventions

**Since Oct 2016 :** download imagery by granule (~100km x ~100km)  
size: ~ 600 MB each granule

- Naming since mid of Dec 2016:  
S2A\_MSIL1C\_20161212T032132\_N0204\_R118\_T48PWC\_20161212T033203  
↑ acquisition date & time      ↑ orbit\_nr      ↑ granule ID      ↑ processing date & time

- Naming from Oct 2016 - beginning of Dec 2016: = old (long) name format as below  
S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20161202T105440\_R118\_V20161202T032112\_20161202T032112

**Before Oct 2016:** download imagery of full S2-swath (~290km x ~290km)  
size: ~ 6 GBII each image

- old (long) name format:  
S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20161009T100311\_R061\_V20161009T035242\_20161009T035237

## Useful links:

Sentinel-2 User Guide:

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi>

Sentinel-2 Technical Guide:

<https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-2-msi>

Sentinel-2 Products Specification:

<https://sentinel.esa.int/web/sentinel/document-library/content/-/article/sentinel-2-level-1-to-level-1c-product-specifications>

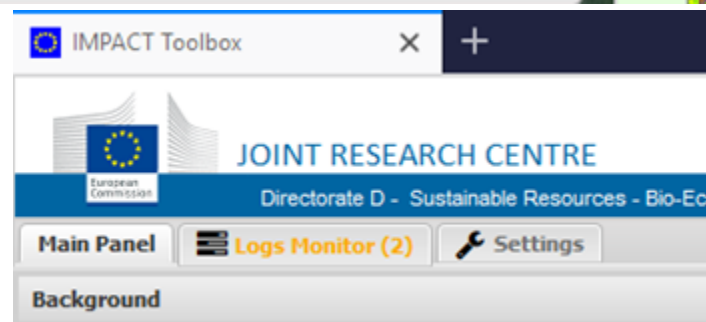
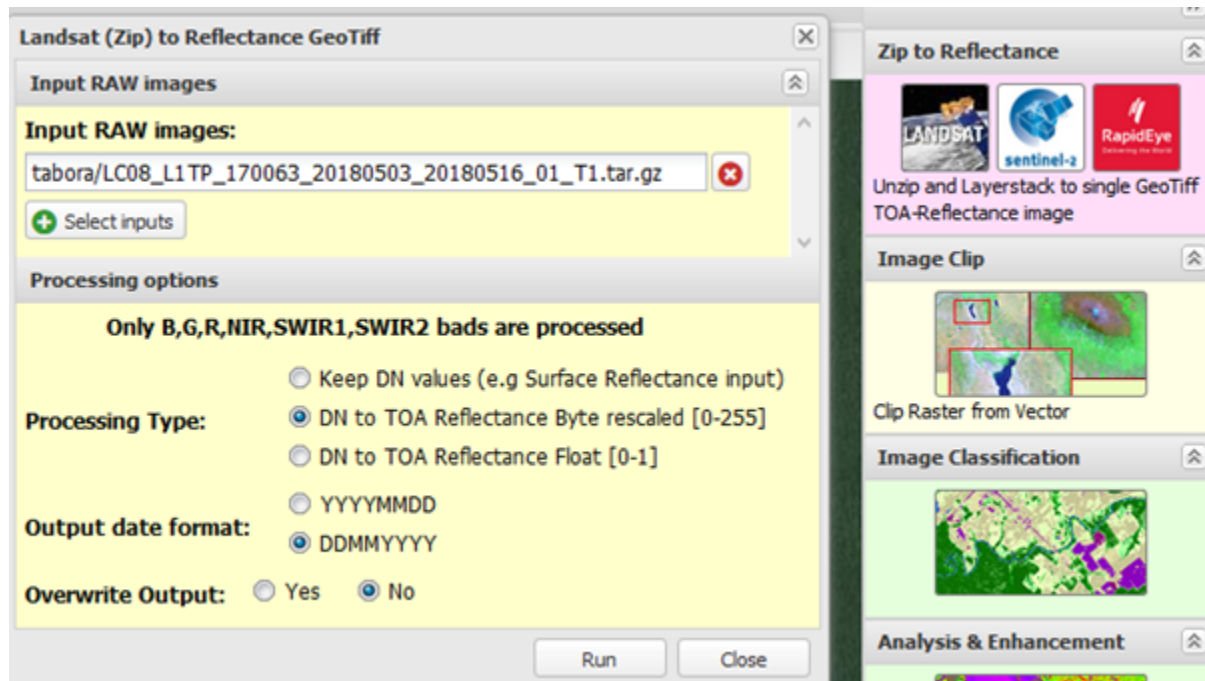
Sentinel-2 User Handbook:

[https://sentinel.esa.int/documents/247904/685211/Sentinel-2\\_User\\_Handbook](https://sentinel.esa.int/documents/247904/685211/Sentinel-2_User_Handbook)

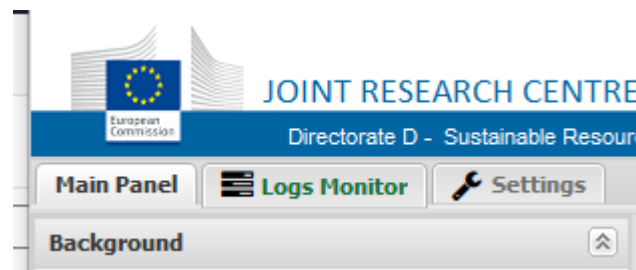
## 2.2.6 Processing Landsat

We pre-process the Landsat file

Select the Zip to reflectance – and navigate to the Landsat zip files in the data folder



When the file has finished processing the Logs Monitor will turn green

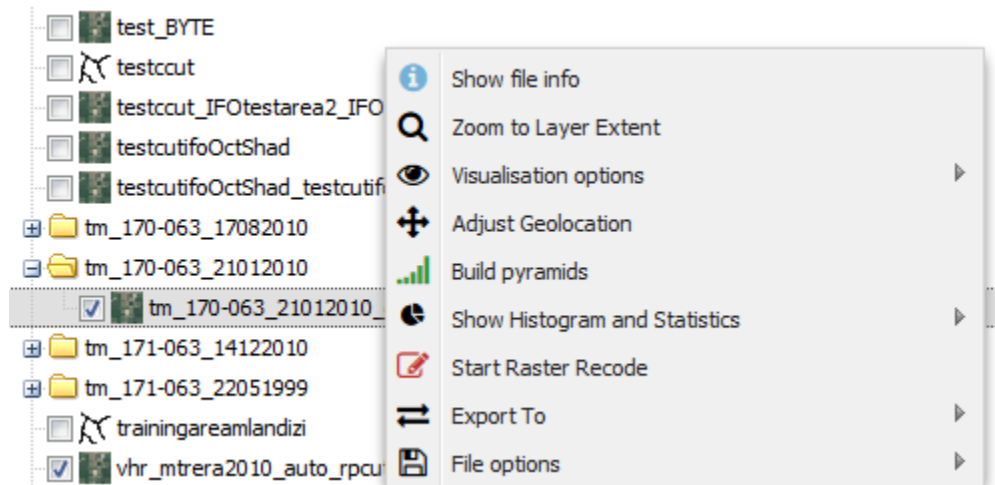


By clicking on the logs monitor – you can review messages – if the logs monitor is red – the process has failed.

### 2.2.7 File information, display and contrast

The file name will now appear in the left-hand Overlays panel – in a directory with the path-row and date.

Double click on the image name and IMPACT will zoom to the image. If you right click on the image name you have a set of options for display, image information etc



The last option 'File options' allows you to copy, delete and rename the file.

Visualisation options allows you to change the band display and the contrast stretch.

Under 'Show file info' you have the details of the image.

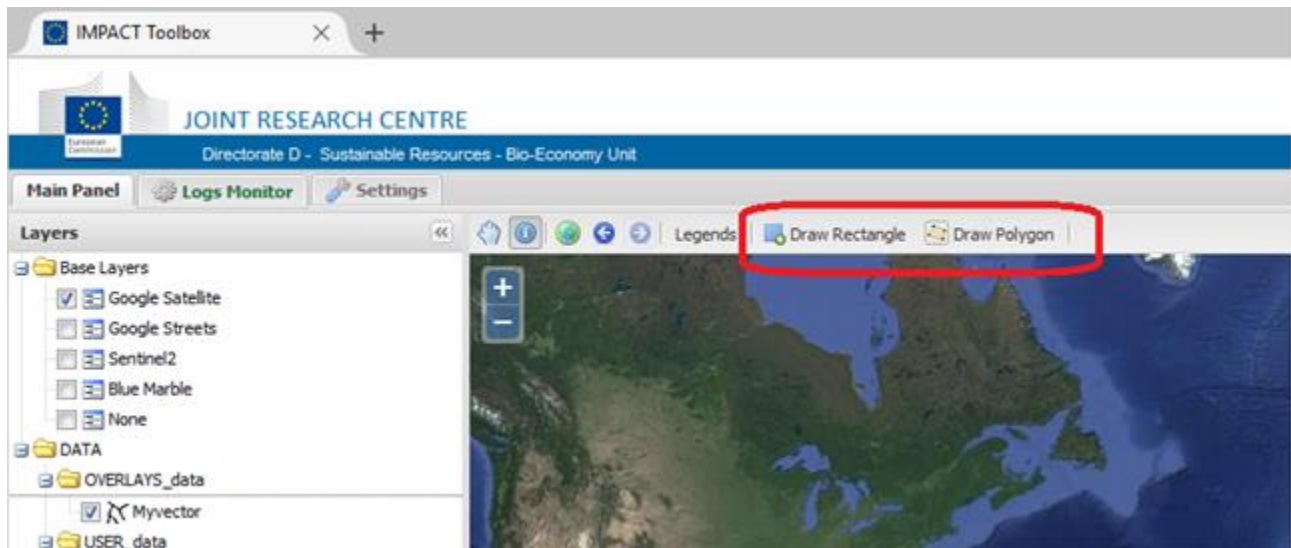
You can move a file up above other files or change its file location by clicking and moving it.





## 2.2.8 Extracting an area to work with.

Drawing an area of interest



To draw an area of interest you need first to activate the function by clicking on "Draw Rectangle" or "Draw Polygon" in the upper left corner of the map. When selected, Edit/Delete/Save buttons appear. Once the button is enabled, the area of interest can be drawn on the map. The draw tool will create an rectangular/polygonal overlay with a orange border (while it is drawn the border is blue).

Use the 'draw rectangle' option from the top of the screen to create a rectangle over the forest reserve. Save the rectangle using the option from the top of the screen (e.g. aoi), and then use 'Image clip'.



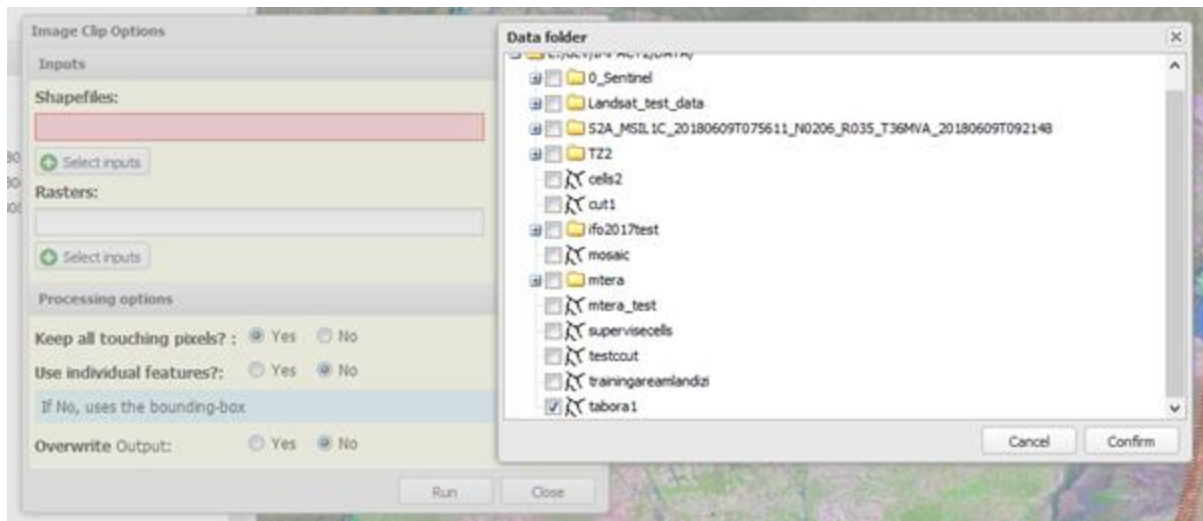
## Image Clip



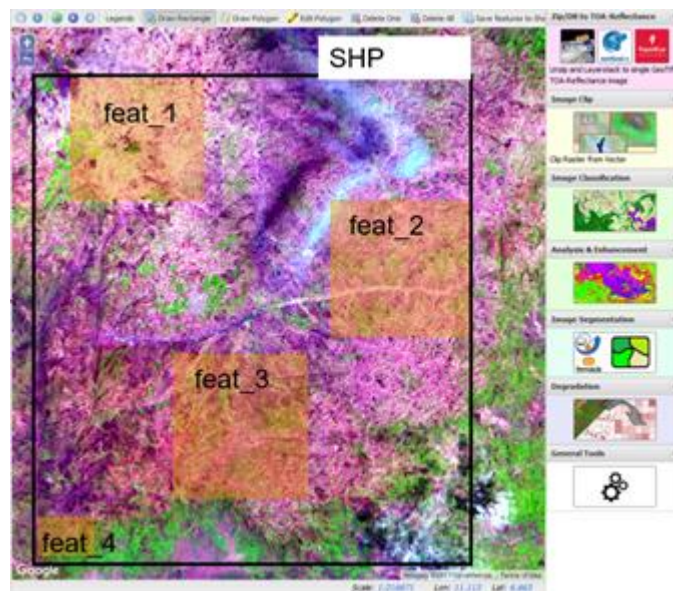
The Image clip tool can be used with any raster layer to create a clipped layer using: 1) a selected GeoTiff image, and 2) a selected vector layer. Image clipping represents a crucial step to reduce processing time and data volume. The user has the possibility to clip any GeoTiff file from the input directory using predefined vector layer(s) containing one or more features each. Vector projection will be on the fly converted to match the raster one. Note that clipping can be done only after Zip/DN to TOA-Reflectance.



The dialogue opens and you select your new shapefile and the Landsat image to clip the area.

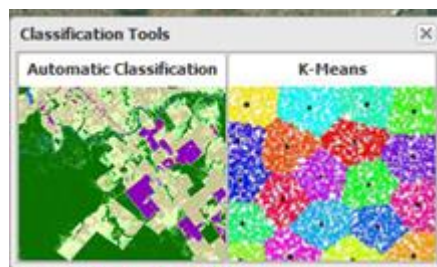


The image is clipped and now appears in the Overlay panel with a pre-fix of the shapefile. Options are available to do multiple clipping with one shapefile (use individual features).



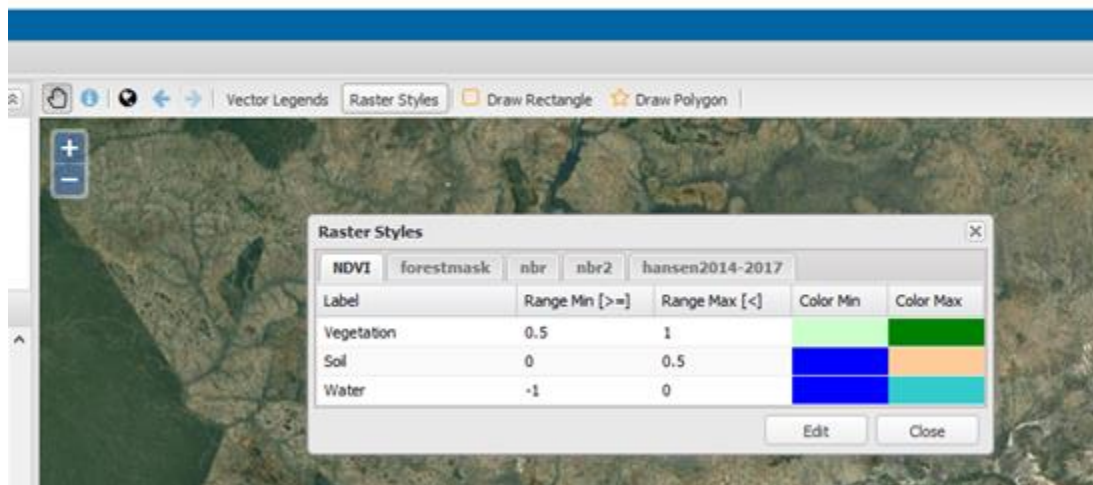
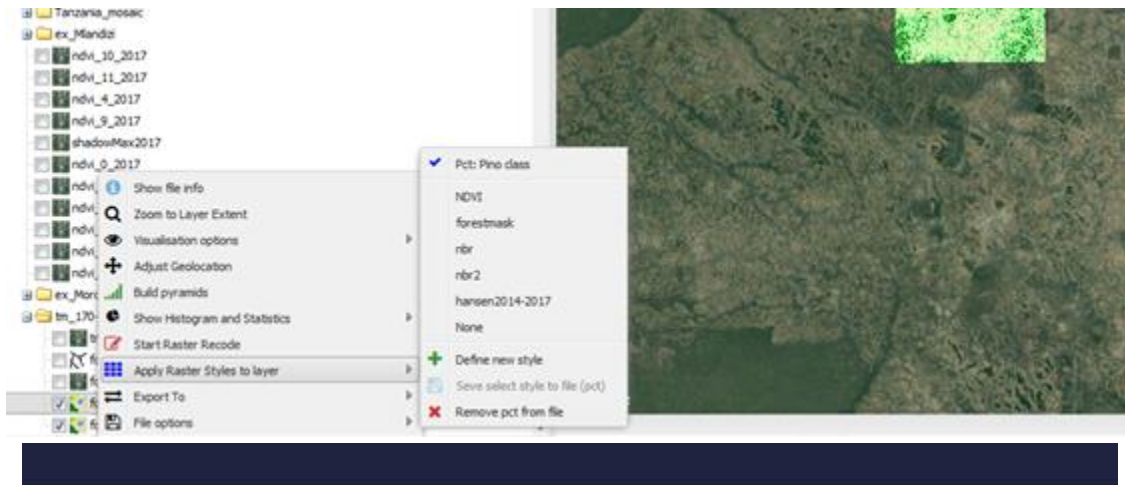
## 2.2.9 Image classification

2 classifiers are provided – one a decision tree and the other k-means. You can try both to see how they perform. The result of the automatic classification has a suffix – class



With Kmeans you can determine the number of classes and add a suffix (e.g. km).

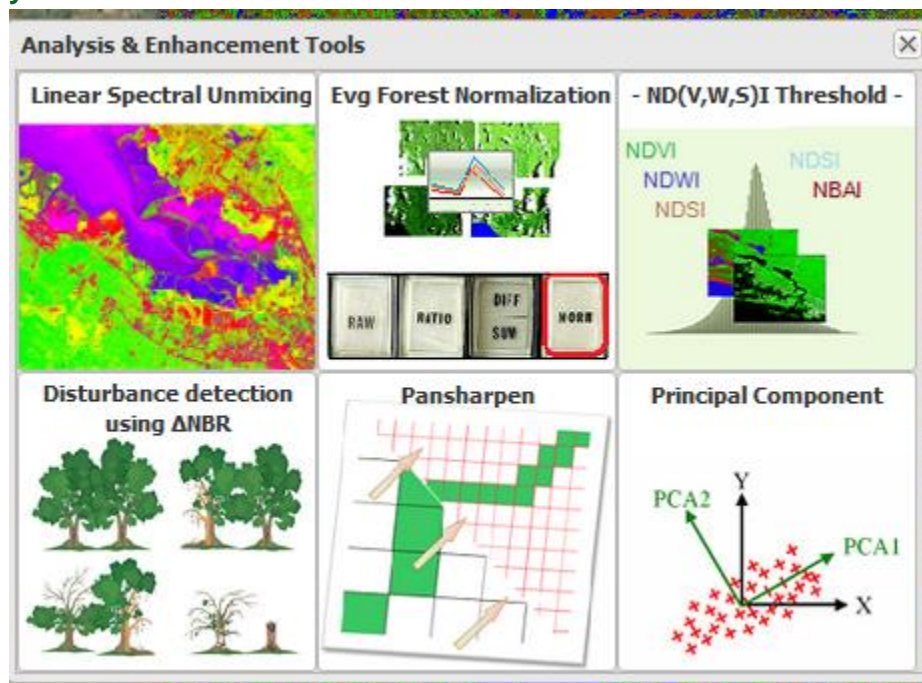
If you right click on the file name you can apply a number of raster styles or define your own either with Define new raster style or from the menu at the top of the screen using Raster Styles.



You can also recode the classes by right clicking on the file name and using 'start raster recode'.



## 2.2.10 Analysis and Enhancement



**Linear Spectral Unmixing** – produces a tree band Vegetation, Soil and Shadow image

**Evg Forest Normalisation** – uses dark object (forest) to normalise the image

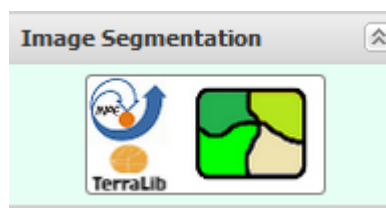
**ND(V,W,S)I Threshold** – creates an index (e.g. NDVI) from the bands of your choice along with a thematic density slice image

**Disturbance using NBR** – takes two images at from different times and looks at the difference in NBR – a forest mask can be used to restrict the analysis only to forest areas.

**Pansharpen** – for use with Landsat 8 pancromatic channel (band 8)

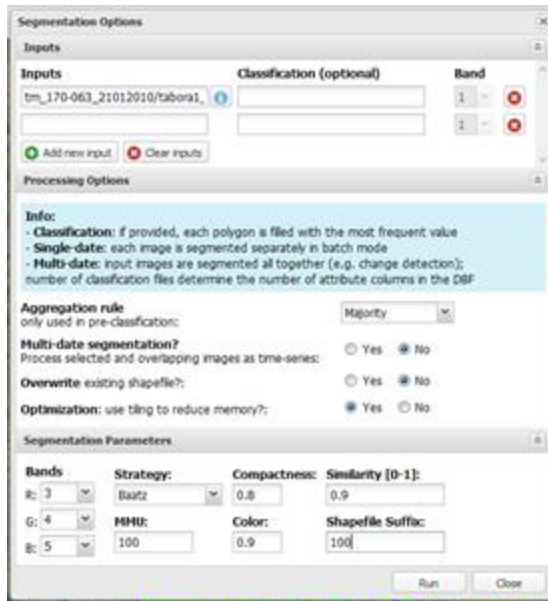
**Principle component** – creates a PCA image

## 2.2.11 Image Segmentation



Uses the Baatz algorithm to produce segments at different sizes.

We can use the tabora subset and segment at different Minimum Mapping Units

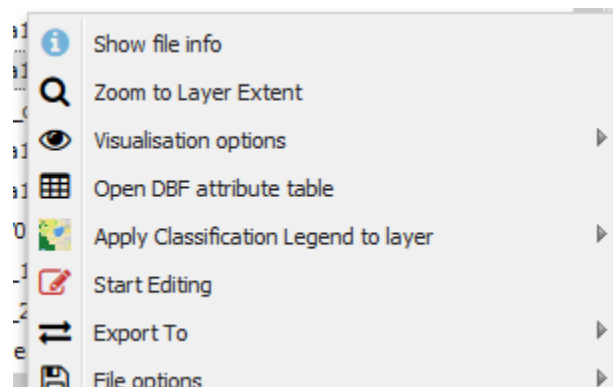


You have the option of giving the resulting polygons a class from a classification that you have produced.

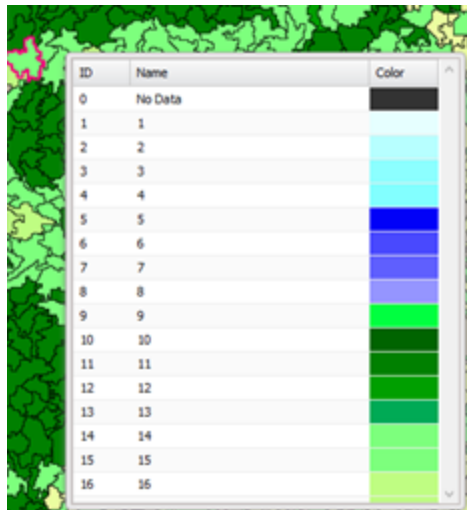
If you have added a classification during the segmentation, you can apply an existing vector style to the polygons – or create your own vector style and apply it. Right click to Apply classification legend to layer. Click on T1\_class to see results.

## 2.2.12 Vector Editing

Your segmentation attributes can be edited by right clicking on the file and selecting Start Editing



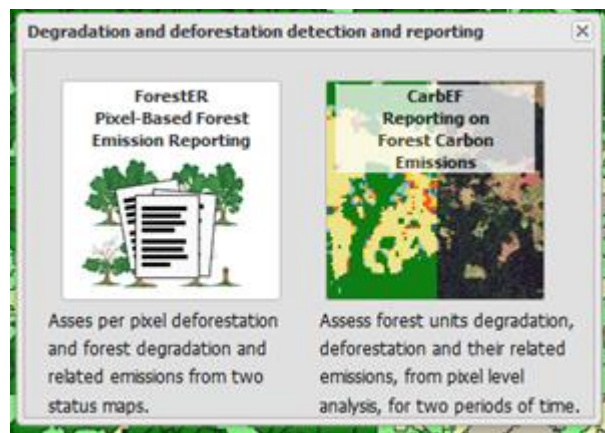
You can select a polygon or set of polygons and recode them.



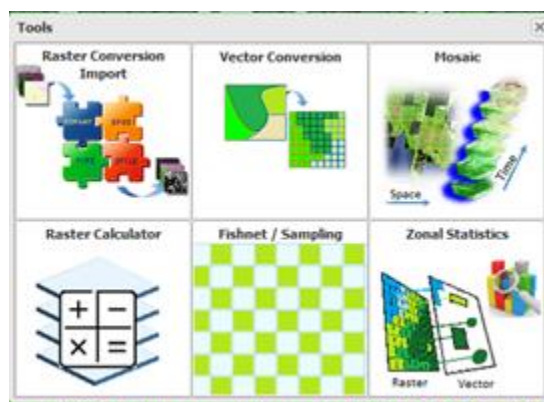
ID	Name	Color
0	No Data	Black
1	1	White
2	2	Light Blue
3	3	Light Cyan
4	4	Light Blue
5	5	Blue
6	6	Dark Blue
7	7	Dark Blue
8	8	Dark Blue
9	9	Dark Blue
10	10	Dark Blue
11	11	Dark Blue
12	12	Dark Blue
13	13	Dark Blue
14	14	Dark Blue
15	15	Dark Blue
16	16	Dark Blue

### 2.2.13 Degradation and deforestation detection and reporting

- Input of forest change maps and emissions factors
- Output of emissions



### 2.2.14 General Tools



## Raster Conversion

Reproject / change pixel size / format / data range / bands

Vector to raster conversion

Mosaic – spatial or temporal

Raster calculation – choose bands and maths / logic to

Create a new file (e.g. shadow index)

Fishnet – creates a sampling scheme (regular or random) over an image in a vector file

Zonal statistics – enables you to fill a vector file with the statistics from a raster file.



## 2.3 Practical Session 2: Processing Sentinel 2

One of the core functions of the IMPACT tool is to enable users to take Sentinel 2 data in the RAW format as provided by ESA, JRC or USGS and process through to a thematic (map) product.

In this exercise we will take Sentinel 2 scenes downloaded from the JRC web site and process them to a land cover map which we will review and show how to edit.

The data for this exercise are in data folder/sentinel2

The steps involved in this exercise are the following:

1. Installing the IMPACT software
2. Processing the S2 input files to a layer stack GeoTIFF with selected bands
3. Clipping the image to a user selected outline (shapefile)
4. Producing a supervised (decision tree) classification of the image



5. Producing a segmentation of the image with pre-labels
6. Reviewing the classification – with the possibility of editing the classes.

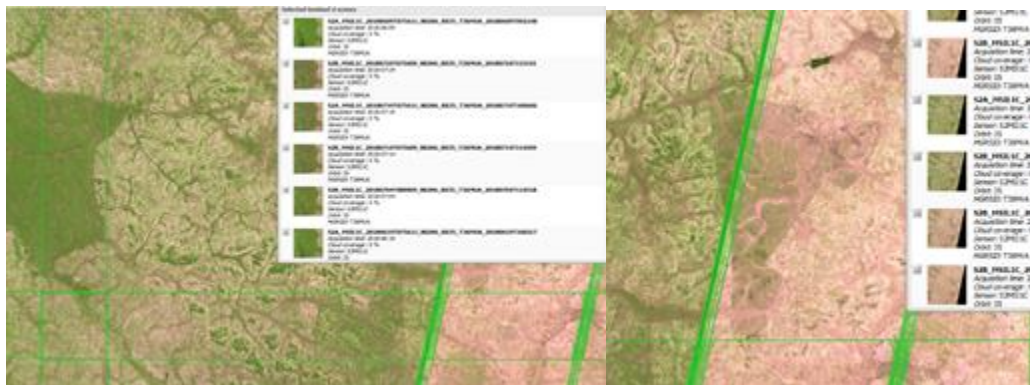
## 2.3.1 Processing test data set – Sentinel 2 – clipping, classification segmentation and recording

### 2.3.1.1 Loading Sentinel 2 data

Directory Structure – under the IMPACT/DATA folder you can organise your data in folders as you wish

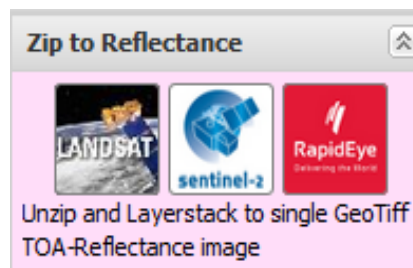
Under the IMPACT directory you will find the START\_Impact.bat file to launch the software – this can be moved as a link.

Copy the two RAW ZIP files into your DATA directory

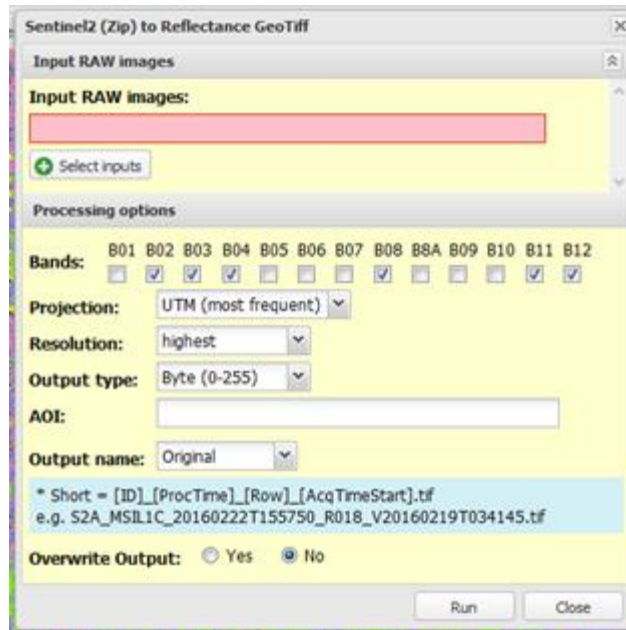


The files have been download from the JRC Web site – see above.

### 2.3.2 Processing the input S2 file



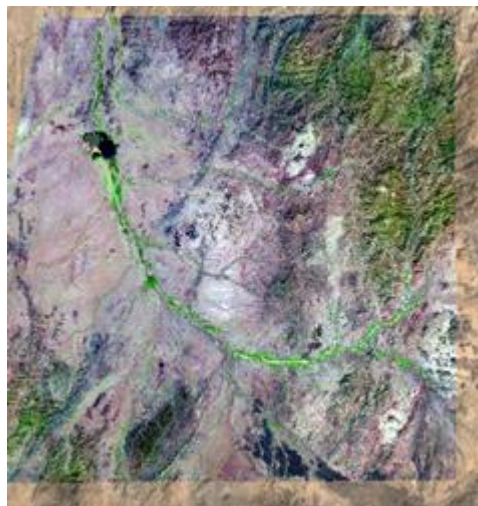
The dialogue appears – navigate to the folder where the S2 zip files are located and select them.



Here you can choose the bands, the resolution and projection. We can take the default settings – except we choose the SHORT naming version.

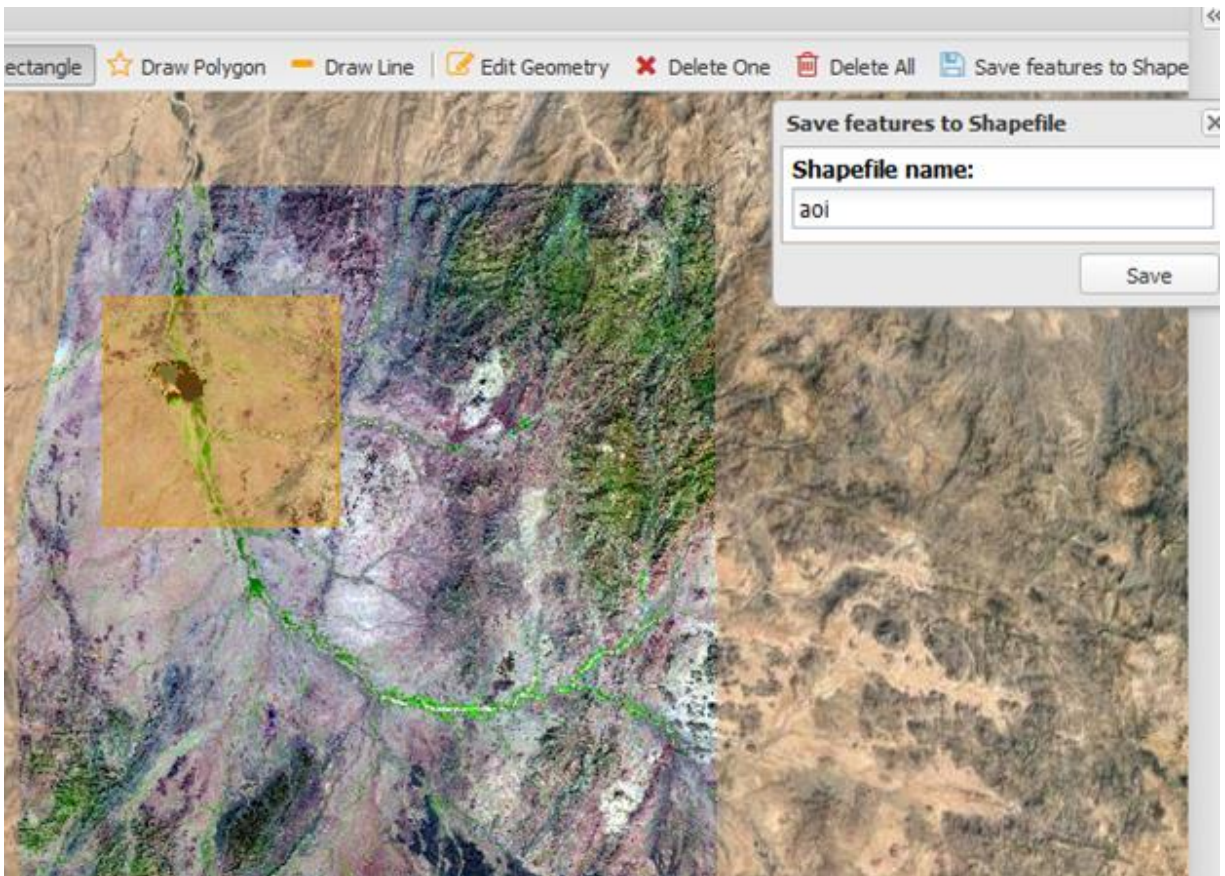
### 2.3.3 Display the processed images

In the left hand panel right click on the image name zoom to layer and display the bands and the stretch you want. Below we see the two images side-by-side.



### 2.3.4 Image clipping

Zoom to the image and then using Shift + Mouse zoom to an area of interest. Use DRAW RECTANGLE to highlight an area which we will then use for processing. We select the forest reserve of Katitiu to the east of the images – and save to file - you a shapefile in your Sentinel directory called tabora.shp to help.

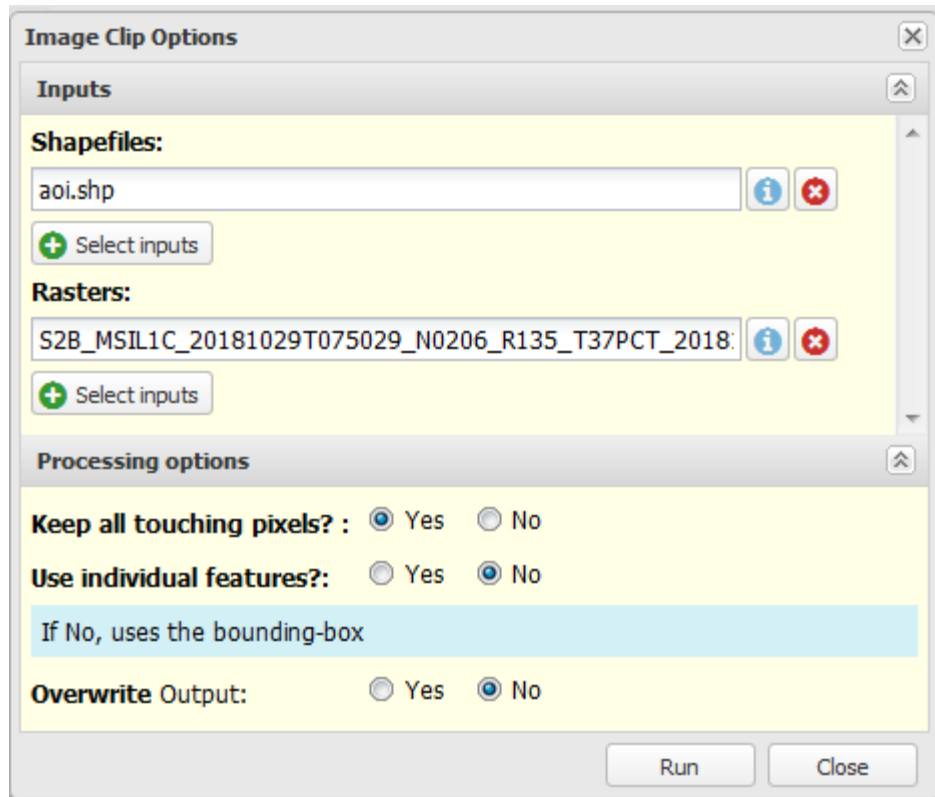


Now save the area of interest as a shape file in the left hand layer panel under VECTOR with a name of your choice.

This layer will now be used to CLIP the image.

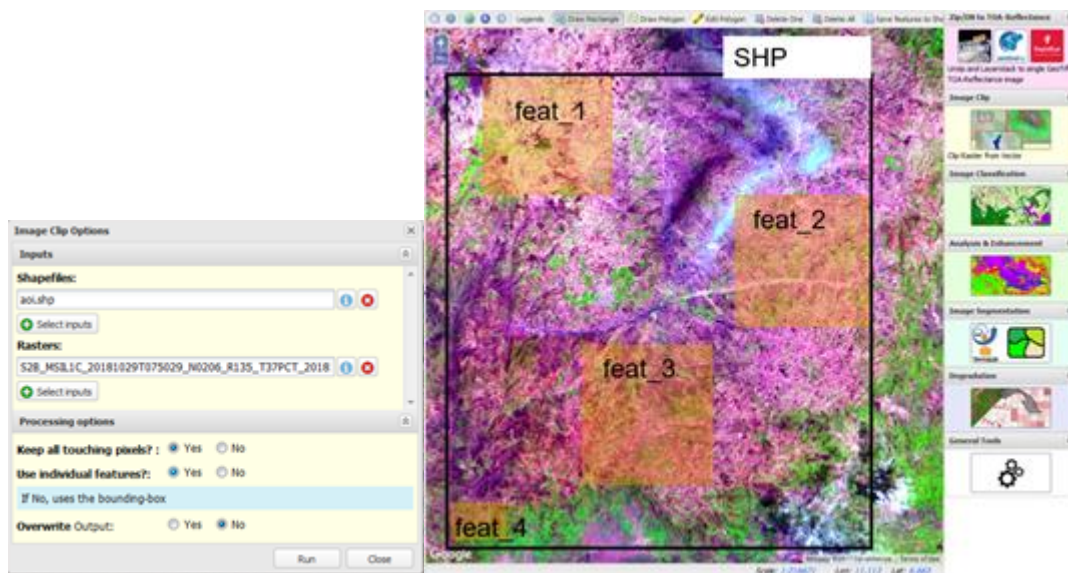
CLICK the IMAGE CLIP module on the right hand processing panel. From the drop down menu, select the shapefile you saved and the name of your input S2 image.

Use Individual feature: this option creates output files as many as the individual features of the vector. When No is selected, a unique output files containing the bounding box of the features will be used.



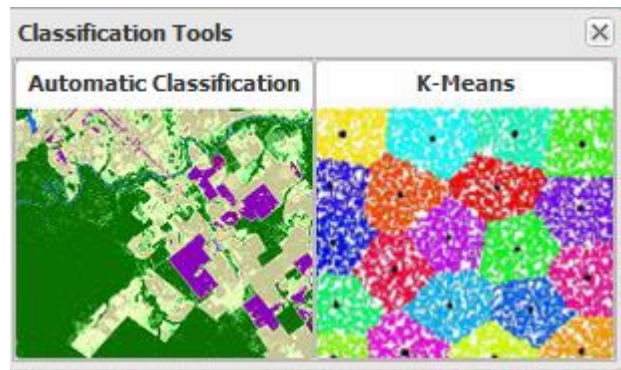
When you press RUN a clipped subset of the input image will be created – the name will start with

Clip' and include the name of the shapefile and the input image. The image can now be seen in the viewer. As with other images you can zoom to layer and change the bands and contrast.





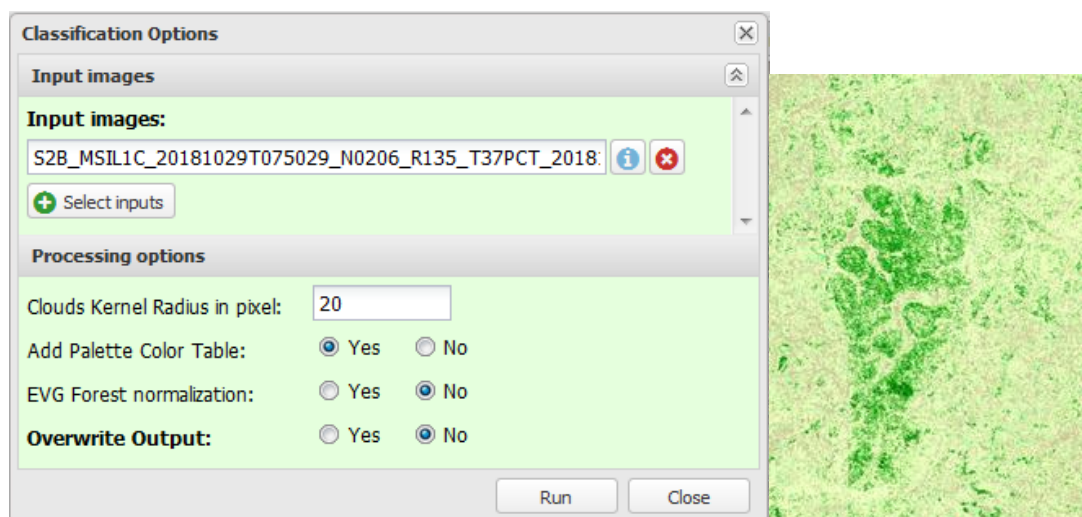
### 2.3.5 Producing a Supervised (Decision Tree) Pixel Classification of the Clipped Image



Under **classification tools** we use **automatic classification** to produce a pixel based classification. The process produces a TIFF file that can be visualised in the IMPACT tool and in other GIS software. The resulting classes are:

Class	Label	Colour
0	No data	Black
1,2	Cloud	White
3	Snow / Ice	Cyan
5,6,7,8	Water	Blue
9	Grass/Shrub	Light Green
10,11,12	Dark vegetation	Dark Green
13	Dense Shrub	Bright Green
14,16	Shrub / open forest	Light Blue
21,22	Grass	Olive Green
30,13,32,33,34,35	Soil	Tan
40,41	Shadow	Red
42	Low illumination	Grey

CLICK on the AUTOMATIC CLASSIFICATION button and select your clipped image. The classification will appear the left hand panel.



Interface and result. You can also use K-Means, an unsupervised classifier to create an output file with number of classes you want.

### 2.3.6 Producing a segmentation of the image with pre-labels

We will segment the image into polygons and give the polygon a preliminary class name by using the pixel based classification we produced in the section above.

As inputs the process requires: the clipped image; the classification and some parameters to define the level of segmentation. Depending on your computer, the segmentation might take some time.

**Segmentation Options**

**Inputs**

**Inputs** **Classification (optional)** **Band**

S2A\_MSIL1C\_20180609T075611 S2A\_MSIL1C\_20180609T075611 1

1

+ Add new input x Clear inputs

**Processing Options**

**Info:**

- **Classification:** if provided, each polygon is filled with the most frequent value
- **Single-date:** each image is segmented separately in batch mode
- **Multi-date:** input images are segmented all together (e.g. change detection); number of classification files determine the number of attribute columns in the DBF

**Aggregation rule** only used in pre-classification: Majority

**Multi-date segmentation?** Process selected and overlapping images as time-series: ☐ Yes ☒ No

**Overwrite existing shapefile?:** ☐ Yes ☒ No

**Optimization: use tiling to reduce memory?:** ☒ Yes ☐ No

**Segmentation Parameters**

**Bands** **Strategy:** **Compactness:** **Similarity [0-1]:**

R: 3 Baatz 0.8 0.9

G: 4 **MMU:** **Color:** **Shapefile Suffix:**

B: 5 100 0.9 100

Run Close

### 2.3.7 Segmentation Options:

- Multi-date segmentation:



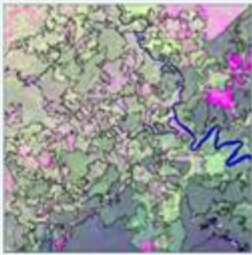


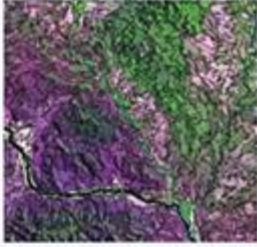

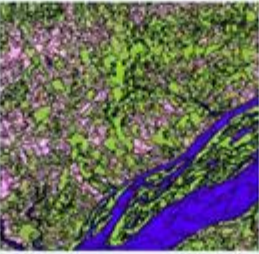
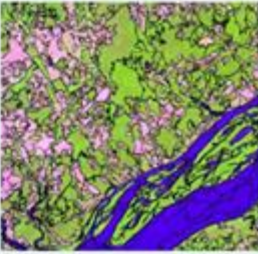
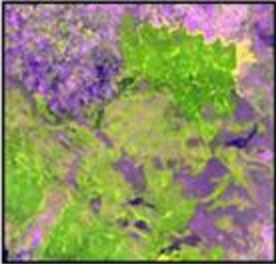
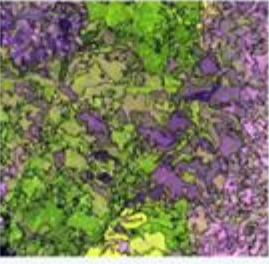
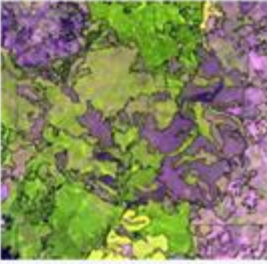
- “No”: selected images are treated individually and the correspondent vector file (ESRI Shapefile format) is saved within the image directory; please ensure that segmentation parameters are applicable to all selected images, bands selection above any other.
- “Yes”: selected images are layer stacked (only selected bands) into a single one using the selected bands and weight. Please ensure the geographical overlap. First file is use to extract output location and reference projection

- Use classification to pre-label objects: selected raster files (thematic or not) are used to pre-label objects according to occurrence rules (majority, min, max') either in single or multi-date mode. In the latter case, the .dbf file will reflect the top-down order in which files have been selected in the interface, saving (after the ID field) as many fields as the input images as on Table 3.

- Overwrite: set to “Yes” to automatically delete output files (if any)

- Optimization: if “Yes”, input images are processed using a tiling approach reducing the total amount of memory; however, the final segmentation might reflect the tiling patters; do not use in case of small images.

We can use different MMU to determine the size of the polygons. The size of the polygons is determined by the MMU and the image properties – so you need to experiment. Below are suggestions from different sensors. You can experiment with the S2 data and observe the results.

Sensor	MMU	MMU
Landsat 30m  --- 20km ---	100 	400 
Spot5take5 10m  --- 10km ---	100 	400 
Sentinel 10m  --- 15km ---	100 	400-500 
RapidEye 5m  --- 6km ---	400-500 	800-1000 

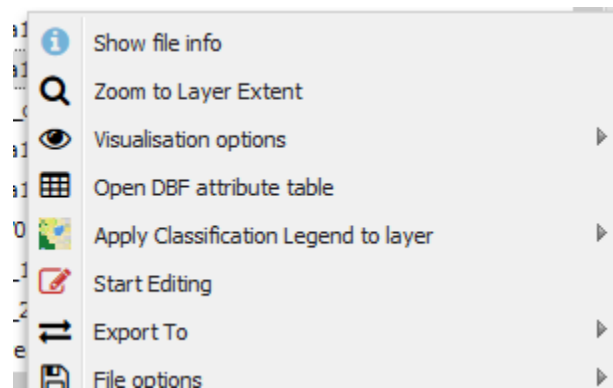
Load Classification Layers with legend – land cover.



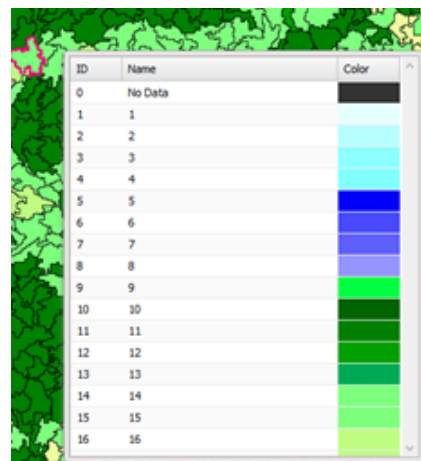


### 2.3.8 Recording

Your segmentation attributes can be edited by right clicking on the file and selecting Start Editing



You can select a polygon or set of polygons and recode them.



## **Module 3:**

# **Spatial Analysis and Hazard Assessment**

## 3 Module 3: Spatial Analysis and Hazard Assessment

### Learning objectives

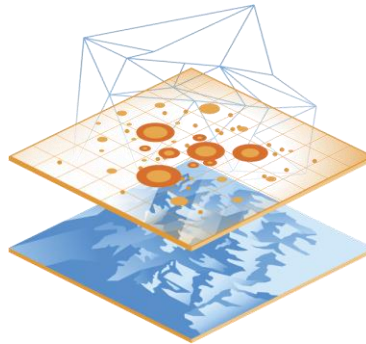
By the end of this module you will be able to:

- Introduce the fundamental concepts in spatial analysis
- Elaborate basic terminologies and concepts in DRM together with Global and Continental DRM frameworks
- Demonstrate how to undertake hazard assessment and derive some of the indicators and thresholds on drought and flood hazards
- Grasp methods used to produce drought and flood hazard vulnerability and risk maps

### 3.1 Introduction to Spatial Analysis

**Spatial analysis** is a type of geographical analysis which seeks to explain patterns of human behavior and its spatial expression in terms of mathematics and geometry, that is, locational analysis (Dartmouth). The main focus of spatial analysis is to understand the spatial distribution, variation, interaction and relationships of features or phenomena. According to Carleton College definition, spatial analysis is a set of techniques for analyzing spatial data. The results of the spatial analysis are dependent on the locations of the objects being analyzed. Software that implements spatial analysis techniques requires access to both the locations of objects and their attributes. The other description is from ESRI "Spatial analysis is how we understand our world—mapping where things are, how they relate, what it all means, and what actions to take. From the computational analysis of geographic patterns to finding optimum routes, site selection, and advanced predictive modeling, spatial analysis is at the very heart of Geographic Information System (GIS) technology."

The goal of the spatial analysis is to answer spatial questions related to location, pattern, change, scenarios, and others. GIS software's are designed to provide a state of the art tools to process data and answer such complex space based questions. There are hundreds of tools under the ArcGIS toolbox to help you carry out spatial analysis, however, it is very important to first design a methodology or a model which needs to be supported with scientific methods to reach a conclusion.



### Common Types of Spatial Analysis

- a) **Proximity Analysis** is an analytical technique used to determine the relationship between a selected point and its neighbors. Proximity analysis is a crucial tool for business marketing and site selection. Marketers analyze demographics and infrastructure to determine trade areas. Trade areas are continuous geographic areas around a site that generate the majority of revenue. This analysis is also called Neighborhood Analysis.
- b) **Overlay Analysis**

## Multi-Criteria Analysis (Suitability Analysis)

In most cases spatial analysis involves multiple layers and criteria for selecting a suitable site or identifying specific areas that fulfill certain requirements. For instance, one may need to identify areas in Eritrea that are above 1000m above sea level and slope of < 10 degrees. But also the area needs to be very close to roads and towns. Such analysis involves multiple parameters and criteria and such analysis is called multi-criteria analysis.

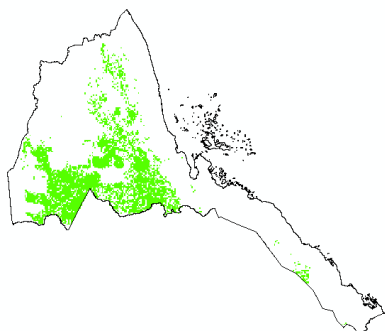
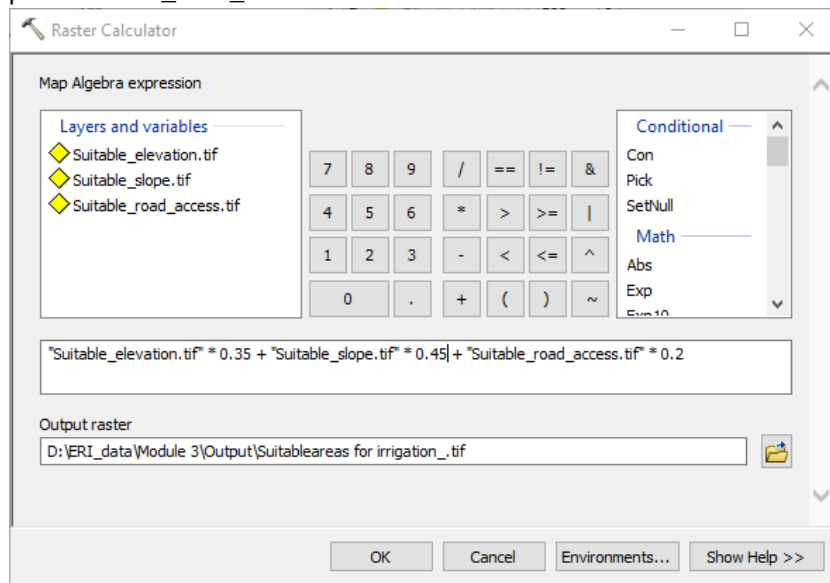
### Exercise

Suitability Analysis for irrigation farming (For exercise purposes)

Parameter	Criteria	Weight
Elevation	>700m	35%
Slope	<=10 degree	45%
Access to main road	<10km	20%

- 1) Open ArcMap and Load the following layers from Spatial Analysis folder under X:/Eri\_data/Module3
  - Suitable\_elevation.tif
  - Suitable\_slope.tif
  - Suitable\_road\_access.tif
- 2) Go to windows/Search and key-in **Raster Calculator**

Now we are going to combine all the three layers considering their weight. Double click on Suitable\_elevation.tif and click on multiply (\*) and add 0.35. Plus the Suitable\_slope.tif file times 0.45 plus Suitable\_road\_access.tif times 0.2. The raster calculator tool should look like this;



## 3.2 Disaster Risk Management

### 3.2.1 Basic Concepts and Terminologies in Disaster Risk Management

The following are some of the common concepts in Disaster Risk Management (DRM) which are useful to understand DRM as a process. Some of the following materials are excerpts from Asian Disaster Preparedness Center (ADPC).

1. A disaster occurs when a hazard impacts a vulnerable community causing damage, casualties and disruption.
2. Vulnerability is a set of prevailing or consequential conditions, which adversely affect the Community's ability to prevent, mitigate, prepare for and respond to hazardous events.
3. Capacities are resources, means and strengths, which exist in households and in the Community and which enable them to cope with, withstand, prepared for, prevent, mitigate or quickly recover from a disaster.
4. Disaster Risk = Hazard (Exposure) x Vulnerability/Capacity
5. Disaster risk reduction includes all measures, which reduce disaster-related losses of life, property or assets by either reducing the hazard or vulnerability of the elements at risk or by increasing the capacity of at risk communities.
6. DRM is multi sectoral and Multi-hazard by its very nature

The common definitions given to the main terminologies in DRM are as follows;



**The glass & the water** in this example are the hazard – In this example, an unstable glass of water is the hazard threatening our laptop on the table.

**The position of the laptop represents the exposure** – Exposure in this example is determined by the position of the laptop right under the shelf: our laptop is situated in a “hazard prone” area.

**The characteristics of the laptop represent its vulnerability** – the laptops is vulnerable to water falling from the glass because it is an electronic device that can be heavily damaged by water. If we had a plastic bowl on the table, instead of a laptop, vulnerability levels would be much lower, or even non-existent.

**Disaster Risk** – The combination of hazard, exposure and vulnerability generates a risk of disaster: if the glass full of water falls from the shelf, it is likely to spill water on the laptop and, in consequence, affect the functioning of the laptop, which is very sensitive to water, being an electronic device.

## DISASTER

A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts. (UNISDR, 2016)

A disaster happens when a hazard impacts on a vulnerable population or community whose capacity is inadequate to withstand or cope with its adverse effects, resulting in damages, loss and disruption in community/society functioning. An earthquake in an uninhabited desert cannot be considered a disaster,

no matter how strong the intensities produced. An earthquake is only disastrous when it affects people, their property and socio-economic activities.

## **HAZARD**

A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. (UNISDR -2016)

The hazards of concern to disaster risk reduction as stated in footnote 3 of the Hyogo Framework are, “hazards of natural origin and related environmental and technological hazards and risks.” Such hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis. (UNISDR, 2009)

Hazards can be single, sequential or combined in their origin and effects. For example, an earthquake causes landslides, which dam a river and then causes flooding. A community may be exposed to multiple hazards when there is simultaneous occurrence of different hazards.

## **VULNERABILITY**

The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards. (UNISDR, 2016)

Vulnerability is a set of prevailing or consequential conditions that adversely affect people’s ability to prevent, mitigate, prepare for and respond to hazardous events. These long-term factors, weaknesses or constraints affect a household’s or community’s ability (or inability) to absorb losses after a disaster or to recover from the damage. Vulnerabilities precede disasters, contribute to their severity, impede disaster response, and may continue to exist long after a disaster has struck.

Anderson and Woodrow (1989) categorize vulnerabilities into three areas, namely:

### **1) Physical/Material Vulnerability:**

For example, poor people who have few physical/material resources usually suffer more from disasters than rich people. People who are poor often live on marginal lands; they don’t have any savings or insurance; they are in poor health. These factors make them more vulnerable to disasters and means that they have a harder time surviving and recovering from a calamity than people who are better off economically.

### **2) Social/Organizational:**

Experience shows that people who have been marginalized in social, economic or political terms are vulnerable to suffering from disasters whereas groups that are well organized and in which there is a high commitment to each other suffer less when catastrophe strikes. Weakness in social and organizational areas may also cause disasters. For example, deep divisions can lead to conflict and war. Conflict of resources due to poverty can also lead to violence. The second area of vulnerability, then, is the social/organizational and economic realm.

### **3) Attitudinal/Motivational Vulnerability:**

Experience also shows that people who have low confidence in their ability to affect change or who have “lost heart” and feel defeated by events they cannot control, are harder hit by disasters than those who have a sense of their ability to bring about the changes they desire. Thus, the third area of vulnerability is the attitudinal and motivational realm.

## **CAPACITY**

The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience. (UNISDR, 2009). Capacity may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills and collective attributes such as social relationships, leadership and management. Capacity may also be described as capability. Capacity assessment is a term for the process by which the capacity of a group is reviewed against desired goals, and the capacity gaps are identified for further action. (UNISDR, 2009). Capacity (in contrast to Vulnerability) has been included in disaster management initially as a guide for both international and local agencies who work with vulnerable communities to link disasters to development even in emergency situations disaster survivors have capacities. They are not helpless

victims but have coping mechanisms on which to build on for emergency response and recovery. As the developmental and risk reduction paradigms in disaster management emerged, for many vulnerable groups, the viable track to reduce vulnerabilities has been by increasing their social/organizational capacities.

Capacities are resources, means and strengths, which exist in households and communities and which enable them to cope with, withstand, prepare for, prevent, mitigate, or quickly recover from a disaster. People's capacity can also be categorized in the same categories as was done with vulnerabilities in the previous section.

1) Physical/Material Capacity:

Even the very people whose houses have been destroyed by a typhoon or whose crops have been destroyed by floods can salvage things from their homes and from their farms. Sometimes they have food in storage or crops that can be recovered from the fields or farm implements for planting again. Some family members have skills, which enable them to find employment if they migrate, either temporarily or permanently.

2) Social/Organizational Capacity:

In most disasters, people suffer their greatest losses in the physical and material realm. Rich people have the capacity to recover soon because of their wealth. In fact, they are seldom hit by disasters because they live in safe areas and their houses are built with stronger materials. However, even when everything physical is destroyed, people still have their skills and knowledge; they have family and community organization. They have leaders and systems for making decisions. They have tribal loyalties or church affiliations. They have capacities in the social and organizational realm.

3) Attitudinal/Motivational Capacity:

People also have positive attitudes and strong motivations such as the will to survive, love and concern for each other, bravery and willingness to help each other. These are also important capacities, and form the basis for development just as much as the physical resources that people have. Coping mechanisms/strategies are generally considered capacities for survival.

## **DISASTER RISK REDUCTION (DRR)**

Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development. (UNISDR, 2016)

## **DISASTER RISK MANAGEMENT (DRM)**

Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses (UNISDR, 2016)

## **PREVENTION**

Prevention refers to the outright avoidance of adverse impacts of hazards and related disasters (ISDR, 2009).

## **MITIGATION**

Mitigation refers to lessening or limiting the adverse impacts of hazards and related disasters (ISDR, 2009). Mitigation can broadly be divided into structural mitigation and non-structural mitigations. Structural mitigation includes engineering measures such as retrofitting, retaining walls, flood barriers etc. Non-structural measures include land-use zoning, building codes, construction policies and bylaws, training on structural mitigations etc.

## **PREPAREDNESS**

Preparedness refers to the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions (UNISDR, 2009).

## **EMERGENCY MANAGEMENT**



Emergency management is the organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps (ISDR, 2009).

## **RESPONSE**

Response is the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected (ISDR, 2009).

## **RECOVERY**

Recovery is the restoration and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors (ISDR, 2009).

## **DISASTER RESILIENCE**

Disaster resilience is the capacity of a system, community or society to resist or to change in order to obtain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself, and the ability to increase its capacity for learning and adaptation, including the capacity to recover from a disaster.

### **Disaster Risk Management Process**

Disaster Risk Management, as a process can be seen from different points of views; some of these include processes from the hazard, disaster governance, and disaster cycle points of views. According to a training manual prepared by ADPC, DRM process in general requires the following:

- Establish the context and build partnerships and rapport based on the mandates and context;
- Identify the hazards (Hazard Assessment);
- Determine the elements at risk (people and health, property, livelihoods, Community structures, critical facilities, environment etc.) (Exposure Assessment);
- Determine conditions and factors of vulnerability. Why can the elements at risk be damaged? (physical, economic, social, motivational reasons) (Vulnerability Assessment);
- Identify existing coping strategies and capacities/resources (material, human, institutional/organizational, motivational, etc.) (Capacity Assessment);
- Assess risks (based on the Hazard, Vulnerability and Capacity Assessment);
- Identify measures or solutions to reduce the vulnerability of the elements at risk. How to protect and strengthen the elements at risk and how to reduce the impact of the hazard?
- Prioritize risk reduction measures to undertake: immediate, short-term, medium-term, long-term;
- Implement the risk reduction measures as planned;
- Monitor and evaluate the programs

## **3.3 Global, Continental and National Frameworks/Platforms on DRR**

### **a) The Sendai Framework for Disaster Risk Reduction**

The Sendai Framework is a 15-year, voluntary, non-binding agreement which recognizes that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including local government, the private sector and other stakeholders. It aims for the following outcome: The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. The Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) stresses that there has to be a broader and a more people-oriented preventive approach to disaster risk. DRR practices needs to be multi-hazard and multi-sectoral, inclusive, and accessible in order to be efficient and effective. Governments should engage with relevant stakeholders, including women, children and youth, persons with disabilities, people living under poverty, migrants, indigenous peoples, volunteers, and the community of practitioners and older persons in the design and implementation of policies, plans and standards.



## Priorities for Action

### ***Priority 1: Understanding disaster risk***

Disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be used for risk assessment, prevention, mitigation, preparedness and response.

### ***Priority 2: Strengthening disaster risk governance to manage disaster risk***

Disaster risk governance at the national, regional and global levels is very important for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.

### ***Priority 3. Investing in disaster risk reduction for resilience***

Disaster risk governance at the national, regional and global levels is very important for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.

### ***Priority 4. Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction***

The growth of disaster risk means there is a need to strengthen disaster preparedness for response, take action in anticipation of events, and ensure capacities are in place for effective response and recovery at all levels. The recovery, rehabilitation and reconstruction phase is a critical opportunity to build back better, including through integrating disaster risk reduction into development measures.

Based on the experiences from the implementation of the HFA, and in order to reach the targets and goals, there is a need for focused actions within and across sectors by States, at the local, national, regional, and global levels in four priority areas. An enabling international environment and means of implementation are needed to stimulate and contribute to developing the knowledge, capacities and motivation for disaster risk reduction at all levels, particularly for developing countries.

## **The Seven Global Targets**

1. Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015.
2. Substantially reduce the number of affected people globally by 2030, aiming to lower average global figure per 100,000 in the decade 2020 -2030 compared to the period 2005-2015.
3. Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.
4. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.
5. Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.
6. Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030.
7. Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

The Sendai Framework document is provided for you under X:\ERI\_data\Module3\DRM reading materials folder.

## **b) African Programme of Action**

Programme of Action for the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 in Africa was crafted in line with the Africa Regional Strategy for Disaster Risk Reduction. The Program of Action (PoA) details the need to align all DRR activities in the continent of the four priority areas of the Sendai Framework. The document explains the role of key stakeholders from the UN to AU and national to Sub-national actors in the implementation of the programme. Issues related to resource mobilization strategies and monitoring of the progress are all covered. The document is provided for your additional reading under DRM reading documents folder.

## National DRR Platforms

Countries have been striving to put in place functional institutions and DRR strategies, policies, plans and acts which are all aimed at reducing the negative impacts of disasters and building the resilience capacity of their respective communities to Disaster risks. In the region several countries have already developed national strategies/policies in DRM and this is a very positive step towards resilience building in the region.

## 3.4 Hazard, Vulnerability and Risk Assessment

According to Caribbean handbook on disaster risk information management, Hazard data is generally the most difficult to generate. For each hazard type (e.g. Drought, flooding, landslide, etc.) so- called hazard scenarios should be defined, which are hazard events with a certain magnitude/intensity/frequency relationship (e.g. flood depth maps for 10, 50 and 100 year return periods). Different types of modelling approaches are required for the hazard scenario analysis, depending on the hazard type, scale of analysis, availability of input data, and availability of models. Generally speaking a separate analysis is required to determine the probability of occurrence for a given magnitude of events, followed by an analysis of the initiation of the hazard. Under this section we are going to work on two scenarios on the main hazards in Eritrea namely drought and floods.

### 3.4.1 Drought Hazard Assessment

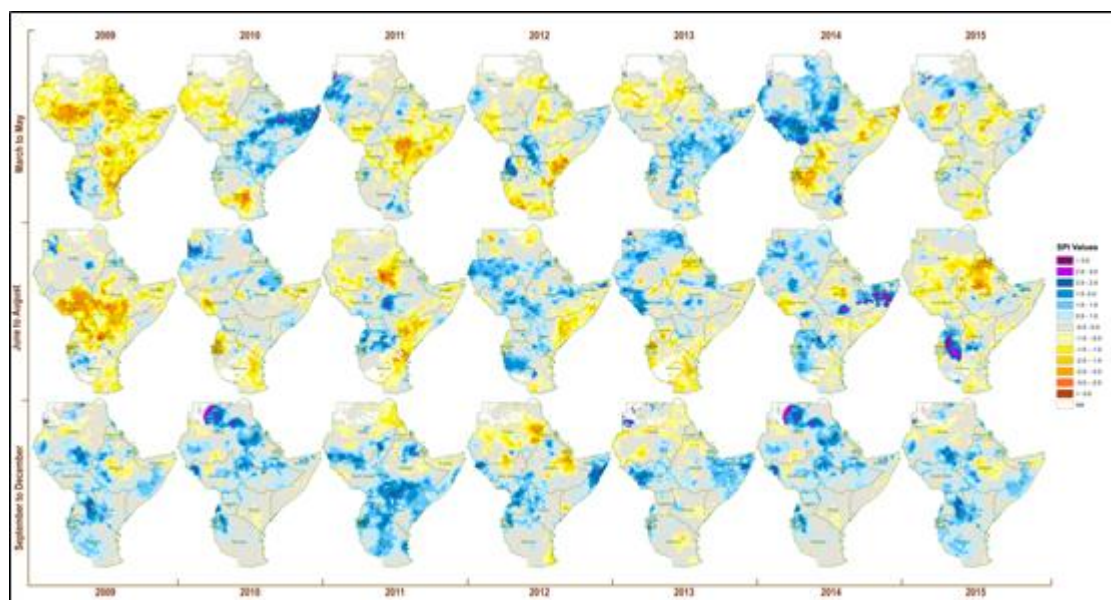
Drought is an insidious natural hazard that results from lower levels of precipitation than what is considered normal. When this phenomenon extends over a season or a longer period of time, precipitation is insufficient to meet the demands of human activities and the environment. The east African region is susceptible to recurrent droughts that immensely devastated lives and livelihoods for millions of people in the region. The drought cycle in the region is cyclical and when strike often sustained for more than one season which often end up in catastrophic damages both to life and property. The trend in the number of people affected by drought from 1900 to 2015 is given below (Source: EM-DAT/CRED).

The American Meteorological Society (AMS) categorizes drought in to meteorological/climatological, agricultural, hydrological and socio-economic drought. Meteorological drought refers to monitoring of rainfall conditions and where rainfall is below normal conditions. Meteorological and climatological drought is defined in terms of the magnitude of a precipitation shortfall and the duration of this shortfall event. Agricultural drought links the various characteristics of meteorological drought to agricultural impacts, focusing on precipitation Shortages, differences between actual and potential evapotranspiration, and soil moisture deficits. Hydrological droughts are related to the effects of periods of precipitation shortfall on surface or subsurface water supply, rather than to precipitation shortfalls directly. Socioeconomic drought is associated with the supply and demand of some economic good with elements of meteorological, agricultural, and hydrological drought. For monitoring and mapping of drought in the greater horn of Africa region meteorological and agricultural drought conditions are considered in this training.

**Meteorological Drought:** Monitoring of the meteorological drought can be done in different ways and one of the most common ways is the Standard Precipitation Index (SPI). McKee, Doesken and Kleist (1993) developed the Standardized Precipitation Index (SPI) for the purpose of defining and monitoring drought. The SPI was designed to quantify the precipitation deficit for multiple time scales, and to reflect the impact of drought on the availability of different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short time scale, while groundwater, stream flow and reservoir storage reflect longer-term precipitation anomalies. Akinremi, McGinn and Barr (1996) state that the spatial and temporal dimensions of drought create problems in generating a drought index because not only must an anomaly be normalized with respect to location, but the anomaly must also be normalized in time if it is to produce a meaningful estimate of drought; the SPI accomplishes both. It also provides spatial and temporal drought vulnerabilities from the point of rainfall scarcity. For you to make meaning to your SPI data there need to set a standard intervals as proposed by the developers. For now let's set it to 9 classes as follows;

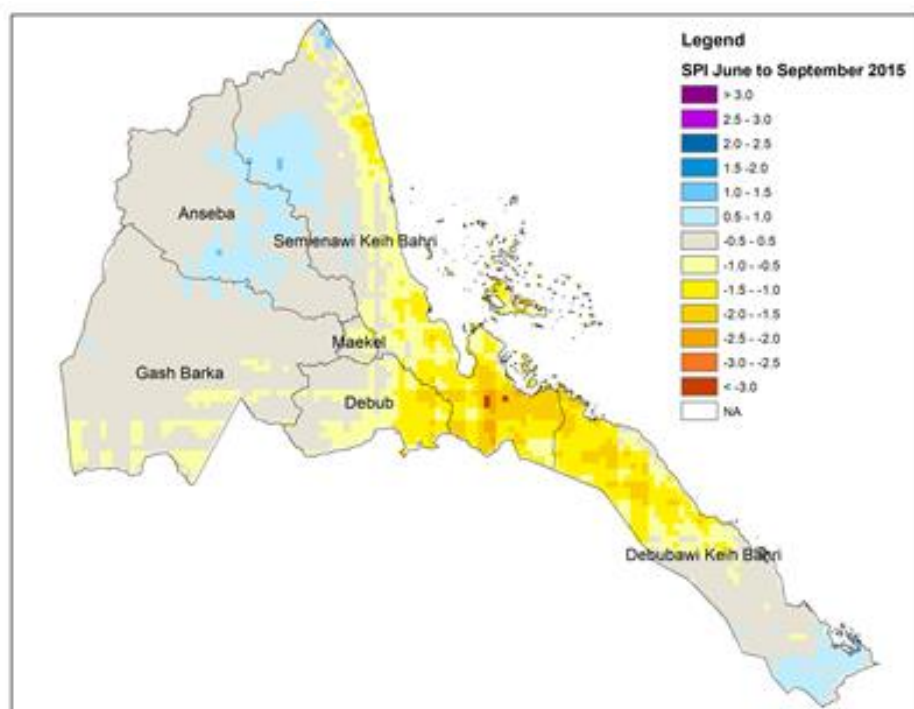
A regionally blended (observed rainfall with Chirps satellite data) at 5km resolution is used to produce seasonal SPI for 1984, 2009, 2011 and 2015. One distinct seasons are used in this analysis for the region and these are from March to May (MAM), June to August (JJA) and September to December (SOND). The MAM is the main rainfall season for GHA countries in the equatorial and some parts in the Southern sectors.

JJAS is the main rainfall season for countries in the northern sector. A sample map of SPI at seasonal scale for the Greater Horn of Africa is given below:



NOTE: The weakness of SPI is over estimation in dry and desert areas and thus careful analysis is advised.

A sample SPI for Eritrea for June to September 2015 is given below.



In drought hazard assessment we are going to use two indicators for drought severity, namely the rainfall anomaly as calculated through Standardized Precipitation Index (SPI) and the Vegetation Anomaly as calculated through Vegetation Health Index (VHI).

### 3.4.2 SPI based drought hazard assessment

Standardized Precipitation Index (SPI) can be calculated as a function of the difference between current rainfall condition and Long Term Average (LTA) and normalized by standard deviation of the rainfall for the years under consideration. The World Meteorological Organization (WMO) recommends to use data from 1981-2010 to calculate long term average.

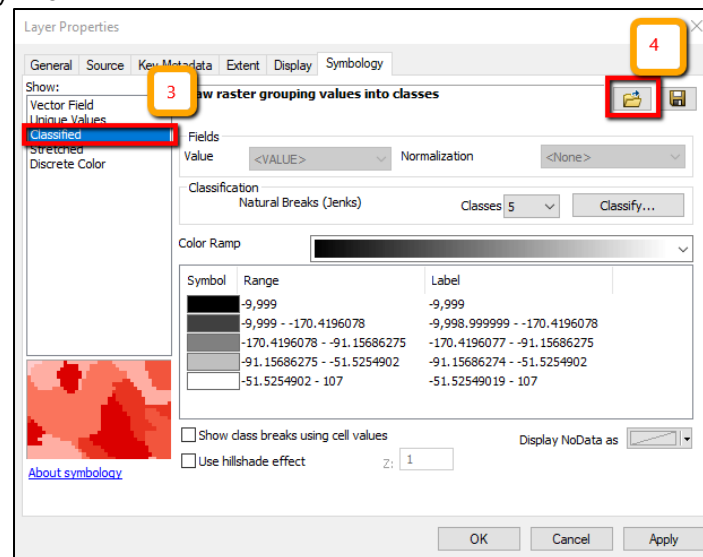
#### 3.4.2.1 Working with SPI

For this exercise SPI data layers for Eritrea are generated based on the combined rainfall seasons from April to October. Please open these layers by following the steps below;

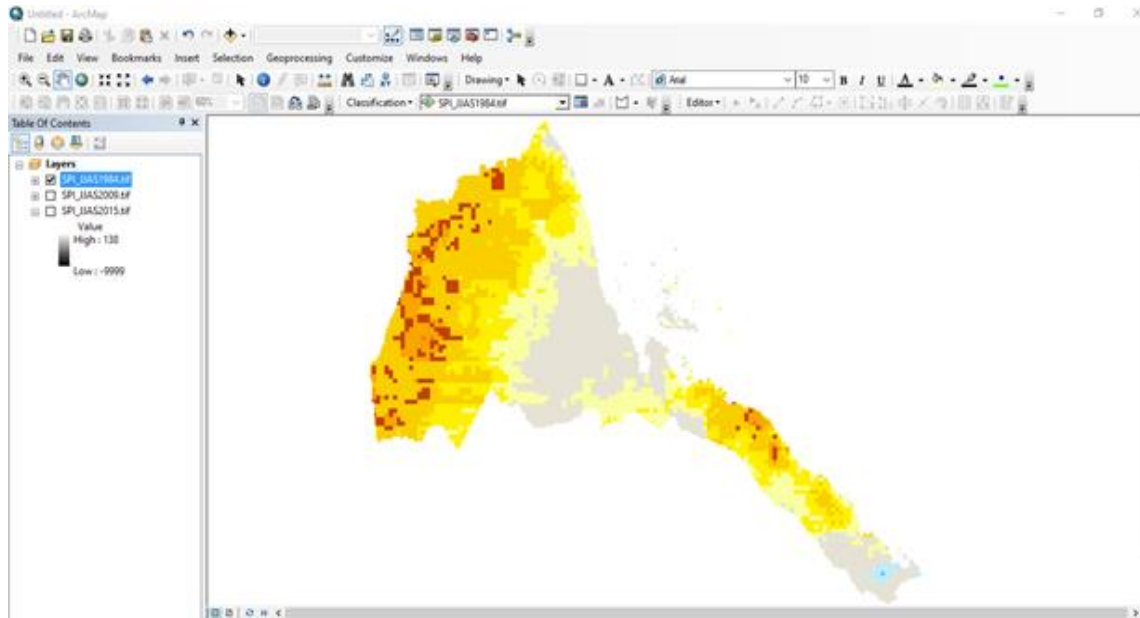
- 1) Open ArcMap and add the following layers from X:\ERI\_data\Module3\Drought\SPI folder
  - **SPI\_JJAS1984.tif**
  - **SPI\_JJAS2009.tif**
  - **SPI\_JJAS2015.tif**

The black and white images has got values and the symbology can be set manually or imported from the existing \*.lyr file. For this exercise we will import a symbology.

- 2) Double click on SPI\_JJAS1984.tif and go to symbology and under show click classified.
- 3) Now click on import and go to X:\ERI\_data\Module3\Drought\SPI folder and select SPI\_symbology.lyr file

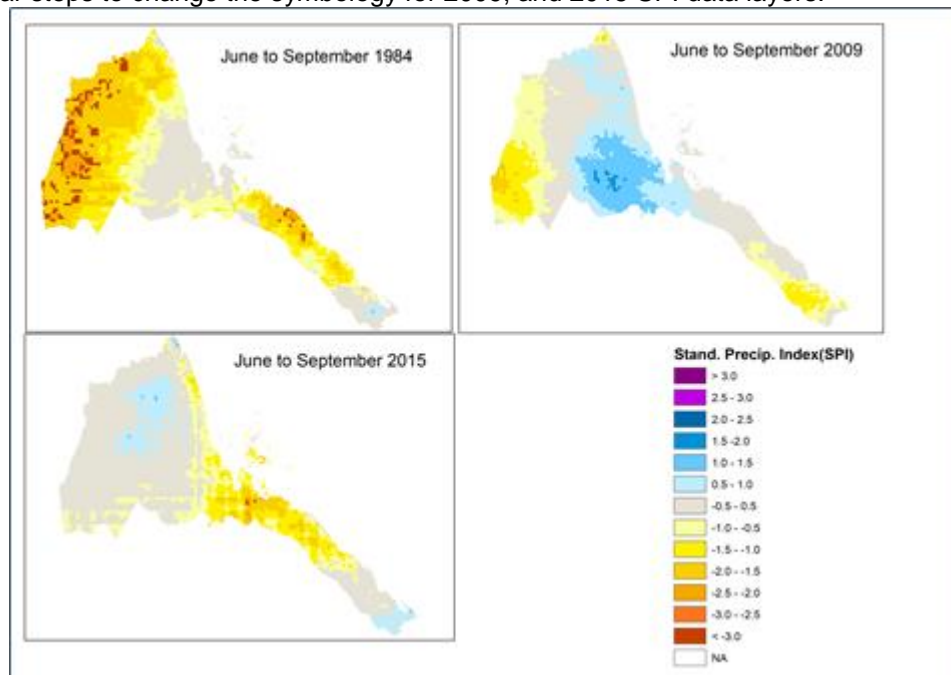


- 4) Click Ok and now your map view should look something similar to this.



### Exercise 3.1

Follow similar steps to change the symbology for 2009, and 2015 SPI data layers.



### 3.4.3 Zonal Statistics

Calculate Zonal Statistics to produce seasonal meteorological drought hazard map for Admin Level 2 of Eritrea

1. Add the ERI\_Adm2 layer from **X:\ERI\_data\Module 1\Admin**
2. Go to the main menu in ArcMap *Windows >> Search* now type *Zonal Statistics* and click on *Zonal Statistics as a Table*
3. Set ERI\_adm2 as input raster or feature zone data and NAME 2 as zone field.
4. Select SPI\_JJAS2009.tif file as input value raster and save the output table under **X:\ERI\_data\Module3\Output** folder by the name *Zonal StatisticsSPI\_2009.dbf*.
5. Select MEAN as statistics type and click Ok

Once completed you should be able to see table added to your table of contents. You can open the table under the values field, you can see which district has the lowest mean SPI value.

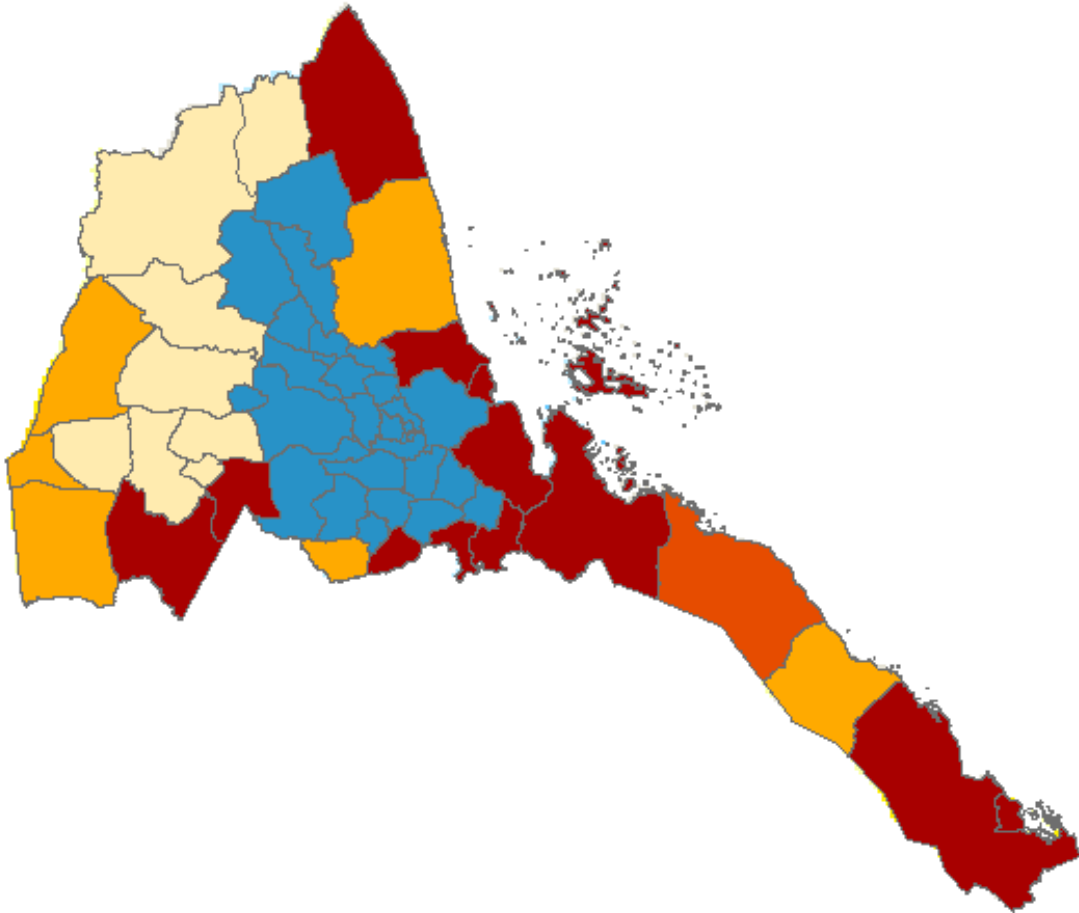
If you wish to produce the drought severity map based on the rainfall anomaly as measured by the SPI you can follow these steps;

Now we are going to join the two tables ERI\_adm2 and Zonal statistics\_SPI2009 using the common field "NAME2" which is Zone

6. Right click on ERI\_adm2 layer and click on the Join and relate >> Join
7. Select ERI\_adm2 in the first drop down field and Zonal statistics table in the second and NAME 2 under the third dropdown
8. Click Ok and you can open attribute table of ERI\_adm2 and you find that the two tables are joined. Now we are ready to produce drought severity map of districts based on the SPI values.
9. To save the merged tables as one shapefile you need to right click on ERI\_adm2 and export data. Save it under **X:\ERI\_data\Module3\Output** with the file name *Drought\_hazard\_severity.shp*. Your new map will be added automatically to the table of contents.
10. Let's produce a drought hazard severity map based on the mean SPI with the following 3 range (-150 to -200; -200 to -250 and -250 and less).
11. Double click on the *Drought\_hazard\_severity.shp* layer and go to symbology
12. Go to Quantities and graduated colors. Now choose MEAN as value field and set the number of classes to 5.
13. Click on Class and set the above range and choose a color (Blue to dark red) and Click Ok

**Now you should get a map something similar to this.**





### 3.4.4 Downloading SPI Data

Standardized Precipitation Index (SPI) can be obtained from ICPAC Data library & Maproom (<http://digilib.icpac.net/>). Step by Step on how to access the data is shown below:

- Open this link (<http://digilib.icpac.net/>) and click on Data by Source.

**Climate Data Library**

The Data Library is a powerful and freely accessible online data repository and analysis tool that allows a user to view, analyze, and download hundreds of terabytes of climate-related data through a standard web browser.

It is a powerful tool that offers the following capabilities at no cost to the user:

- access any number of datasets;
- create analyses of data ranging from simple averaging to more advanced EOF analyses using the Ingrid Data Analysis Language;
- monitor present climate conditions with maps and analyses in the Maproom;
- create visual representations of data, including animations;
- download data in a variety of commonly used formats, including GIS-compatible formats.

**ICPAC Map Room**

The maproom is a collection of maps and other figures that monitor climate and societal conditions at present and in the recent past. The maps and figures can be manipulated and are linked to the original data. Even if you are primarily interested in data rather than figures, this is a good place to see which datasets are particularly useful for monitoring current conditions.

**Data by Source**

Datasets organized by source, i.e. creator and/or provider.

**Navigating Through the IRI Data Library: A Tutorial**

The goal of this tutorial is to introduce you to the structure of the Data Library and the many ways to navigate through it.

**Statistical Techniques in the Data Library: A Tutorial**

Statistical techniques are essential tools for analyzing large datasets; this statistics tutorial thus covers essential skills for many data library users.

**Function Index**

Index for functions that can be used to analyze data within the Data Library.

**Help Resources**

The Help Resources include basic and statistics tutorials, function documentation, and other resources to help you get the maximum utility out of the Data Library.

- Click on **ICPAC>>CHIRPS-BLENDED>>monthly>>**

## Datasets and Variables

<a href="#">ENACTS</a>	Enhancing National Climate Service initiative.	2
<a href="#">Features</a>	Features[ <b>Political</b> ]	
<a href="#">ICPAC</a>	ICPAC[ <b>Projections CHIRPS-BLENDED Forecasts CHIRP-BLENDED</b> ]	
<a href="#">Indices</a>	Indices[nino]	
<a href="#">KADUNA</a>	KADUNA[ <b>EXTENDED</b> ]	

## Datasets and Variables

<a href="#">CHIRP-BLENDED</a>	ICPAC CHIRP-BLENDED[ <b>seasonal dekadal monthly</b> ]	3
<a href="#">CHIRPS-BLENDED</a>	ICPAC CHIRPS-BLENDED[ <b>seasonal dekadal monthly</b> ]	
<a href="#">Forecasts</a>	ICPAC Forecasts[ <b>WRF CPT</b> ]	
<a href="#">Projections</a>	ICPAC Projections[ <b>RCA-MPI</b> ]	

## Datasets and Variables

<a href="#">dekadal</a>	ICPAC CHIRPS-BLENDED dekadal[ <b>rainfall</b> ]	4
<a href="#">monthly</a>	ICPAC CHIRPS-BLENDED monthly[ <b>rainfall WASP</b> ]	
<a href="#">seasonal</a>	ICPAC CHIRPS-BLENDED seasonal[ <b>rainfall</b> ]	

## Datasets and Variables

<a href="#">rainfall</a>	ICPAC CHIRPS-BLENDED monthly rainfall[ <b>spi precipitation</b> ]	5
<a href="#">WASP</a>	ICPAC CHIRPS-BLENDED monthly WASP[ <b>12-month 3-month 1-month</b> ]	

Last updated: Tue, 15 Aug 2017 15:51:28 GMT

The screenshot shows a web interface for data selection. At the top, there is a map of Africa with a red box around it. Below the map, there is a table with columns for 'Data Library', 'Time', 'X', and 'Y'. The 'Data Library' column contains the text 'ICPAC CHIRPS-BLENDED monthly rainfall spi'. The 'Time' column contains 'Jan 1981 - Aug 2018'. The 'X' column contains '21.83E - 51.48E'. The 'Y' column contains '11.8S - 23.15N'. Below the table, there is a row of tabs: 'Description', 'Views', 'Data Filters', 'Data Selection', 'Data Files', 'Data Tables', and 'Expert Mode'. The 'Data Selection' tab is highlighted with a red box and a yellow circle containing the number 6.

- Change **Time**, **Longitude** and **Latitude** as shown below
- Then **Restrict Ranges>Stop Selecting**
- Click on **Data Files>** then Click on **GeoTIFF Image** as shown below
- Once you are sure of the month, Click on e.g. **200908 GeoTiff for GIS**
- Download all the four months to make a season.



**ICPAC CHIRPS-BLENDED monthly rainfall spi Data Files**

This dataset has bytes (4719680 4.5010376MB) of data in it, which should give you a rough idea of the size of any file that you ask for.

GIS-Compatible Formats	
There are three GIS-compatible formats available.	
<a href="#">2-Dimensional Table</a>	A 2-dimensional ascii file that includes an Arcinfo Header.
<a href="#">IDA Image</a>	File(s) in the Image Display and Analysis format. Typically used with WinDisp.
<a href="#">LAN Image</a>	File(s) in the ERDAS LAN format. Typically used with various GIS programs, including ArcView and  Mapper.
<a href="#">GeoTIFF Image</a>	File in GeoTIFF format. Typically used with various GIS programs, including ArcView and ENVI.

**GeoTIFF Image Format Downloads**

**ICPAC CHIRPS-BLENDED monthly rainfall spi**

Time: **Aug 2009** Jul 2009 Sep 2009

23.15N

Latitude

10°N 20°N 30°N

25°E 30°E 35°E

Longitude

5.999999N Aug 2009 21.83E 39.03E

false color image reload

**200908 GeoTiff for GIS**

### 3.4.5 Vegetation anomaly based drought hazard assessment

Vegetation Condition Monitoring is an important activity and can be done in many different ways. The Vegetation Health Index (VHI) represents overall vegetation health and it is a combination of Vegetation Condition Index (VCI) and temperature condition index (TCI). While VCI indicates the short-term weather-related NDVI fluctuations from the long-term mean, the TCI shows the relative change in thermal condition of brightness temperature (NOAA Star).

Compared to ground-based and NDVI-based (two-channel algorithm) detection systems, this new method provides earlier drought warnings. It also makes it possible to estimate areas under droughts of different severity, and to diagnose the potential for drought development prior to the actual start of drought conditions. One of the important advantages of this method is that it makes use of a combination of the normalized difference vegetation index (NDVI), normally used alone, and the 10.3-11.3-um thermal channel. Assessment of temperature conditions permits one to identify subtle changes in vegetation health because the effect of drought is more dramatic if a shortage of moisture is accompanied by excessive temperatures. This method was validated in all major agricultural countries around the world. (Kogan 2002)

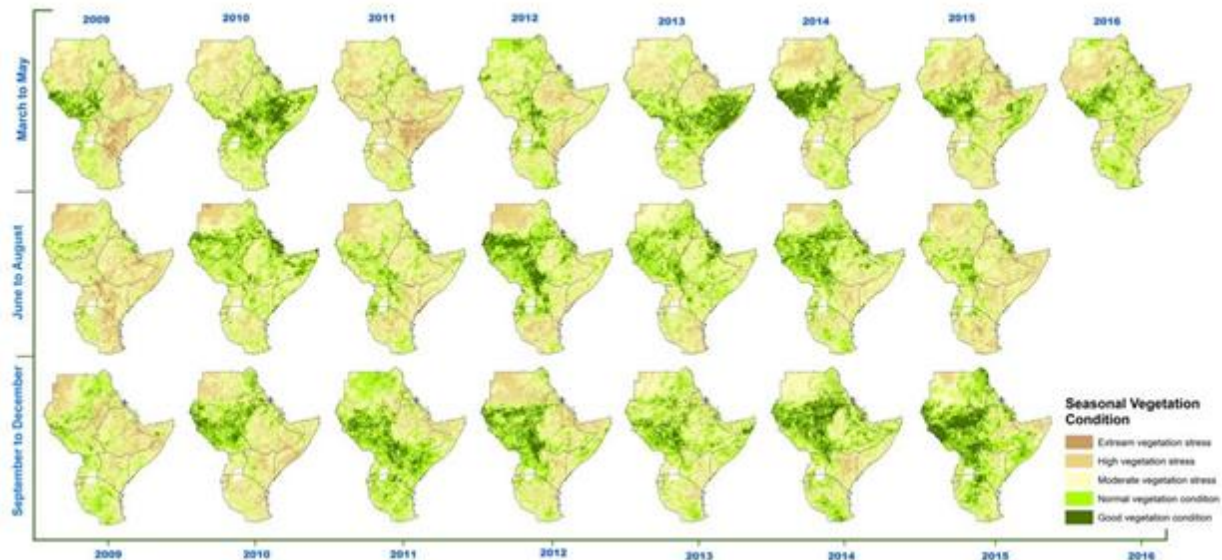
The VCI and TCI were useful to assess the spatial characteristics, the duration and severity of drought, and were in a good agreement with the precipitation patterns. (Ghosh 2007). NOAA STAR website stated that

the VHI reflects indirectly a combination of chlorophyll and moisture content in the vegetation health and also changes in thermal conditions at the surface. This new approach combines the visible, near infrared, and thermal radiances in a numerical index characterizing vegetation health. This approach is extremely useful in detecting and monitoring such complex and difficult-to-identify phenomenon as drought. The VHI values below 40 are used for identifying vegetation stress which is an indirect drought indicator. The VHI is very useful for early drought detection, assessing drought area coverage, duration, and intensity, and for monitoring drought impacts on vegetation and agricultural crops. Vegetation condition index (VCI). VCI was first suggested by Kogan (1995, 1997). It shows how close the NDVI of the current month to the minimum NDVI calculated from the long-term record.

Where,  $NDVI_{max}$  and  $NDVI_{min}$  are calculated from the long-term record (e.g., 18 years) for that month (or week) and  $j$  is the index of the current month (week).

For compositing the weekly VHI values a maximum of the season is calculated and the following map presents the results for the three seasons from 2009 to 2016 in the atlas map of IGAD/ICPAC. For compositing the weekly VHI values a maximum of the season is calculated and the following map [presents the results for the three seasons from 2009 to 2016.

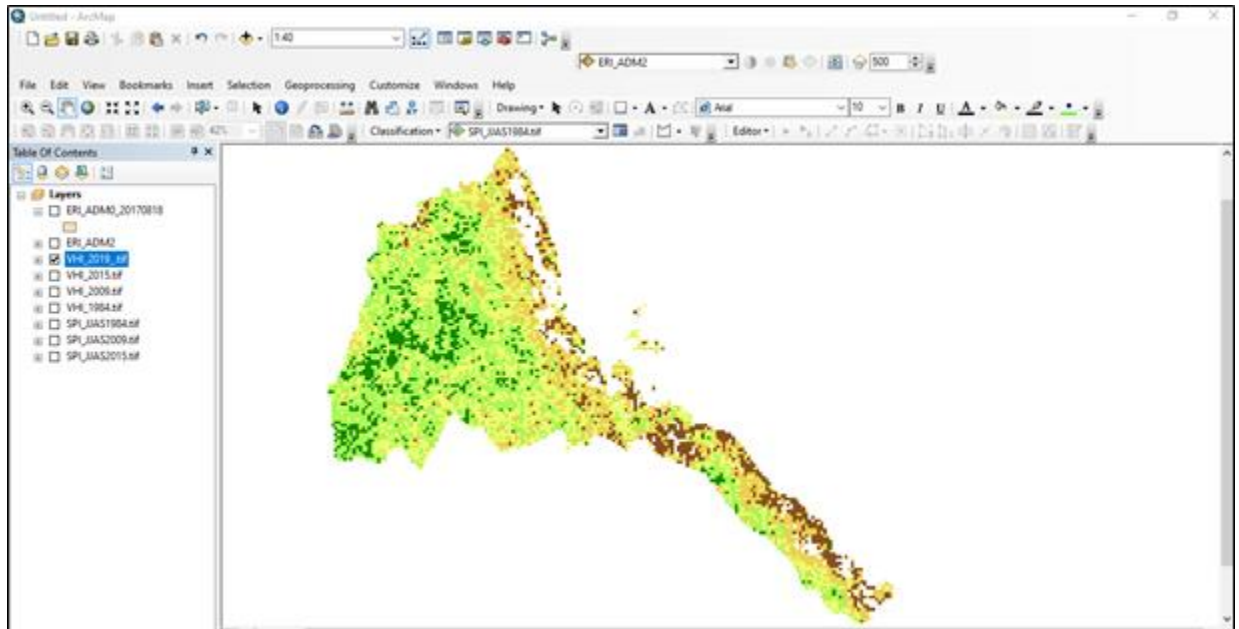
To generate the agricultural drought using VHI, the techniques used for SPI are similar except the range and thresholds of the values.



### 3.4.6 Classify VHI values to standard classes

1. Open ArcMap and add the following VHI layers from **X:ERI\_data\Module3\Drought\VHI** folder
  - **VHI\_Week 4 November 1984.tif**
  - **VHI\_Week 4 November 2009.tif**
  - **VHI\_Week 4 September 2019.tif**
2. Now classify the layers. Right click on the VHI\_Week 1 September 2009 layer and go to symbology. Under show click on classified and set the number of classes to 6 and click on classify to set upper limits of the classes.
3. Set the class interval 0, 20,40,60,80,100 and click Ok

- Now import symbology from X:\ERI data\Module3\Drought\VHI folder and click Ok choose the color range from the color ramp and click Ok.



Your map looks similar to the one below

VHI values under 40 are considered to be vegetation under stress condition and some literature indicated that this is a proxy indicator for agricultural drought. This threshold can be used for monitoring agricultural drought in croplands and rangelands.



### Exercise 3.2

Produce the agricultural drought map for the first week of November 20015 and 2009 for all the districts of Eritrea and identify top three districts under severe vegetation stress conditions during these Week of the month.

#### 3.4.7 Downloading vegetation Health Index (VHI) data


Vegetation Health Index (VHI) data can be obtained from NOAA's Advanced Very High Resolution Radiometer (AVHRR). Note that this is available at 4 km resolution and if higher resolution is needed, consider using data from other sources such as MODIS.

- Open the webpage for downloading VHI's from NOAA's AVHRR.

[ftp://ftp.star.nesdis.noaa.gov/pub/corp/scsb/wguo/data/Blended\\_VH\\_4km/geo\\_TIFF/](ftp://ftp.star.nesdis.noaa.gov/pub/corp/scsb/wguo/data/Blended_VH_4km/geo_TIFF/)

- Scroll to the bottom of the page (note that this is a weekly data, each TIFF file is for the entire world, the naming convention includes the year followed by the week). For Example: P201801 is the first week of January
- Download all the required weeks to average if you need monthly data.

## Index of /pub/corp/scsb/wguo/data/Blended\_VH\_4km/geo\_TIFF/

 [parent directory]

	Name	Size	Date Modified
	VHP.G04.C07.NC.P1981035.SM.SMN.tif	29.0 MB	12/10/15, 3:00:00 AM
	VHP.G04.C07.NC.P1981035.SM.SMT.tif	21.3 MB	12/10/15, 3:00:00 AM
	VHP.G04.C07.NC.P1981035.VH.TCI.tif	28.4 MB	12/10/15, 3:00:00 AM
	VHP.G04.C07.NC.P1981035.VH.VCI.tif	28.0 MB	12/10/15, 3:00:00 AM
	VHP.G04.C07.NC.P1981035.VH.VHI.tif	32.1 MB	12/10/15, 3:00:00 AM
	VHP.G04.C07.NC.P1981036.SM.SMN.tif	28.8 MB	12/10/15, 3:00:00 AM
	VHP.G04.C07.NC.P1981036.SM.SMT.tif	21.2 MB	12/10/15, 3:00:00 AM

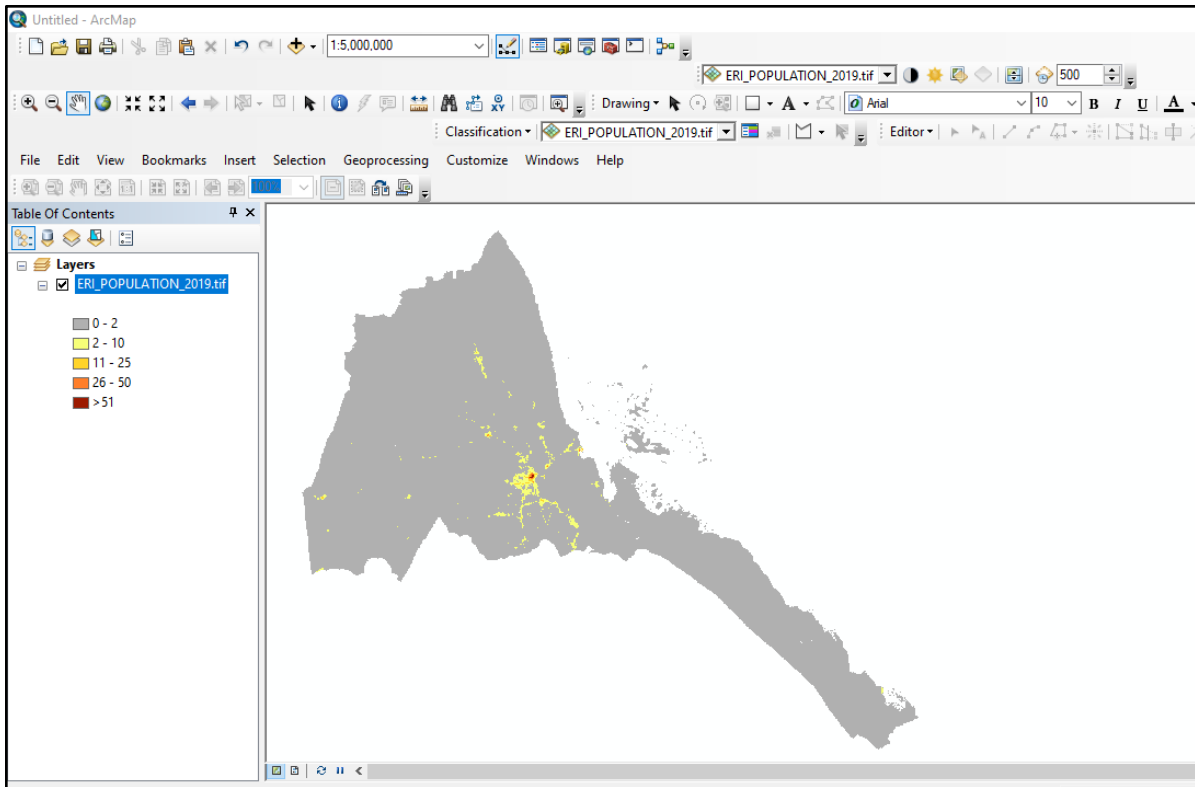
### 3.5 Drought, vulnerability and risk assessment

One of the most important aspects of vulnerability assessment is to identify the elements that are at risk of an impending disaster. Depending on the nature of the hazard we can list a number of elements that can be at risk and in this case we are working on drought hazard. Let's consider human and livestock population as two elements at risk to further make a meaning to our hazard and risk assessment. These information are also key for preparedness, mitigation and response plans.

#### 3.5.1 Elements at Risk

Human Population estimates from Worldpop data Layer (100 meter resolution) for 2019

1. Open ArcMap and load **ERI\_Population\_2019.tif** layer from **X:\ERI\_data\Module1\Population** folder
2. Double click on **ERI\_Population\_2019.tif** and import a *Pop\_symbology* from **X:\ERI\_data\Module1\Population** folder
3. Now your population map should look something like this

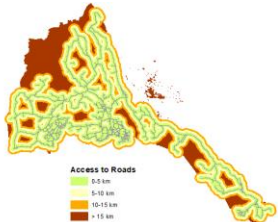
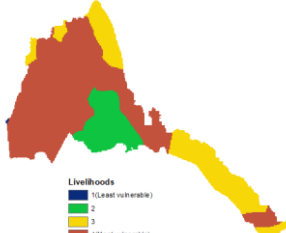


1. Now load the *Drought\_hazard\_severity.shp* layer you produced earlier under **Step 9**
2. You have hazard and population layers. Now in order to identify the total population exposed to the drought hazard based on JJAS SPI values you can generate the total population from the population raster above.

### 3.5.2 Vulnerability

The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. Some countries are more vulnerable to a certain hazard than others. Even in one country some regions and districts can be more vulnerable to a specific type of hazard than the others. This is due to several factors including physical, economic, social, cultural...etc factors. The east Africa region, for instance is vulnerable due to over dependence on natural resources and primary activity, over reliance on rain- fed agriculture, low level of development, and inadequate institutional and economic capabilities among many others.

Mapping vulnerability requires to look at several factors including those mentioned above and even more. For now we will be using the following indicators;

Factor	Indicator	Range/threshold/criteria	Remark
PHYSICAL & ECONOMIC	<p>Access to major Roads</p> <p>(Primary, Secondary and tertiary roads only)</p> <p><i>(data source: Roads/HDX)</i></p>	<p>Very poor/Inaccessible (&gt;15km)</p> <p><i>Poor Access(10-15km &gt; 3 hrs)</i></p> <p><i>Moderate Access(5-10km) 2 hrs</i></p> <p><i>Very Good Access (&lt;5km) 1 hrs</i></p>	
	<p>Livelihoods</p> <p><i>(data source: FAO-geonetwork)</i></p>	<p>Very highly</p> <p>High</p> <p>Low</p> <p>Very low</p>	
Also consider adding the layers of your choice			

You can combine all of these layers to produce a vulnerability map that shows a combined effects of factors across the country.

### 3.5.3 Vulnerability Map

#### How to Combine Several Layers to Produce Vulnerability Map

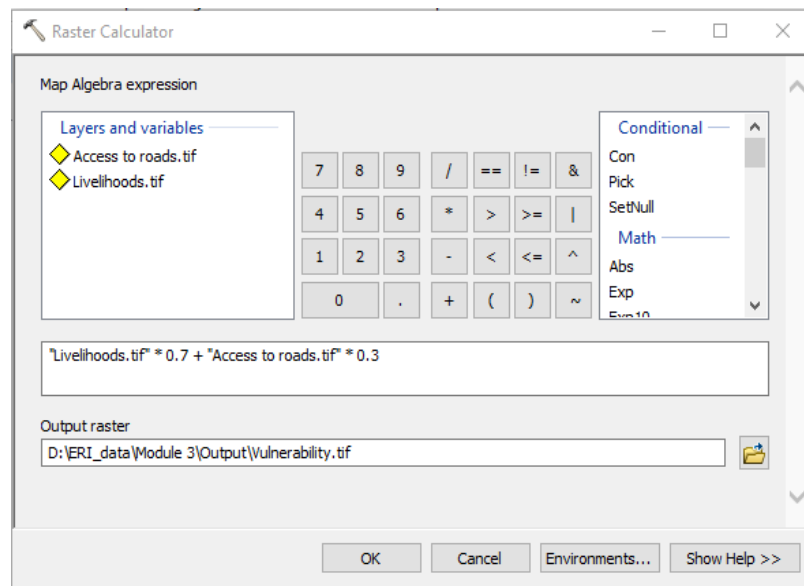
**Important:** Before you start, make sure that all the layers are important indicators and represented with a correct data. All you GIS data needs to be in raster format and the layers have the same number of classes. It is also important to make sure the number ranking reflects or measures the level of importance or level of severity for vulnerability.

- Load the following three layers from **X:\ERI\_data\Module3\Drought\Vulnerability** folder
  - Livelihoods.tif**
  - Access to roads.tif**
- Go to Windows >> **Search >> raster calculator**. Open raster calculator
- Now you will add all the layers and combine both. But before that you need to give weight to each of your parameters based on their importance to decide the output. For this

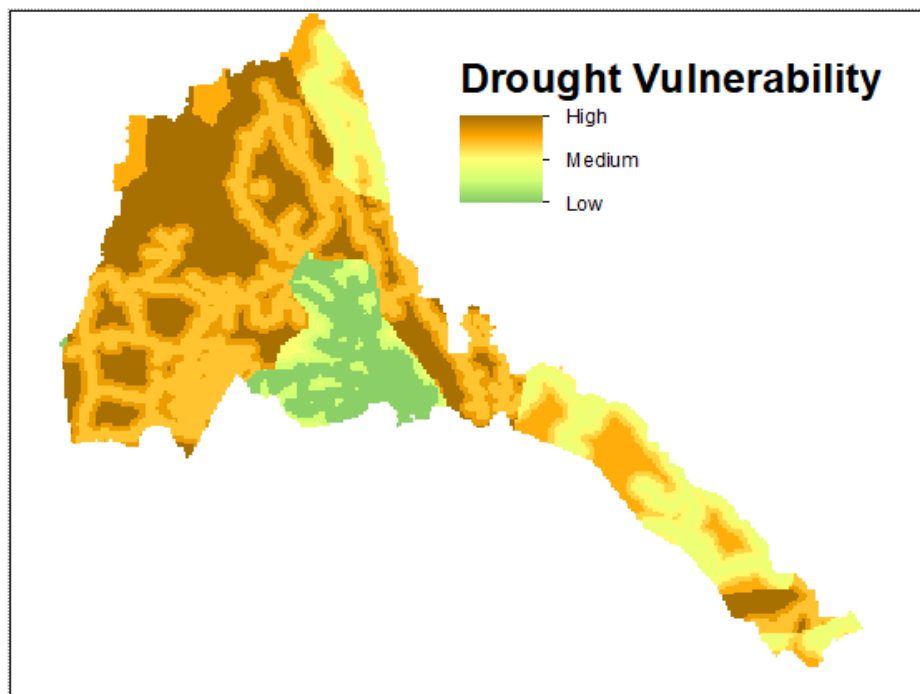


exercise Let's assume that livelihood is the most important factor to determine Vulnerability and gets **70%** weight and Access to roads will get **30%** importance.

4. Double click **Livelihoods layer** to add it to the raster calculator and use multiplication (\*) operator and give a weight (0.6). Click on the plus sign (+) and add **Accessibility and** multiply it by 0.3. The raster calculator should look something like this.



5. Name the output raster as Drought vulnerability.tif and save it under **X:\ERI\_data\Module3\Output** folder and click Ok
6. The values of the pixels indicate level of vulnerability and go to symbology and use stretched the raster from high to low values. You can see such a map







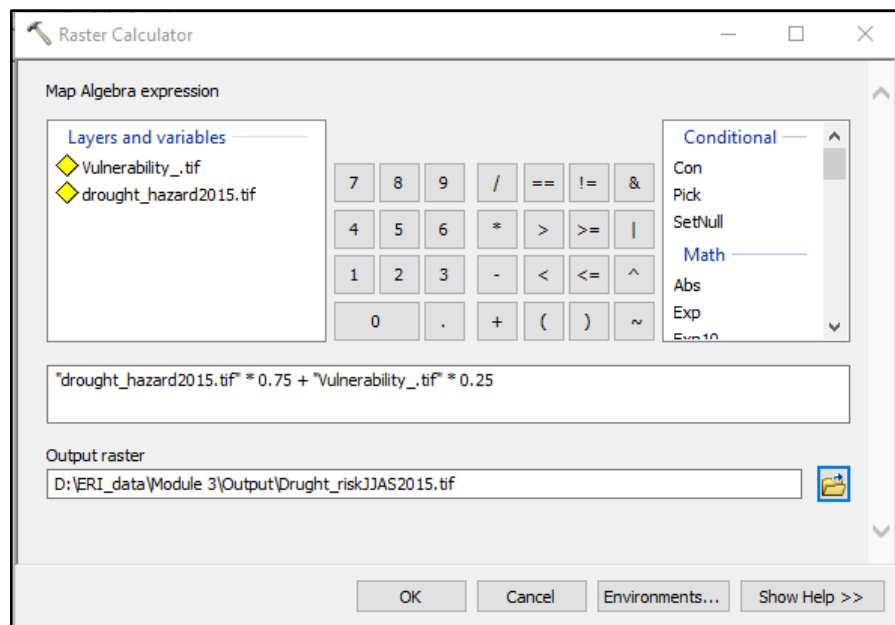
**Can you explain this map with the necessary precautions for preparedness planning?  
What are the strengths and weaknesses of this map?**

You can also take this result further to combine it with drought hazard map (SPI) for JJA 2015 to produce drought **risk** map. The poverty and related layers can be added to depict the lack of capacity indicated in the risk equation.

### How to Produce a Risk Map (Example)

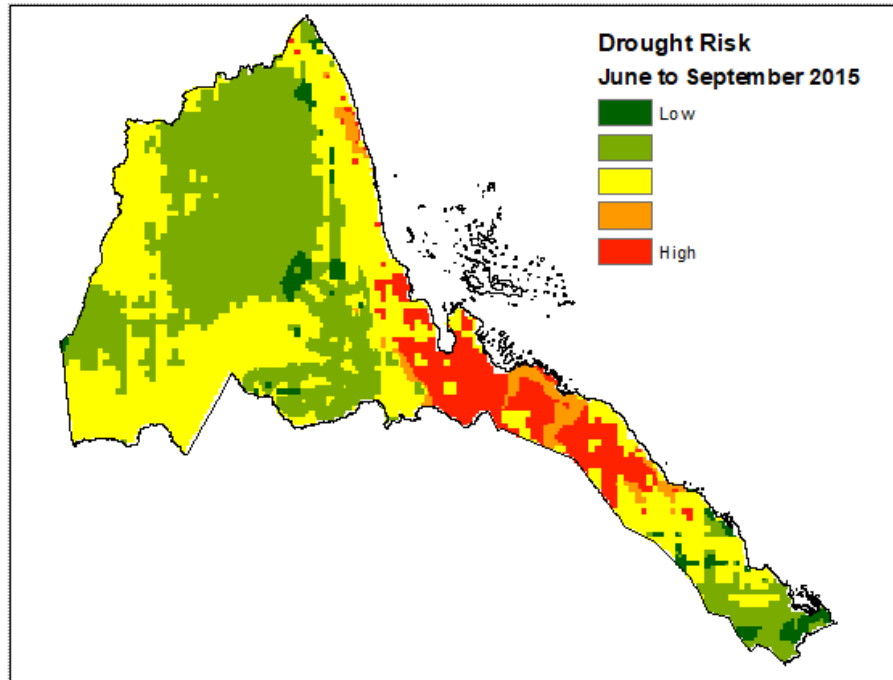
3.5.3.1.1 Risk is a factor of hazard, exposure and vulnerability versus capacity. You have two of the layers

1. Open the **Drought\_hazard2015.tif** and **vulnerability.tif** layers from  
**X:\ERI\_data\Module3\Risk** folder
2. As you can notice the two layers are standardized and classified into three classes. Now go to **Windows >> Search for Raster calculator** and open it
3. In the **Raster calculator** double click on **Drought\_hazard2015** and give it a weight of **0.75** and click on **multiplication (\*)** sign and double click on **vulnerability** and multiply it with **0.25**. This is to indicate that the hazard map is by far the most important determining factor (3/4<sup>th</sup>) compared to the vulnerability. This is to say where there is no hazard vulnerability alone can't produce a risk.



3. Set the output name to **Drought Risk\_2015.tif** and save it under **X:\ERI\_data\Module3\Outputs** folder and click **Ok** to run the operation

Now you can open the drought risk layer and choose appropriate legend as to show low,



Which districts are at high drought risk for the given season/year?

### 3.6 Flood Hazard/Risk Assessment

#### Learning Objectives:

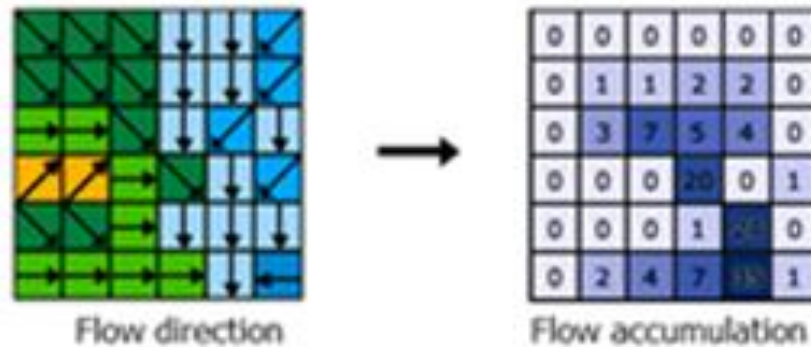
- Causes of Floods?
- What is a Flood Hazard?
- Flood Hazard Assessment Methods
  - Use of Historical data (the past flood approach)
  - Hydrological and hydraulic approach (flood modelling)
  - Temporal Satellite Data Analysis

#### 3.6.1 GLOSSARY

**Cross section** is the distance perpendicular to the direction of flow

**Discharge** is the rate of flow of water measured in terms of volume over time (i.e. the amount of water moving past a point). Discharge and flow are interchangeable.

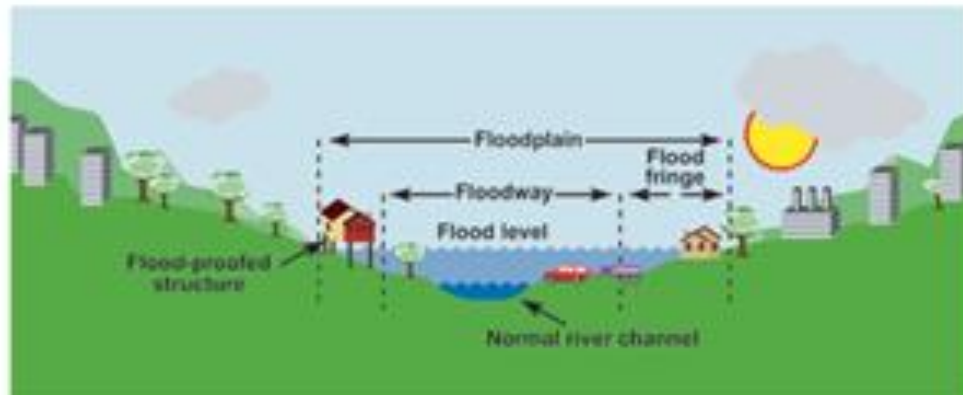
**Flow Accumulation** tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell. The result of Flow Accumulation is a raster of accumulated flow to each cell, as determined by accumulating the weight for all cells that flow into each downslope cell.



Source:ESRI

**Flow direction** tool calculates the direction water will flow using slope from neighboring cells. This is usually determined by the direction of the steepest descent in each cell. The result is a raster of flow direction from each cell to its steepest downslope neighbor.

**Flood level** is the height or elevation of floodwaters relative to a datum.



Source:Environment and Climate Change Canada

**Floodplain** is the land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood event.

**Hydrologically conditioned DEM(Hydro DEM)** is a DEM whose flow direction defines expected flow of water over the terrain (DEM).

**Peak flood level, flow or velocity** is the maximum flood level, flow or velocity occurring during a flood

**Runoff** is the amount of rainfall from a catchment that ends up as flowing water in the river or creek.

**Watershed** is the area where all the water that is under it or drains off of it goes into the same place.



Source: NASA

### Causes of Floods?

Causes of floods can be due to various reasons, such as natural, man-made and Effect of climate change. These are categorized into,

**Natural:** Flash floods, Flood, Coastal Flood (due to cyclones/typhoons)

**Man-made:** Urban development/ drainage congestion, Dam failures, Watershed activities (deforestation)

### Climate Change Effect.

**Flood:** An overflow or inundation that comes from a river or other body of water and causes or threatens damage. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream is known as flood.

**Flash flood:** The result of heavy or excessive amounts of rainfall within a short period of time, usually less than 6 hours, causing water to rise and fall quite rapidly.

### What is a Flood Hazard?

To analyse the nature and mechanisms of flooding including frequency, velocity and magnitude. Floods need to analyse floods qualitatively and quantitatively with the aim of gaining an understanding of the nature of flooding to:

- Identify the probability of a flood occurring.
- Identify the specific future time period.
- Identify the area and intensity of impact.

Source: UNISDR, 2004.

### Flood Hazard Assessment Methods

Flood hazard assessment can be conducted in various ways depending on the data availability. The method of carrying out the assessment depends on the information, technology and resources available. Most commonly used methods are

- identifying the probability of flood occurrence
- Flood Modelling (Hydrological and Hydraulic) approach
- Temporal Satellite Data Analysis

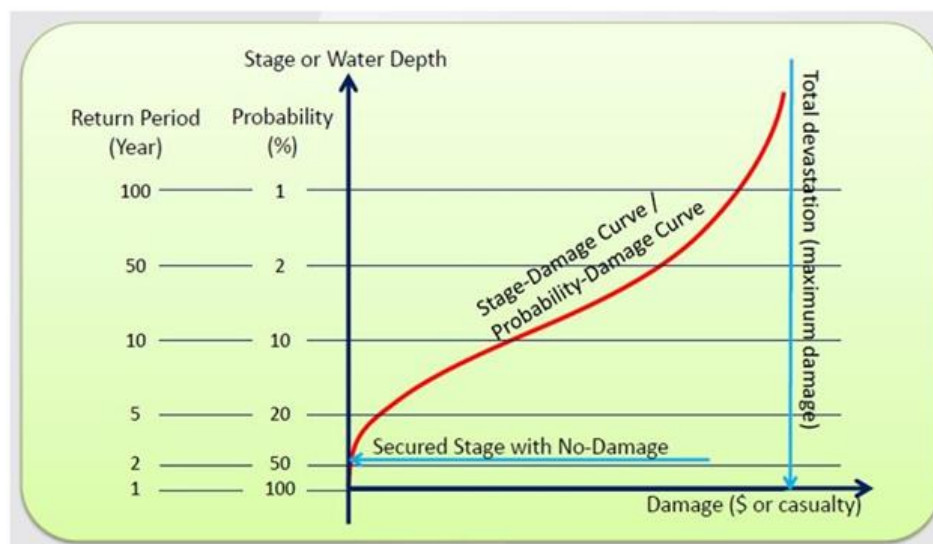
**Identifying the probability of flood occurrence:** The return interval, or return period, places magnitude of floods in terms of their expected frequency giving a probability of a particular flood occurring. There are

a vast number of methods that can be used to calculate or determine return intervals based on the data or lack of data available. This is assessed using the historical data of past flood events and popularly known as flood frequency analysis.

The 100-year flood is a common design flood use delineate floodplains and design structures. Often there are not enough records to determine the magnitude of the 100-year flood; this must then be done by empirical extrapolation using frequency distributions (WMO 1999).

Output from the probability of flood occurrence (Flood Frequency Analysis) will be Flood gauge height for different probability of flood occurrence. Different gauge heights can be used to map flood extents of different probability of flood occurrences in a GIS environment to delineate flood hazard zones.

The relationship between the return period and probability of occurrence, stage / water level and damage is shown in the figure below.



Flood Hazard is usually categorized as high, medium and low and very low intensity as per the magnitude of maximum river discharge return period / probability indicated in the following table.

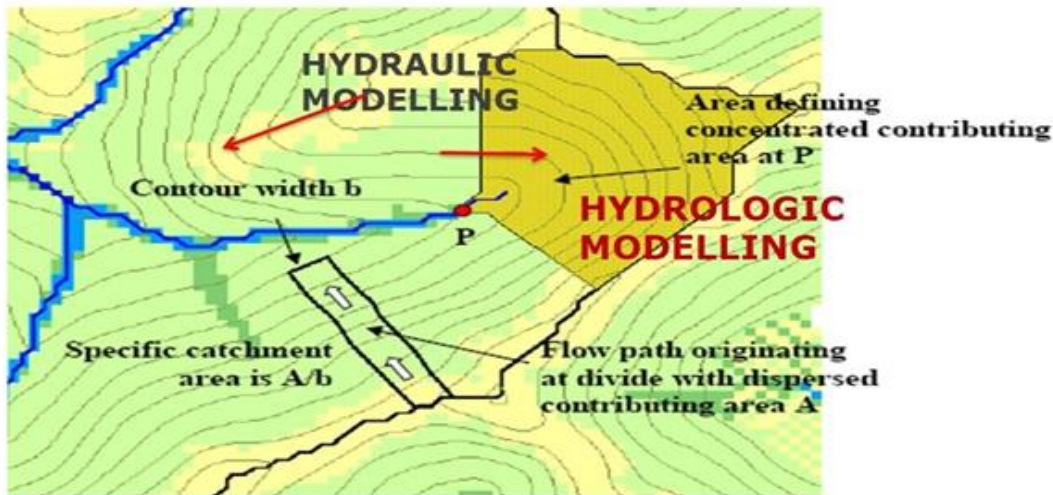
**Table 3.7: Classification of Probability**

Flood Hazard Category	Return Period (years)	Probability (%) of occurrence
High	< 10	> 0.1
Medium	10 to 50	0.1 to 0.02
Low	50 to 200	0.02 to 0.005
Very Low	> 200	< 0.005

Source: Review of Flood hazard Mapping, EU, 2008.

### Flood Modelling (Hydrological and Hydraulic) approach:

Models can be used to determine the occurrence of floods based on actual or hypothetical rainfall events. Flood simulation is achieved by combining a hydrological model to predict flood flows with a hydraulic model to predict inundation levels. Conceptually, hydrologic and hydraulic modelling is shown in figure below.



*Hydrologic and Hydraulic Modelling*

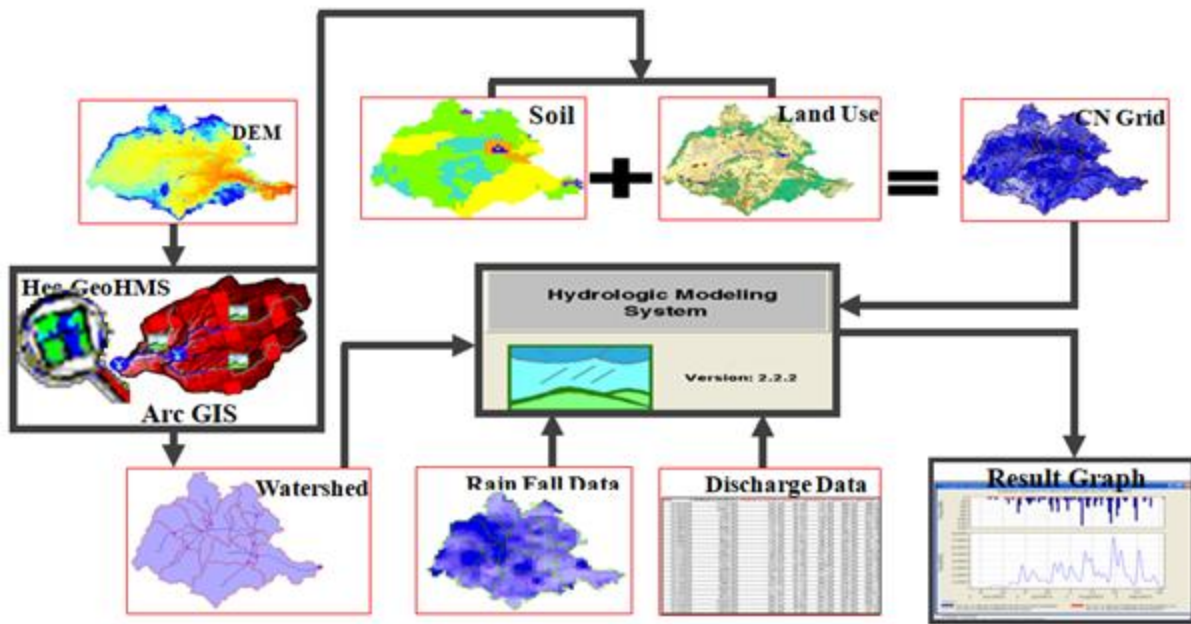
Many hydrologic models exist in literature, however most popularly used models are given here.

Model	Web Link	Model Description
HEC-HMS	<a href="http://www.hec.usace.army.mil/software/hec-hms/">//www.hec.usace.army.mil/software/hec-hms/</a>	Hydrologic model which can be used to generate flood hydrograph at any selected location in the river system
HEC-RAS	<a href="http://www.hec.usace.army.mil/software/hec-ras/">//www.hec.usace.army.mil/software/hec-ras/</a>	HEC-RAS Version 5.0 has the ability to perform one-dimensional (1D) and two-dimensional (2D) hydrodynamic routing within the unsteady flow.

*Note: There are many more models are available. However more easily usable models are given above.*

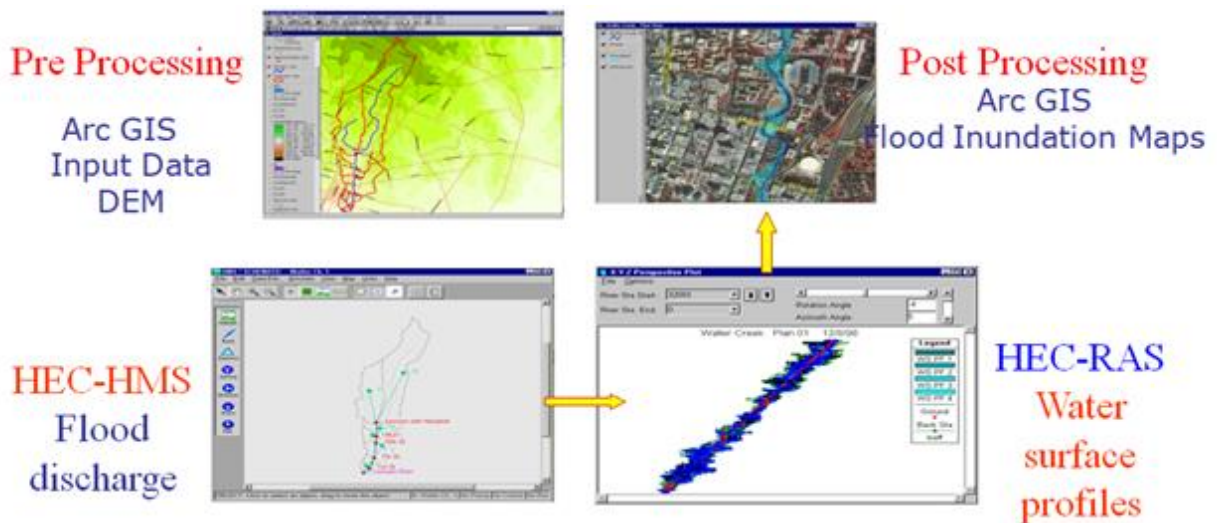
Components of hydrologic modelling using HEC-HMS to predict flood flows is pictorially shown here.





*Components of Hydrological Model*

Components of hydraulic modelling using HEC-RAS to predict inundation levels is pictorially shown here.



*Components of Hydraulic Model*

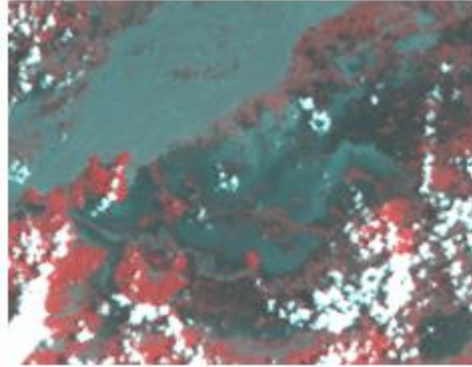
### 3.7 Flood Hazard Assessment using EO Data

#### 3.7.1 Satellite Data Analysis

**Optical Satellite Data:** Optical remote sensors measure the reflectance from objects on the ground. Pure and deep-water bodies absorb most of the electro-magnetic energy and reflect very little energy. Flood water, because of different sediment concentrations, reflects considerable energy in different bands, including near infra-red (NIR) region. The flood water signature generally mixes with cloud shadow and also



with mixed pixels of cloud and cloud shadow. In some cases, it mixes with large urban areas / built up lands. Flood inundation layer is extracted by various techniques such as visual interpretation, unsupervised and supervised classification using satellite data acquired in optical wavelengths. A sample flooded area represented in optical satellite data is shown below.

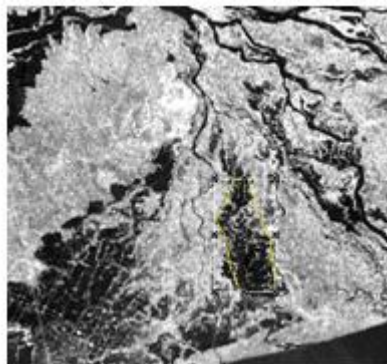


*Flood area represented in optical satellite data*

Using this data, either supervised or unsupervised classification techniques is to be used. In case of supervised classification maximum likelihood classification can be used. Care must be taken to see the different signature of water are given as training sets since the spectral signature varies with turbidity of water. After classification check the classification accuracy. Since no ground information will be available, it is better to overlay the classified layer over the image and check whether the classification is proper or not. The flood image as well as the pre flood image has to be classified.

Using arithmetic operations the extent of water in the pre-flood image has to be subtracted from the flood image so as to delineate the inundation due to flood. In this process, all the permanent water bodies as well as pre Flood River courses will be subtracted resulting net flood inundation.

**Microwave satellite data:** The advantage of using radar data over the optical data is its ability to penetrate cloud cover and also data acquisition during day and night. Water surfaces are generally smooth at radar wavelengths and can be regarded as specular reflectors which yield small backscatter. Hence, water is regarded as low intensity areas whereas the surrounding terrain corresponds to brighter intensities, as shown in figure below.



*Flood area represented in microwave satellite data*

In case of microwave data, backscatter (db) values have to be computed and the image has to be classified. If the data is available in full resolution and with all other parameters only, the db values can be computed. However in case of near real time flood monitoring the data will be received in compressed format (Radarsat data) through ftp. In such case the data has to be classified using threshold technique. Intensities below the threshold are regarded as flood or open water, whereas pixels with intensities above the threshold are regarded as dry land. The threshold will depend on the contrast between the land and water classes, and generally needs to be set for each SAR scene. The backscatter depends on the frequency, incidence angle, polarization and is sensitive to the ripples on the water surface induced by wind waves. The demarcation between water and land is distinct, at higher incidence angle of 45° and is difficult at 23° incidence angle and may lead to error in classification. This is because the contrast decreases with decreasing incidence angle.

Thresholding / density slicing technique are used for satellite data acquired in microwave wavelength. It is most common when the data is classified there will be some scattered pixels will get misclassified may be due to spectral overlap. These unwanted pixel has to be removed either manually or using sieving techniques. Especially cloud shadows in optical data and hill shadows in microwave data will interfere with water delineation. After necessary editing the final inundation layer has to be generated.

**Temporal Satellite Data Analysis:** The pre and post flood satellite data is quite useful for assessing the extent of flood. The pre and post flood satellite data has to be rectified geometrically with a suitable projection system and registered exactly. Otherwise errors will arise while composing and computation of statistics of flood inundation areas. Always rectify a satellite scene with respect to a topographic map and use it as a master for all other scenes so as to maintain the uniformity. The ground control points should be uniformly distributed over the area of interest so that the registration will be perfect. In case of microwave data the speckle has to be removed using filters. From experience it is found median filter will suppress speckle to the satisfactory levels.

### 3.7.2 Selection, Download and Pre-Process Sentinel-1 data

#### Introduction

Floods are one of the most widespread, frequent, and recurring natural disasters. Floods are a consequence of the increasing frequency of heavy rains, changes in upstream land-use, and a continuously increasing concentration of population and assets in the flood plains. Floods can occur anywhere because of heavy rain and can be of different intensities—from small flash floods to sheets of water engulfing huge areas of land, causing destruction either way.

Over the years, advances have been seen in remote sensing measurements, which are gradually replacing or compensating in situ measurements. Aerial reconnaissance has been effective for determining the spatial extent of river flooding in detail for relatively small areas.

Even though the use of image data from optical satellite sensors (like Pan, LISS, etc.) in the visible or infrared portion of the spectrum is very useful for studying land features, their usefulness is limited during the rainy season due to cloud cover being visible on the image. On the other hand, the microwave portion of the spectrum gives cloudless images even during the monsoon season. Microwave remote sensing data can penetrate clouds, which is important for monitoring flood events because they commonly occur during periods of extended rainfall or cyclonic storms. However, for most remote sensing solutions, the revisit frequency (i.e., the time between two measurements in the same place) is too low for monitoring purposes,

or the spatial coverage is limited. Both active and passive microwave data have been extensively explored for flood monitoring.

In this exercise, you will be exploring the freely available microwave satellite data from the first of the Copernicus Programme satellite constellation conducted by the European Space Agency, which consists of two satellites, Sentinel-1A and Sentinel-1B that carry a C-band synthetic-aperture radar instrument which provides a collection of data in all-weather, day or night.

### Learning Objectives:

The objective of this module is to familiarize with Sentinel-1 satellite data sets for flood studies. After completing this session, the course participants will be able to download the Sentinel-1 satellite data of flood affected area and will learn how to use it in the next session.

- Identify an area of interest (AOI) which was flood affected recently
- Search the Sentinel-1 satellite data coverage in the AOI.
- Select and download the Sentinel-1 satellite data for the AOI.

**Data Input:** Area of Interest (to be selected by the participants) Example:

**Output:** Sentinel-1 satellite data covering the AOI

### Accessing the Sentinel-1 satellite data

#### Create a User Account

Go to [Copernicus Open Access Hub](https://scihub.copernicus.eu/dhus) (<https://scihub.copernicus.eu/dhus>) . In the top-right of the web map, click the SIGN UP button. Insert valid entries for your name, email and location. Click register. Validate your email and Login using the username and password.

With a few clicks of the mouse, you will gain access to ESA's Sentinel data.



## Select Your Area of Interest (AOI)

Where is your study area?

Answer:

Using the **SEARCH CRITERIA** text box in the top-left, type in your area of interest.

Example: Type 'Eritrea ' or select an area of interest and Click search option.

Using the Map Layer option (on right side) you can change the background map / image. Use PAN option (at the bottom of the screen) to PAN to the area of interest and zoom into some parts of Eritrea and use BOX option draw a rectangle in the area of interest. (You are free to select any other area of interest, if you know which area is flooded very recently?)

Click on the top left corner of the search window as shown for the advanced options.

Now select the below given options of selecting suitable data.

Sort by: **Ingestion Date**

Order By: **Descending**

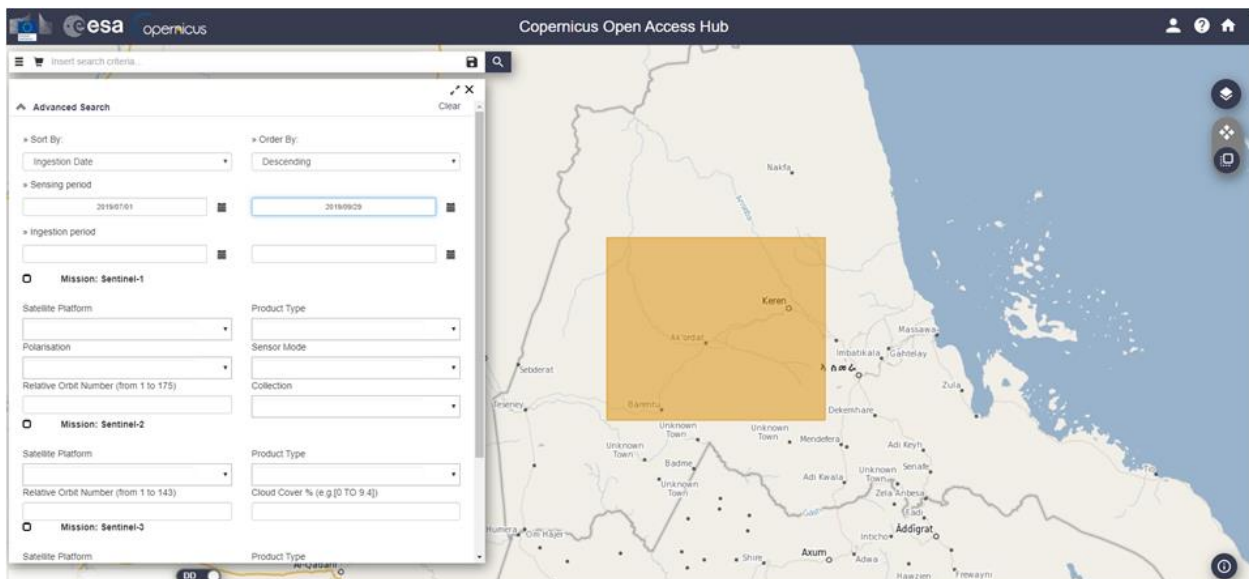
Sensing Period: Select **1 July 2019** to **29 October 2019** (if your AOI is different, please select suitable date)

Product Type: **GRD**

What is Sensing Period?

---

Mission: **Sentinel-1**



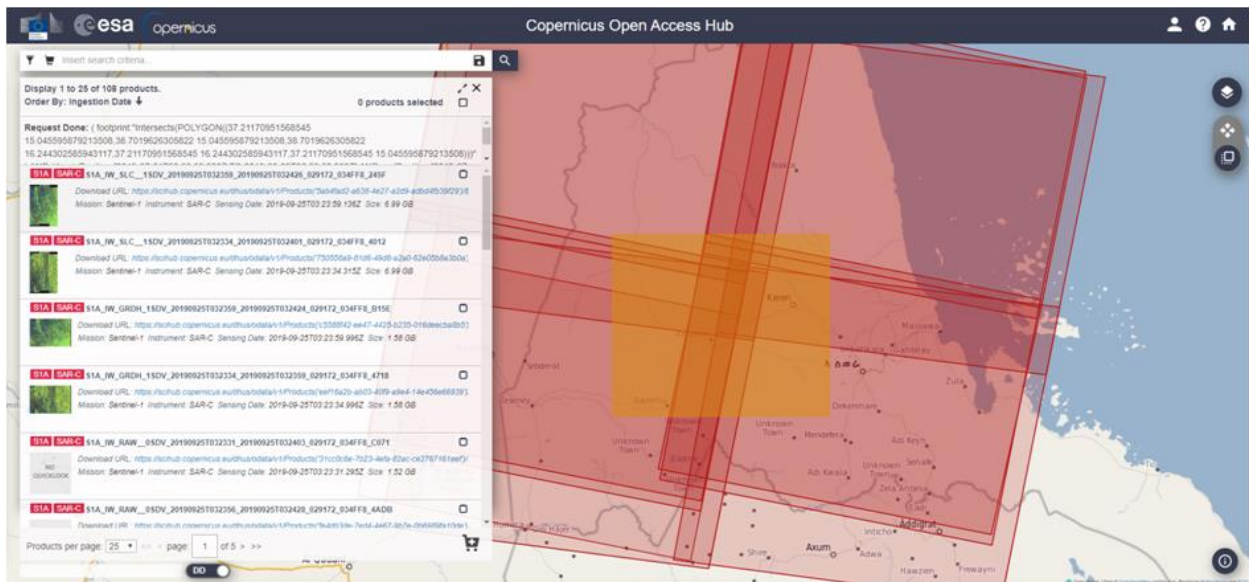
What are these parameters? Explore the Sentinel Product Catalogue at

<https://sentinel.esa.int/web/sentinel/missions/sentinel-1/data-products>

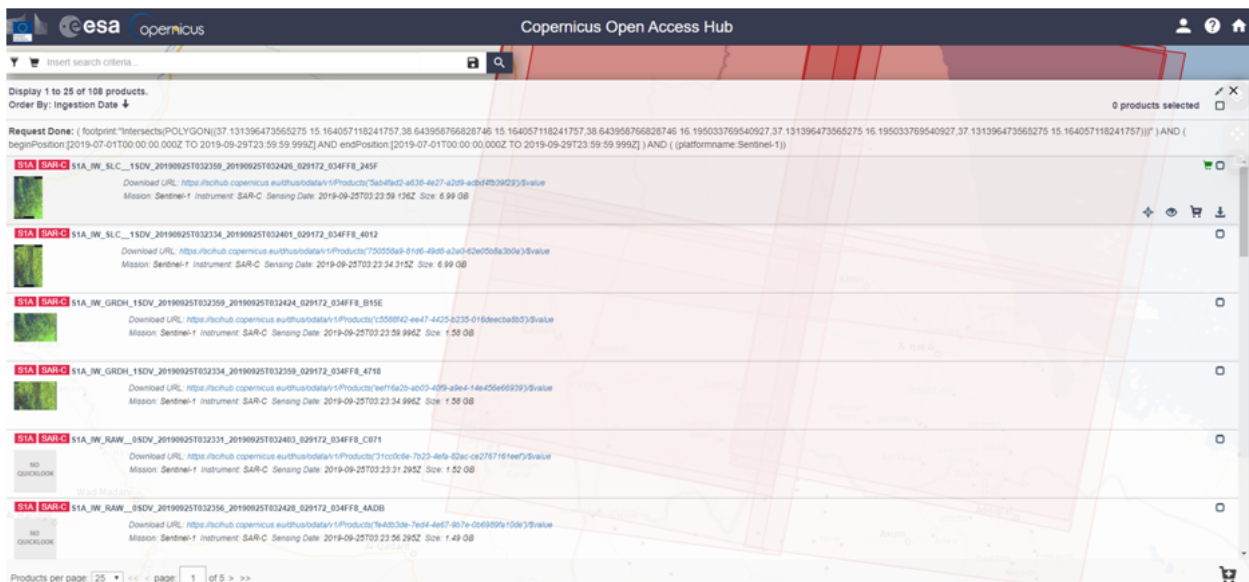
Click Search option.

From here your search will yield results for all the Sentinel satellite data available Sentinel-1 ([Synthetic Aperture Radar C-Band](#)) swaths are depicted in red.

See the product thumbnails for more details of the search results.



Search Results contain how many products?





As we are working with large data sets, you will have to be patient with download speeds. It's easy for the server to timeout during the download.

Select the product you want to download. S1A is Sentinel-1A.

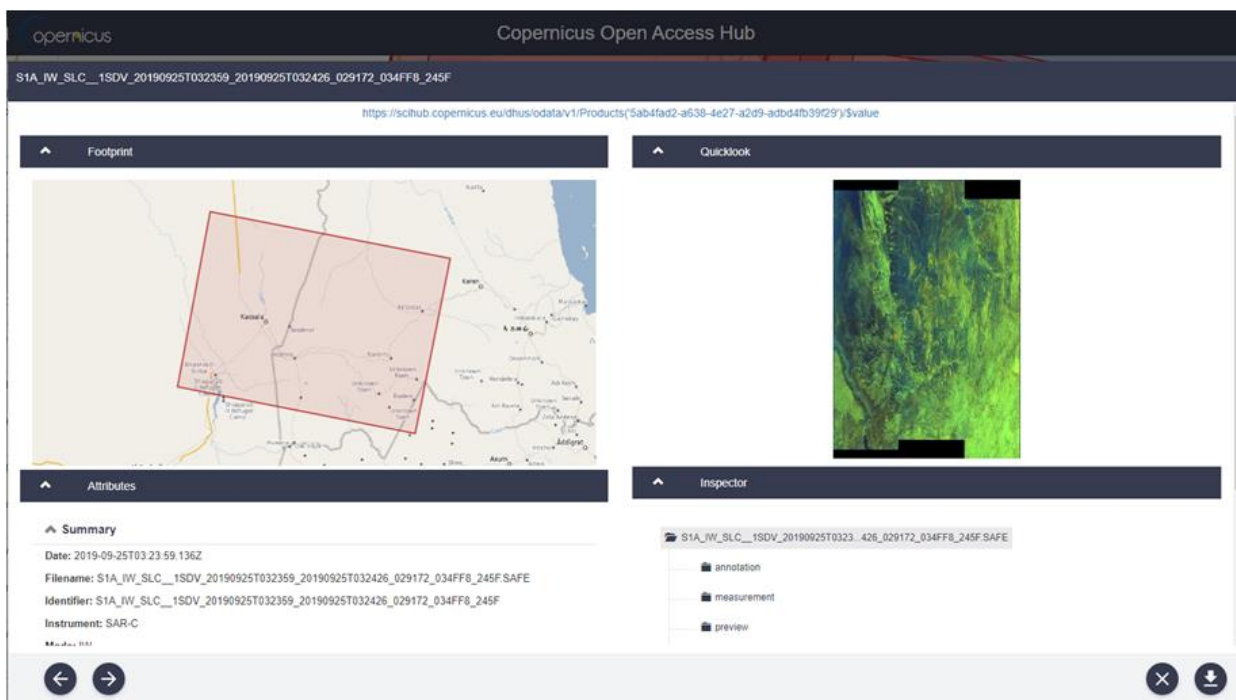
Go through the search results and select this Sentinel-1A data.

**S1B\_IW\_GRDH\_1SDV\_20190907T032258\_20190907T032323\_017926\_021BD7\_99E0.zip**

Why this data is selected?

---

Before downloading, click on the icon 'eye' in the selected data window to preview the data, as shown below.



The area of interest selected earlier and the frame of satellite data selected now are the same or different?

Answer is \_\_\_\_\_

What additional information you can get from this preview window?

---

---

Click on Download URL next to the product thumbnail or Download Arrow @bottom right corner to download the data. Since it will take time to download, we have downloaded the data and provided for use in this session.

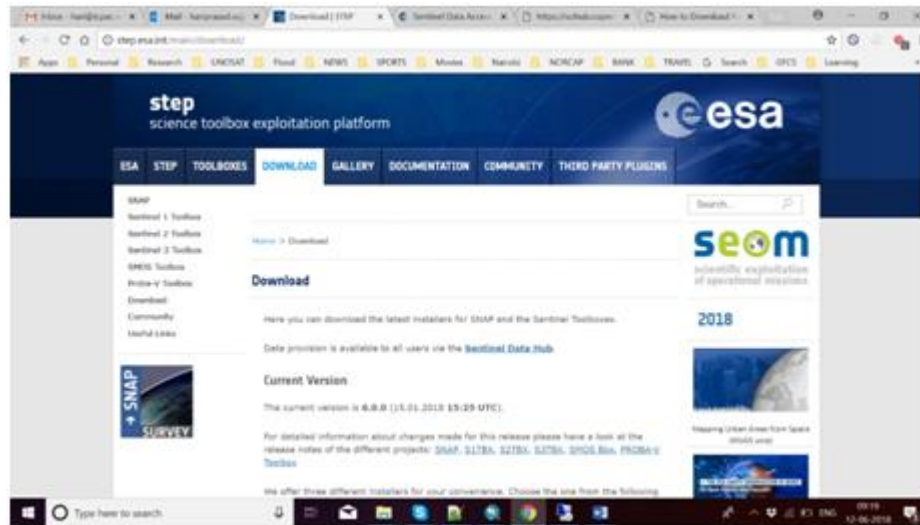
### 3.7.3 SENTINEL – 1 SAR DATA PRE-PROCESSING

#### Download SENTINEL Toolbox

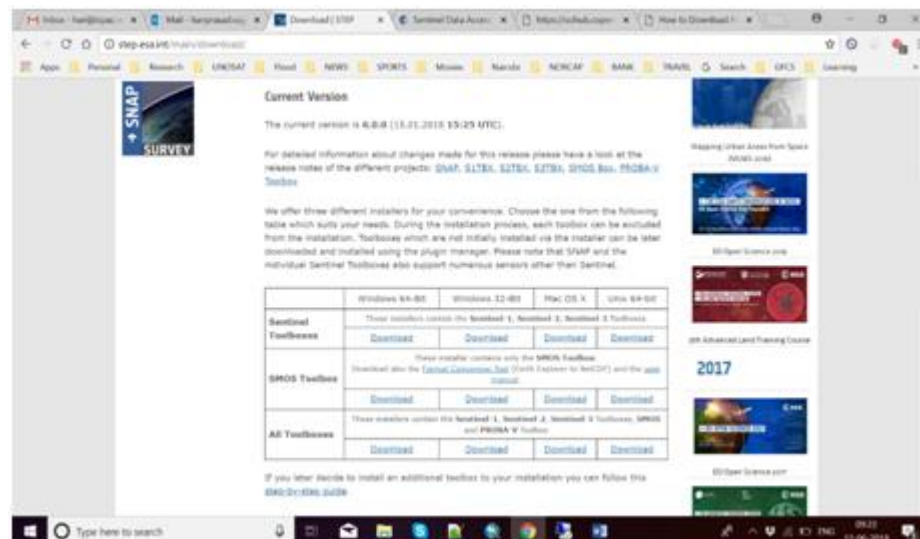
Download and install the latest ESA-SNAP-SENTINEL Toolbox (Open source software from ESA)

Link: <http://step.esa.int/main/download/>

The webpage will look like this.



Select suitable Windows / Mac version suitable for your laptop and download the software.



Install the downloaded SNAP software for using the downloaded Sentinel-1A satellite data, downloaded previously.



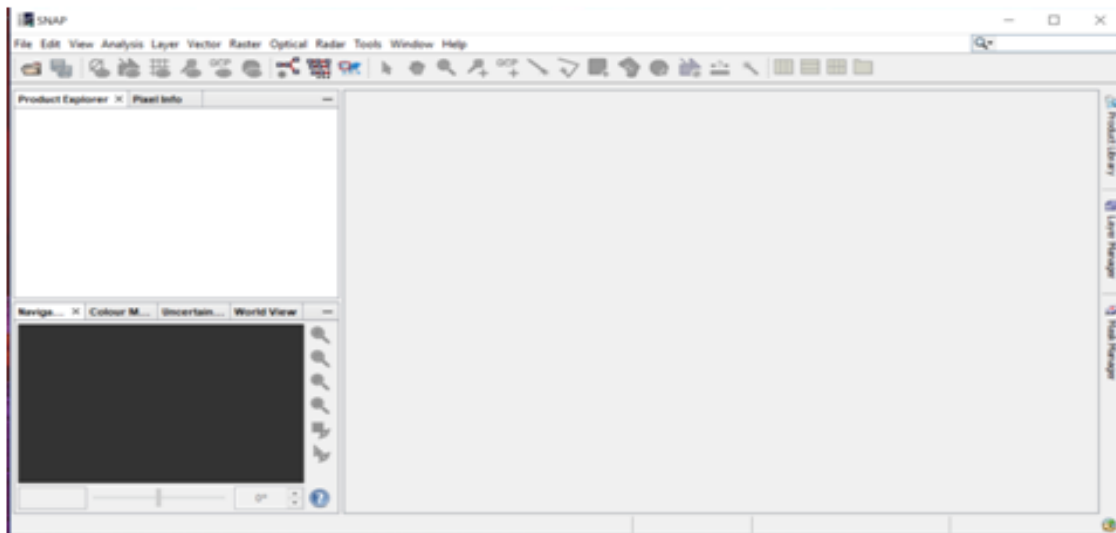
## Displaying, exploring and analyzing crisis satellite data for flood water extraction

### ORTHORECTIFICATION

In this section you are going to perform the main image processing operation required prior to analysing an image. The most appropriate software to process Sentinel-1 imagery is the Open source software from the European Space Agency (ESA) called Sentinel Application Platform (SNAP) TOOLBOX. This platform reunites all Sentinel Toolboxes in order to offer the most complex platform for this mission. The basic functions include: opening a product, exploring the product components such as bands, masks and tie point grids. Navigation tools and pixel information functionality also represent some of the basic capabilities.

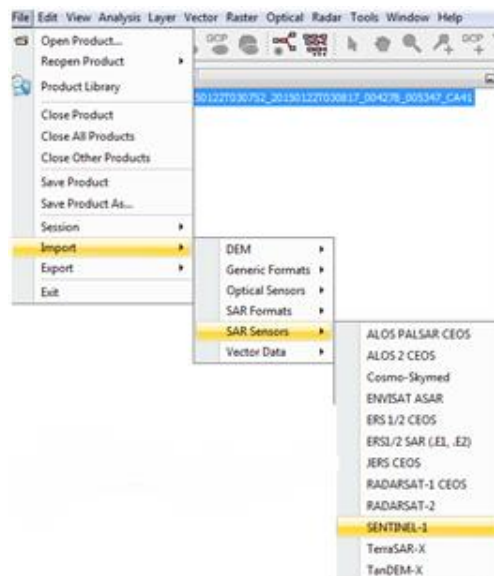
**The steps given below are only for your understanding and future use with your own dataset.**

To **Open** SNAP toolbox, Double Click the SNAP software shortcut on your desktop, which is given below.



### Import the downloaded SENTINEL-1A image

Import the Sentinel-1A data downloaded using File – Import – SAR Sensors – SENTINEL-1 as shown below.



Select the zip file which is downloaded earlier and click on Import Product.

**S1B\_IW\_GRDH\_1SDV\_20190907T032258\_20190907T032323\_017926\_021BD7\_99E0.zip**

Please note that SNAP reads automatically .zip files (no need to unzip):

### Ortho Rectification of SENTINEL-1A image

The most important step after importing the data is to **orthorectify** the image (not optional!)

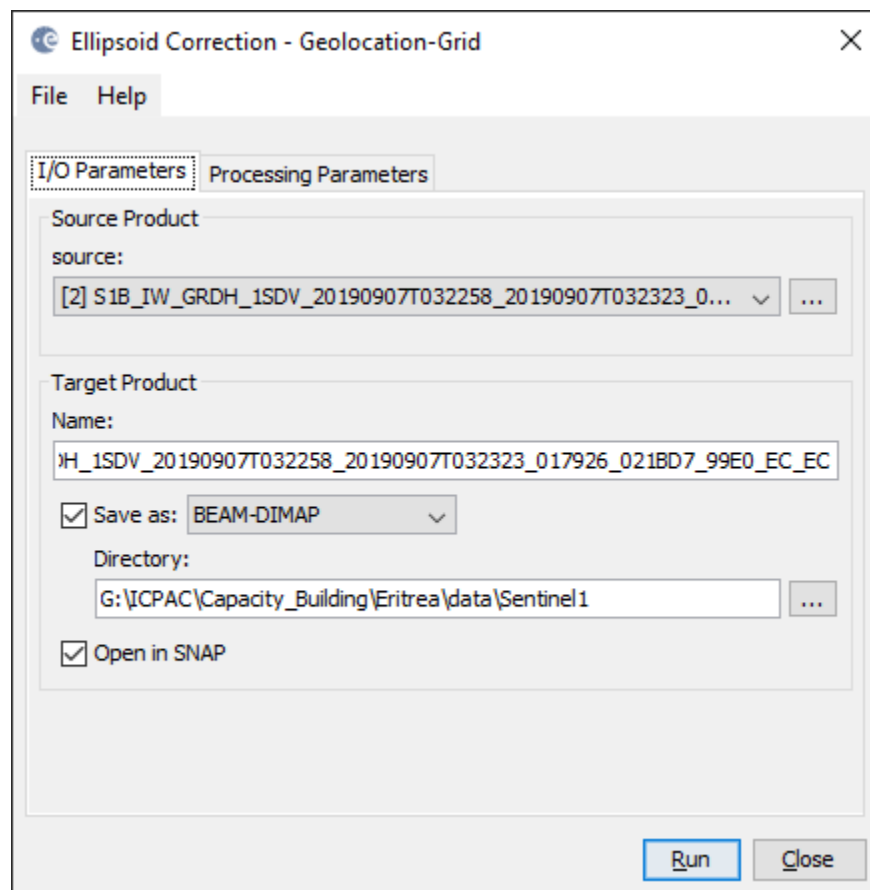
Select Radar > Geometric > *Ellipsoid Correction > Geo-Location Grid*

In *I/O Parameters*, select *Save as: "Geotiff-BigTIFF"* and **navigate** to the output folder for the output.

In *Processing Parameters* select "*Amplitude\_VV*"

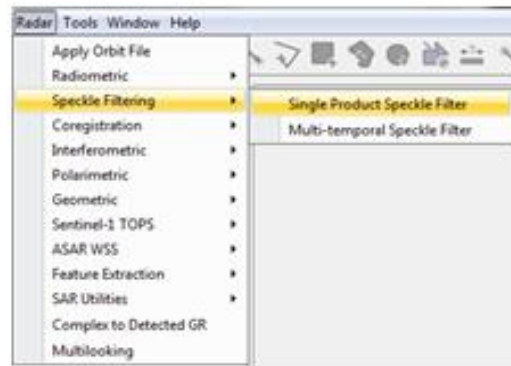
Rest of the parameters keep default.

and **click Run**



It is the processed image obtained after the ortho-rectification (Ellipsoid correction) and speckle filtering, steps are given here, only for your understanding and future use.

In most RADAR products, one of the must do corrections is to remove *speckles* (salt and pepper effect). Again, this step will take a few minutes but it is highly recommended. **Go to Radar > Speckle Filtering > Single Product Speckle Filter**

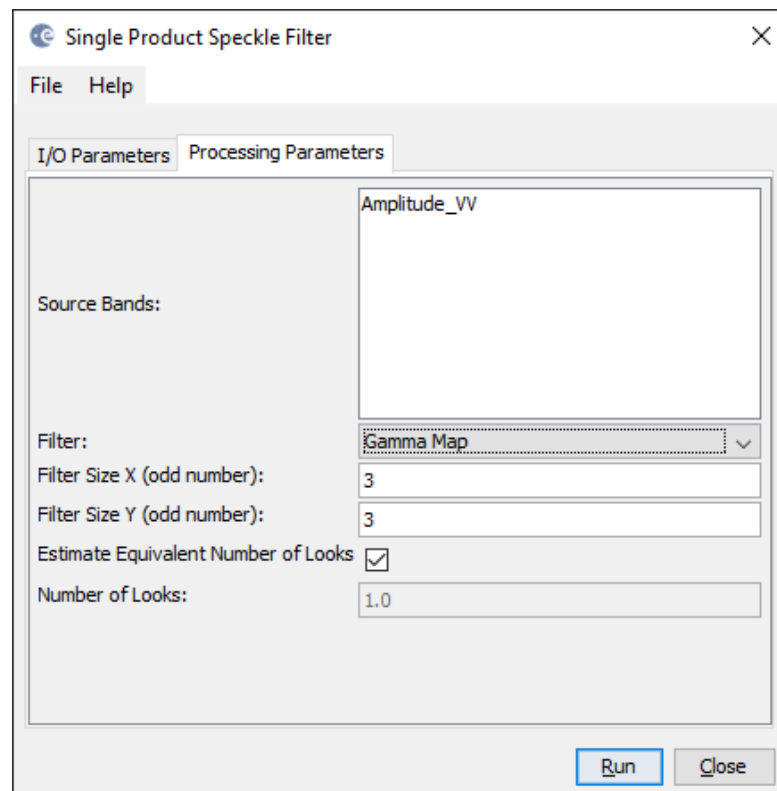


In the *I/O Parameters* tab:

- Select as *Source* the output image of the *SAR-Ellipsoid Correction*
- **Give** a proper *Name* and *Save as*: "*Geotiff-BigTIFF*" and **navigate** to the output folder

In the *Processing Parameters* tab :

- select as *Source Bands* *Amplitude\_VV*
- choose *Gamma Map Filter*, the *Filter Size X*: 3 and *Y*:3 can be used. Feel free to compare with 5x5 and 7x7 as *Filter Size*.
- **Click** *Run* and be patient.



**Given** that the process may take some time to complete, the data is processed and given for using in the next exercise.

### Exercise 3.5: FLOOD WATER EXTRACTION USING SENTINEL-1 RADAR DATA

#### Thresholding

Through this process all pixels that belong to a range of pixel values corresponding to the feature you want to extract are assigned a value 1. All other pixels in the image are assigned a value 0.

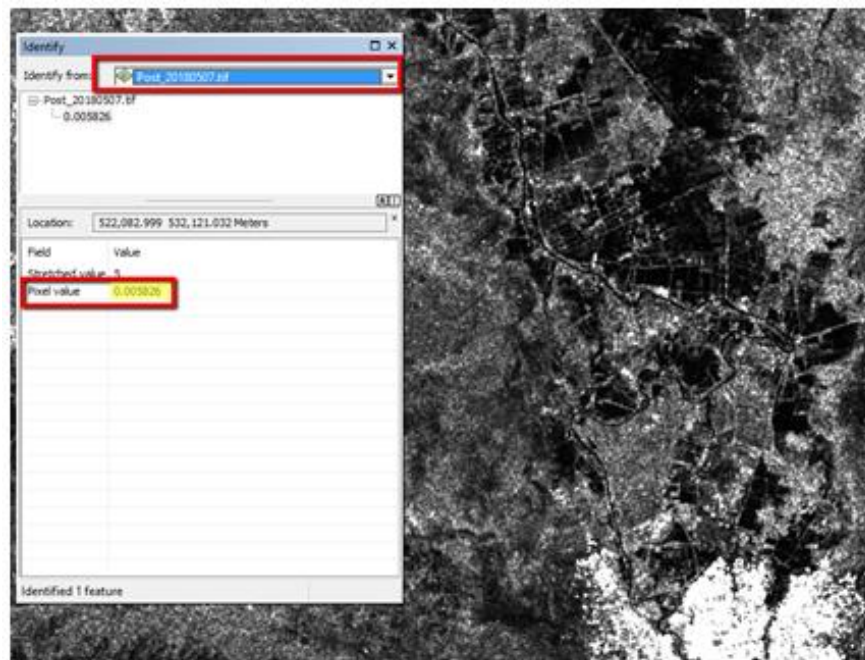
#### Identification of initial threshold value

For this exercise you will now extract the pixel values likely corresponding to water. Before starting,

- Open "Flood\_Hazard\_Analysis.mxd" in *ARCMAP*.

**X:\ERI\_Data\Module\_3\Flood\Hazard\Workspace\**

- Use the *Identify tool* on the *Tools* toolbar to view the attribute information of the raster image including the pixel values corresponding to water, which is the feature you want to extract from the image (make sure that the concerned raster layer is the selected layer in the *Identify tool* Window).



**What is the best threshold of pixel values to apply in order to identify and to extract those pixels likely corresponding to water/flood areas?**

---

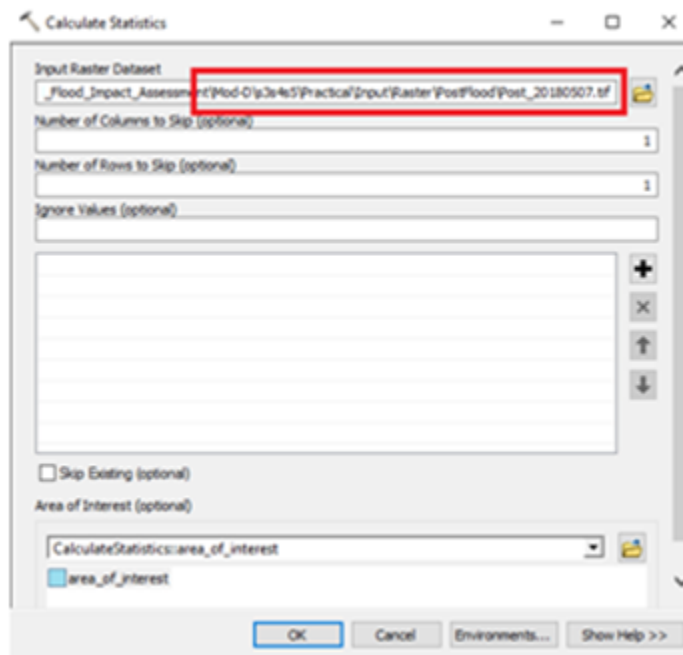
#### Identification of Optimal threshold value

Now that we have an idea of what the threshold value can be, we are going to classify water and not water pixels. First we are going to calculate the statistics of the raster dataset **"Flood\_20190907.tif"**

- Bring up Arctoolbox by clicking the button
- Go to *Data management tools > Raster > Raster properties > Calculate Statistics*
- Select the raster dataset **"Flood\_20190907.tif"**, from the following location:

**X:\ERI\_Data\Module\_3\Flood\Hazard\Input\Raster\**

- **Click OK**



This *Calculate Statistics* operation will allow us to apply classified visualization from the *Symbology* tab.

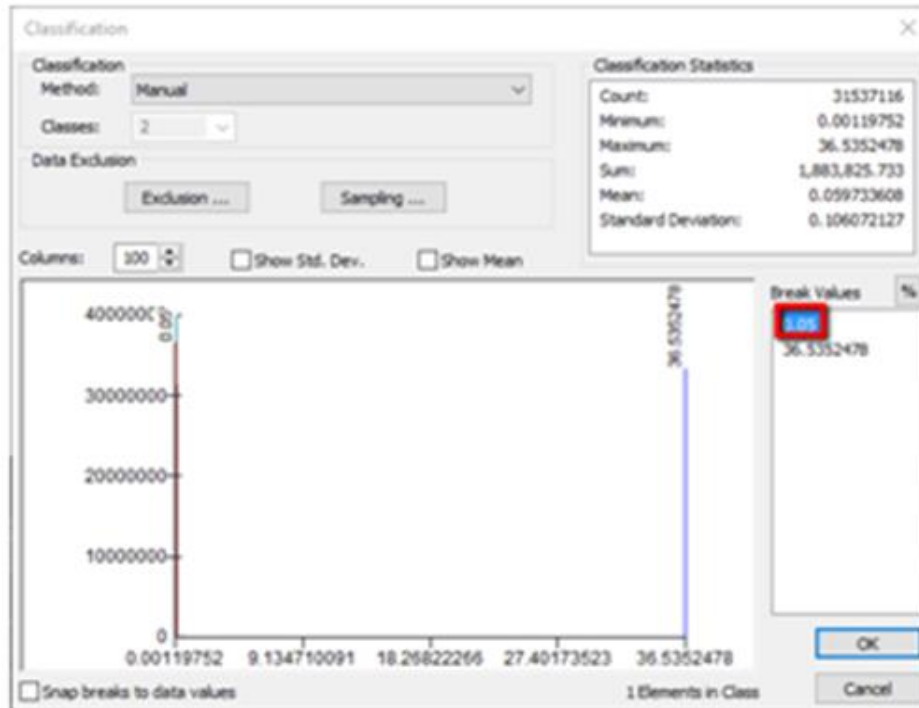
Now we are going to create a duplicate of **"Flood\_20190907.tif.tif"**, and apply a classified visualization to it:

- Right click the image layer **"Flood\_20190907.tif"** > *Copy*
- Right click on Layers and Click Paste. Another copy of **"Flood\_20190907.tif"** will be added to the ToC.

**Note:** This creates a copy within your mxd of the layer you are working with, NOT a copy of the actual image itself.

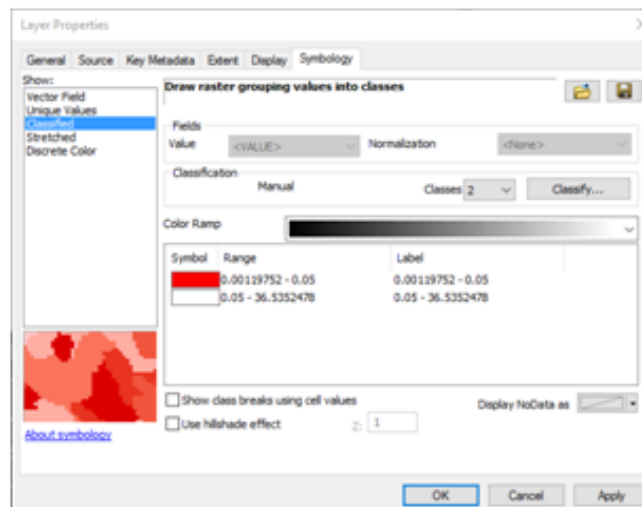
Now you will work on the image copied now (which is above the original image in ToC)

- Right click the image layer **"Flood\_20190907.tif"** > *Properties* > Select the *Symbology* tab.
- Select *Classified*.
- Under *Classes* select 2 and click on the *Classify* button.
- Under *Break Values* enter your threshold value as the first value and click **OK**



You now have two classes in your image, one below your threshold and one above.

- Double Click on the color box next to the class representing water and give it a color (e.g. yellow).
- Double Click on the color box next to the class representing everything else and select NoColor



What is The Threshold you used? \_\_\_\_\_

If you are not satisfied with your threshold for flood water, please change the threshold in the *Break Values* in the *Classification* window.

**Repeat this process until you are satisfied with the suitable threshold value.**

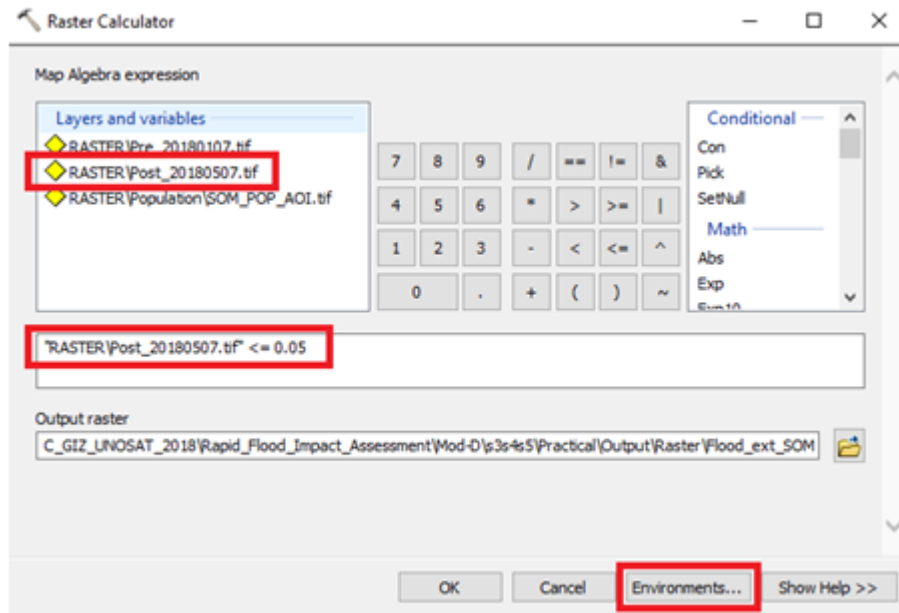
Now that you have identified a suitable threshold of pixel values corresponding to water, you can start to proceed with the pixel-based classification process using a raster calculator:

- Using the *Search* toolbox, open *Raster Calculator*
- In the *Raster Calculator* tab, double click on the raster layer “**Flood\_20190907**” and insert the following mathematical expression using the most suitable identified pixel value threshold:

“*Raster Layer*” <= *Threshold Value*

(Type the numeric value corresponding to the threshold value for water, identified by using the *Identify tool*)

- To set the processing extent, click the *Environments...* > *Processing Extent* > *AOI*



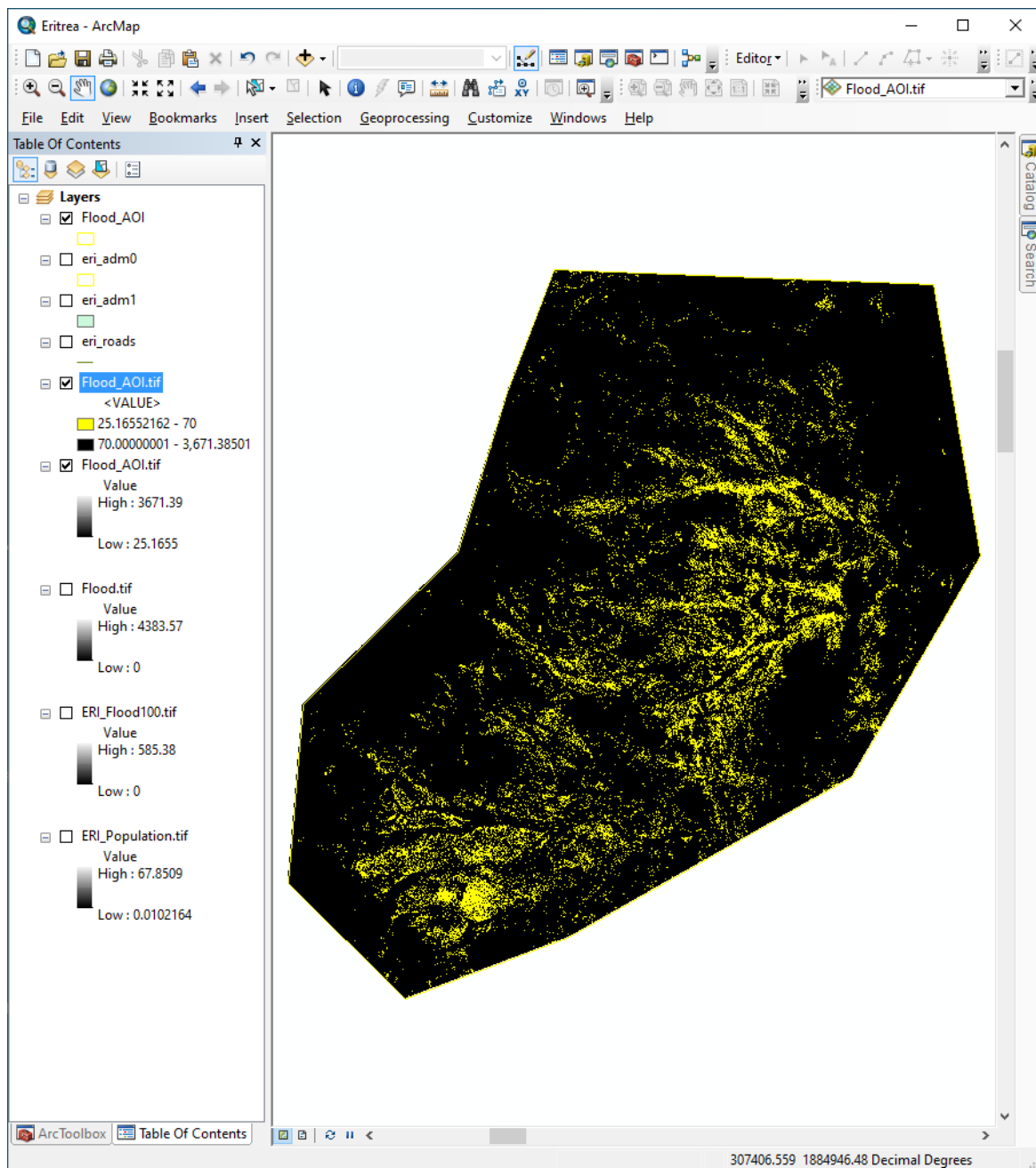
- Name the output raster layer as “*Flood\_ext\_AA.tif*” and save it in the output raster folder:

**X:\ERI\_Data\Module\_3\Flood\Hazard\Output\Raster\**

Pay attention to add also the extension (e.g. “.tif”) in the name of the output raster.

- A new binary raster layer will be added in the ToC: Value 1 is assigned to the pixels values with similar spectral characteristics corresponding to water (as defined by the formula you typed in the *Raster Calculator*), and Value 0 is assigned to the rest of the pixels.
- Use the *Swipe Tool* available from the *Effect Toolbar* and check your raster analysis results by comparing the binary raster layer with the original image. To improve your results, you will probably need to apply different threshold values in the *Raster Calculator* and repeat the above process.

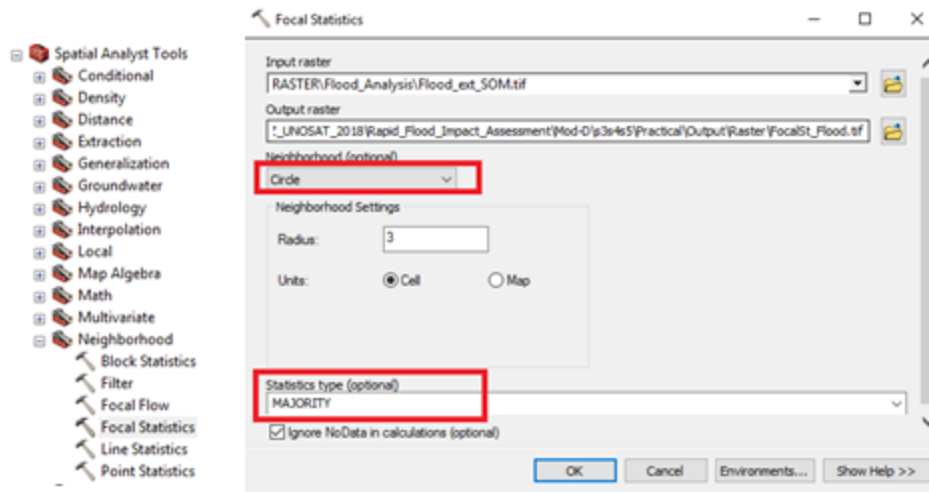




### Filtering and converting extracted flood water from raster to vector

Filters are used to improve the quality of the raster image by eliminating spurious data or enhancing and smoothing features in the data.

- From the *Spatial Analyst tools*>click on *Neighborhood >Focal Statistics*
- Select "*Flood\_ext\_AA.tif*" as input raster and apply the filter parameters as below:



- Name the output raster layer as “*FocalSt\_Flood.tif*” and save it in the output raster folder:

X:\ERI\_Data\Module\_3\FloodHazard\Output\Raster\

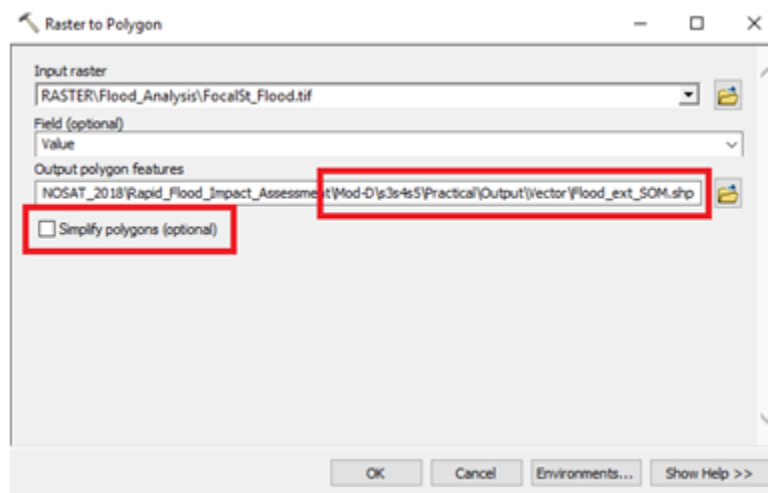
To convert your final flood analysis result from raster to vector:

Search for the tool *Raster to Polygon*

- Add the raster layer from the previous step (“*FocalSt\_Flood.tif*”) and name the vector file to export as “*Flood\_ext\_AA.shp*”
- Choose as output location:

X:\ERI\_Data\Module\_3\FloodHazard\Output\Vector\

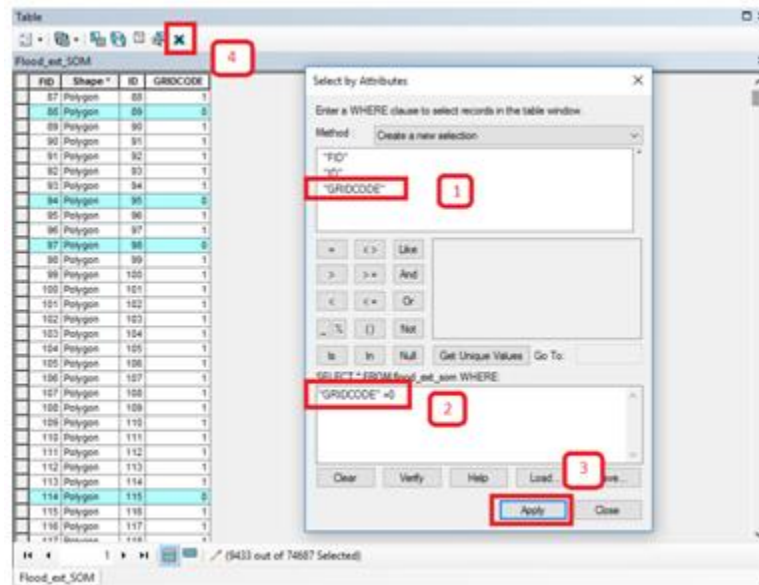
- Uncheck the option *Simplify polygons*



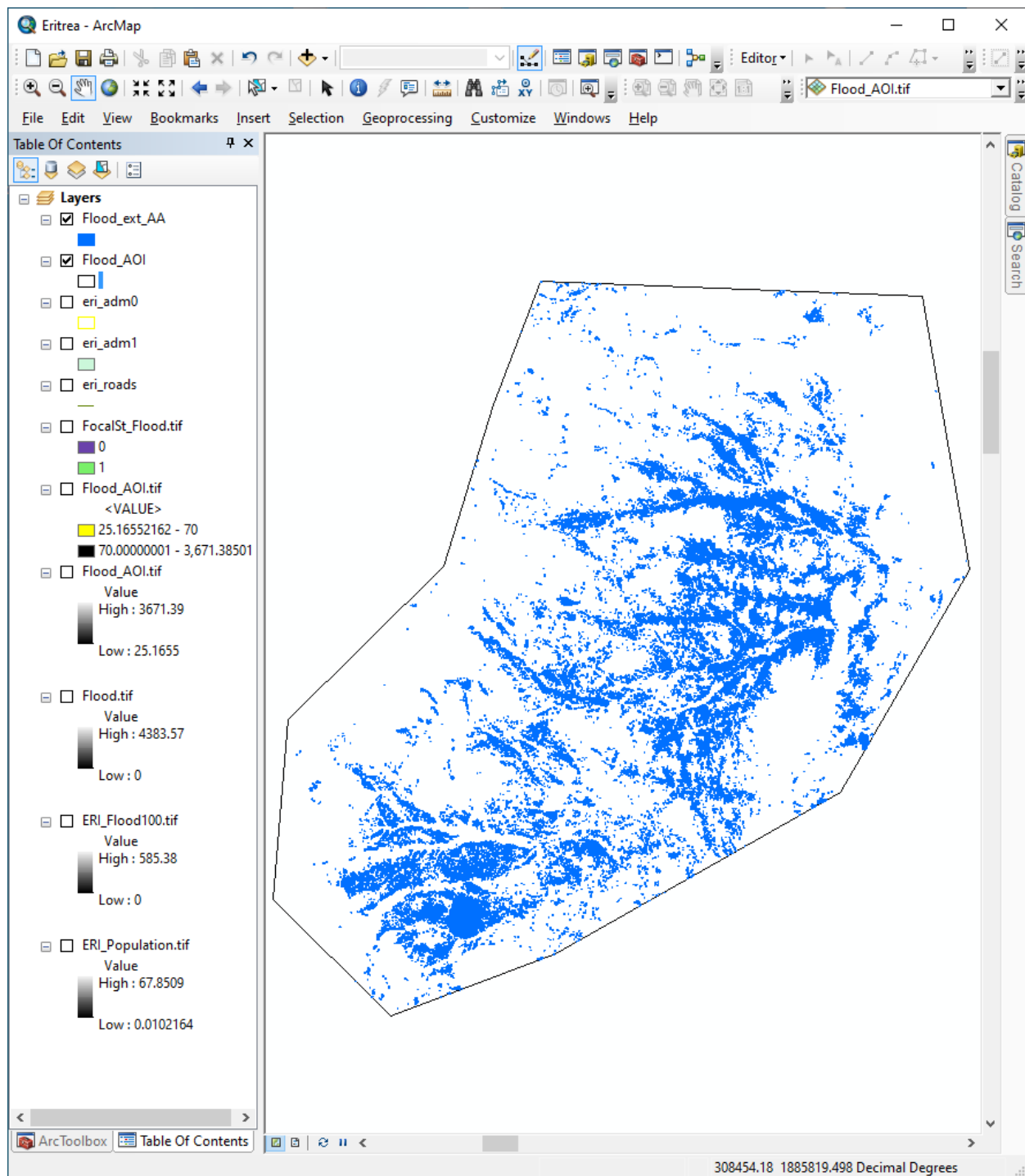
- Add the exported vector layer to your ArcMap project.
- Right click on “*Flood\_ext\_AA.shp*” > *Edit Feature* > *Start Editing*
- Right click on the vector layer “*Flood\_ext\_AA.shp*” > *Open Attribute Table*

- From the *Attribute Table Dialog Box*, click *Table Options > Select by Attributes*
- Double click on *GRIDCODE* and type in the following query expression:

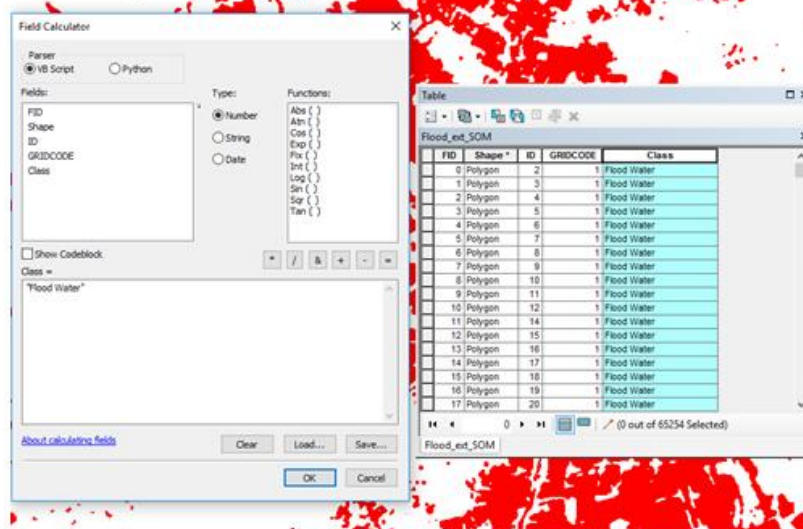
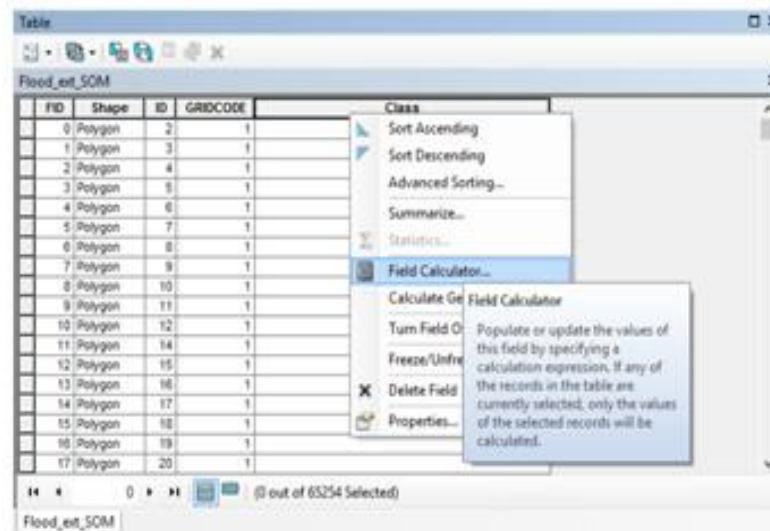
GRIDCODE = 0



- Once all the *GRIDCODE* values = 0 are selected you can **delete** them (step 4)
- Then in the *Editor toolbar* **click** on *Editor > Save Edits > Stop Editing*
- **Change** the symbology of the layer as desired (It is recommended to choose Outline Color: No Color).



- To add a new attribute field to the *Attribute Table*, **open** the *Attribute Table* > *Table Options* > *Add Field* and **type-in** *Class* as name and **select** *Text* as attribute type
- From the *Attribute Table*, **right click** on the field "*Class*" > *Field Calculator* and **assign** to this attribute field the text label "*Flood Water*" (**type** the quotation marks as well):



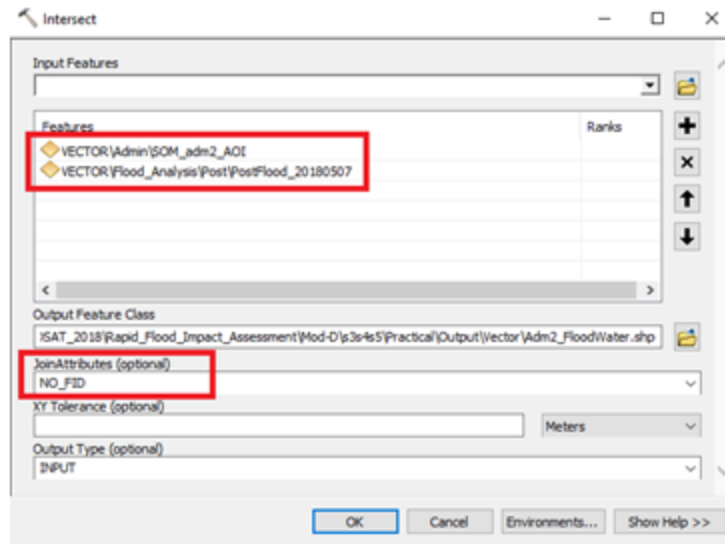
## Satellite Analysis: estimated flood water extent by affected administrative units

Within the immediate aftermath of a disaster, one of the most critical information needed by the humanitarian actors is to know spatial distribution and estimation of the water extent (in case of flooding).

Using the *Search tab*, **open** the tool *Intersect*

- From the *Intersect Dialog Box*, **select** the two layers you want to intersect (“*Flood\_ext\_AA.shp*” and “*ERI\_Adm2\_AOI.shp*”) and “*NO\_FID*” as Join Attributes
- Name** the output layer file “*Adm2\_FloodWater*” and **choose** as output location:

X:\ERI\_Data\Module\_3\Flood\Hazard\Output\Vector\

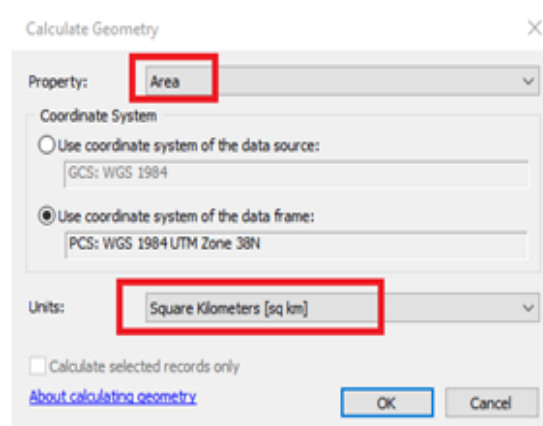


The output file “Adm2\_FloodWater” will be automatically added to the TOC:

- **Open** the *Attribute Table* and you will notice that all records of the table have now the corresponding *Admin1* and *Admin2* names, which in this case are *Name\_1* and *Name\_2*.

To calculate the area (sqKm) for each polygon (record):

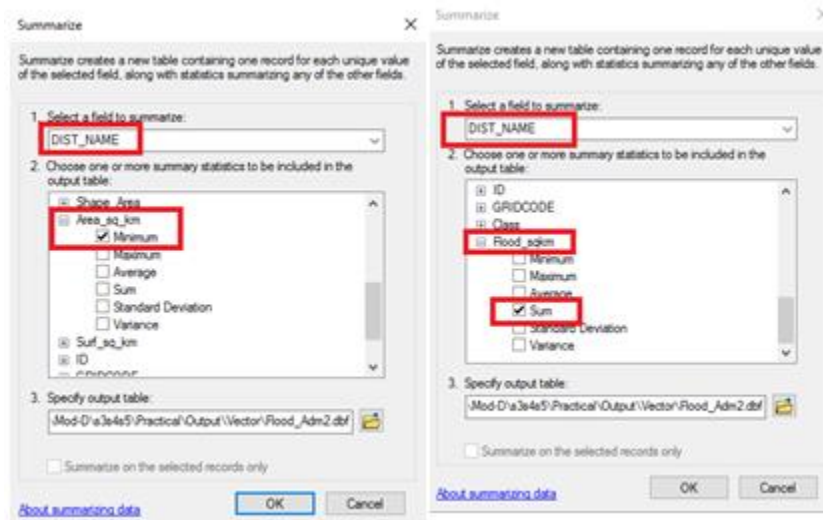
- From the *Attribute Table*, **click** *Table Options > Add Field...* **Enter** “*Flood\_sqkm*” as *Name* and **select** *Double* as *Field Type*
- **Right click** on the field “*Flood\_sqkm*” > *Calculate Geometry*
- From the *Calculate Geometry Dialog Box*, **select** the following parameters:
- **Click OK**



Each record of the attribute table “Adm2\_FloodWater” will be filled out with the area in square kilometers. Using the *Summarize tool* in the attribute table, you can summarize the total flood water for each affected administrative unit.

- Right click on *Name\_2* field in the attribute table, click *Summarize*, select the fields to be included in the output table (*Area\_sq\_km* and *Flood\_sqkm*) and check the operations

- *Minimum* for the field *Area\_sq\_km* (you can alternatively check *Minimum*, *Maximum* or *Average* and the result will be the same value, as this is a property coming from admin level2 boundary and not from the intersect of admin level2 boundary and flood water)
- *Sum* for the field *Flood\_sqkm*.



- Name the output .dbf table as “*Flood\_Adm2*” and choose as output location:

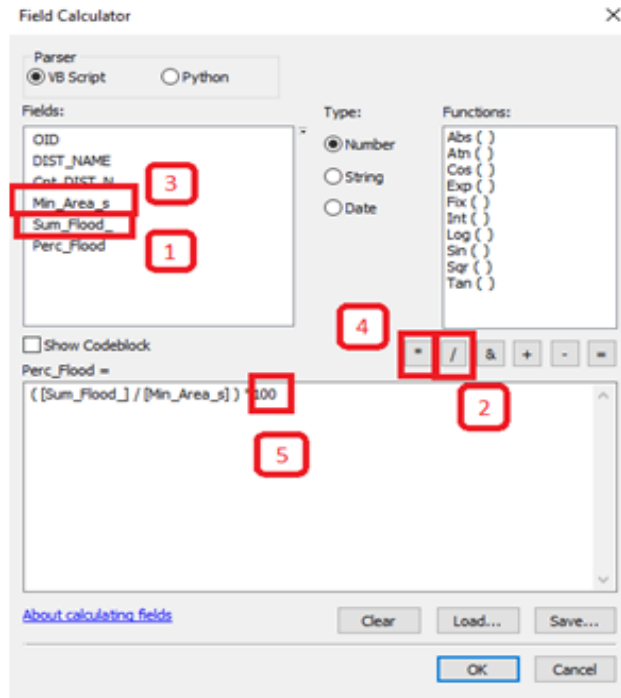
X:\ERI\_Data\Module\_3\Flood\Hazard\Output\Vector\

Now you can calculate the percentage of flood water for each affected administrative unit within the AOI.

- From the *Attribute Table*, click *Table Options > Add Fields...* Enter “*Perc\_Flood*” as *Name* and select *Double* as *Field Type*
- **Right click** on the field “*Perc\_Flood*”> *Field Calculator*
- In the *Field Calculator Dialog Box*, **type-in** the following formula to obtain the percentage of flood area by administrative units (Level 2):

“(“*Sum\_Flood\_sqkm*”/ “*Min\_Area\_sq\_km*”) \*100”





### 3.8 Flood Exposure/Vulnerability/Risk Assessment using GIS tools

#### Exercise 3.6 EXPOSURE ASSESSMENT OF ELEMENTS AT FLOOD RISK

##### Introduction

In this session, the exposure assessment of the elements at risk co-located within the flood affected area is assessed.

##### Learning Objectives

In this session, the participants will be able to combine the flood affected area and the elements at risk data and assess the exposure of the elements at risk to flood.

1. Understand the geographical extent of flood affected area.
2. Quantitative assessment of the exposure of elements at risk to flood, within the Area of Interest.

## Data Input

The input data used in this module is,

Description	Data path	Data Type	File Name
Area of Interest	\\ERI_Data\\Module3\\Flood\\Exposure\\Input\\Vector	Vector (polygon)	AOI.shp
Flood Extent Area	\\ERI_Data\\Module3\\Flood\\Exposure\\Input\\Vector	Vector (polygon)	Flood_AOI.shp
Road Network	\\ERI\\Module3\\Flood\\Exposure\\Input\\Vector	Vector (polyline)	Roads_AOI.shp
Settlements	\\ERI_Data\\Module3\\Flood\\Exposure\\Input\\Vector	Vector (point)	Towns_AOI.shp
Land use	\\ERI_Data\\Module3\\Flood\\Exposure\\Input\\Raster	Raster	Landuse_AOI.tif
Population (Grid) data	\\ERI_Data\\Module3\\Flood\\Exposure\\Input\\Raster	Raster	Population_AOI.tif

## Output

Output expected in this session is,

- Area of Flood Extent
- Length of the road types inundated due to Flood
- Land use categories inundated due to Flood

- Settlements located in Flood area
- Population affected due to flood

### Assessment of elements at risk exposed to flood

- Open Flood\_*Exposure.mxd* at [X:/ERI\\_Data/Module3/Flood/Exposure/Workspace/](#)
- Overlay Flood extent and road network maps to assess the type and length of the roads within flood extent. Calculate percentage of road length exposed to floods.

*Hint: Use Arc Tool Box Analysis Tools > Overlay > Intersect*

- Length of the road types exposed to Flood

Type of Road and length of the road exposed to flood?

---

Percentage of the Road length exposed to flood?

---

- Overlay Flood extent and settlements map to assess the number of settlements located within flooded area. Calculate percentage of settlements located within the flooded area.

*Hint: Use Arc Tool Box Analysis Tools - Overlay – Intersect*

- 
- Overlay Flood extent and land use map to assess the land use categories exposed to flood.

*Hint: Use Arc Tool Box Spatial Analyst Tools > Zonal > Zonal Statistics as Table and use Statistics type 'SUM'*

<i>Land use Category Code</i>	<i>Land use Category</i>	<i>Area (km2)</i>	<i>Total_Area (km2)</i>	<i>Percentage</i>
1	Trees cover areas			
2	Shrubs cover areas			
3	Grassland			
4	Cropland			
5	Vegetation aquatic or regularly flooded			
6	Sparse vegetation			
7	Bare areas			
8	Built up areas			
10	Open Water			

- Overlay Flood extent and Population maps to assess the population exposed to flood. Calculate percentage of population exposed to flood.

*Hint: Use Arc Tool Box Spatial Analyst Tools > Zonal > Zonal Statistics as Table and use Statistics type 'SUM'*

---

## DISCUSSION

Unlike the two previous flood management related modules, in which the accuracy of the results is highly dependent on data that is generated and obtained prior to when the disaster occurs, in this flood impact analysis the most important data related factor is to obtain remotely sensed data of the affected areas as soon as possible and process it quickly, effectively and with reasonable accuracy.

Obtaining damage figures and breakdowns by administrative units is very useful for planning and coordinating humanitarian operations in the field. GIS allows for a very rapid estimation of the extent of flood water within affected areas. The timely production of these map products and data can be used by decision makers and humanitarian actors to prioritize and coordinate disaster response operations.

What are the two datasets used in the flood impact analysis that can be obtained prior to when the disaster occurs (so we are ready to use it when needed)?

---

---

What other sources of data could you have acquired, free of cost, to conduct a similar response mapping?

---

---

Can you identify the potential problems in using Optical data?

---

---

What are the advantages/disadvantages of using WorldPop data?

---

---

Could you briefly explain two limitations of the methodology presented in this exercise that may affect the accuracy of the final output?

---

---

When it comes to flood response mapping, are there any significant issues with the spatial resolution of the image being used? In other words, what – in your opinion – would have been the best spatial resolution for a flood of magnitude similar to the one used in this exercise?

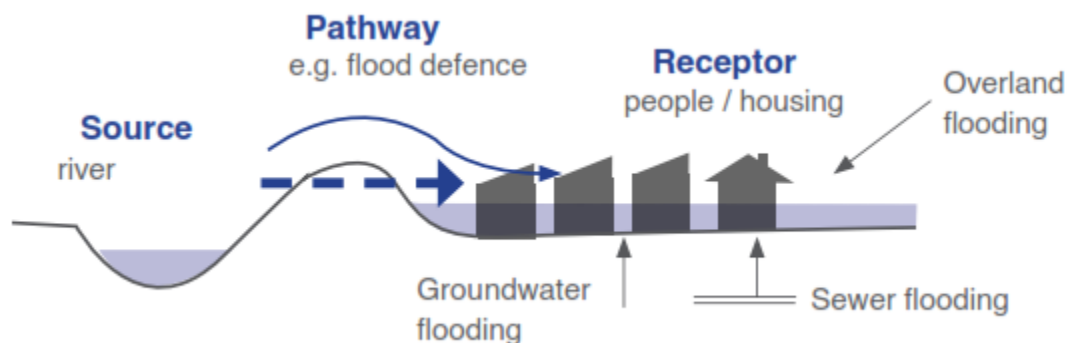
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### 3.9 Flood vulnerability and risk assessment

Flood risk is then normally expressed in terms of the following relationship:

The assessment of flood risk requires an understanding of where the water comes from (i.e. the source), how and where it flows (i.e. the pathways) and the people and assets affected by it (i.e. the receptors). Pictorially it is shown in figure below.



**Source-Pathway-Receptor Model**

**Source:** From where the water comes? This is addressed in Flood Hazard Assessment, such as flash flood or riverine or coastal storm surge?

**Pathways:** How and where it flows? This is also addressed in Flood Hazard Assessment, which areas are inundated due to flood.

**Receptors:** The elements at risk such as population, infrastructure, critical facilities and livelihood which are exposed to floods are considered as receptors.

Likelihood of Flooding which is the flood hazard, explained earlier.

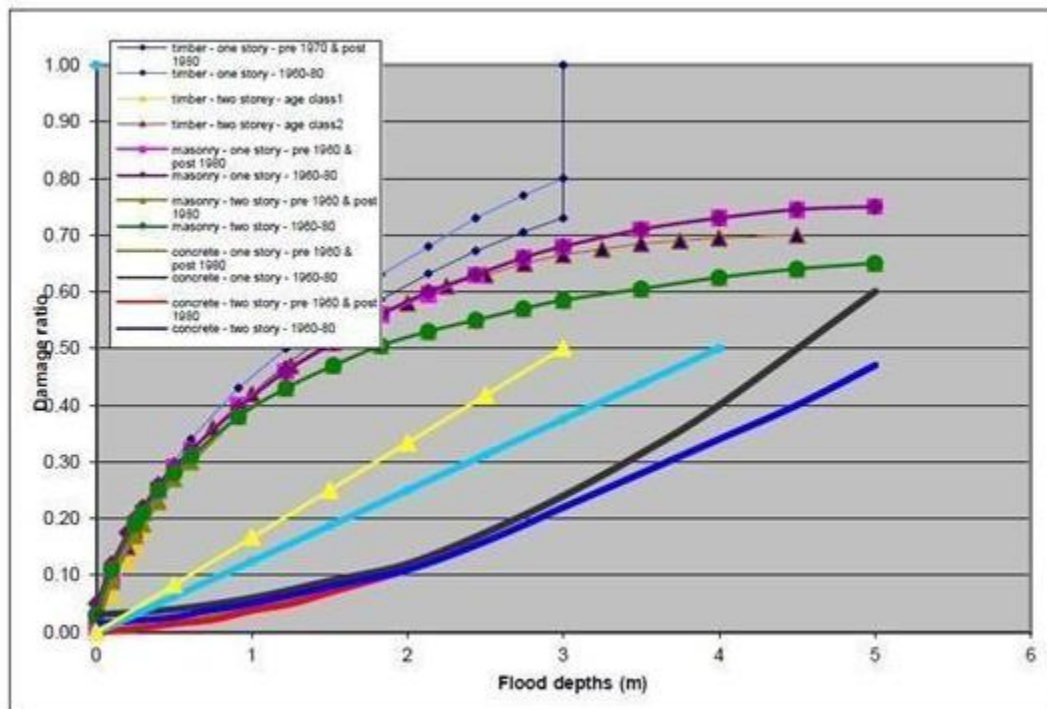
Consequence of flooding is vulnerability of exposed elements at risk to flood hazard. Exposure assessment of elements at risk is discussed earlier and an exercise was also carried out. Now we will understand vulnerability of exposed elements at risk.

Flood vulnerability is one of the significant components in risk management and flood damage assessment. Vulnerability measurement is a complex process because it is influenced by several environmental, economic, and social or even political elements in local scale. In other words, vulnerability is affected by numerous factors such as settlements conditions, infrastructure, authority's policy and capacities, social inequities, economic patterns, etc. So flood vulnerability is varied for people in diverse circumstances.

Human systems are vulnerable to floods due to three vital aspects: Exposure, susceptibility and resilience. Exposure refers to people and their surroundings and every element present in flood-prone areas being exposed to the flood impacts as a subject to potential losses. Susceptibility is considered the status of people, environment and infrastructure tendency to be influenced by a hazard because of the fragility of community or ecosystem and resilience, coping and adaptation ability of a system in addressing disaster stress. Instance, the vulnerability of urban areas is a reflection of the exposure and susceptibility of the city to flood risk and the resilience of that region to cope and recover from the flood effects.

An example vulnerability curve is shown here, which indicates the relationship between flood depth (m) and percentage of the damage for different types of buildings.

Let us use this vulnerability curve with a building footprint map and assess the flood risk in an exercise.



### Exercise 3.7: Flood Risk Assessment Exercise

**Data:** Combined building footprint and flood depth map and flood vulnerability curves





*Building footprint map and flood depth map*

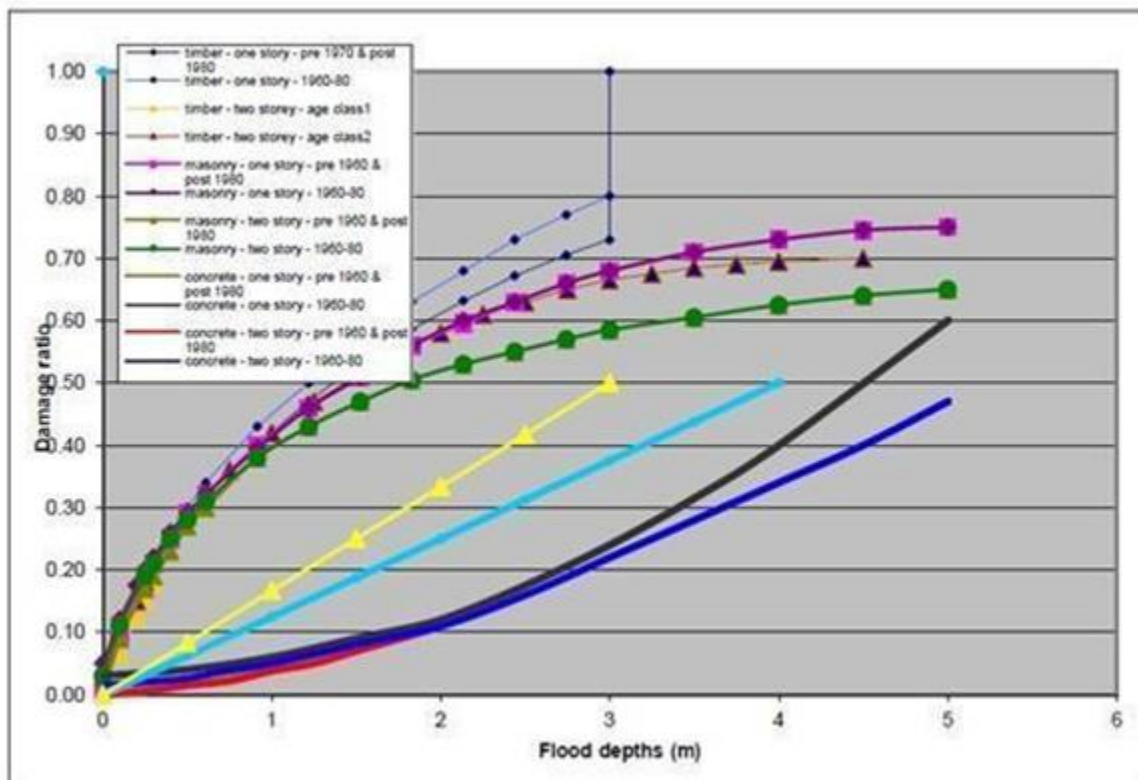
- Flood Depth categories in the given flood map are:

Flood Depth (m)	Color Code in the flood depth map
1.0	Orange
1.5	Yellow
2.0	Blue

- Attribute Table for Buildings with details of material, age class and cost of the building

S.No.	ID	Material	Number of Stories	Age class
1	3951	Timber	1	Class 1
2	3959	Timber	2	Class 2
3	3983	Concrete	1	Class 1
4	3985	Concrete	2	Class 1
5	4355	Concrete	1	Class 1
6	4359	Masonry	2	Class 1
7	4366	Masonry	2	Class 1
8	4373	Masonry	1	Class 1
9	4443	Masonry	1	Class 1
10	4449	Concrete	2	Class 1

- Depth - Damage Ratio Curves



### Methodology

- Using the building footprint map and flood depth map, find the percentage of damage to the buildings using the depth - damage ratio curves.
- Using the cost estimate of buildings, calculate the damage (\$) for each type of building.

**Result:** Using the above data calculate the Damage of each type of building and fill up the table.

ID	Flood Depth (m)	Damage Ratio	Cost of the Building (\$)	Damage (\$)
3951			1000	
3959			1600	
3983			7000	
3985			10000	
4355			7000	
4359			6000	
4366			6000	
4373			3500	
4443			3500	
4449			10000	

### Conclusions based on the analysis:

What is the important information in this analysis, based on your opinion?

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To develop a depth-damage curve for **Nairobi/Kenya**, what data you need to collect and how do you plan to collect?

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