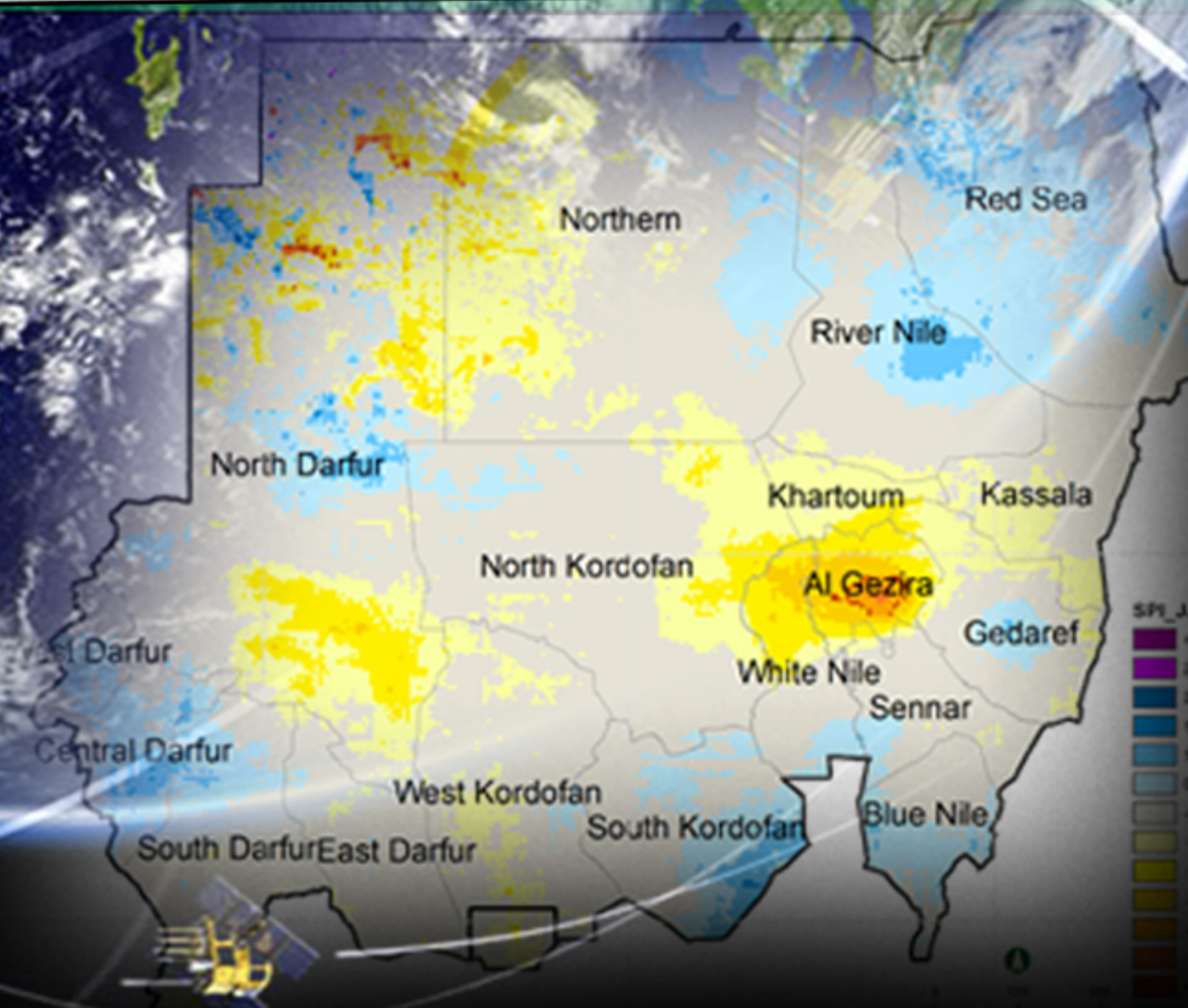




TRAINING MODULE

IN-COUNTRY TECHNICAL TRAINING ON HAZARD ASSESSMENT USING EARTH OBSERVATION AND GIS FOR SUDAN

**IGAD Climate Prediction and Applications Centre (ICPAC)
Disaster Risk Management Program**



ACP-EU Natural Disaster Risk Reduction Program

An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR United Nations Institute for Training and Research



Foreword

Dear Participants,

First of all, I would like to extend my warm welcome to you all to this in-country training workshop for Sudan. The Greater Horn of Africa region is a land of contrasts. If you look at the two most common hazards in the region notably droughts and floods, they are characterized by severe shortage or excess rainfall, respectively. Disasters pose multifaceted challenges in our region. Drought, for instance, is a phenomenon that not only puts the lives and livelihoods of the communities in the region at risk but also destroys the hard-earned development gains of communities and countries at large. The resources that countries are investing for years in drought disaster response and recovery could have significant contributions to advance sustainable development. There is a strong need to put in place all the necessary mechanisms to prepare for and respond to disaster risks. One of such a mechanism is understating hazards/risk and putting in place monitoring and early warning systems that would enable us to reduce their adverse effects.

This training is organized with the objective of strengthening the capacity of national DRM institutions and relevant sector ministries through technical training on hazard assessment, monitoring, and early warning. Such technical training sessions provide a platform for sharing good practices in DRM practices among member states. In this five days training, you will have practice sessions and also an opportunity to discuss recent methods and tools in hazard assessment which are believed to strengthen your national efforts in disaster risk reduction.

The IGAD/ICPAC DRM Program will continue to support the efforts of Member States to develop national DRM strategies, regional frameworks to integrate DRM and Climate Change Adaption, including in the schools'/education curricula and other relevant sectors; from organizing DRM technical training activities to supporting the incubation of climate-resilient agricultural practices; and so on.

With those few remarks, I wish you a successful training workshop and I assure you our continued support to strengthen national DRM institution to achieve effective disaster risk reduction as enshrined in the global, continental and national DRR strategies and frameworks.

Dr. Guleid Artan,
Director
IGAD Climate Prediction and Applications Centre (ICPAC)

Partners & Donors

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

21 – 25 OCTOBER, 2018

This training was made possible by the support of the following partners:



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**MODULE 1:
INTRODUCTION TO GEOGRAPHIC
INFORMATION SYSTEMS (GIS)**

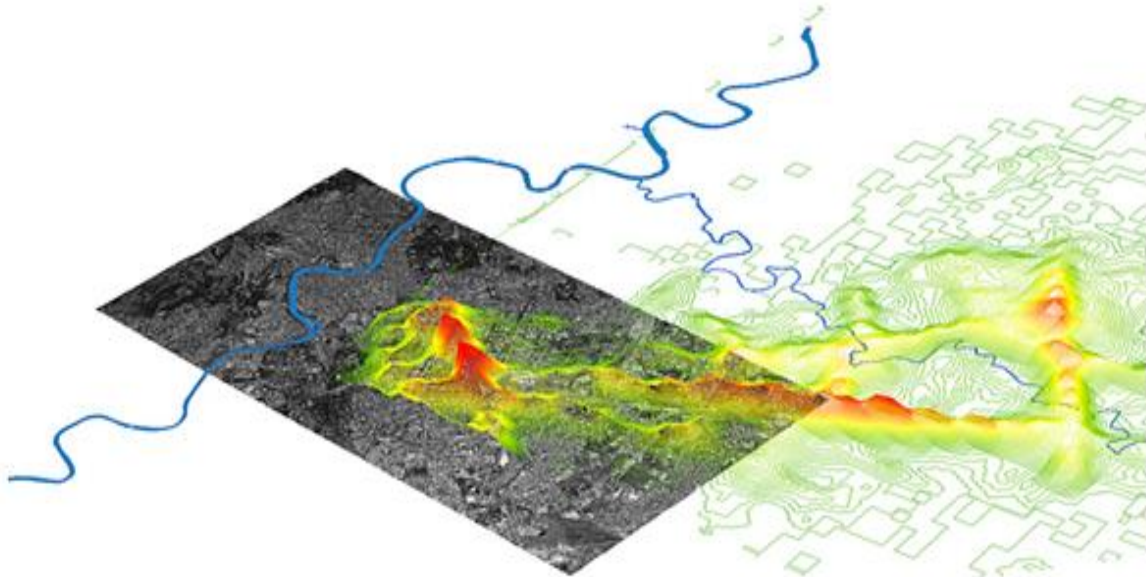
1.1 Theories and Concepts of GIS

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 geo-processing tools and spatial analysis
- Identify main open GIS data sources in relation to 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 Figure 1.



Source: Senseable City Laboratory, MIT

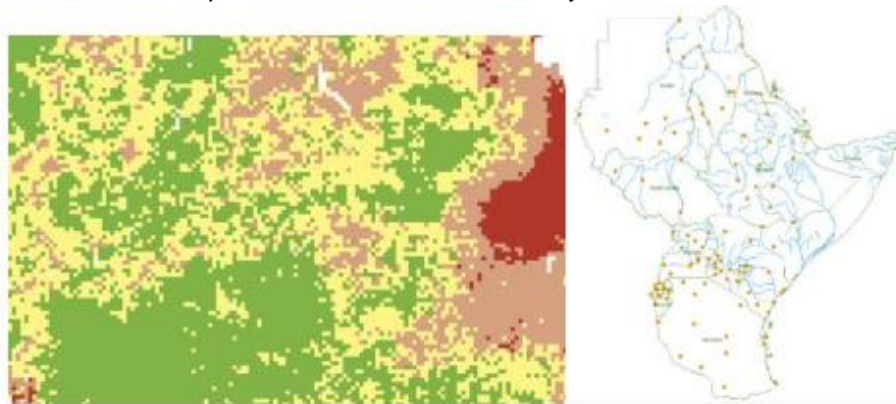
1.1.2 Source and Nature of Spatial Data

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, 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 softwares we may choose to use.



Raster Data Model

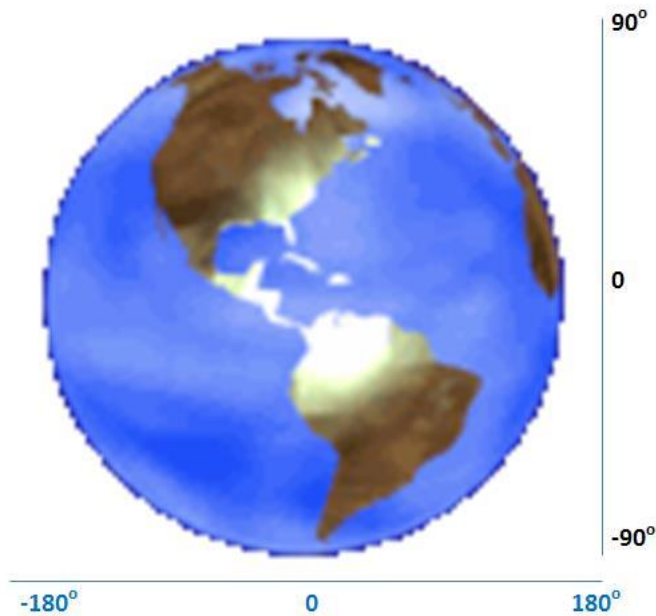
Vector Data Model

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

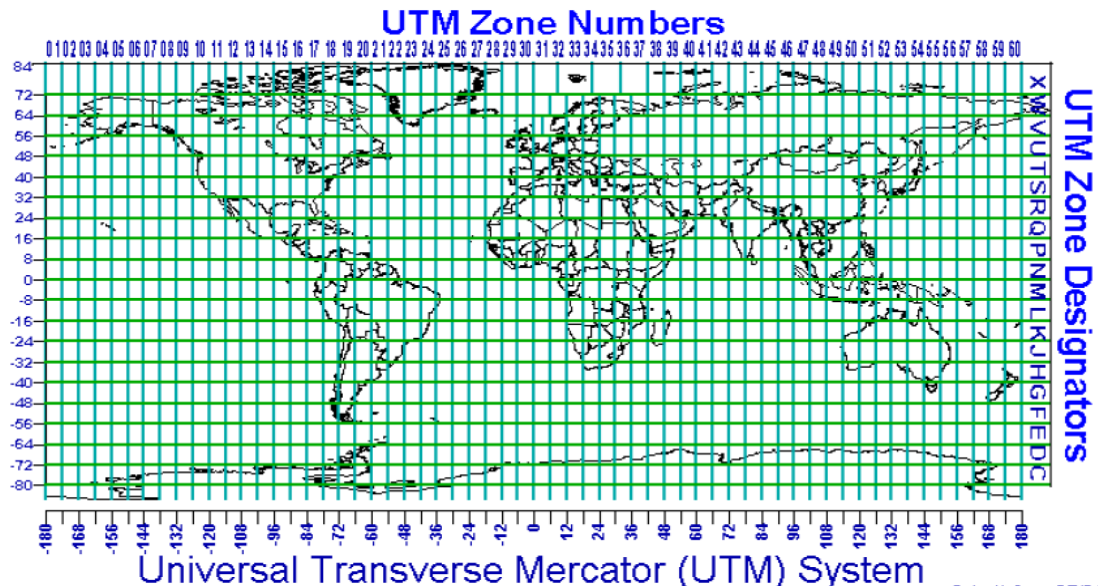
a) Geographic Coordinate Systems

It uses Latitudes (0-90oN-S) and Longitudes (0-180oE-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 born and air borne (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 component 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

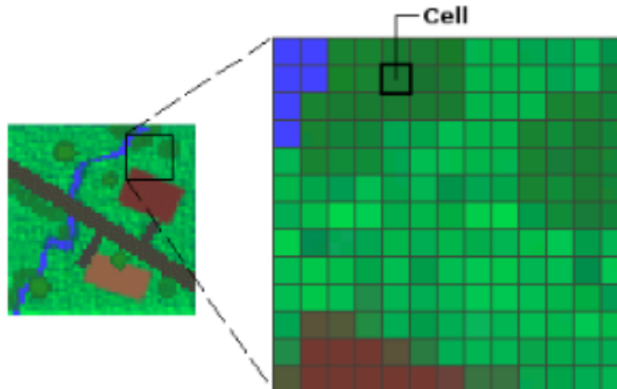
ArcMap and you will be able to:

- 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

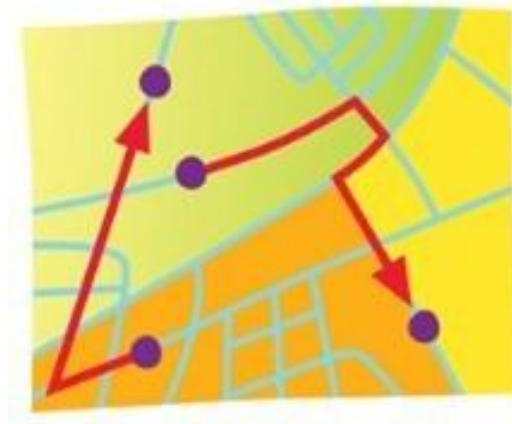
Geographic Information System (GIS): A system for capturing, storing, checking and displaying data related to positions on Earth’s surface. GIS can handle data as several layers, in two predominant data models.

Raster consists of 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 feature such as land cover class or area or administrative division. So every field (column) in an attribute table refers to the attributes. Rasters consists on only of a cell value associated with that pixel.

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

 **STEP (1)**

1.4 Basic Geoprocessing and Spatial Analysis

1.4.1 Getting Familiar with ArcMAP

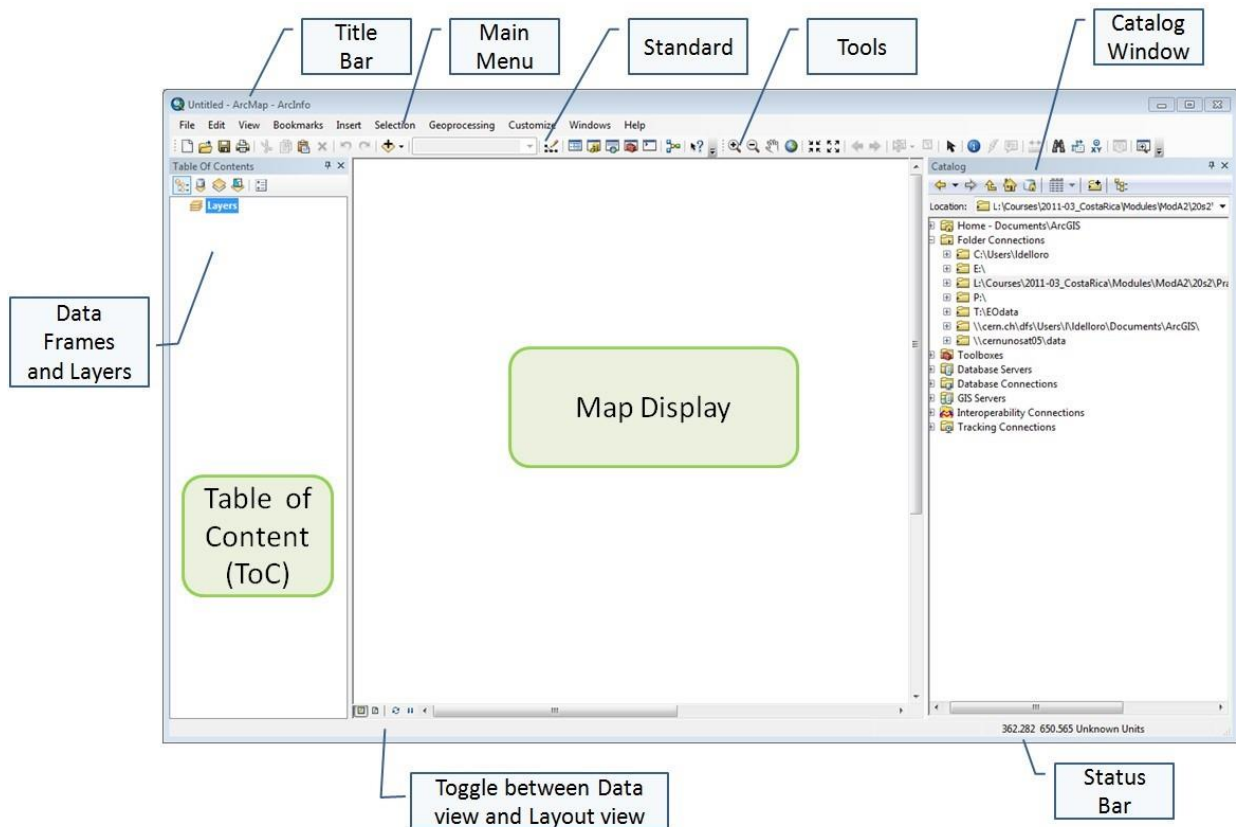
- **Start** ArcMap by double-clicking on the ArcMap icon on your desktop . If an icon is not present, you can use the Start Menu: *Programs > ArcGIS > ArcMap*.
- You can specify, whether or not to start with a new empty map, a template or an existing map

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.

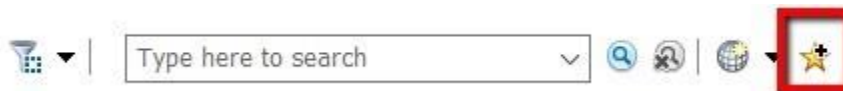
- From table of contents, **right click** on the data frame name “Layers”

- **Select Properties > General tab**
- In the *Name* section, **type** “Sudan Data”
- In the *Units* section, **select** *Decimal Degrees* for both *Map* and *Display Units* and **click** *Apply*

The screenshot shows the 'Data Frame Properties' dialog box with the following settings:

- General Tab:** Selected.
- Name:** Sudan Data
- Description:** (Empty)
- Credits:** (Empty)
- Units:**
 - Map: Decimal Degrees
 - Display: Decimal Degrees
- Tip:** See Customize > ArcMap Options > Data View tab for additional options for displaying coordinates in the status bar
- Reference Scale:** <None>
- Rotation:** 0
- Label Engine:** Standard Label Engine
- Simulate layer transparency in legends
- Allow assignment of unique numeric IDs for map service publishing
- Buttons:** OK, Cancel, Apply (highlighted)

- **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*





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.

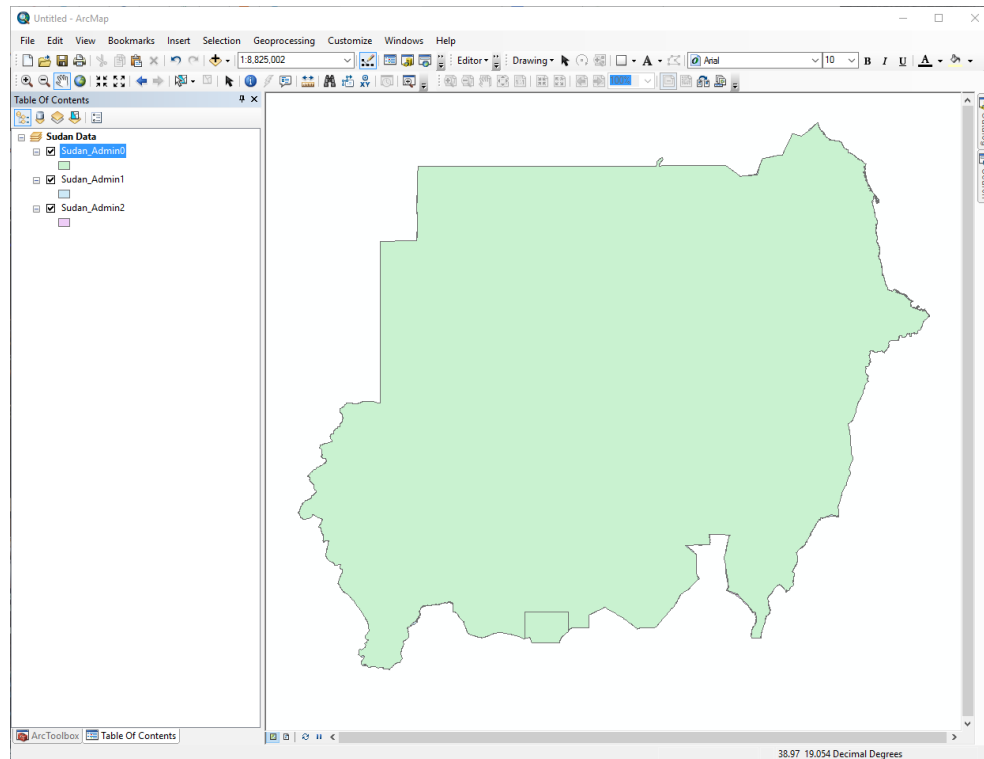
When ArcMap is started with a new, empty map, the coordinate system for the default data frame is not defined.

STEP (2)

1.5 Working with Baseline data

1.5.1 Add data into ArcMAP

- From the standard toolbar, **click** the *Add Data* button 
- Browse to: **X:\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 
- In the vector folder, select *Sudan_Admin0.shp*, *Sudan_Admin1.shp* and *Sudan_Admin2.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.

1.5.2 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.



1.5.3 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.

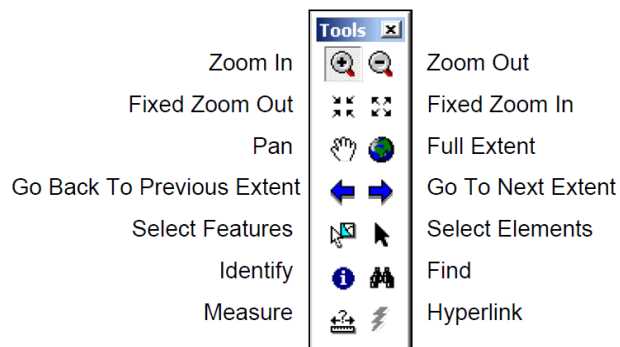
1.5.4 Creating a Group Layer

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.

1.5.5 Zoom and Pan

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

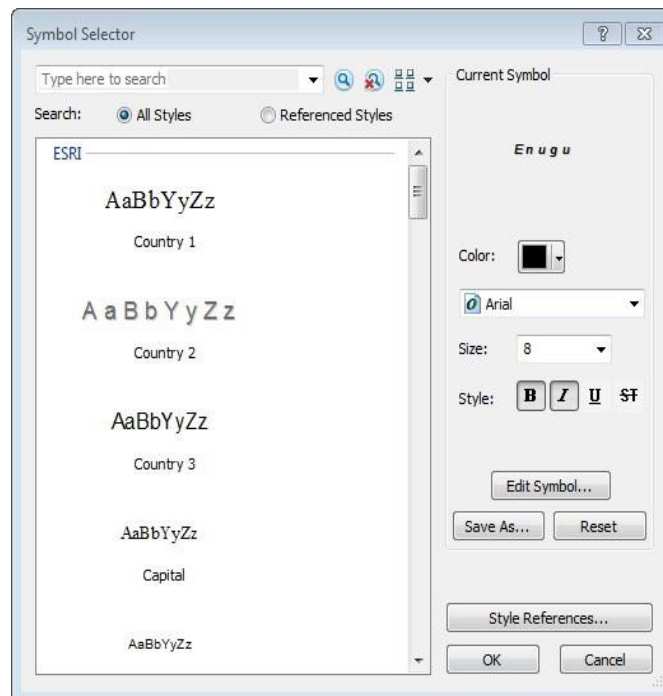


Notice that as you move the cursor around the map, the cursor position displayed at the bottom left of ArcMap window changes respectively.

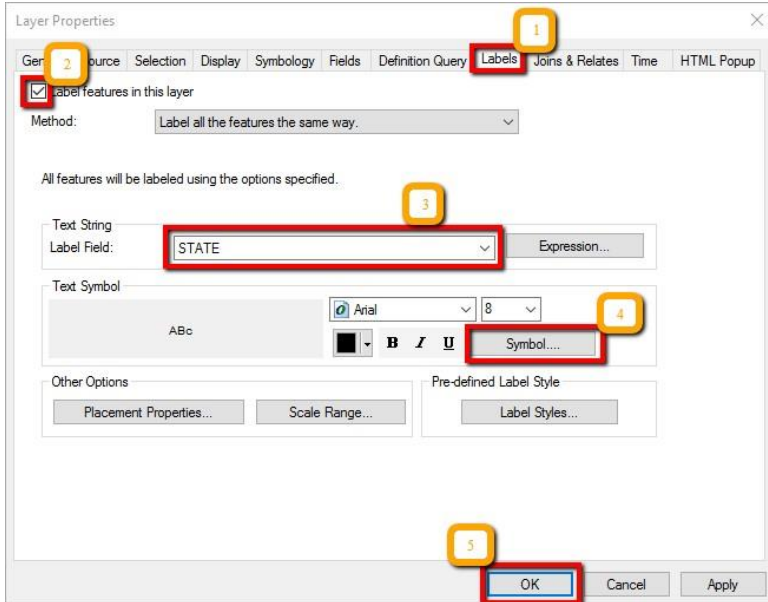
1.5.6 Labeling Features

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



1.5.7 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 State(s) from Sudan_Admin1.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"*




STEP (3)

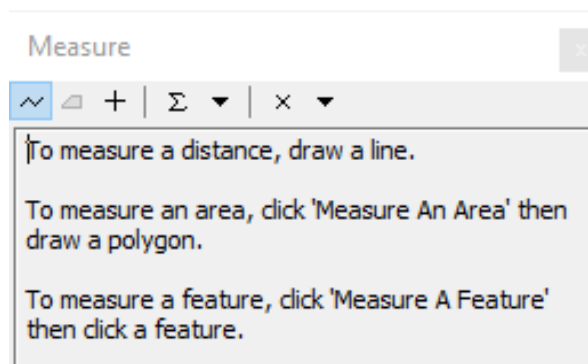
1.6 Information Extraction

1.6.1 Measure Distances

To measure horizontal distances on your map you can use the Measure Tool.

- **Add** "*Sudan_Capitals*" data to ArcMAP from **X:\Module1\Admin**
- Label the Capitals using "**Name1**" you can also change point symbols.
- From the ArcMap toolbar, **click** the Measure button 

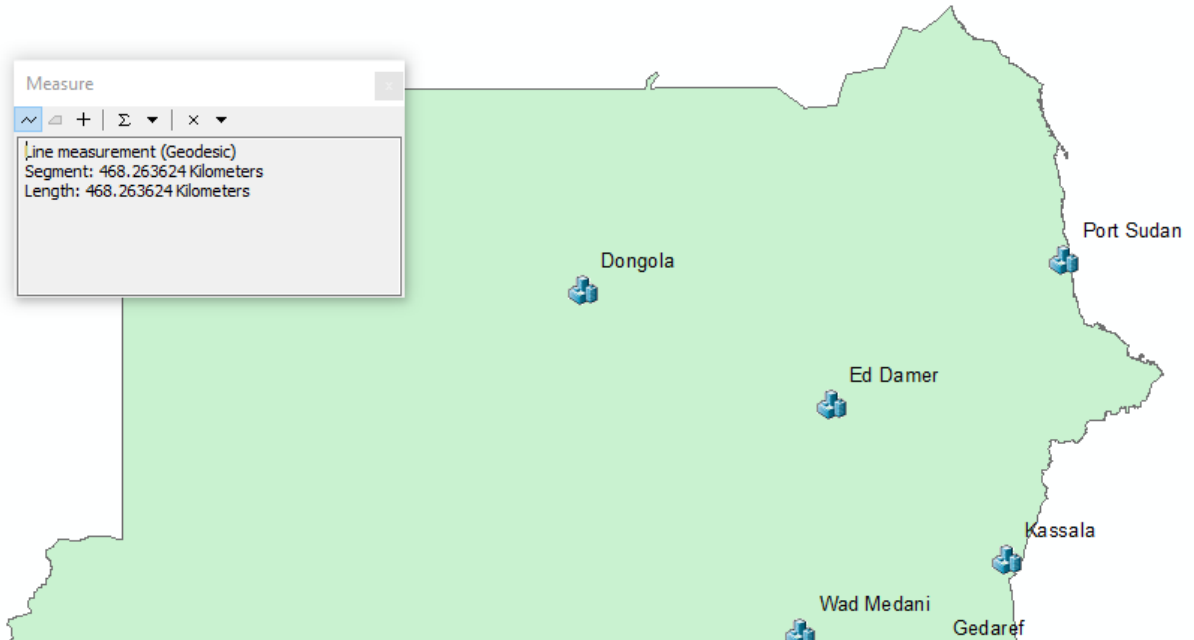
The Measure window opens with the measure line tool enabled as shown below



- **Click** the *Choose Units* button and **choose** *Kilometers* for distances
- **Draw** a line between two different Capitals in your layer (***Port Sudan*** and ***Kassala***)
- **Click once** to fix the line's starting point and move your mouse to the desired ending point
- You can see the distance automatically appearing in the Measure toolbar




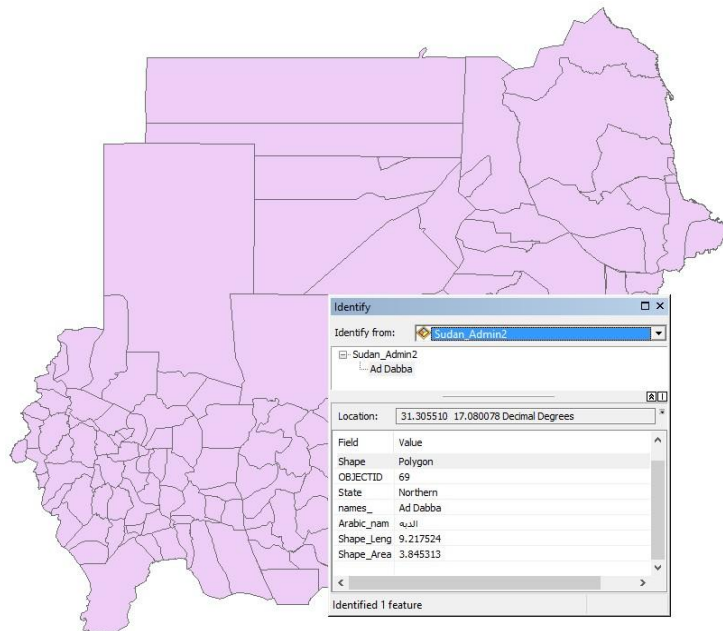
What is the Distance between Port Sudan and Kassala in Kilometers? _____



1.6.2 Identify Features

To display the data attributes of a map feature, **click** over the feature with the *Identify* tool.

- **Zoom** to full extent
- From the ArcMap toolbar, **click** the *Identify* button 
- **Click** inside an y boundary




The identified feature temporarily flashes and its attributes appear in the Identify dialog box

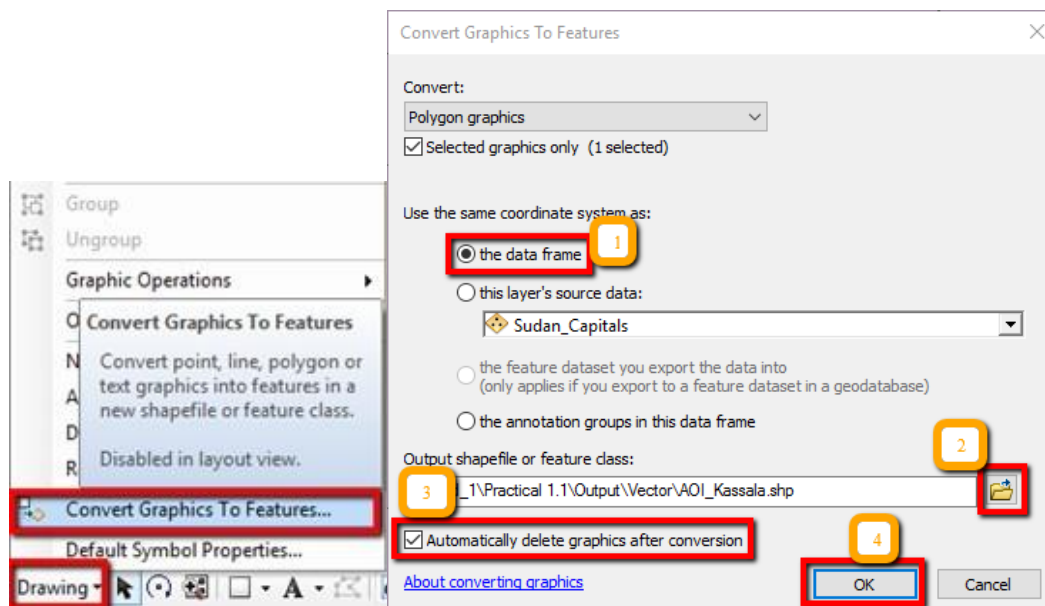
- **Right click** on the layer in the Identify window and **click** “*Zoom to*”

- **Choose** the *Identify from*: to be the layer that you want to work with

1.6.3 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 so that *Kassala* region/town falls inside the rectangle (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_Kassala.shp*” and save it on: *X:\Module1\Output\Vector*




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

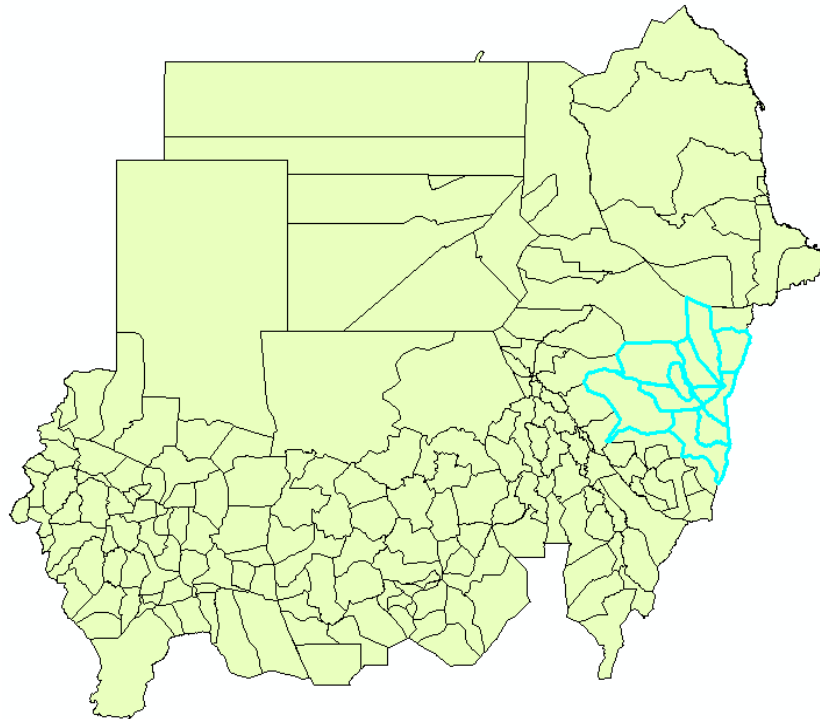


What is the purpose of creating an AOI layer?

1.6.4 Select Features

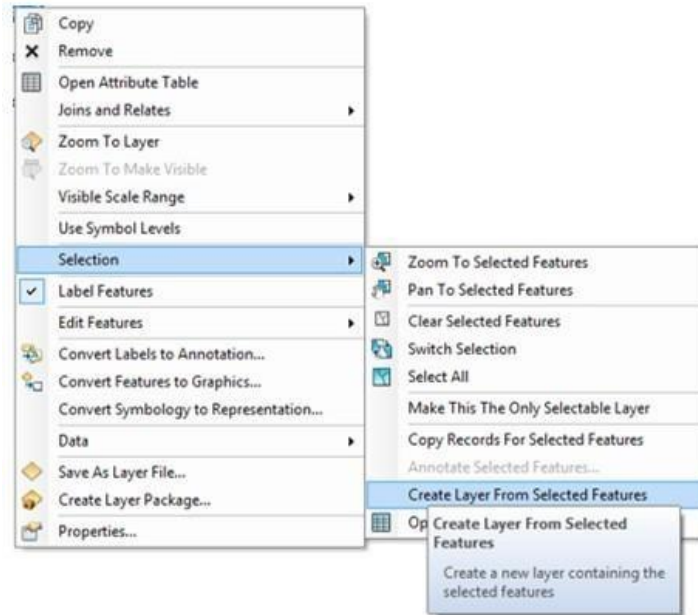
This tool lets you select the features on which you want to perform certain operations (e.g. move, delete, edit, copy, etc.). You have multiple options for selecting features (i.e. by rectangle, circle, polygon, etc).


- 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. 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*).



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.

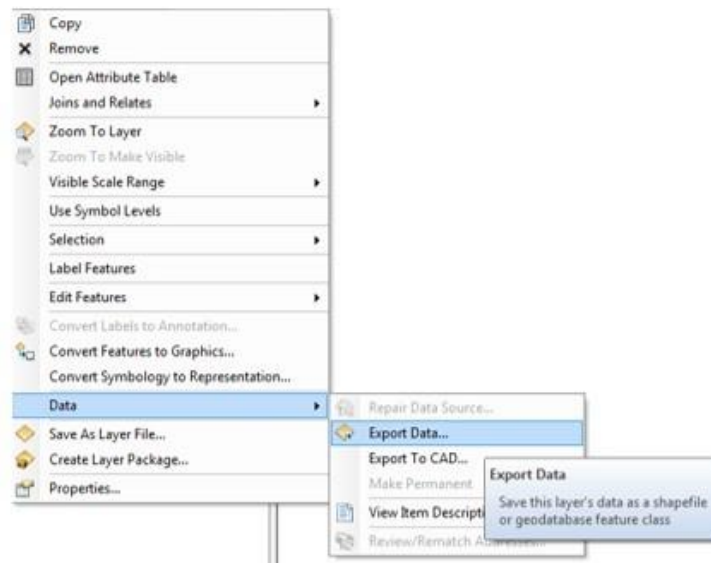
- From the *Table of Contents*, **right click** on the feature of interest
- **Go to** *Selection > Create a Layer from Selected Features*



- 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*

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:\Module1\Output\Vector**
- **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*

1.6.5 Working with Attribute Tables

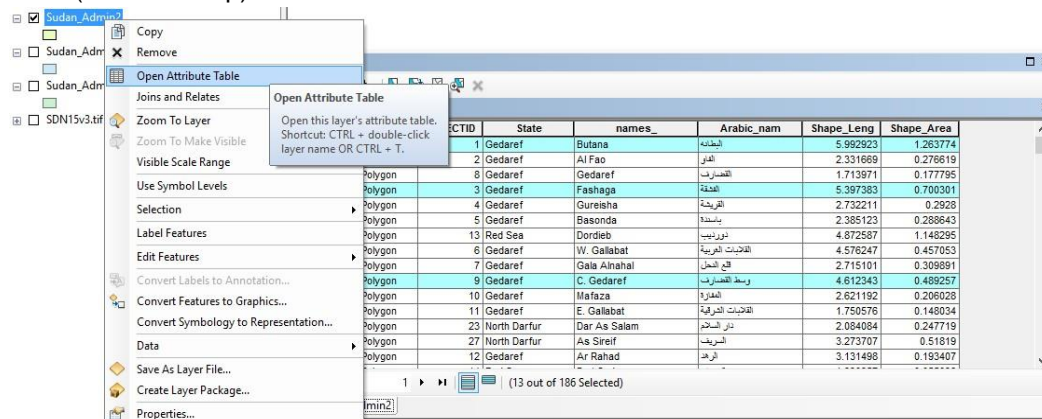
In GIS, a feature on a map may be associated with lot of information (attribute values) stored in a table. A layer’s attribute table contains a row (or record) for each feature and a column (or field) for each attribute or category (attribute field).

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

- **Right click** on “*Sudan_Admin2*” 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.

1.6.6 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**

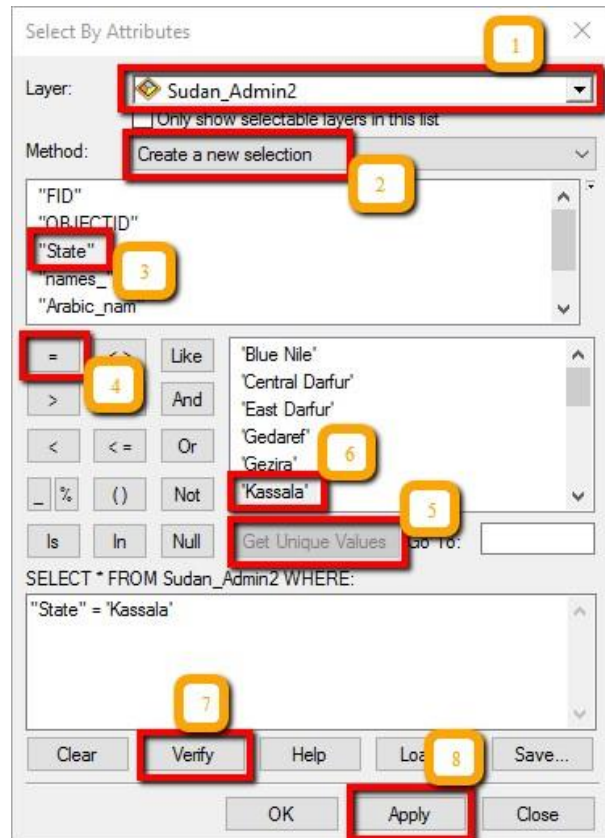
The Select by Attributes dialog box appears

- **Select** “Sudan_Admin2” under Layer
- **Select** Create a new selection
- **Select** the attribute field “State” and
- **Double click** on “State”, **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. “Kassala”.

In the dialog box below, the expression should appear as follows: “State” = “Kassala” (Choose a State of your interest, Ex: “Blue Nile”).

- **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*.



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.

We will now select populated places that are located inside our boundary.

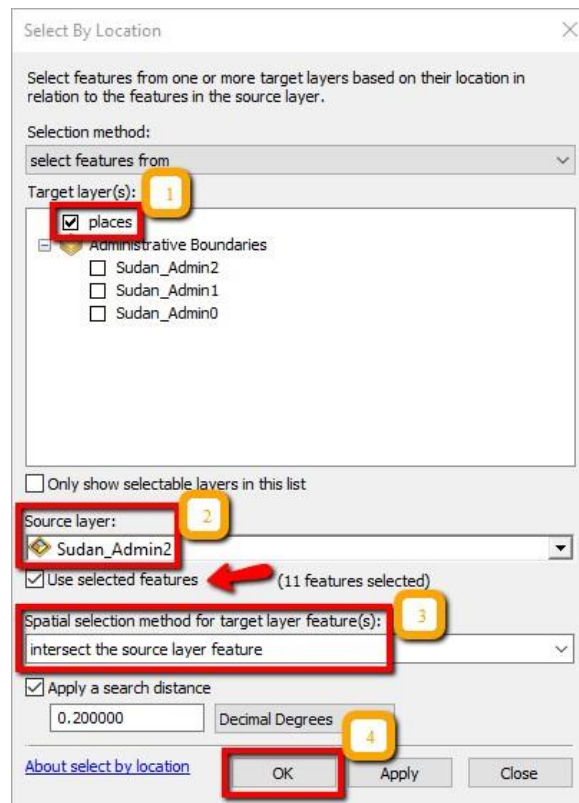
- From the standard toolbar, **click** the *Add Data* button. Alternately you can also drag and drop using the Catalog Window.
- **Select** the *Sudan_settlement.shp* from the vector folder under *Input* (same as above).
- Using either the selection tool or the *Select by Attributes* dialog box, **select** a feature (in this case, any country) from the *Sudan_Admin1.shp* layer.
- From the *Main Menu* toolbar, **click** *Selection > Select by Locations*

The Select by Locations dialog box appears:

- **Select** features from “places” data layer, **choose** *Source Layer* as *Sudan_Admin2*.

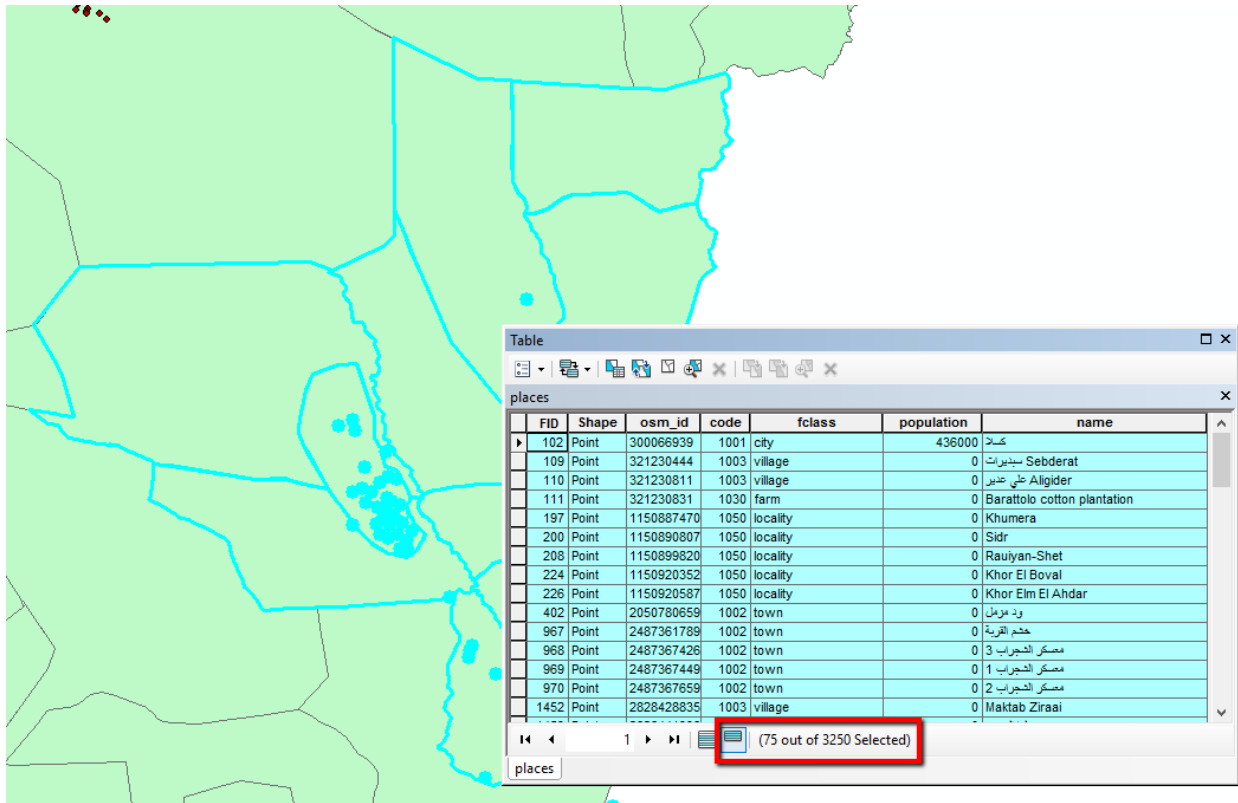
Make sure that *Use selected feature box* under the source layer is checked.

- **Under** *Spatial selection method for target layer feature(s)* **choose** “*intersect the source layer feature*”
- **Click** **OK**



- **Click** *Selection > Zoom to Selected Features*
- **Right click** on *places > Open Attribute Table*
- **Click** *Selected* (at the bottom of the Attribute Table) to display in the table only selected attributes.

This is how your map should look (of course, depending on the country of your selection):



- Click *Clear Selection* button and then zoom to *full extent*

1.6.7 Joining Tables

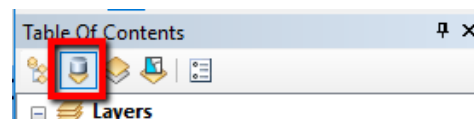
Attribute tables contain predefined fields that hold data on geometry and the object ID. We can also add excel table into ArcGIS workspace and view the table. This table can be joined with existing layer or converted into a shape file.

Exercise

In this exercise you will be joining the 2010 Sudan population data to the level 1 (State) administration boundary polygons.

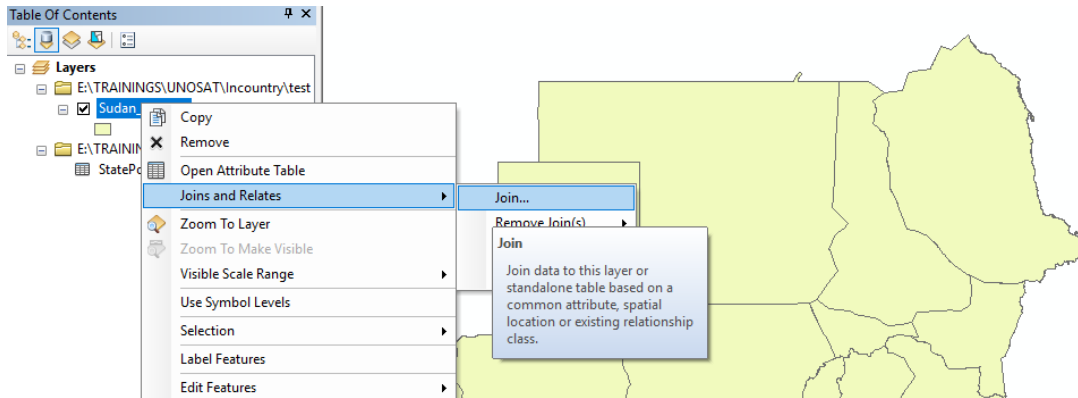
- Add “*Sudan_Admin1*” and “*StatePop2010*” data to ArcMap from this location;
<X:\Module1\Baseline>

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.

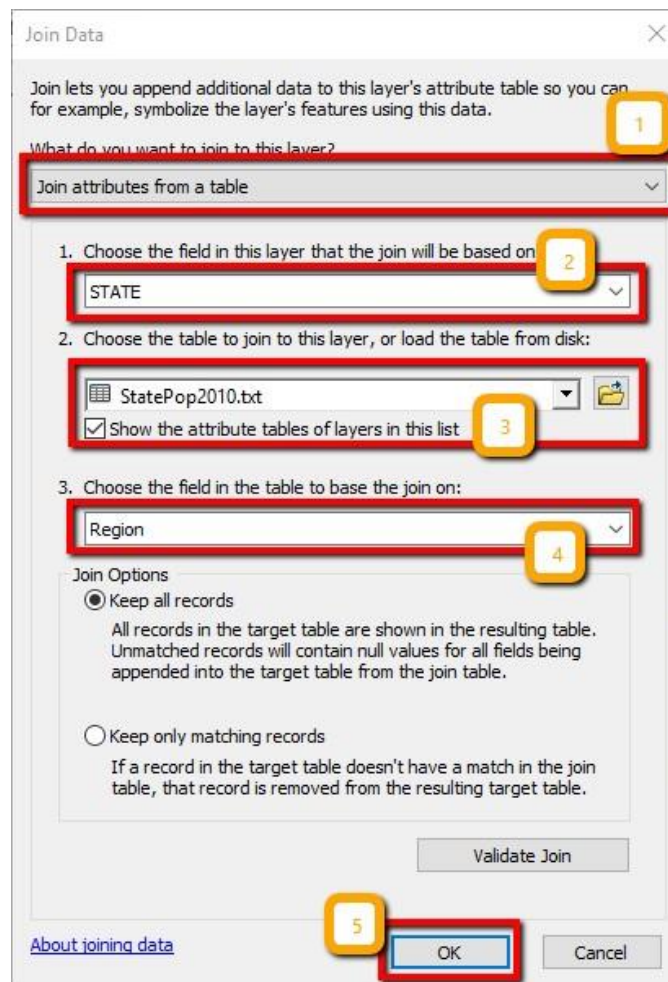


Join the attributes of the “*StatePop2010*” table to the Attribute table of “*Sudan_Admin1*”.

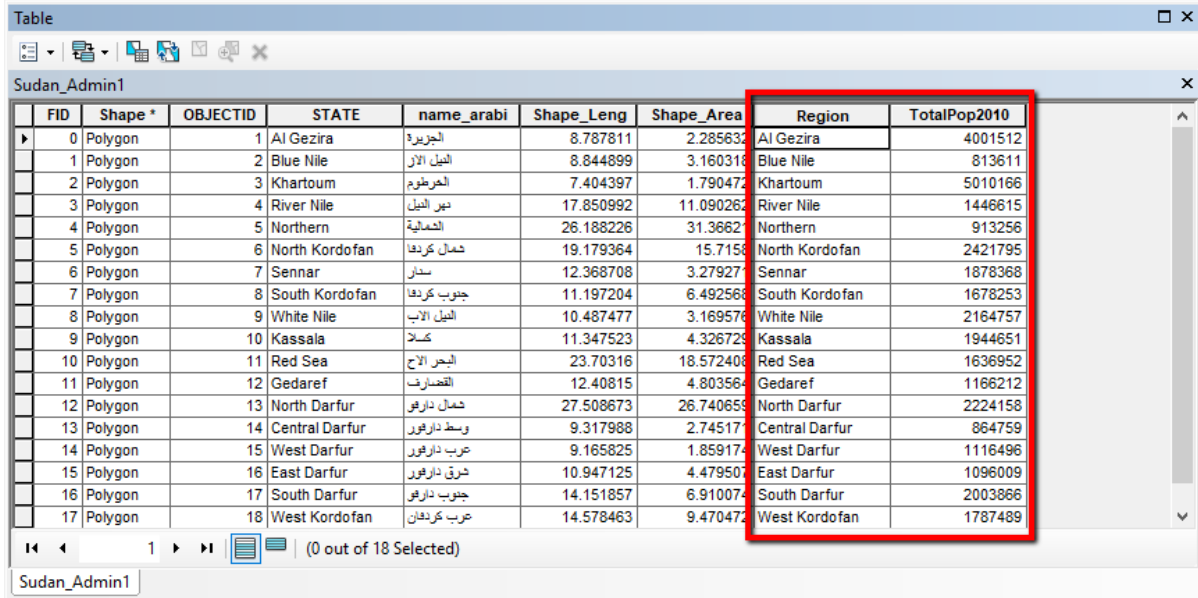
- **Right-click** the layer or table you want to join (*Sudan_Admin1*), point to *Joins and Relates* > click *Join*.



- **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 “STATE” on which the join will be based.
- **Click** the third drop-down arrow to **choose** the table to join to the layer “StatePop2010.txt”.
- **Click** the fourth drop-down arrow and **click** the field in the table on which to base the join “Region”.
- **Click** OK

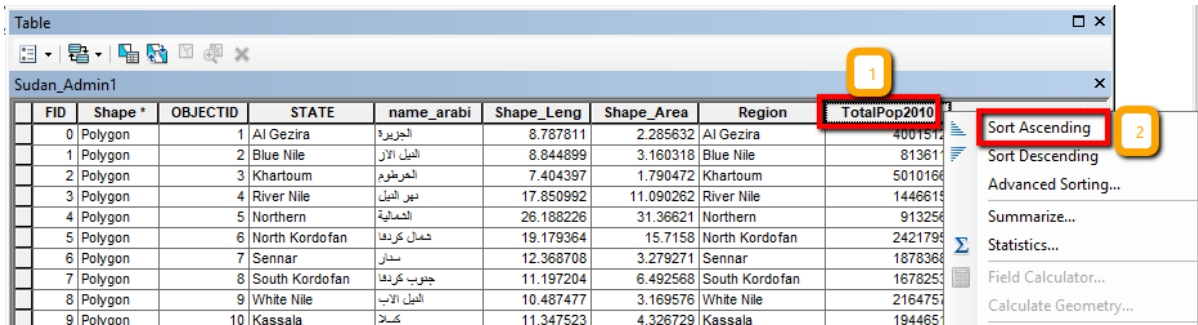


Open the attribute table of “Sudan_Admin1”. The attributes of the table are appended to the layer's attribute table.



FID	Shape *	OBJECTID	STATE	name_arabi	Shape_Leng	Shape_Area	Region	TotalPop2010
0	Polygon	1	Al Gezira	الجزيرة	8.787811	2.285632	Al Gezira	4001512
1	Polygon	2	Blue Nile	النيل الاز	8.844899	3.160318	Blue Nile	813611
2	Polygon	3	Khartoum	الخرطوم	7.404397	1.790472	Khartoum	5010166
3	Polygon	4	River Nile	نهر النيل	17.850992	11.090262	River Nile	1446615
4	Polygon	5	Northern	الشمالية	26.188226	31.36621	Northern	913256
5	Polygon	6	North Kordofan	شمال كردفان	19.179364	15.7158	North Kordofan	2421795
6	Polygon	7	Sennar	سندار	12.368708	3.279271	Sennar	1878368
7	Polygon	8	South Kordofan	جنوب كردفان	11.197204	6.492568	South Kordofan	1678253
8	Polygon	9	White Nile	النيل الاب	10.487477	3.169576	White Nile	2164751
9	Polygon	10	Kassala	كسلا	11.347523	4.326729	Kassala	1944651
10	Polygon	11	Red Sea	البحر الاح	23.70316	18.572408	Red Sea	1636952
11	Polygon	12	Gedaref	الغضارف	12.40815	4.803564	Gedaref	1166212
12	Polygon	13	North Darfur	شمال دارفور	27.508673	26.740659	North Darfur	2224158
13	Polygon	14	Central Darfur	وسط دارفور	9.317988	2.74517	Central Darfur	864759
14	Polygon	15	West Darfur	غرب دارفور	9.165825	1.859174	West Darfur	1116496
15	Polygon	16	East Darfur	شرق دارفور	10.947125	4.479507	East Darfur	1096009
16	Polygon	17	South Darfur	جنوب دارفور	14.151857	6.910074	South Darfur	2003866
17	Polygon	18	West Kordofan	غرب كردفان	14.578463	9.470472	West Kordofan	1787489

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



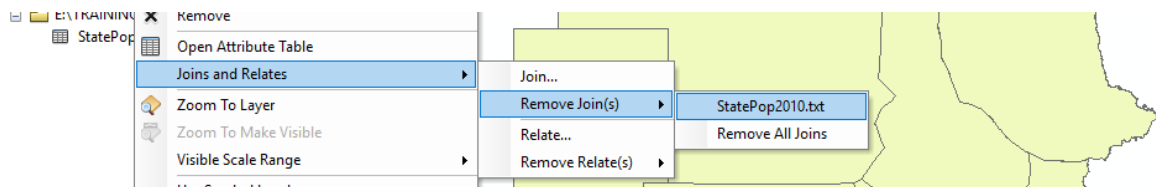
FID	Shape *	OBJECTID	STATE	name_arabi	Shape_Leng	Shape_Area	Region	TotalPop2010
0	Polygon	1	Al Gezira	الجزيرة	8.787811	2.285632	Al Gezira	4001512
1	Polygon	2	Blue Nile	النيل الاز	8.844899	3.160318	Blue Nile	813611
2	Polygon	3	Khartoum	الخرطوم	7.404397	1.790472	Khartoum	5010166
3	Polygon	4	River Nile	نهر النيل	17.850992	11.090262	River Nile	1446615
4	Polygon	5	Northern	الشمالية	26.188226	31.36621	Northern	913256
5	Polygon	6	North Kordofan	شمال كردفان	19.179364	15.7158	North Kordofan	2421795
6	Polygon	7	Sennar	سندار	12.368708	3.279271	Sennar	1878368
7	Polygon	8	South Kordofan	جنوب كردفان	11.197204	6.492568	South Kordofan	1678253
8	Polygon	9	White Nile	النيل الاب	10.487477	3.169576	White Nile	2164751
9	Polygon	10	Kassala	كسلا	11.347523	4.326729	Kassala	1944651

Which state has the highest number of Population? _____

Which State has the least number of Population? _____

NOTE: You may want to remove the current join from “Sudan_Admin1” 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 “StatePop2010.txt”.



1.7 Basic Geoprocessing and Spatial Analysis

Rational: The main rational 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 decisions.

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 QGIS to handle the various chores of a day to day GIS activities.

1.7.1 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.”



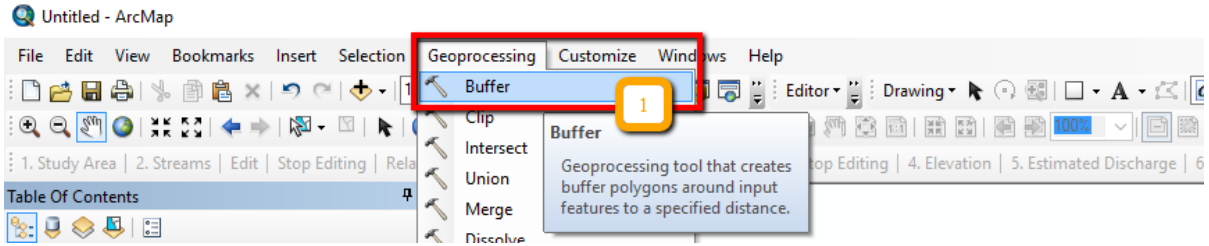
The goal of the spatial analysis is to answer spatial questions which might be related to location, pattern, change, scenarios and others. GIS software’s are designed to provide a state of the art tools to process data and answer such complex space based questions.

There are hundreds of tools under the QGIS 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 at a conclusion.

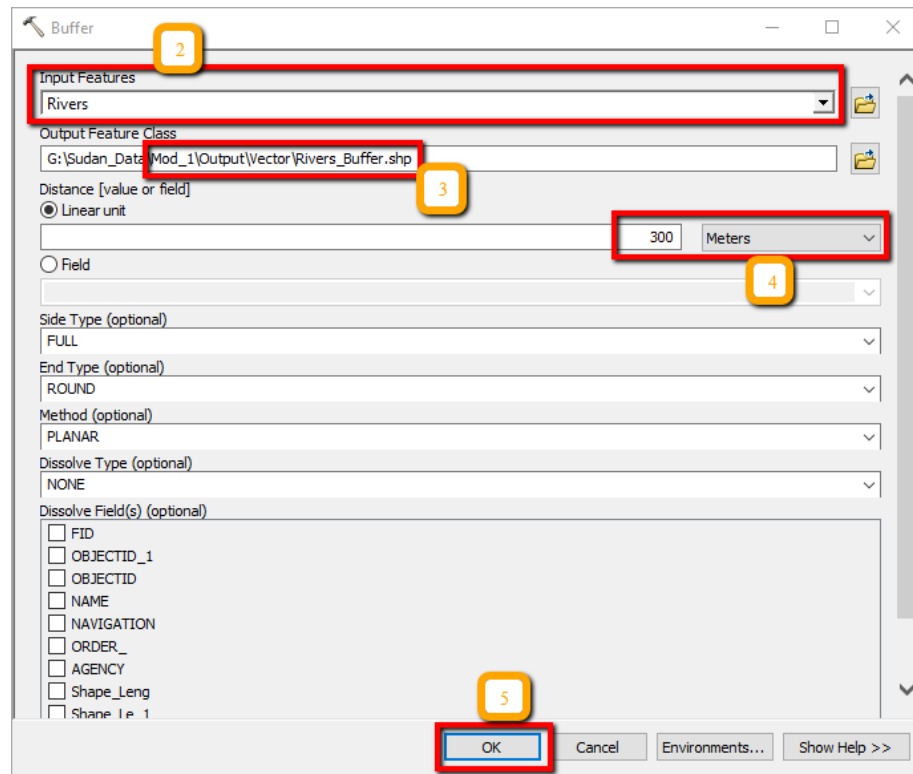
1.7.2 Buffer Analysis


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 with in 3km of water points you can easily identify them. Let’s create a buffer of 300m from a river and see how far people should build of farm from the river.


- Add the layer for *River* to ArcMap
- Click on *Geoprocessing* from the Menu Bar > then Click on *Buffer*



- Under *Input Features* select “Rivers”
- Save Out Feature Class as *River_Buffer.shp* X:\Module1\Output\Vector
- Linear Unit should be 300 meters > Click OK
- Zoom in to one river line to see the buffer area of 300m.



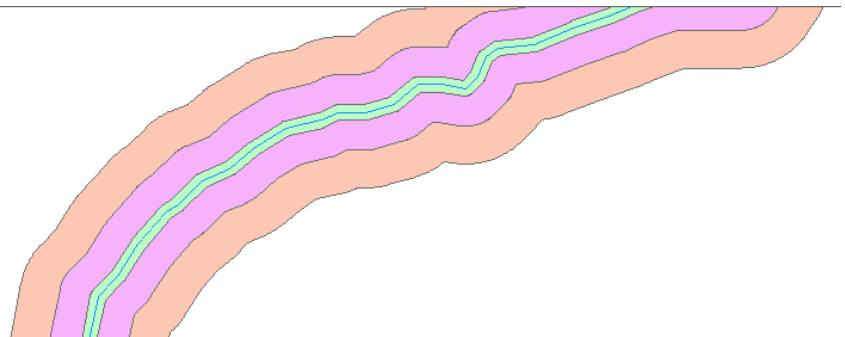
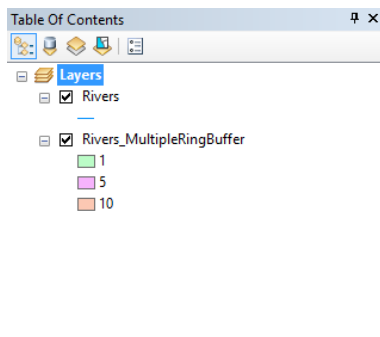
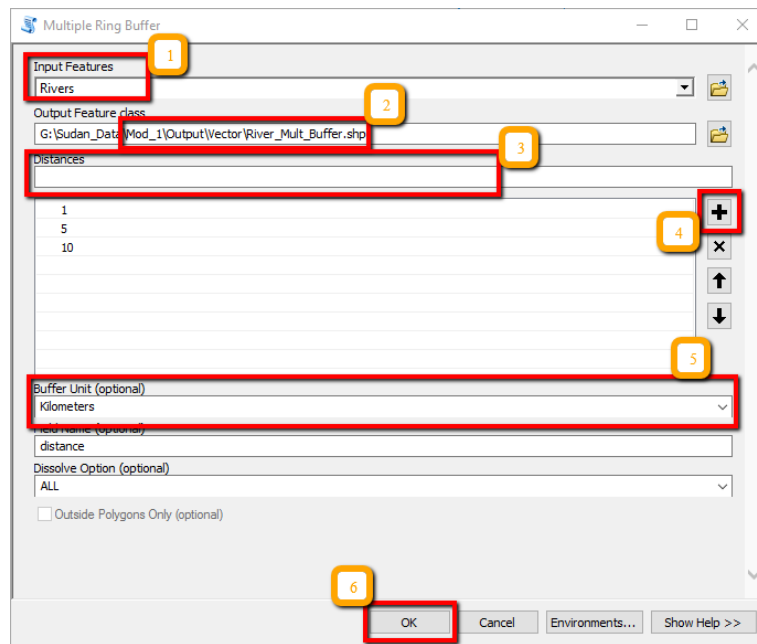
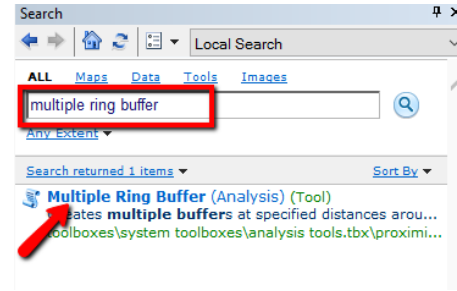
 What are the different areas this can be used? _____

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

1.7.3 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 Rivers**
- Save the Output as “*River_Mult_Buffer.shp*” to the path **X:\Module1\Output\Vector**
- Under *Distances* **give** the following three levels, 1, 5, and 10 km. **Type** each and **click** on the *plus button (+)*.
- **Change** the *Buffer Unit* option to **Kilometers** >> **Click OK**
- Now **Zoom in** to *River_Mult_Buffer* and see the different levels of Buffer distances.



1.7.4 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 you identify the total length of a railway line in the different states of Sudan intersect works well.

Steps

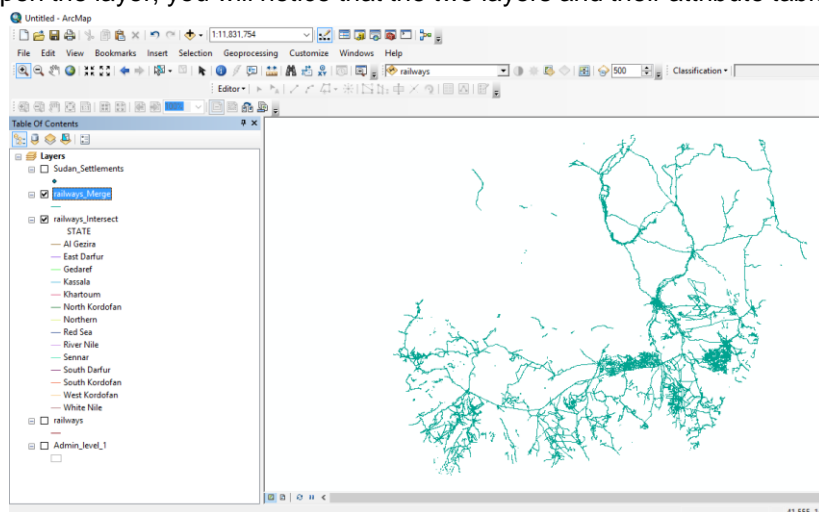
- Open ArcMap and open **railways** layer and **Sudan_Admin1** from **X:\Module1\Baseline_data** and **Admin/** folder respectively
- Now go to windows in the main menu and click on search. Key in **intersect** and search and then open the **intersect (analysis)** tool
- Now give **railways** layer and **Sudan_Admin1** as intersect features
- Save the Output feature class to **X:\Module1\Output** folder with the name **railway_state.shp** and **click** Ok.
- Now you can open the attribute table of the **railway_state.shp** to see that the state names are attached to the railway table. This means that you can also calculate the distance of a railway line in each of the states. You can classify the **railway_state.shp** to see the railway map I each states.

1.7.5 Merge

Merge is another important tool for combining two or more layers. This tool provide an opportunity to compile data of similar nature. Take for instance five GPS survey crew working to collect oil well data from the different parts of Sudan came up with their respective data layers. Now if you wish to merge all the data layers in to one Sudan oil well data you need merge tool in ArcGIS.

Let's merge the roads and rail way layers in Sudan to show the transport infrastructure of Sudan.

1. Add the roads and railways layers from **X:\Module1\Baseline_data**
2. Search for a tool **merge** and open. Set the roads and railways as inputs layers
3. Save the **Output feature class** to **X:\Module1\Output** folder with the name **transport_infrastructure.shp** and click Ok
4. If you open the layer, you will notice that the two layers and their attribute tables are combined.

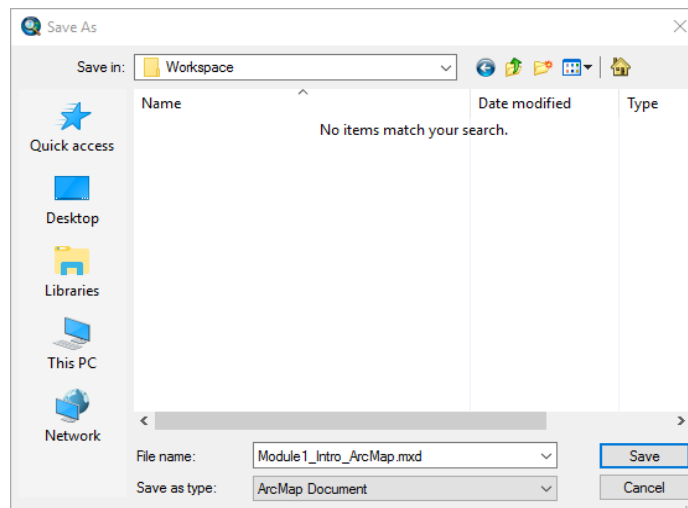


1.7.6 Saving a Map

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:\Module1\Workspace**



STEP (4)

1.8 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.

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



ACP-EU Natural Disaster Risk Reduction Program



unitar

An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR United Nations Institute for Training and Research

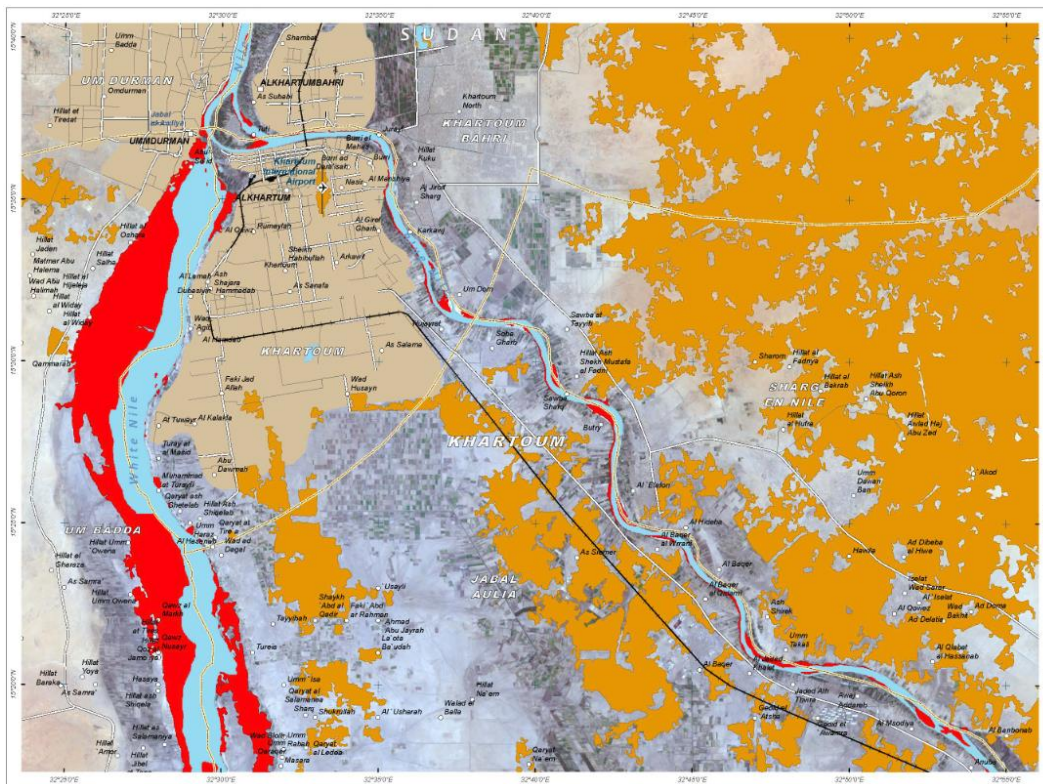
MODULE: 2
INTRODUCTION TO EARTH
OBSERVATION/REMOTE SENSING

2.1 Theories and Concepts on Earth Observation/Remote Sensing

2.1.1 Introduction

Remote sensing is a valuable data source to obtain information about the surface of the Earth. Several platforms have been historically used to collect data, starting from kites to balloons, airplanes, satellites and very recently, unmanned aerial vehicles. The applications of remotely sensed data are extremely broad, and it is increasing exponentially due to recent improvements in data resolution and availability.

In this module, we will explore the basics of remote sensing and how ArcMap tools could be used to perform basic image pre-processing such as Composing, Mosaicing, and Clipping.



Flooded areas over Khartoum State, Sudan. Image Source: UNOSAT

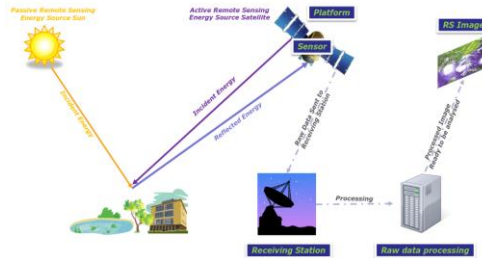
Learning Objectives

By going through this exercise you will be familiarized with basic image pre-processing involved in remote sensing and you will be able to:

- Understand the concept of Remote Sensing.
- Download Sentinel-2 data from the Web.
- Load satellite imageries into ArcMap.
- Perform band combinations (Composing).
- Mosaicing for different screens.
- Clip raster data with using AOI.
- Perform unsupervised/supervised image classification

2.2 GLOSSARY

Remote sensing is the science of collecting and interpreting information about the environment and the surface of the earth from a distance, primarily by sensing radiation that is naturally emitted or reflected by the earth's surface or from the atmosphere, or by sensing signals transmitted from a device and reflected back to it.



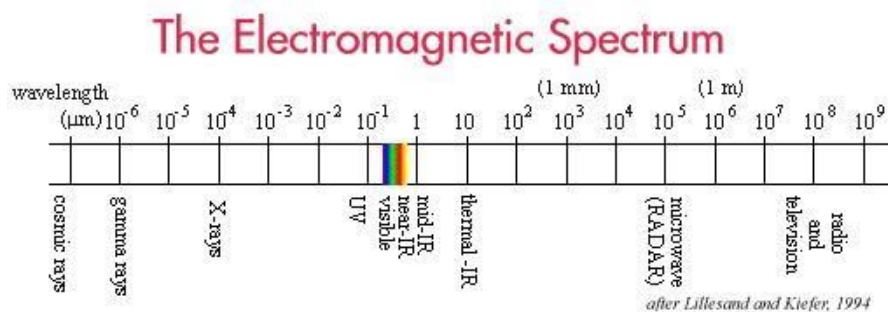
Platform is the structure or vehicle on which the remote sensing instrument (sensor) is mounted.

Sensor is the instrument that detects and conveys the information that constitutes an image. Sensors are of two primary types active and passive.

Active sensors provide their own source of energy to illuminate the objects they observe. Example: Radio Detection and Ranging (RADAR) and Light Detection and Ranging (LiDAR)

Passive sensors detect sunlight radiation reflected from the earth and thermal radiation in the visible and infrared of the electromagnetic spectrum. They measure signals at several spectral bands simultaneously, resulting in so-called multispectral images. When an image consists only of one band, it is called panchromatic image.

The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of electromagnetic radiation.



Resolution: Spatial (pixel size), spectral (wavelength interval size and number of intervals or bands), temporal (amount of time needed to revisit and acquire data for the exact same location), and radiometric (ability to detect differences in brightness).

Band: Multispectral remote sensors capture image data at specific frequencies across the electromagnetic spectrum. When a multispectral sensor captures a scene, all data captured at different range of electromagnetic spectrum are saved in different digital raster files. Each of these raster refers to a specific band.

Normalized Difference Vegetation Index (NDVI) is one of the most common indices used to assess vegetation from satellite data. It is a unique band combination that takes advantage of the high reflectance properties of vegetation in Red and Near Infrared bands (NIR).

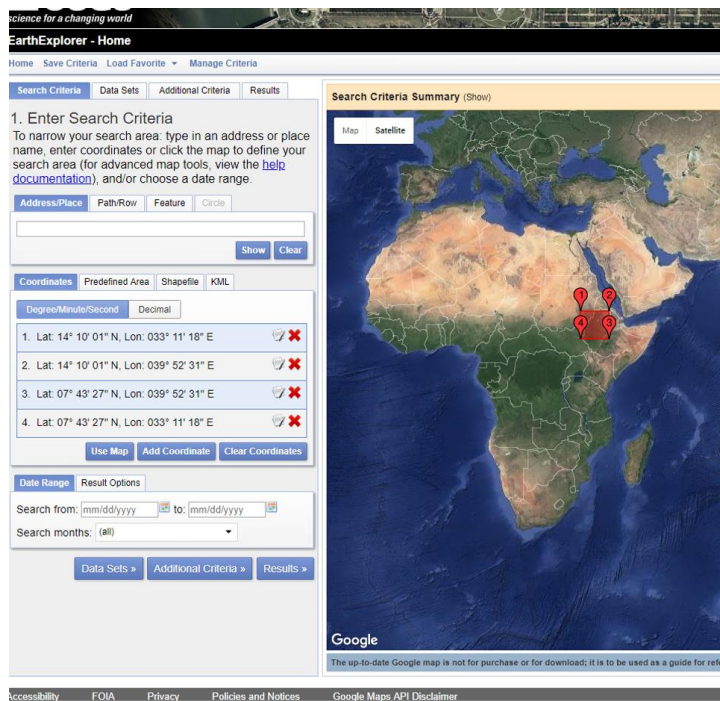
STEP (5)

2.3 Image Pre-processing

Image Pre-processing is done prior to data analysis, it's carried out to correct for any distortions. These procedures include radiometric correction to correct for uneven sensor response, Geometric correction to correct for geometric distortion due to Earth's rotation or to conform to a specific map projection system and Image Georeferencing where Ground Control Points (GCP's) are used.

2.3.1 Searching, exploring and downloading sentinel-2 imagery

From the Earth Explorer <https://earthexplorer.usgs.gov/> you can download radar and optical data. For first time users, you need to register and create an account. Make sure you select Sentinel-2 satellite or Landsat 8 on the data search, specify the cloud cover percentage and define area of interest.



Steps

- 1) Enter Search Criteria
- 2) Define Area Of Interest
- 3) Set the date Range
- 4) Select the data Sets –
i.e Sentinel-2 or Landsat 8
- 5) Additional Criteria, select cloud cover %
- 6) Results – displays the available images as per the set parameters



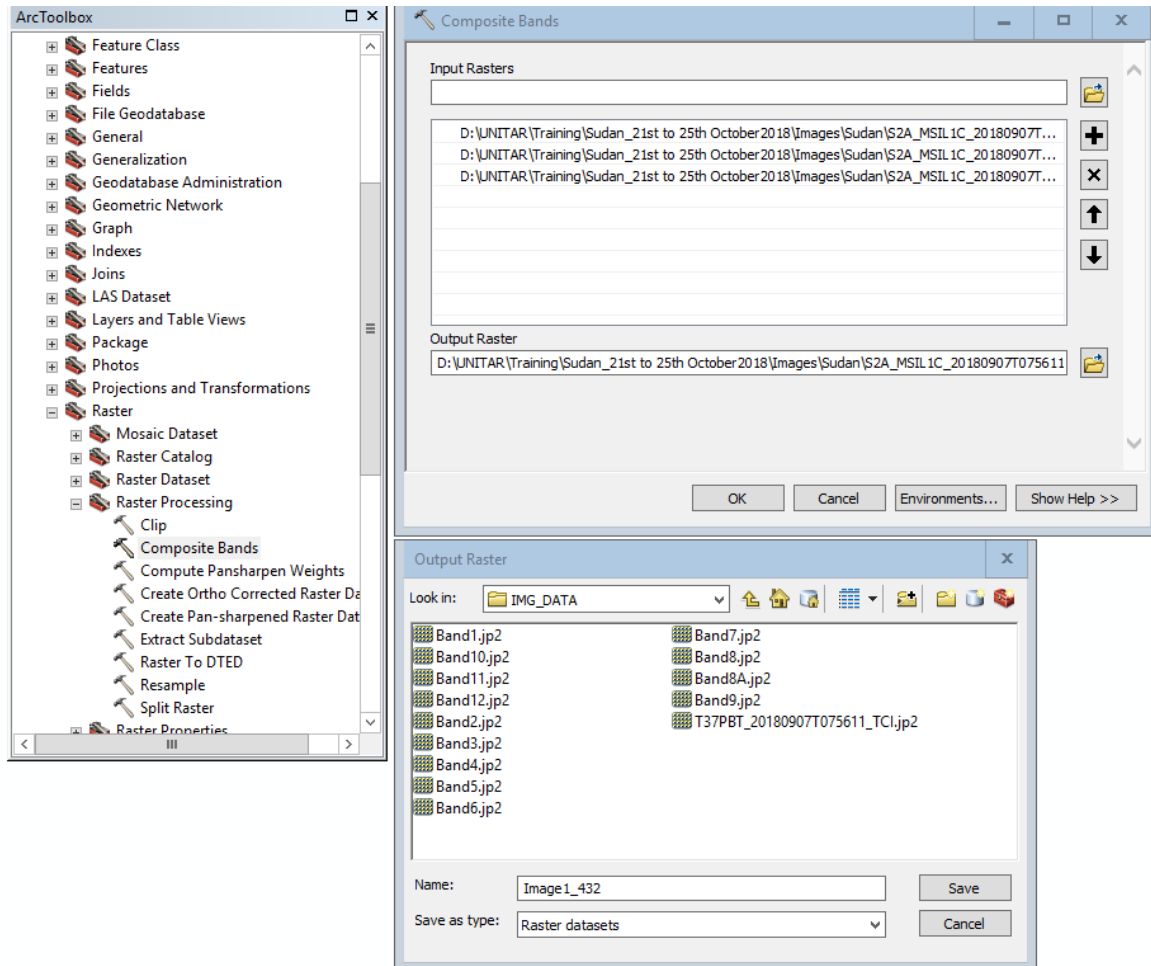
Click on the download option

For Sentinel-2 data, the downloaded product contains multiple folders. Within the Granule folder you will find all the subsets that conform the whole scene downloaded. Each folder (subset) contains (within the IMG_DATA folder) the 13 raster layers (13 spectral bands) for such subset. Layers 4,3,2 and 8 are the Red, Green, Blue and Near Infrared(NIR) respectively.

2.3.2 Compositing, Mosaicing, and Clipping

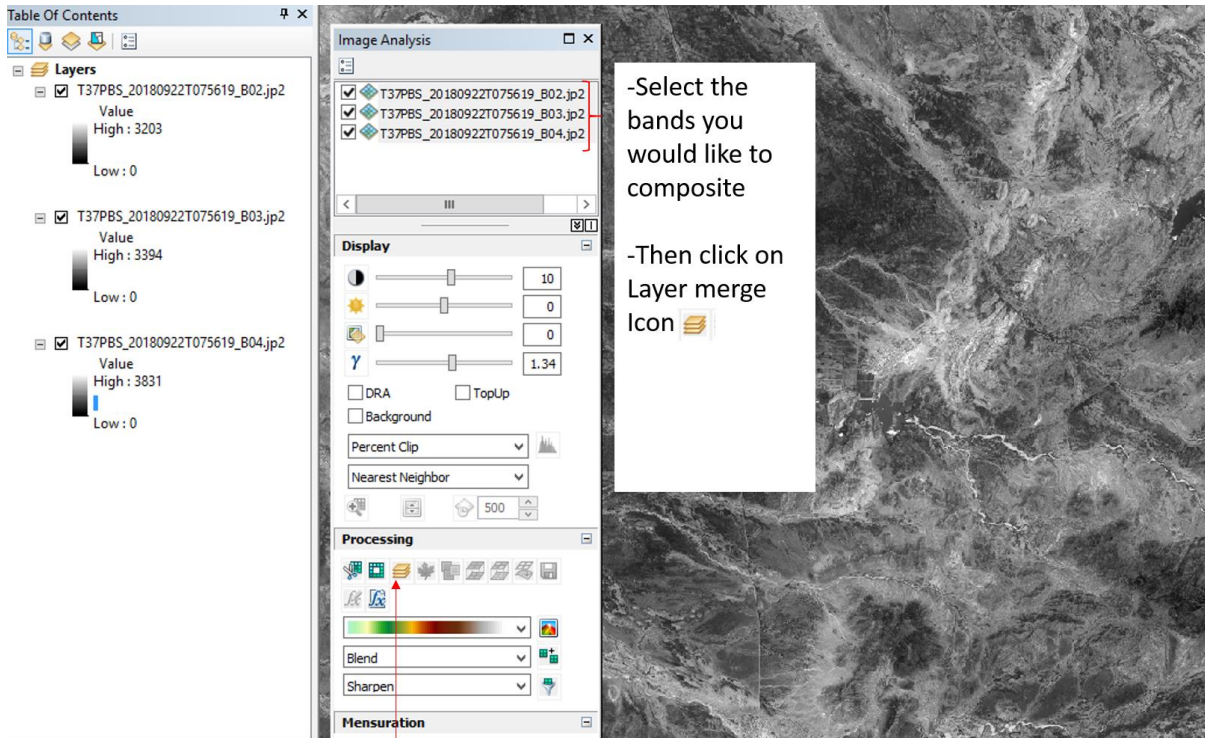
Image Compositing allows you to combine raster bands to create various RGB band combinations.

- In ArcMap, navigate to **Geoprocessing > ArcToolbox > Data Management Tools > Raster > Raster Processing > Composite Bands**.
- **Click** the *browse* button and search for the desired input raster bands.



Another option is to use the Composite button in the **Image Analysis** window,

- Load the different bands in ArcMap in our case **bands 234 > Navigate to Windows > Images Analysis**



Layer Merge Icon

A multi layered true color image is automatically displayed, composite the other image provided using the same procedure above.

Note: The composite image is added as a temporary layer. To save the output layer as a raster dataset, **click** the *export* button on the *Image Analysis* window and specify the output location.

Image Mosaicing allows you to combine two or more images into one.

- **Navigate** to *Geoprocessing > ArcToolbox > Data Management Tools > Raster > Raster Dataset > Mosaic*
- **Click** the *browse* button and load the two images.

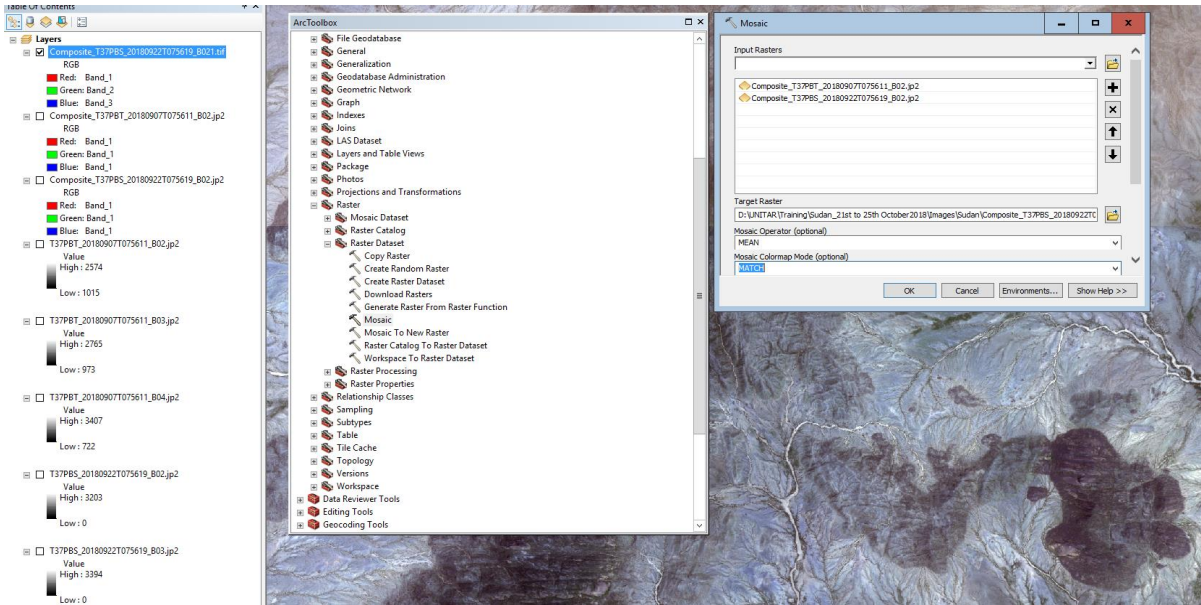
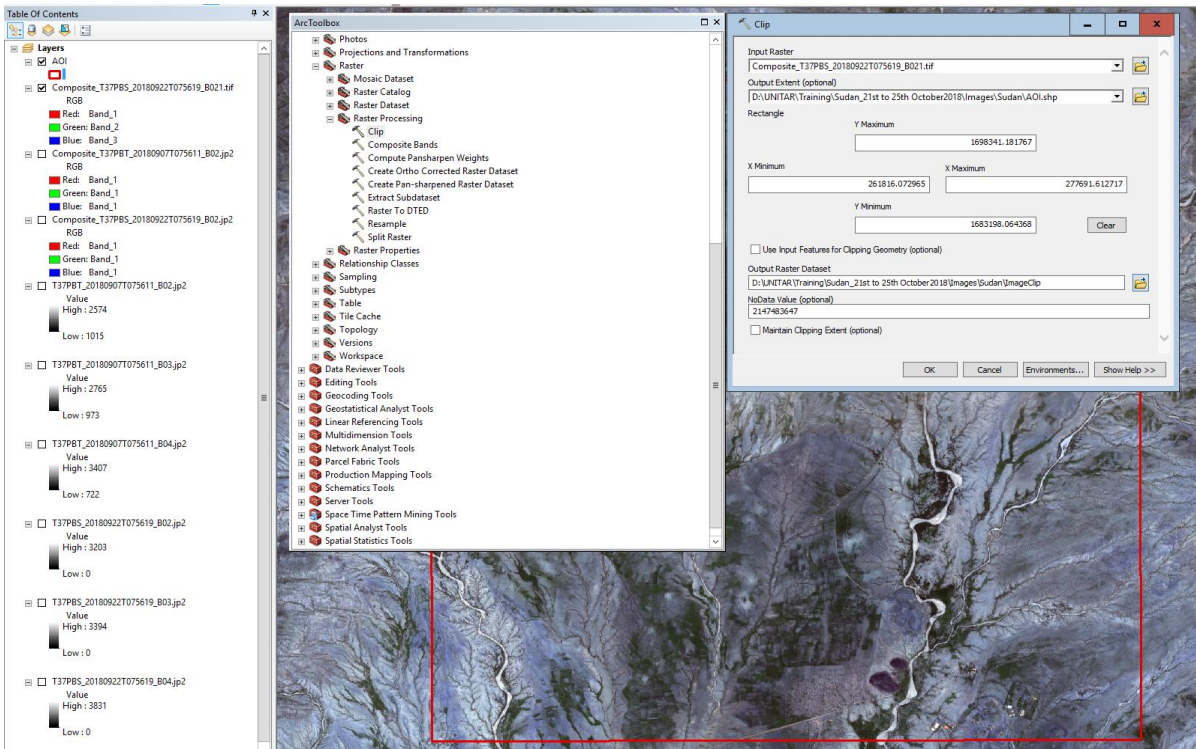


Image Clipping allows you to clip a smaller area of interest from a bigger Image.

- **Create** an Area Of Interest (AOI) by drawing a polygon shapefile. Use it to clip the Image that you have just mosaicked.
- **Navigate** to *Geoprocessing > ArcToolbox > Data Management Tools > Raster > Raster Processing > Clip*



Output Extent, input the AOI Shapefile.

 **STEP (6)**

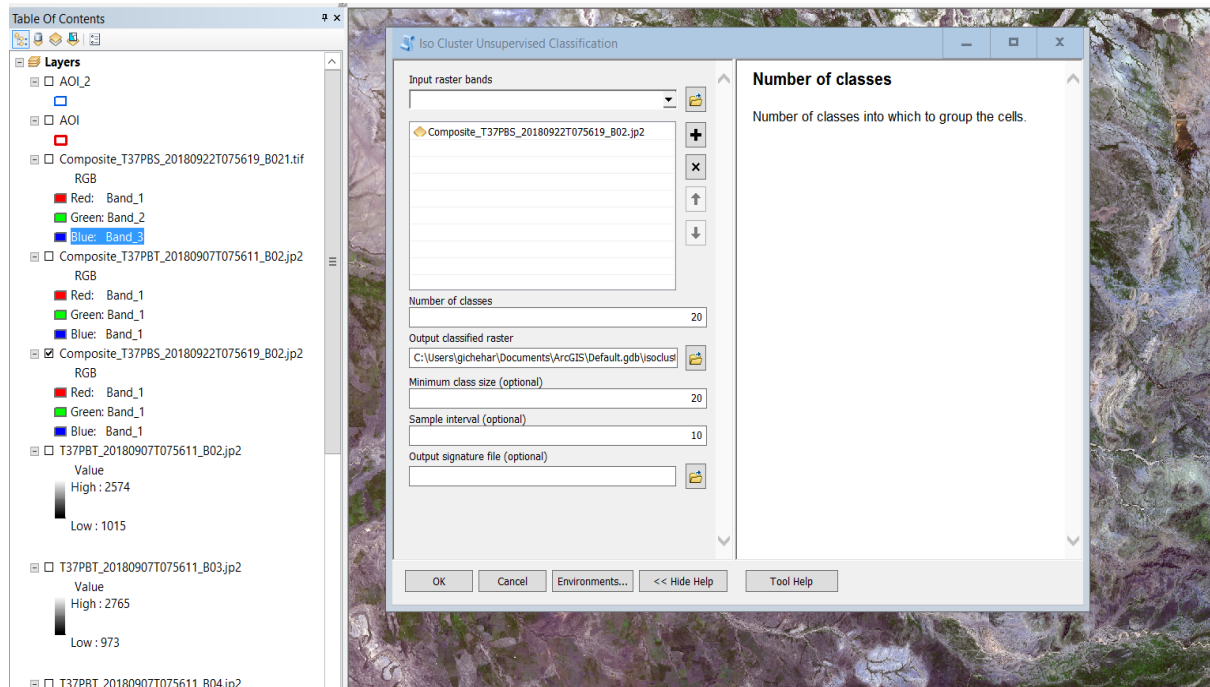
2.4 Image Classification

Image classification refers to extracting information from multiband raster. The resulting raster from image classification can be used to create thematic maps.

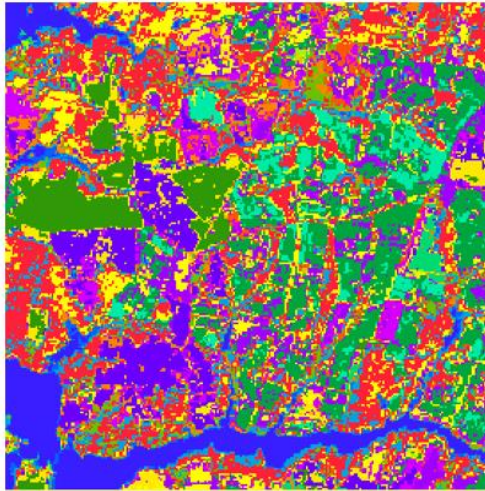
2.4.1 Unsupervised Classification

Unsupervised classification works well when the user doesn't know how many classes are present in the image. The computer uses the spectral signature to determine which class to place the pixel in.

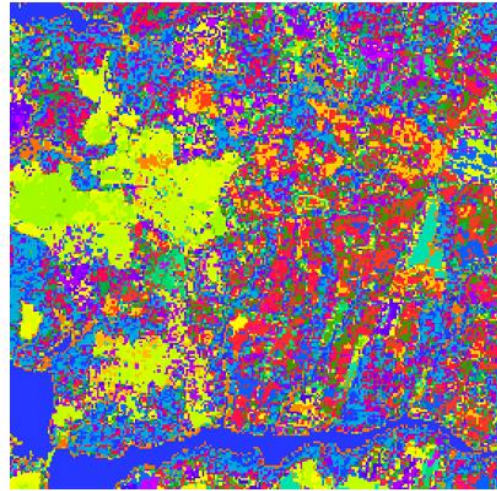
- **Go to** *Customize > Extensions > Make sure the spatial analyst box is checked.*
- **Go to** *ArcToolbox > Multivariate > Iso Cluster Unsupervised Classification.*
- **Place** the Image to be classified in the Input Raster Bands.



- Output of an unsupervised classification is shown below:



20 SPECTRAL CLASSES

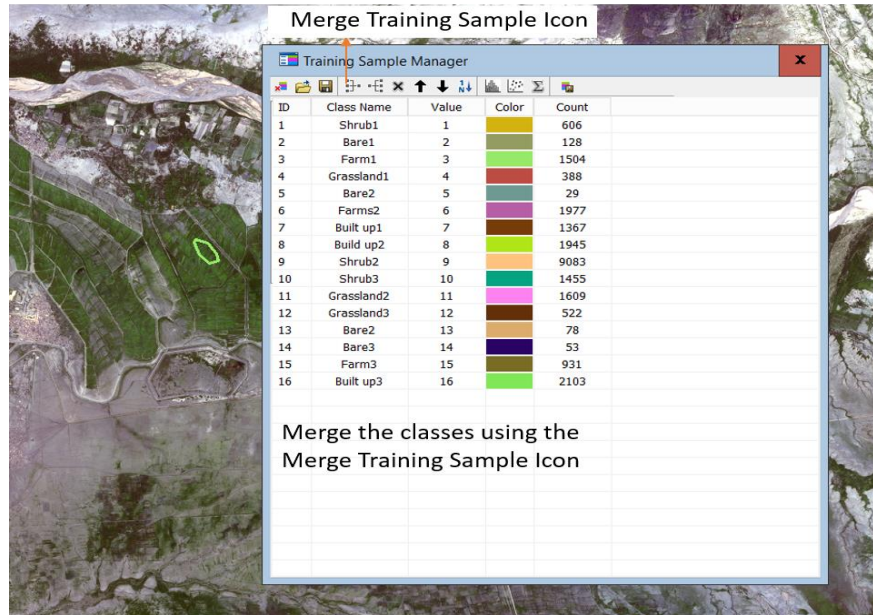


100 SPECTRAL CLASSES

2.4.2 Supervised Classification

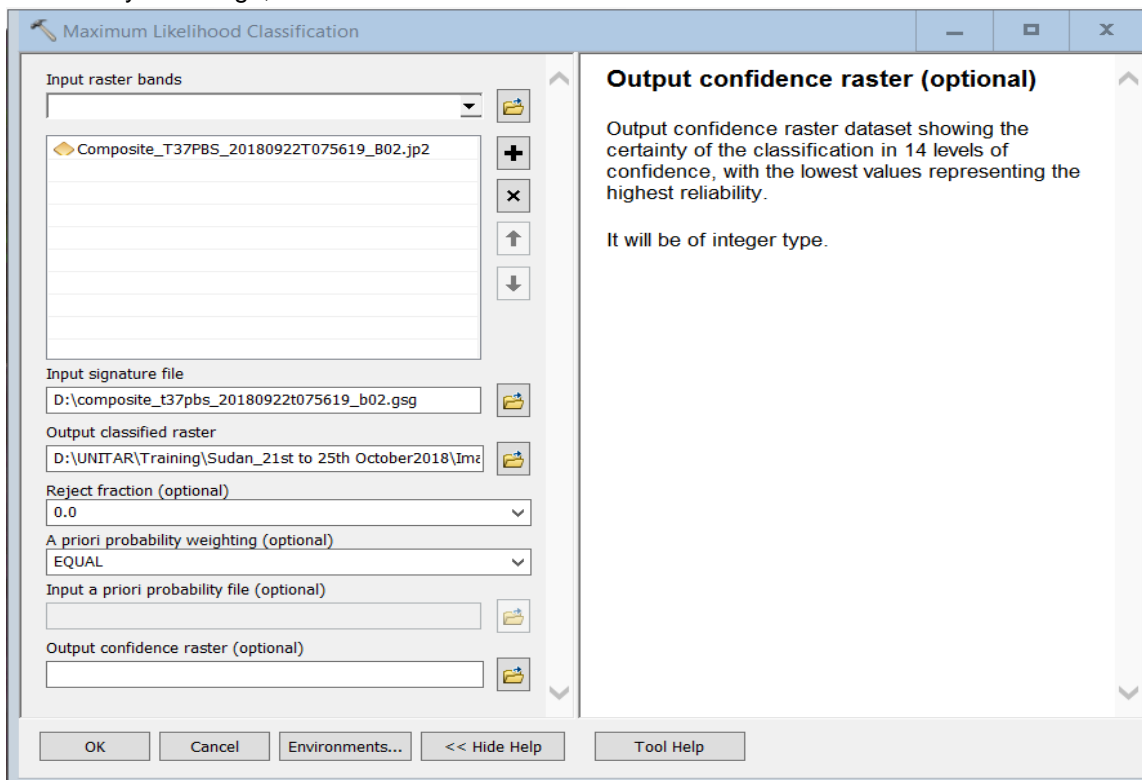
Supervised classification uses the spectral signatures obtained from training samples to classify an image. The image interpreter determines the classes and identifies the training samples for different land cover types. The process involves

- Creating training areas
 - Creating signature file
 - Classifying the image
- **Go to** Customize > Extensions > Make sure the spatial analyst box is checked.
 - On the tool bar, make sure the *Image Classification* is checked.
 - **Create** training areas of the following classes
 - 1) Farms
 - 2) Shrub land
 - 3) Bare
 - 4) Grassland
 - 5) Built up



- Save the training signature as **Training Sites.gsg**

To Classify the Image, Use *Maximum Likelihood* on the classification window



- *Input Raster Bands* -Input the Image you would like to classify and Input the signature file,
- Then **click Ok**. An Image will be displayed with the 5 classes.

Exercise 2.1: Analysis of Elements at Risk

Introduction

In this session, analysis of the elements at risk within the area of interest will be carried out.

Learning Objectives

In this session, the participants will be able to analyse the elements at risk with the area of interest near Khartoum.

- Understand the geographical extent of area of interest near Khartoum.
- Understand the elements at risk database given.
- Quantitative assessment of the exposed elements at risk within area of interest near Khartoum.

Data Input

The input data used in this module is,

Description	Data path	Data Type	File Name
Area of Interest Boundary	X:\Module3\Floods\Exposure	Vector (polygon)	TX_2060811_Khartoum_Analysis_Extent.shp
Road Network	X:\Module3\Floods\Exposure	Vector (polyline)	Roads_Sudan.shp
Settlements	X:\Module3\Floods\Exposure	Vector (point)	Settlements_Sudan.shp
Land use	X:\Module3\Floods\Exposure	Vector (polygon)	Landuse_Landcover.shp
Population (Grid) data	X:\Module3\Floods\Exposure	Raster	Sudan_Population_WP.tif

Output

Output expected in this session is,

- Types of Roads and their length within the Area of Interest
- Land use categories and their area in sq.km within the Area of Interest.
- Number of Settlements within the Area of Interest.
- Number of Population within the Area of Interest.

Understanding the elements at risk

Open ARC GIS software and add all the data given and view each of the data and answer these questions:

Hint: Use Attribute Table tool to answer.

- How many Road types are existing within the Area of Interest, what are they and what is the total length of each road category within the Area of Interest?

- How many settlements exists within the Area of Interest?

- How many land use categories exist within the Area of Interest and what are they and the area of each land use category?

- What is the range of population within the Area of Interest and total population within the Area of Interest?

Exercise 2.2 Selection and Download Sentinel-1 data for a Flood Event g

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 sessions.

- Identify an area of interest (AOI) which was flood affected recently (Sudan or your country)
- 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: Abu Hamed, River Nile State, Sudan was flooded on 29 May 2016.

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.



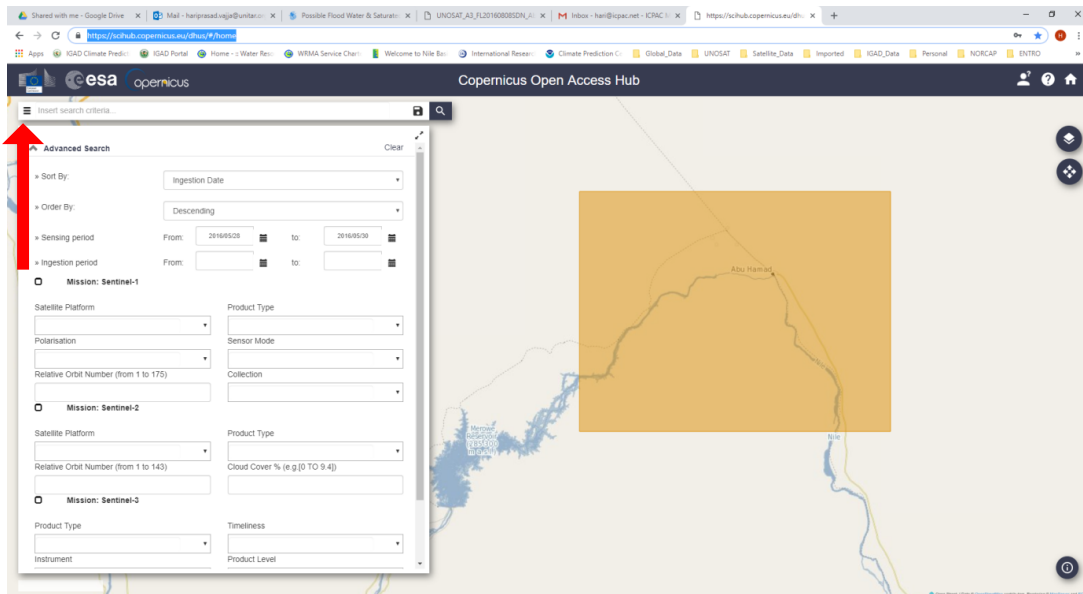
With a few clicks of the mouse, you will gain access to ESA's Sentinel data.

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 'Sudan' 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 the 'Abu Hamed' in North-East Sudan 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?)

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 28 May 2016 to 30 May 2016 (if your AOI is different, please select suitable date)

What is Sensing Period?

Satellite Platform: S1A_*

Product Type: GRD

Sensor Mode: IW

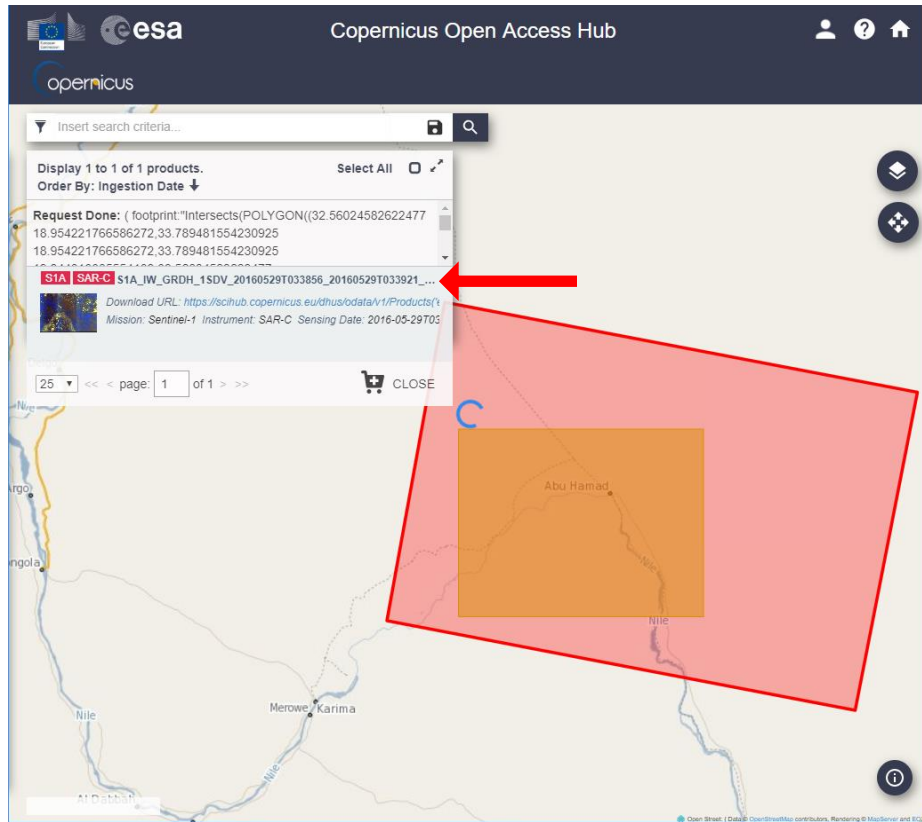
What are these parameters? Explore the Sentinel Product Catalogue at <https://sentinel.esa.int/web/sentinel/missions/sentinel-1/data-products>

Click Search option.

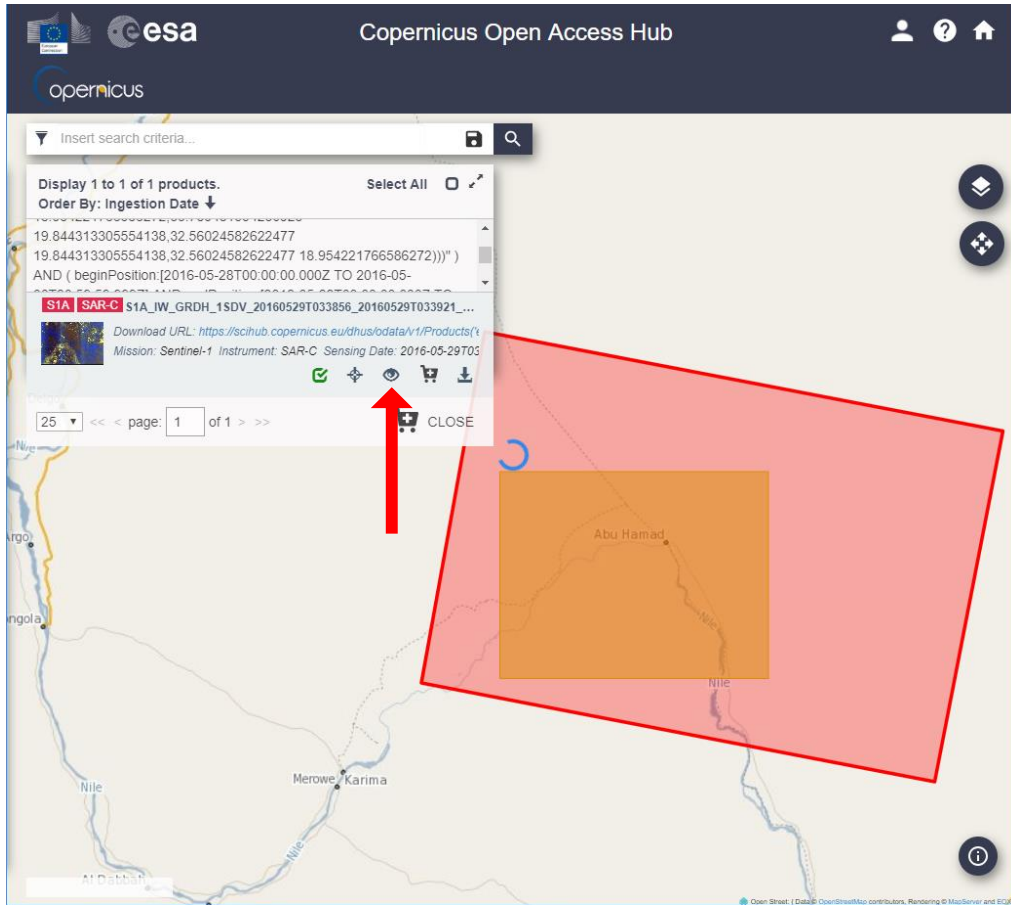
From here your search will yield results for all the Sentinel satellite data available (S1A is Sentinel-1A).

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?



Download SENTINEL-1 SAR Data

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.

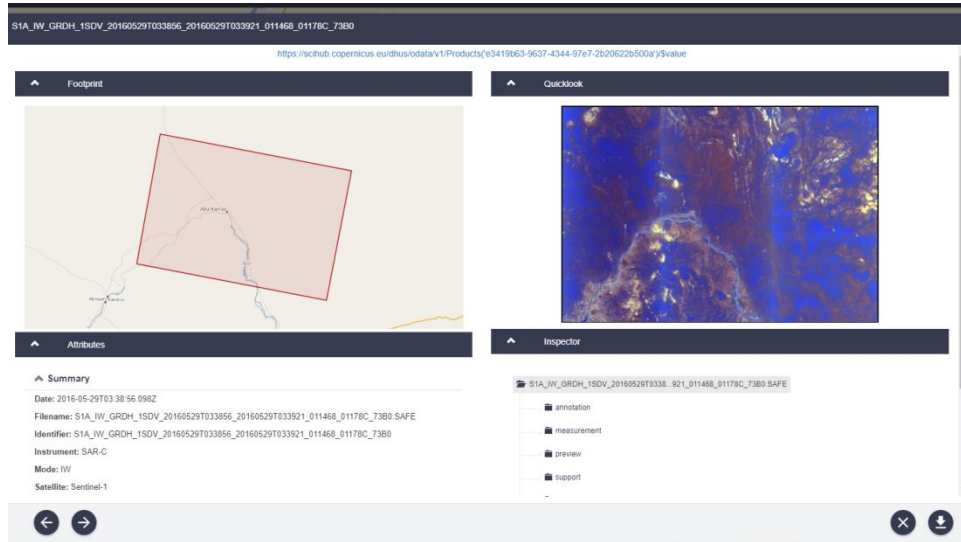
Select the product you want to download. S1A is Sentinel-1A.

Go through the search results and select this Sentinel-1A data (Abu Hmad, North-East of Sudan).

[S1A_IW_GRDH_1SDV_20160529T033856_20160529T033921_011468_01178C_73B0.zip](https://scihub.copernicus.eu/dhus/odata/v1/Products('19.844313305554138,32.56024582622477,18.954221766586272')))

Why this data is selected?

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



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.

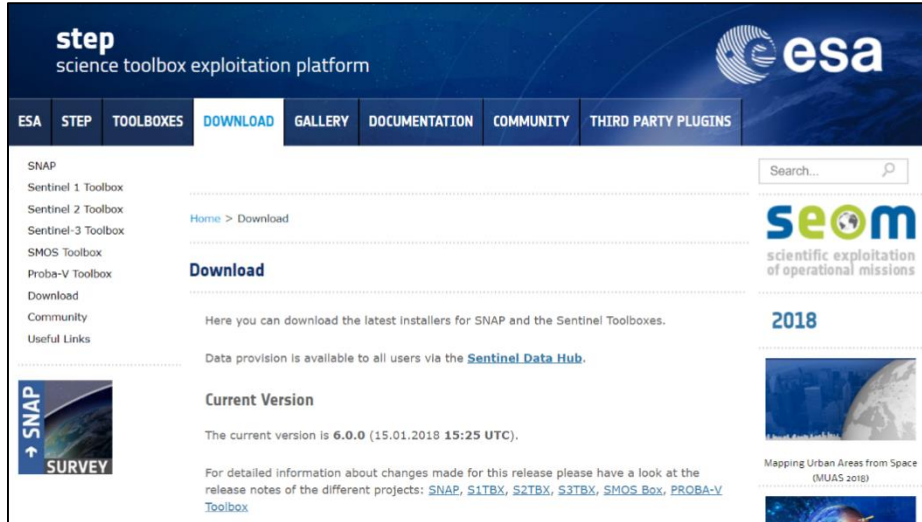
SENTINEL – 1 SAR DATA PRE-PROCESSING

- **Download SENTINEL Toolbox**

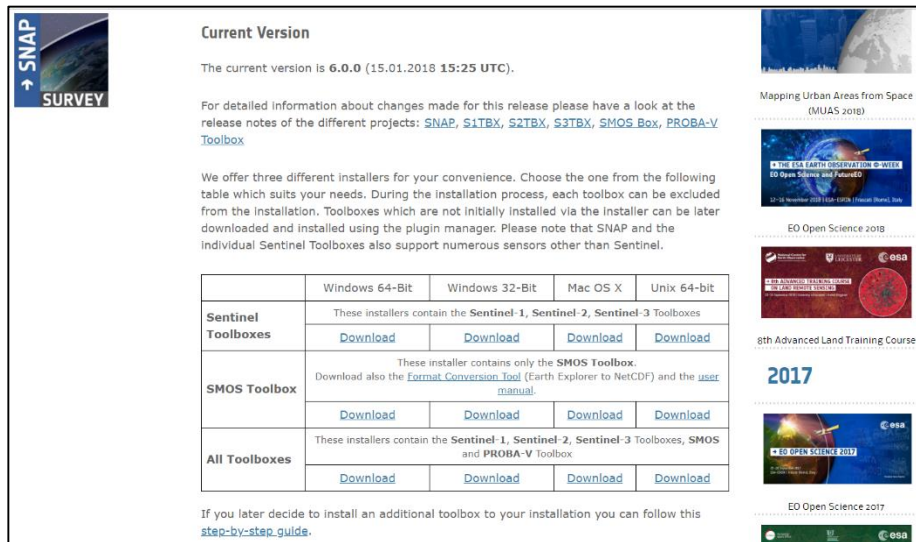
Download and install the latest ESA-SNAP-SENTINEL Toolbox (Open source software from ESA)

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.



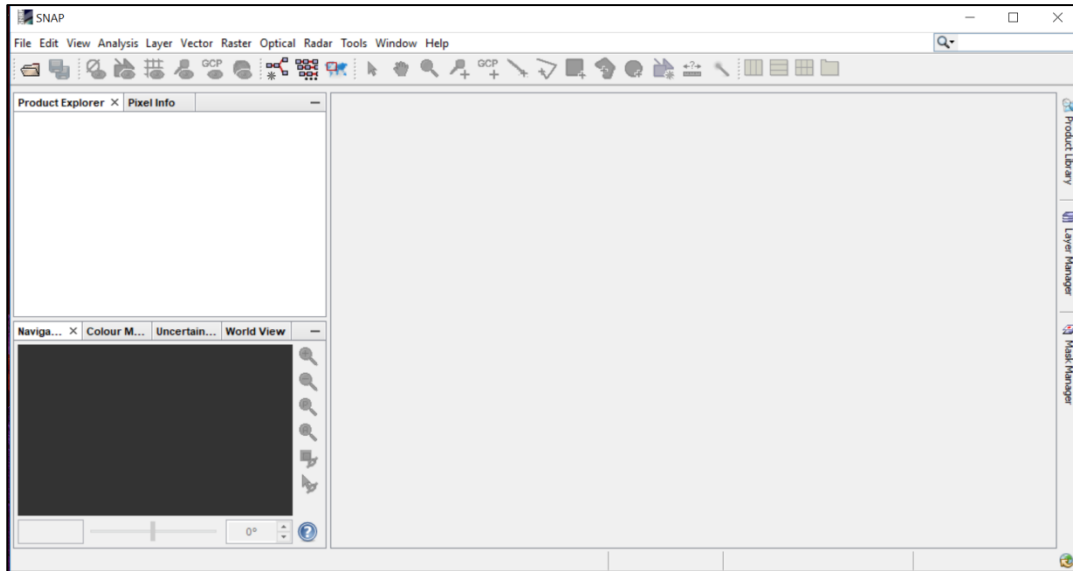
Install the downloaded SNAP software for using the downloaded Sentinel-1A satellite data, downloaded previously.

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 Opensource 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.

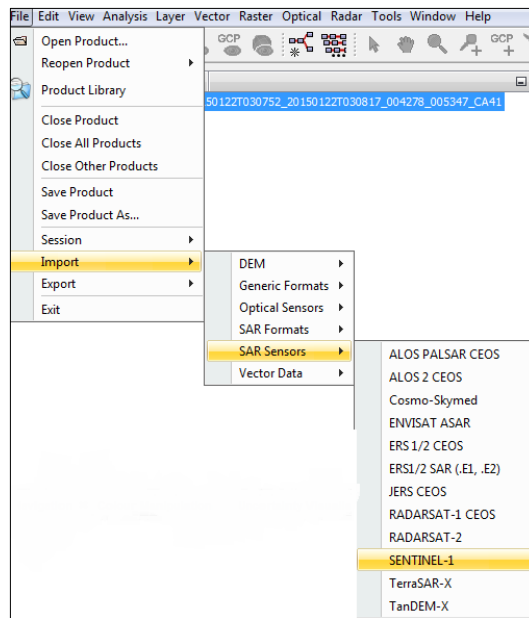
- To **Open** SNAP toolbox, Double Click the SNAP software shortcut on your desktop, which will be as given below.



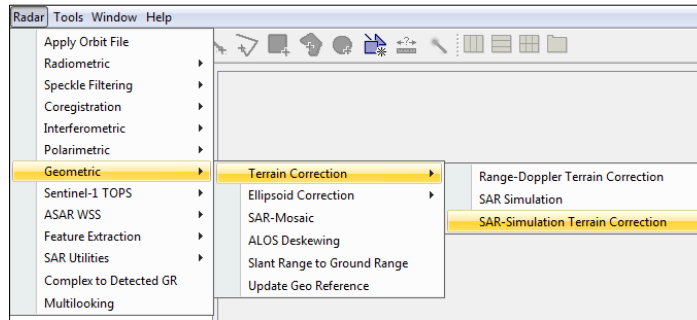
- Import** the downloaded SENTINEL-1A image
“S1A_IW_GRDH_1SDV_20160529T033856_20160529T033921_011468_01178C_73B0.zip”
(select “.safe” file or “.zip”) from *X:\Module_2\Sentinel-1*

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

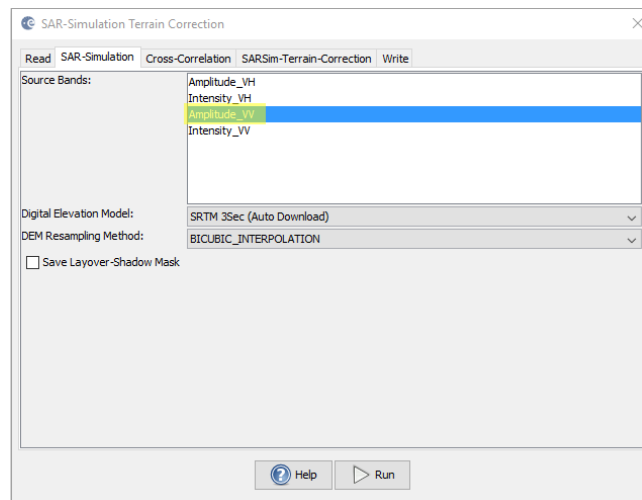
Import the Sentinel-1A data downloaded using File – Import – SAR Sensors – SENTINEL-1 as shown below.



- **Optional** Step: *Radar > Radiometric > Calibrate*
- The most important step after importing the data is to **orthorectify** the image(not optional!)

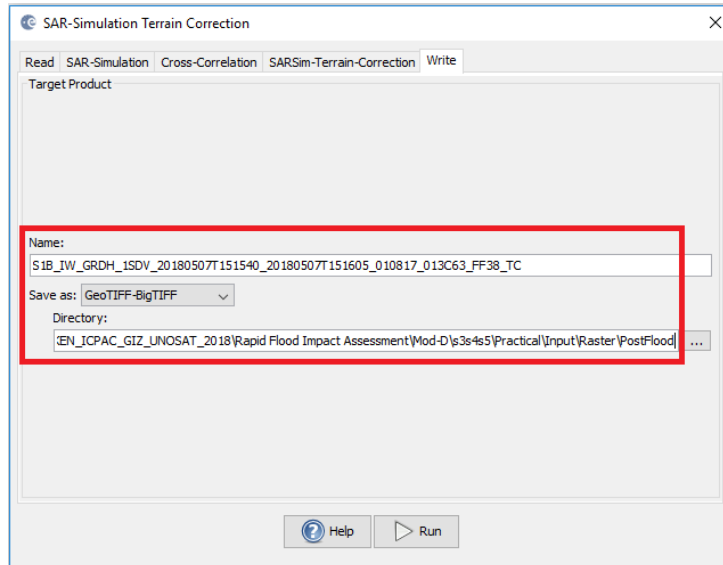


- There are five steps in the *Geometric SAR-Simulation Terrain Correction* – it is highly recommended to do as little modification as possible, to make the process faster:
 - 1-Read: **Choose “Any Format” or “Sentinel-1”** under *Data Format*
 - 2-SAR-Simulation: Select “Amplitude VV”

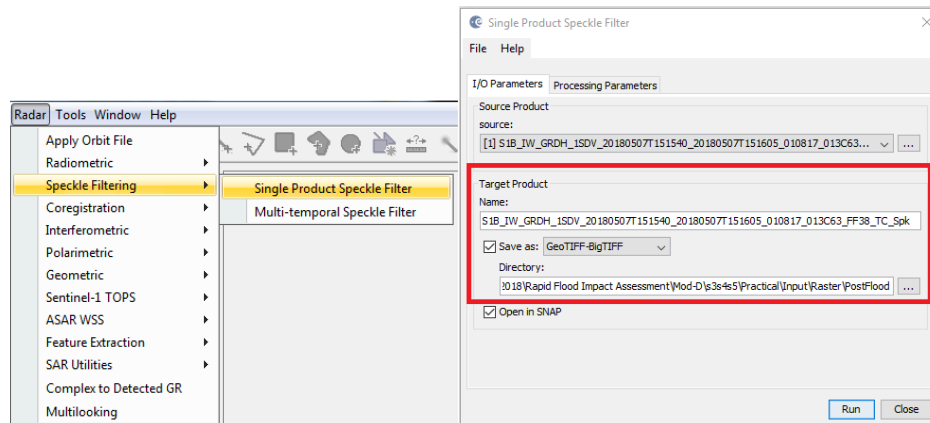


- 3-GCP-Selection: GCPs can be reduced to a desired value if it fails to find enough points (default value is 2000). It is advised to leave it as default
GCPs or the Ground Control Points are defined as the points on the surface of the earth of known location that could be used to geo-reference remotely sensed data
- 4-SARSim-Terrain-Correction: Recommended to leave it as default
- 5-Write. **Give** a proper Name and **Save as: “Geotiff-BigTIFF”** and **navigate** to the output folder and **click Run**
- **Note:** Processing can take quite a while, feel free to go grab your cup of coffee and walk around. However for this exercise the output image (“*Post_20160529.tif*”) is provided at **X:Module_2\Sentinel-1\Input**

It is the processed image obtained after the orthorectification procedure (terrain correction) and the speckle filtering.

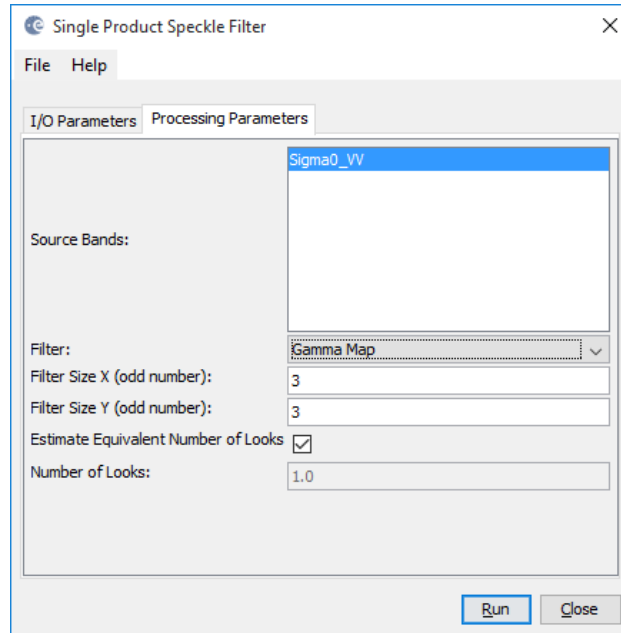


- In most RADAR products, one of the must do corrections is to remove *speckles* (salt and pepper effect). Again, this step will take few minutes but it is highly recommended. **Go to Radar > Speckle Filtering > Single Product Speckle Filter**



- In the *I/O Parameters* tab:
 - Select as *Source* the output image of the *SAR-Simulation Terrain 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* *Sigma0_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 sometime to be completed, as already stated previously, you can find the processed image ("*Post_20160529.tif*") at *X:\Module_2\Sentinel-1\Input*

Opening ArcMap and exploring crisis satellite data

Once the image has been processed, before quantitatively analyzing the data, it is important to do a visual interpretation of the input data available.

- **Open** the existing ArcMap project (workspace) "*Flood_Hazard_Analysis.mxd*" stored on: *X:\Module_2\Sentinel-1\Workspace*

In the ToC, **make sure** that "*Post_20160529.tif*" is turned on.

- For your convenience, a smaller tile is provided for this exercise.
- From the ToC, **right click** on *AOI >Zoom to layer*

What is the coordinate system of the image?

**MODULE 3:
HAZARD, VULNERABILITY, AND RISK ASSESSMENT**

3.1 Introduction to Disaster Risk Management (DRM)

Learning objectives

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

- 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

3.1.1 Basic Concepts and Terminologies

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 = $\frac{\text{Hazard} \times \text{Vulnerability}}{\text{Capacity}}$
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 laptop 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 disaster is a serious disruption on the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources (*UNISDR, 2009*).

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 hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (*UNISDR -2009*).

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 dams a river and then causes flooding. A community may be exposed to multiple hazards when there is simultaneous occurrence of different hazards.

VULNERABILITY

Vulnerability refers to the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. (*UNISDR, 2009*)

Vulnerability is a set of prevailing or consequential conditions that adversely affect people’s ability 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) also 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 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

Capacity refers to the combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals.

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 the concept and practice of reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events (*UNISDR, 2009*).

DISASTER RISK MANAGEMENT (DRM)

Disaster Risk Management is the systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster (*UNISDR, 2009*).

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 in 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.

3.1.2 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

The Disaster Risk Management Cycle takes the form indicated below.



3.1.3 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 need 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, the community of practitioners and older persons in the design and implementation of policies, plans and standards.

3.1.3.1 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.

3.1.3.2 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:\DATA\Module 3\DRM reading materials folder.

3.1.3.3 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.

Please discuss and share the status and processes in developing a national strategy for DRM in your respective countries.



STEP (7)

3.2 Hazard, Vulnerability and Risk Assessment

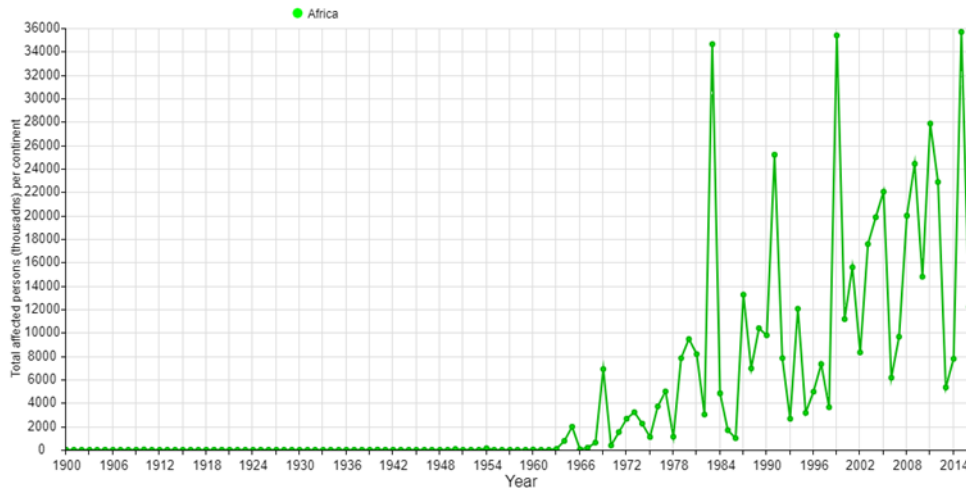
3.2.1 Introduction to Hazard Assessment

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 the greater Horn of Africa region and Sudan namely drought and floods.

3.2.2 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 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.

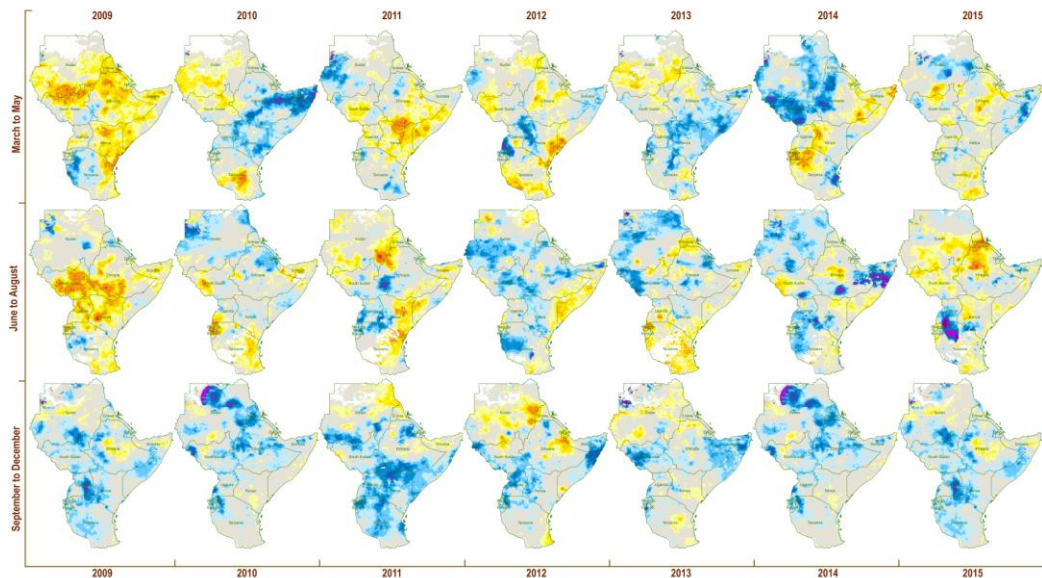
Meteorological Drought: Monitoring of the meteorological drought can be done in different ways and one of the most common ways is the Standard Precipitation Index (SPI). McKee, Doesken and Kleist (1993) developed the Standardized Precipitation Index (SPI) for the purpose of defining and monitoring drought. 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;

Table 1. SPI values

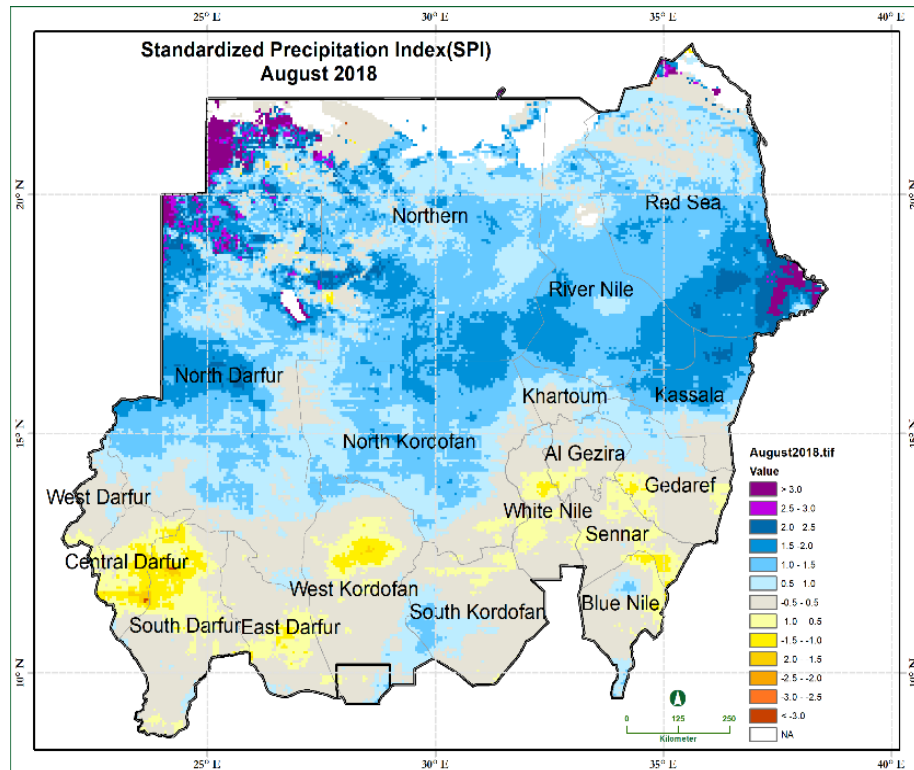
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

A regionally blended (observed rainfall with Chirp 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 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 northern sectors. JJAS is the main rainfall season for countries in the northern sector. A sample map of SPI at seasonal scale of greater horn of Africa is given below;



A sample SPI for Sudan in August 2018 is given below.

NOTE: The weakness of SPI is over estimation in Dry and Desert areas.



In drought hazard assessment we are going to use two indicators of drought severity, namely the rainfall anomaly as calculated through SPI and the Vegetation Anomaly as VCI and VHI.

3.2.2.1 SPI based drought hazard assessment

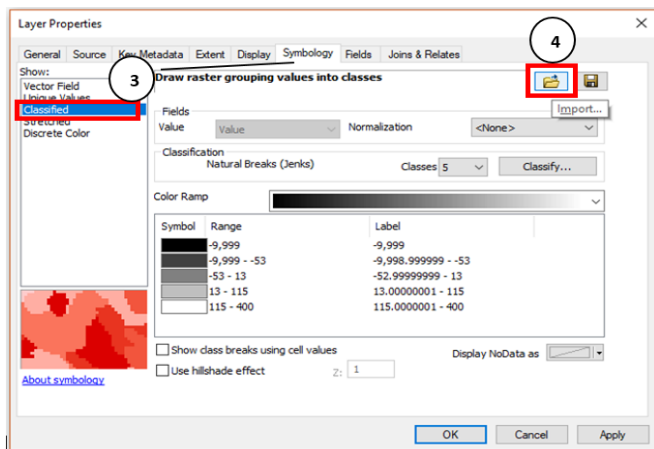
Standardized Precipitation Index (SPI) can be calculated as a function of the difference between current rainfall condition and Long Term Average (LTA) and normalized by standard deviation of the rainfall for the years under consideration. World Meteorological Organization (WMO) recommends to use data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



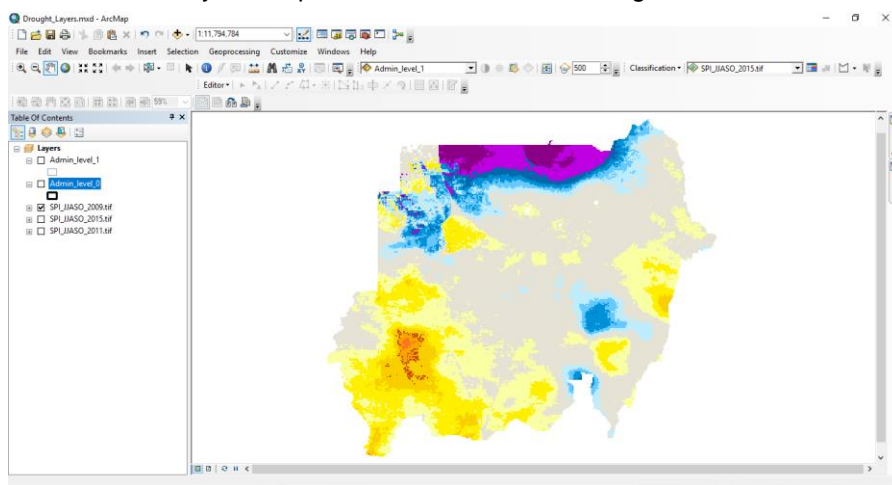
STEPS (8): Working with SPI

For this exercise SPI data layers for Sudan are generated please open these layers by following the steps;

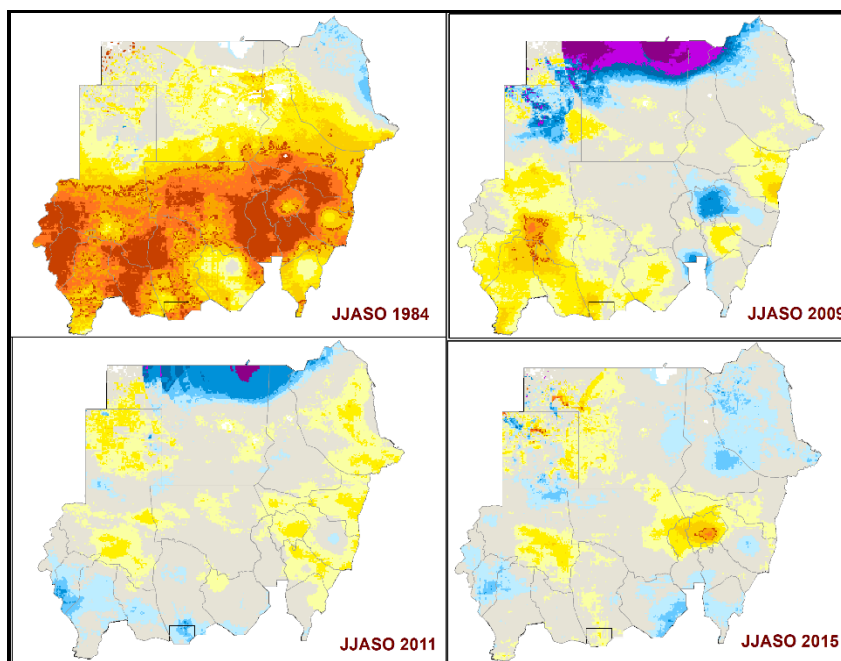
- 1) Open ArcMap and **add** the following layers from **X:\Module3\Drought** folder
 - **SPI_JJASO_2009.tif**
 - **SPI_JJASO_2011.tif**
 - **SPI_JJASO_2015.tif**
- 2) The black and white images has got values and the symbology can be set manually or import from the existing *.lyr file. For this exercise we import a symbology.
- 3) Double click on **SPI_JJASO_2009.tif** and go to **symbology** and under show click **classified**.
- 4) Now click on **import** and go to **X:\Module3\Drought** folder and select **SPI_symbology.lyr** file



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



6) Follow similar steps to change the symbology for 1984, 2011 and 2015 SPI data layers.

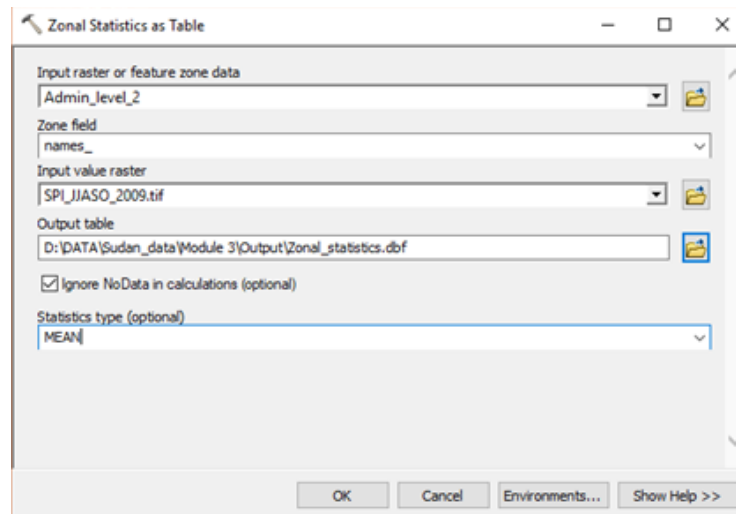




STEPS (9):

Calculate Zonal Statistics to produce seasonal meteorological drought hazard map for districts

1. Add the **Sudan_Admin2** layer from **X:\Module1\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 **Sudan_Admin2** as **input raster or feature zone data** and **name_** as **zone field**.
4. Select **SPI_JJASO_2009.tif** file as **input value raster** and save the output table under **X:\Module3\Output** folder by the name **Zonal_Statistics.dbf**.
5. Select **MEAN** as **statistics type** and **click Ok**

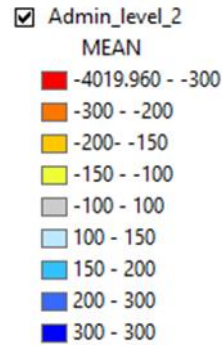
Once the processing is completed you should be able to see table added to your table of content. If you can open the table and see the values you can see which district has the lowest mean SPI value.

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

Now we are going to join two tables **Sudan_Admin2** and Zonal statistics using the common field "names_"

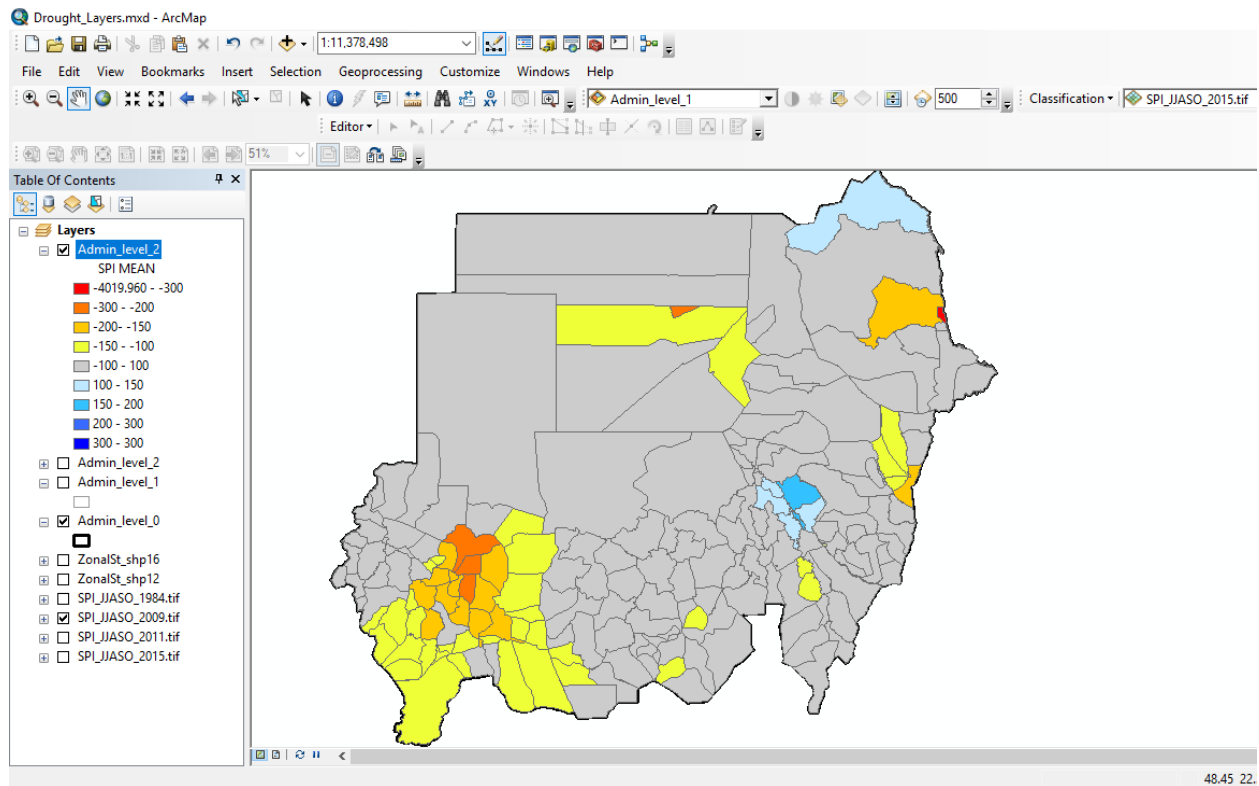
6. **Right click** on **Sudan_Admin2** layer and click on **Join and relate >> Join**
7. Select **names_** in the first drop down field and **Zonal statistics table** in the second and **names_** under the third dropdown
8. Click **Ok** and you can open attribute table of **Sudan_Admin2** and you find 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 table merge you need to right click on **Sudan_Admin2** and export data. Save it under **X:\Module3\Output** with the file name **Drought_hazard_severity.shp**. Your new map will be added automatically to the table of content.
10. Let's produce a drought hazard severity map based on the mean SPI with the

following range.



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 10.
13. Choose a color (blue to red) and Click **Ok**

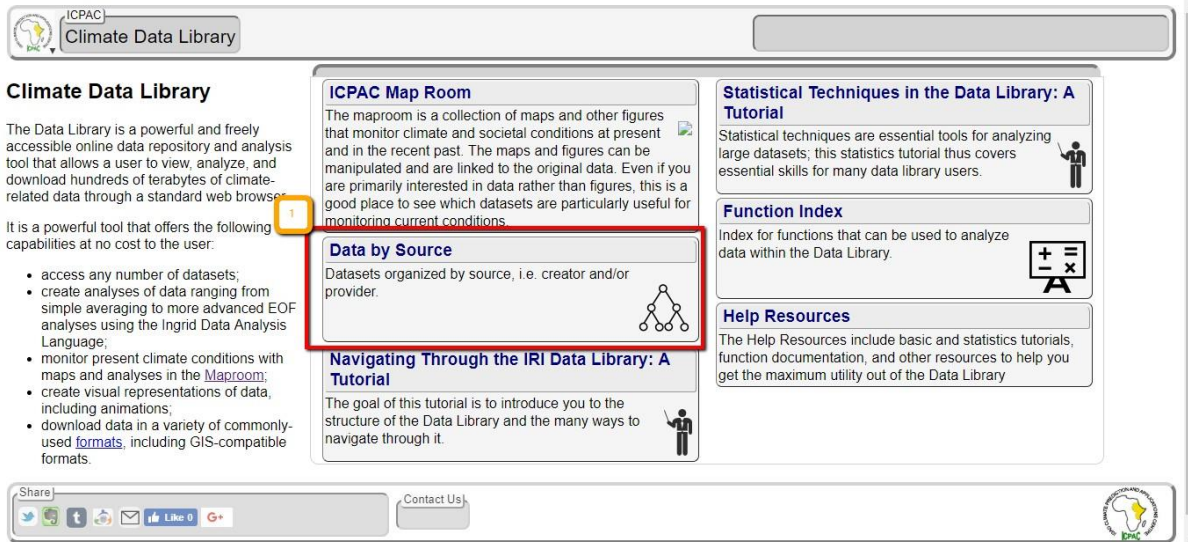
Now you should get a map something similar to this.



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.

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

ENACTS	Enhancing National Climate Service initiative.	2
Features	Features[Political]	
ICPAC	ICPAC[Projections CHIRPS-BLENDED Forecasts CHIRP-BLENDED]	
Indices	Indices[nino]	
KADI AN	KADI AN[EYTEMDED 1]	

Datasets and Variables

CHIRP-BLENDED	ICPAC CHIRP-BLENDED [seasonal dekadal monthly]	3
CHIRPS-BLENDED	ICPAC CHIRPS-BLENDED [seasonal dekadal monthly]	
Forecasts	ICPAC Forecasts[WRF CPT]	
Projections	ICPAC Projections[RCA-MPI]	

Datasets and Variables

dekadal	ICPAC CHIRPS-BLENDED dekadal[rainfall]	4
monthly	ICPAC CHIRPS-BLENDED monthly[rainfall WASP]	
seasonal	ICPAC CHIRPS-BLENDED seasonal[rainfall]	

Datasets and Variables

5

rainfall ICPAC CHIRPS-BLENDED monthly rainfall[**spi precipitation**]

WASP ICPAC CHIRPS-BLENDED monthly WASP[12-month 3-month 1-month]

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

Data Library: ICPAC CHIRPS-BLENDED monthly rainfall spi
 T: Jan 1981 - Aug 2018
 X: 21.83E - 51.48E
 Y: 11.8S - 23.15N

6

Description Views Data Filters **Data Selection** Data Files Data Tables Expert Mode

- **Change Time, Longitude and Latitude** as shown below
- **Then Restrict Ranges > Stop Selecting**

Data Selection

You can interactively pick out the data you would like with the [Data Viewer](#).

You can reduce the amount of data by restricting the range of the grids.

The current settings for the grids are

- grid: /T (months since 1960-01-01) ordered (Jan 1981) to (Aug 2018) by 1.0 N= 452 pts :grid
- grid: /X (degree_east) ordered (21.855E) to (51.455E) by 0.05 N= 593 pts :grid
- grid: /Y (degree_north) ordered (11.775S) to (23.125N) by 0.05 N= 699 pts :grid

If this is what you want, choose **Stop Selecting**

3

Setting Ranges

If you want to restrict the range along a grid, choose here.

1

name	range
T Time	Jun 2009 to Oct 2009
X Longitude	21.5E to 39.0E
Y Latitude	06.0N to 24.0N

Restrict Ranges

2

- **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.

Data Library
ICPAC CHIRPS-BLENDED monthly rainfall spi Jun-Oct 2009 21.83E - 39.03E 5.999999N - 23.15N

Description Views Data Filters Data Selection **Data Files** Data Tables Expert Mode

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.	
2-Dimensional Table	A 2-dimensional ascii file that includes an ArcInfo Header.
IDA Image	File(s) in the Image Display and Analysis format. Typically used with WinDisp.
LAN Image	File(s) in the ERDAS LAN format. Typically used with various GIS programs, including ArcView and Mapper.
GeoTIFF Image	File in GeoTIFF format. Typically used with various GIS programs, including ArcView and ENVI.

Data Library

Finding Data
Tutorial
Questions and Answers
Function Documentation

ICPAC CHIRPS-BLENDED monthly rainfall spi dataset

help

GeoTIFF Image Format Downloads

ICPAC CHIRPS-BLENDED monthly rainfall spi

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

23.15N

Latitude 20°N 15°N 10°N

Longitude 25°E 30°E 35°E

5.999999N Aug 2009 21.83E 39.03E

false color image reload

200908 GeoTiff for GIS

3.2.2.2 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-

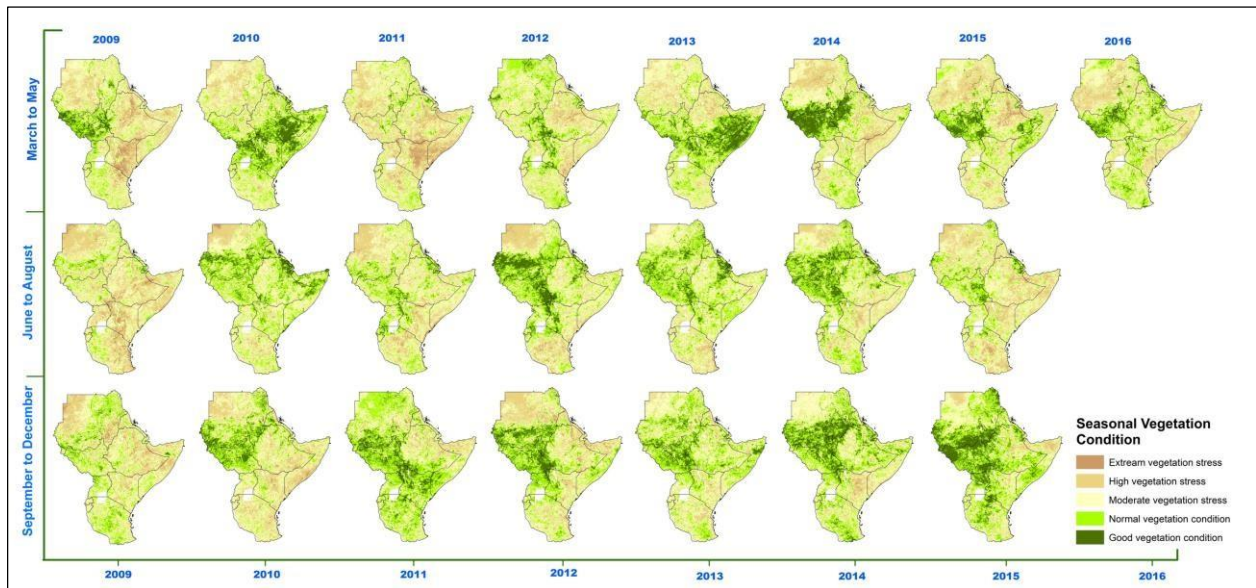
11.3-um thermal channel. Assessment of temperature conditions permits one to identify subtle changes in vegetation health because the effect of drought is more dramatic if a shortage of moisture is accompanied by excessive temperatures. This method was validated in all major agricultural countries around 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 VH values below 40 are used for identifying vegetation stress which is an indirect drought indicator. The VH 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 is to the minimum NDVI calculated from the long-term record.

$$VCI_j = \frac{(NDVI_j - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} * 100$$

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 of the values and thresholds

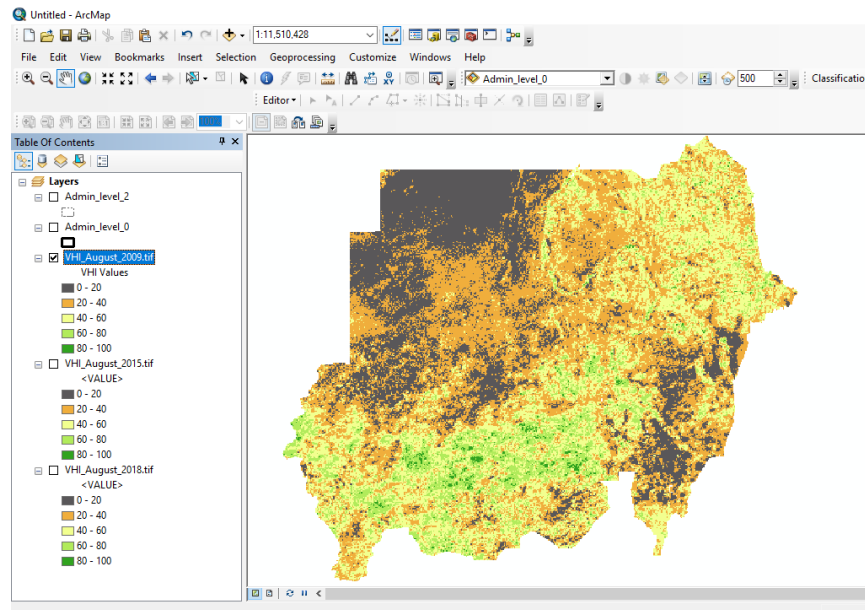


STEPS (10):

Classify VHI values to standard classes

- Open ArcMap and add the following VHI layers from **X:\Module3\Drought\VHI** folder
 - VHI_August_2009.tif**
 - VHI_August_2012.tif**
 - VHI_August_2015.tif**
- Now classify the layers. Right click on the **VHI_August_2009.tif** layer and go to symbology. Under **show** click on classified and set the number of classes to **5** and click on **classify** to set upper limits of the classes.
- Set the class interval 20,40,60,80,100 and click **Ok**
- Now choose the color range from the color ramp and click **Ok**.

Your map looks something like this.



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 the croplands and rangelands).



Exercise 3.1

Produce the agricultural drought map for August 2015 for all the districts of Sudan and identify top ten districts under severe vegetation stress conditions during this month.

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 to use 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/

- **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

3.2.3 Drought, vulnerability and risk assessment

Elements at Risk

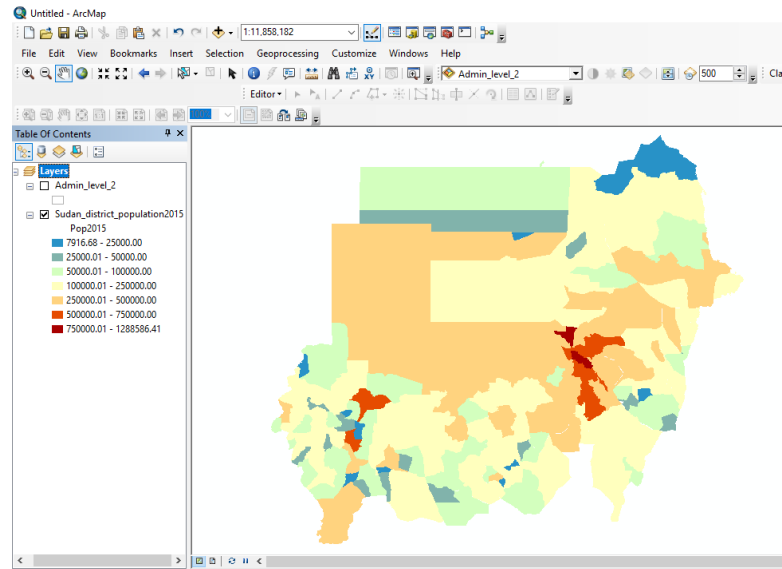
One of the most important aspect of vulnerability assessment is to identify the elements that are at risk of an impending disaster. Depending on the nature of the hazard we can list a number of elements that can be at risk and in this case we are working on drought hazard. Let's consider human and livestock 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.



STEPS (11):

Human Population Counts from Worldpop Data Layer (100 meter resolution)

1. Load the **Sudan_district_population2015** vector layer from **X:\Module1\Population** folder
2. Double click on **Sudan_district_population2015** and go to **symbology >> quantities** and import a **pop_symbology** from **X:\Module1\Population** folder
3. Now your district population map should look something like this



1. Now load the ***Drought_hazard_severity.shp*** layer you produced **earlier** under **Step 10**
2. You have hazard and population layers. Now in order to identify population vulnerable to the drought hazard based on August 2015 SPI values you need to blend these two layers.
3. Right click on **Sudan_district_population2015** layer and **Join and Relate >> Join**
4. Set **names_** as common field and **drought_hazard_severity** as a table to join with.
5. Click Ok and now open the attribute table of **Sudan_district_population2015** and **right click** on the field **MEAN** and **Sort Ascending** and **select all records with SPI value < -100**
6. Now go to the **Pop2015** field and right click and click on **statistics** to see the total population of districts with SPI value at less than – 100. (Total population 5,148,873)



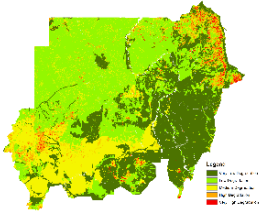
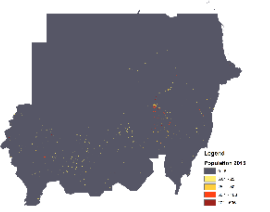

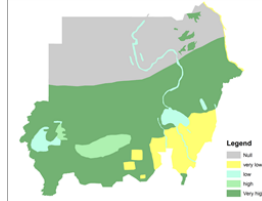
Exercise 3.2

- 1) What is the total population under drought condition at less than -150?
- 2) For an emergency response planning there is a need to identify districts that are “Very Dry” and “Extremely Dry” for this season based on SPI grades. How many people are in need of humanitarian assistance assuming that 60% of the population are vulnerable in each of the districts? Hint: Select target SPI grades and calculate the total population.

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, environmental, cultural...etc. 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, inadequate institutional and economic capabilities.

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
ENVIRONMENTAL	Land degradation <i>(data source: MESA)</i>	High, Medium, Low	
PHYSICAL	Population Density <i>(data source: Worldpop)</i>	High, moderate, low	
	Access to Roads <i>(data source: Roads/ICPAC)</i>	<ul style="list-style-type: none"> - very poor (>25km) - Poor Access(20-25km > 4/5hrs) - Medium Access(15-20km3/4hrs), - Good Access(120-15km-2hrs) - Very Good Access (<10km) 1 ½ hrs 	
ECONOMIC	Livelihoods <i>(data source: FEWSNET)</i>	Very highly, High low Very low Null	
	Level of Poverty	Very high (>50) High (40-50%), Medium (20-40%) Low (<20%)	

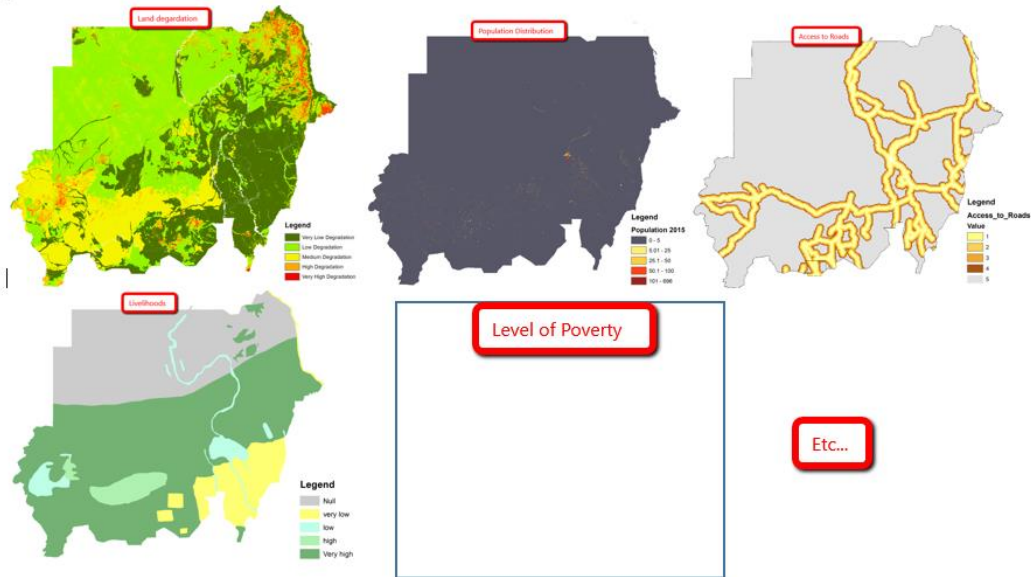
You can combine all of these layers to produce a vulnerability map that shows a combined effects of factors across the country.



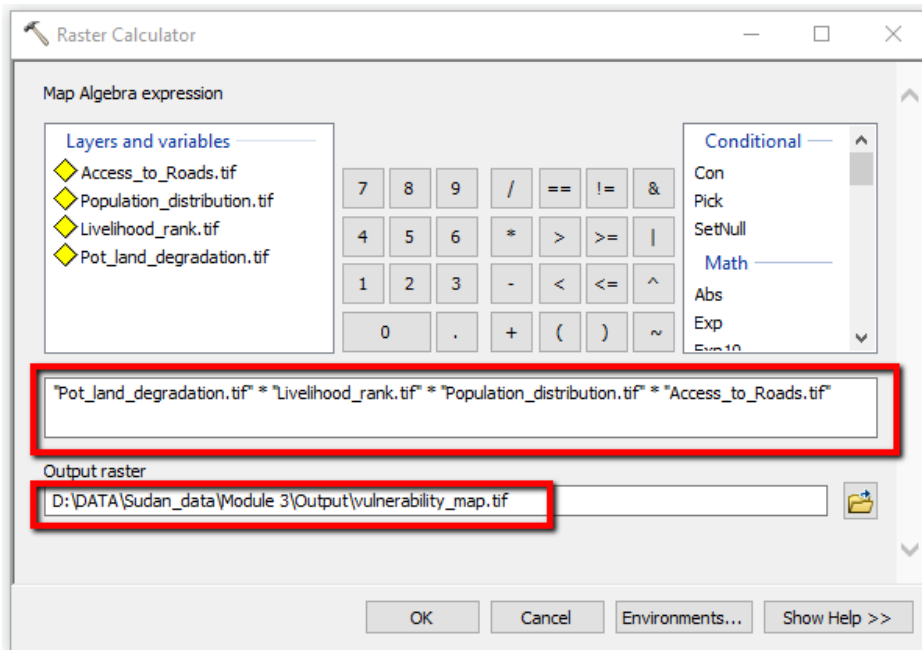
STEPS (12):

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 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.

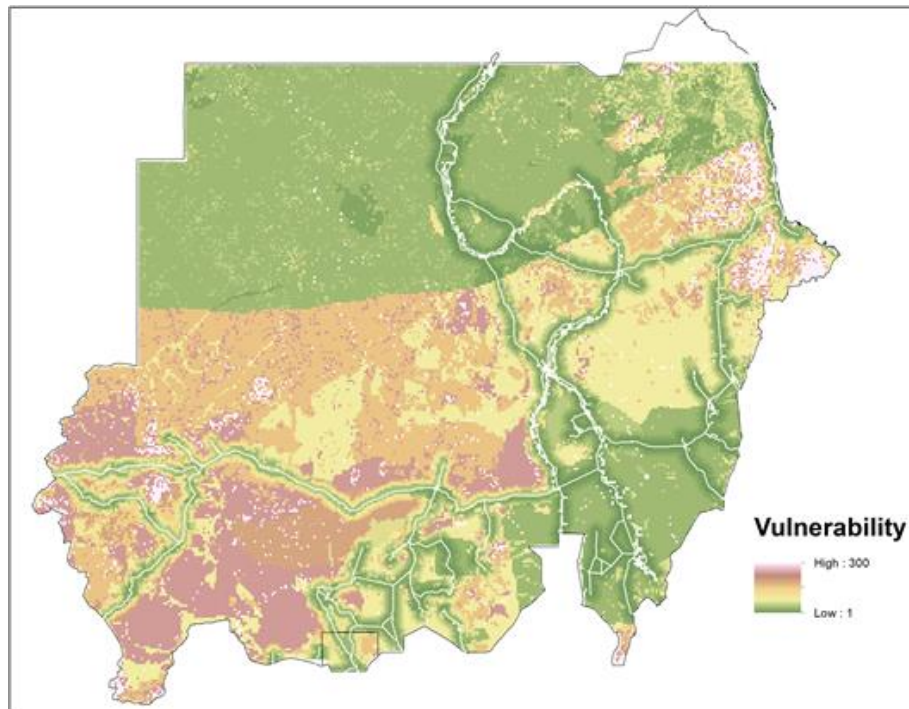


1. Load the following five layers from `X:\Module3\Population\Vulnerability` folder
 - **Pot_land_degradation.tif**
 - **Livelihood_rank.tif**
 - **Population_distribution.tif**
 - **Access to Roads.tif**
2. Go to Windows >> Search >> raster calculator. Open raster calculator
3. Add each layer and use multiplication (*) operator to combine all values from all the layers.



4. Name the output raster as **vulnerability_map.tif** and save it under `X:\Module3\Output` folder and click **Ok**
5. 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 precaution for preparedness planning? What are the strength and weaknesses of this map?.

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



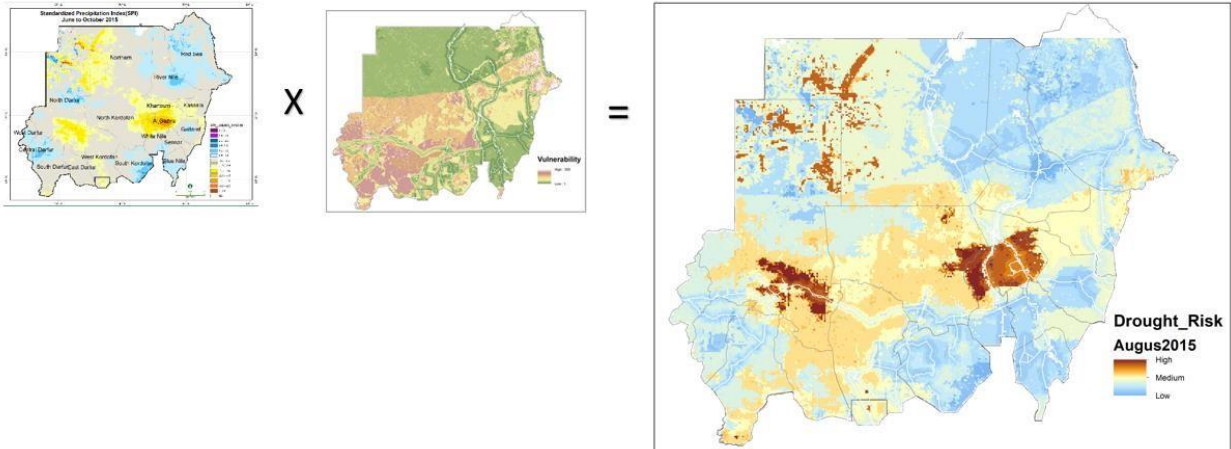
STEPS (13):

How to Produce a Risk Map (Example)

3.2.3.1.1 Risk is a factor of hazard exposure and vulnerability. You have both layers

1. Open the hazard map and vulnerability map from **X:\Module3\Risk** folder
2. As you can notice the two layers are standardized and classified in to four classes. Now go to **Windows >> Search** for **Raster calculator** and open it
3. In the **Raster calculator** double click on **hazard** 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 important determining factor (3/4th) compared to the vulnerability. This is to say where there is no hazard vulnerability alone can't produce a risk.
4. Set the output name to **Drought Risk.tif** and save it under **X:\Module3\Outputs** folder and click **Ok** to run the operation
5. Now you can open the drought risk layer and classify it in to three natural break classes for

example to show low, medium and high risk areas for the August 2015.



Which districts are at high drought disaster risk for the given month?

3.2.4 Flood Hazard Assessment

Learning Objectives:

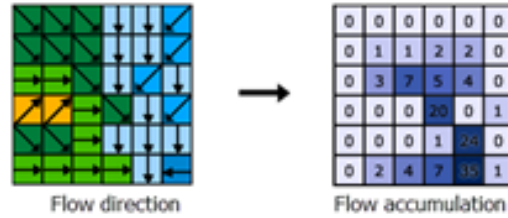
- Causes of Floods?
- What is a Flood Hazard?
- Flood Hazard Assessment Methods
 - Use of Historical data (the past flood approach)
 - Hydrological and hydraulic approach (flood modelling)
 - Temporal Satellite Data Analysis
- Understand Flash Flood hazard assessment using Flash Flood Potential Index (FFPI).
- Understand Riverine Flood hazard assessment using GIS Flood Tool (GFT)
- Understand the advantages and limitations of various flood hazard assessment methods

3.3 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.

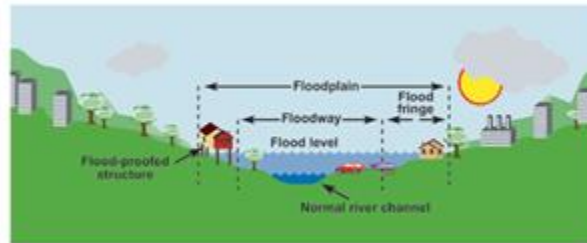
Flow Accumation tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each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

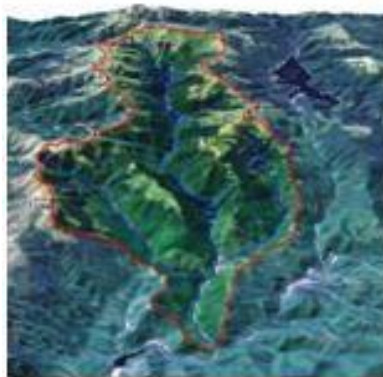
Floodplain is the land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood event.

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.

An example of flood frequency is shown in box below.

Flood frequency calculations based on the annual maximum flood series

This method is widely used for determining the probability and return period for floods. Ideally there should be records for more than 20 years for it to be more representative.

Data Required:

Peak Flood discharge (Q) every year for a particular gauging station Date and time peak discharge occurred.

Rank the Data set with the largest discharge (Q) volume ranked as 1, second largest as 2, etc.

Q	M (rank)
21	1
19	2
14	3
14	4
13	5
9	6
9	7
8	8

Compute the recurrence interval (or return period) of each flood using the formula:

$$Tr = (N+1) / M$$

M = rank; N = total number of floods; The units of Tr are years.

When Q = 19m /sec, M = 2, N = 8

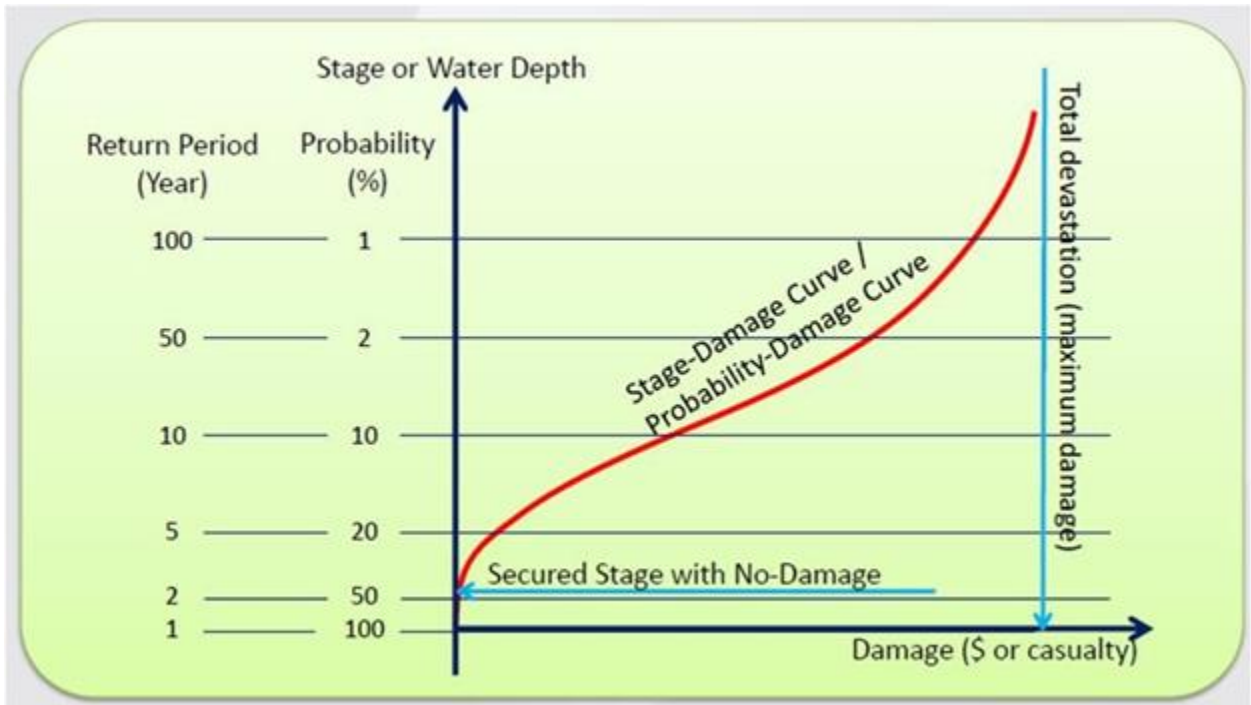
$$Tr = (8+1) / 2 = 9 / 2 = 4.5 \text{ years}$$

To determine the probability use the formula: $P = 1 / Tr$

Probability = $1/4.5 = 0.22$ probability (22%) for any year that a flood of that size will be equalled or exceeded.

Note: The probability information (0.22 or 22%) is most useful as it easier for the public to understand. Using the recurrence interval (4.5 years) may confuse people and lead them to believe that the flood will only happen at the given intervals.

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.

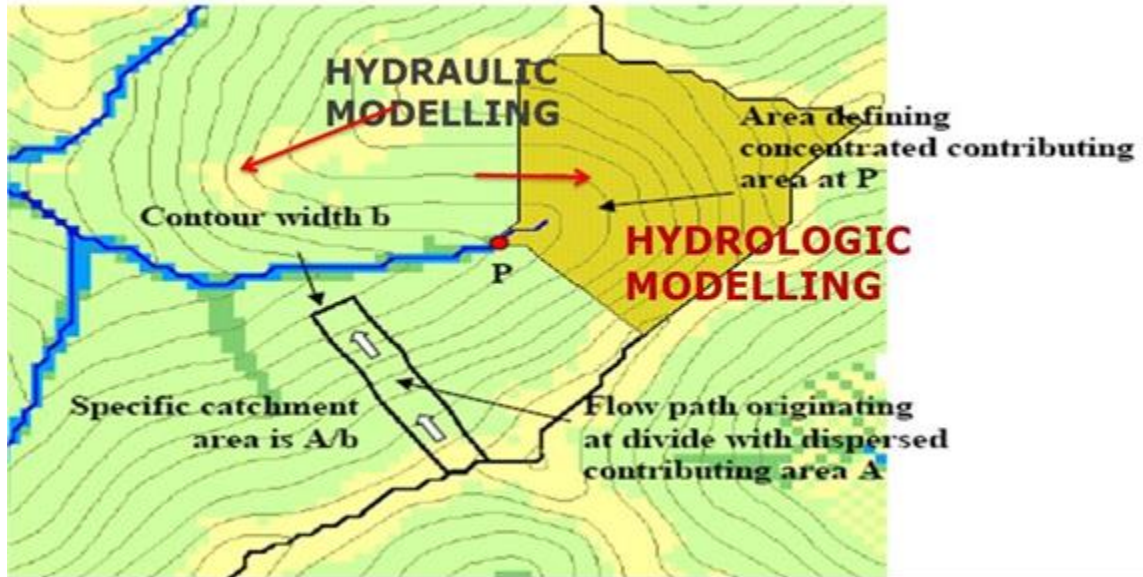
Table 3.7: Classification of Probability

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.



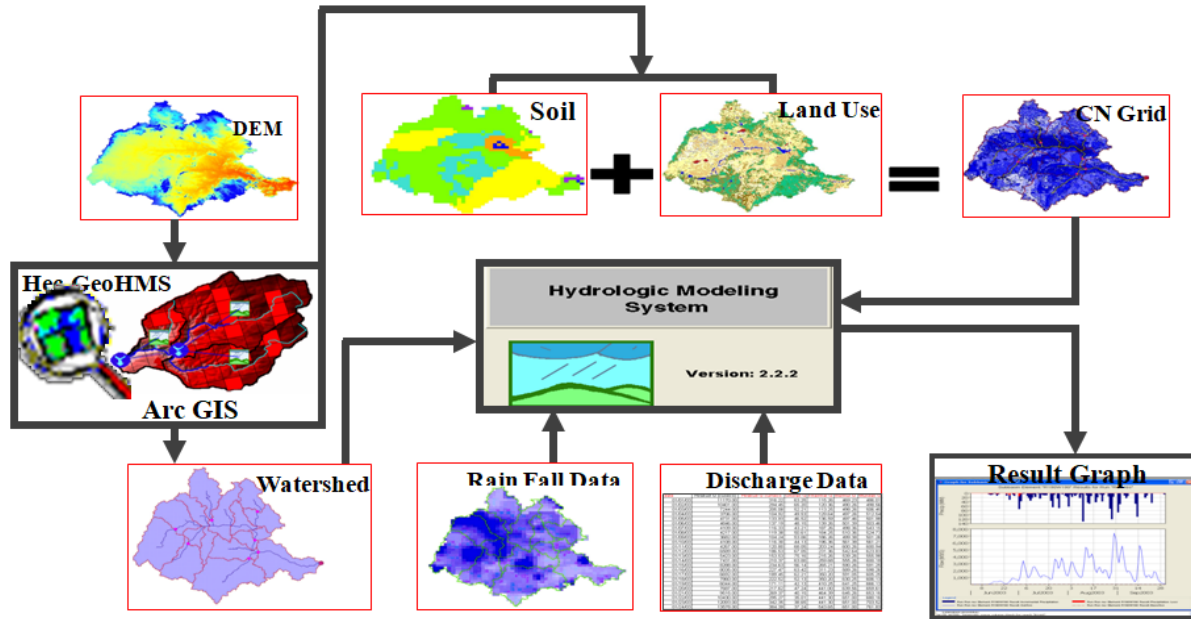
Hydrologic and Hydraulic Modelling

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

Model	Web Link	Model Description
HEC-HMS	//www.hec.usace.army.mil/software/hec-hms/	Hydrologic model which can be used to generate flood hydrograph at any selected location in the river system
HEC-RAS	//www.hec.usace.army.mil/software/hec-ras/	HEC-RAS Version 5.0 has the ability to perform one-dimensional (1D) and two-dimensional (2D) hydrodynamic routing within the unsteady flow.
GIS FLOOD TOOL (GFT)	Provided to you in this course	A software tool for rapid flood inundation mapping

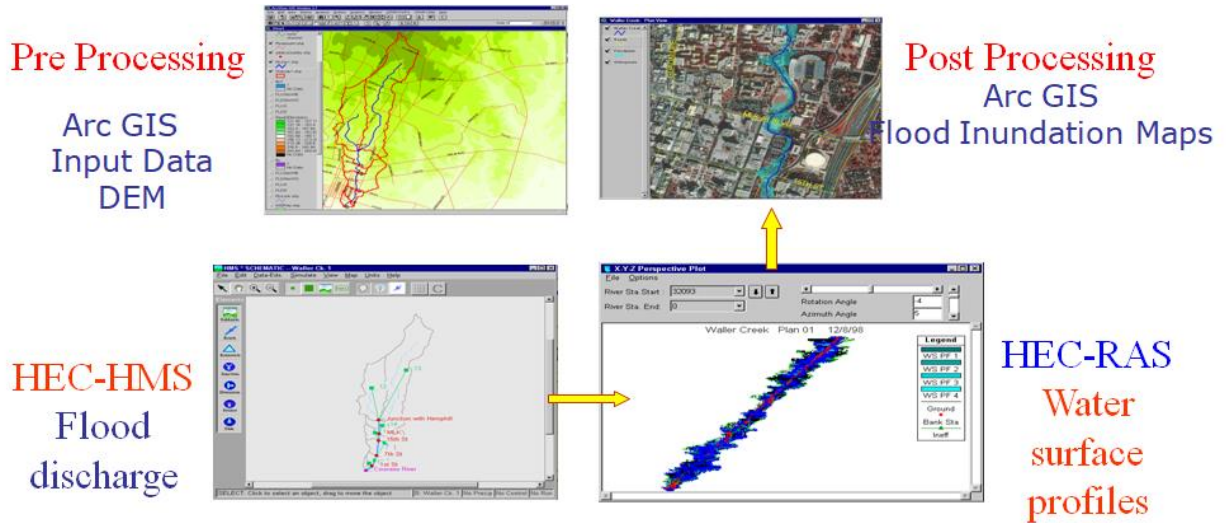
Note: There are many more models are available. However more easily usable models are given above.

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.

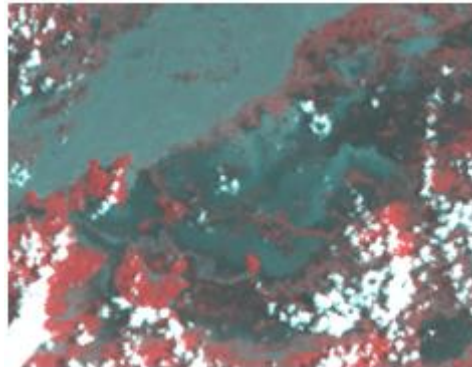


Components of Hydraulic Model

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.

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.

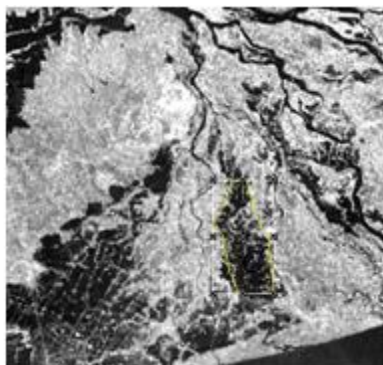


Flood area represented in optical satellite data

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, back scatter (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.



Exercise 3.3: Flash Flood Hazard Assessment using Flash Flood Potential Index (FFPI)

What is Flash Flood Potential Index (FFPI)?

Flash flooding is the top weather-related killer, responsible for severe damages including causality of people in many countries. Although precipitation forecasting and understanding of flash flood causes have improved in recent years, there are still many unknown factors that play into flash flooding. Despite having accurate and timely rainfall reports, some river basins simply do not respond to rainfall as meteorologists might expect. The Flash Flood Potential Index (FFPI) was developed (Smith, 2003) in order to gain insight into these “problem basins”, giving meteorologists insight into the intrinsic properties of a river basin and the potential for swift and copious rainfall runoff. Thus, the FFPI can be added to the situational awareness tools, which can be used to help assess flash flood risk.

The concept of FFPI is fairly simple and the goal is to quantitatively describe a given sub-basin’s risk of flash flooding based on the process involved acquiring or developing raster (gridded) datasets that represent the type of physiographic characteristics i.e. **slope, land cover, land use and soil type/texture** that influence the hydrologic response and flash flood potential. A relative flash flood potential index ranging from 1 to 10 was assigned to each data layer based on the layer attributes associated with the hydrologic response. By indexing a given sub-basin’s risk of flash flooding, the FFPI allows the user to see which sub-basins are more predisposed to flash flooding than neighboring cells. The values are unit-less.

This index was created utilizing GIS mapping software to overlay four physical elements that relate to precipitation runoff. These properties are: slope of the terrain, land cover/use, soil type/texture and vegetation cover/forest density. These elements were each scaled to create an overall indexed value that forecasters could use to locate basins that may respond more quickly than expected. An index value of 1 indicates a minimum flash flood threat and an index of 10 indicates a maximum flash flood threat.

The FFPI is composite index value the physiographic characteristics of a basin represented by the layers of Slope, Soil and Land Cover/Use (L) and Vegetation Cover/Forest Density (V). These datasets can be compiled from the available local or global datasets. FFPI is composite index value of the layers of Slope, Soil and Land Cover/Use (L) and Vegetation Cover/Forest Density (V) index maps averaged together, as given in the equation below by Smith (2003).

$$FFPI = \frac{(M + L + S + V)}{N} \quad (1)$$

Where: M = Slope; L = Land Cover/Use; S = Soil Type/Texture; V = Vegetation Cover/Forest Density; N = Sum of weightings.

Calculation of Flash Flood Potential Index (FFPI) for Sudan in ARCGIS.

Data Given:

Data	Type of Data / File Format	Specifications	Source	Data Path
Digital Elevation Model (DEM)	Raster / Tif	Resolution: 90 m	SRTM	X:/Sudan_Data/Module 3/Floods/Sudan_DEM.zip
Land Cover/Use	Vector / Shapefile	-	http://www.fao.org/geonetwork/srv/en/main.home	X:/Sudan_Data/Module 3/Floods/Sudan_Lulc.zip
Soil Type/Texture	Raster / Tif	Resolution: 1 Km	FAO Harmonized World Soil Database V 1.21	X:/Sudan_Data/Module 3/Floods/Sudan_Soil.zip
Sudan Admin Boundary (level 1 and level 2)	Vector / Shapefile	-	ICPAC	X:/Sudan_Data/Module 3/Floods/Sudan_Admin.zip

Slope (M): Slope is an important component in flash flooding potential, due to the potential for rapid runoff. Experience suggests that any slope exceeding 30 percent leads to extremely quick runoff and a rapid response in local creeks and streams. Therefore, the formula below was created to reclassify percentage slope into an FFPI value, setting any slope of 30% or higher to an FFPI of 10.

$$Slope\ index = 10^{n/30} \quad (2)$$

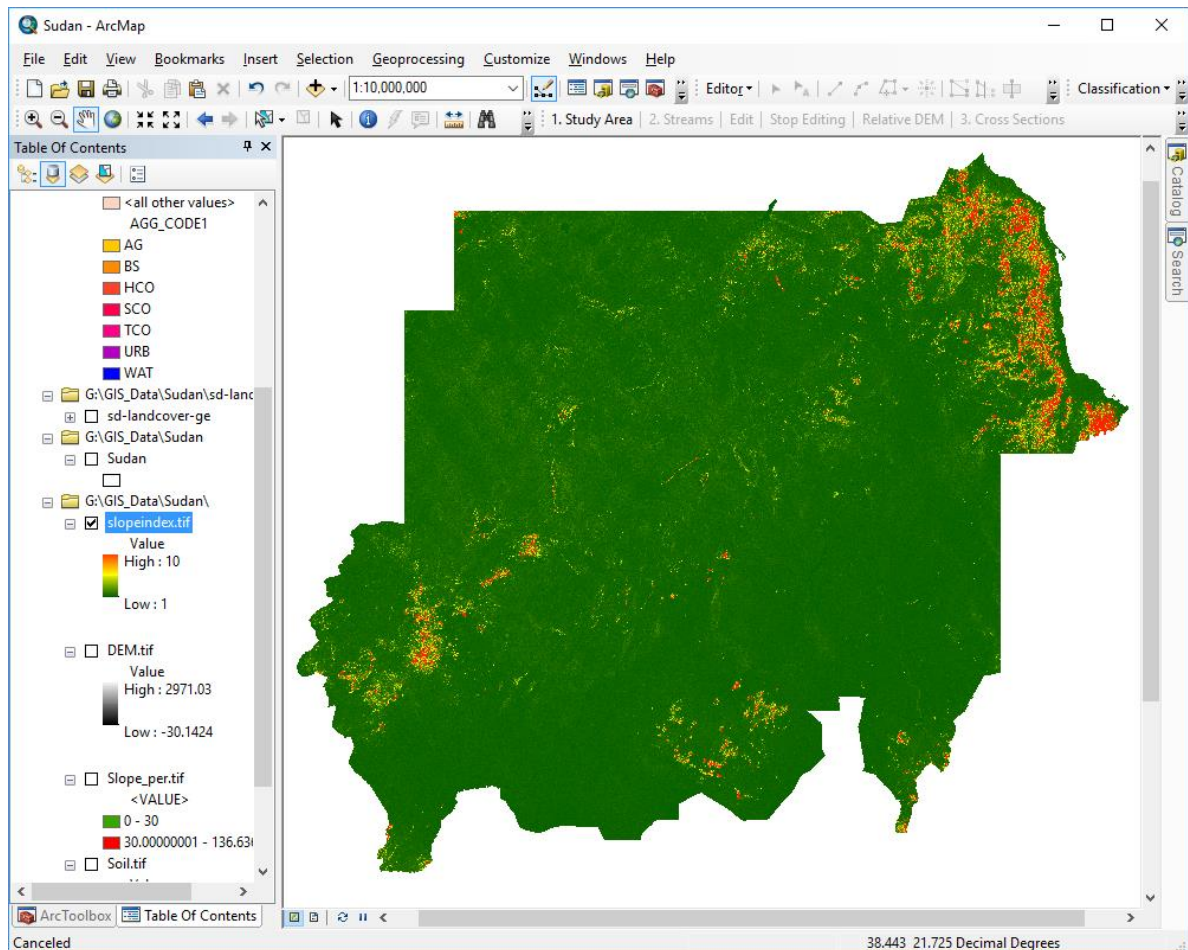
Where

n = percent slope ≤ 30. If n > 30, then FFPI = 10.

1. Open a blank map in ARCGIS and add DEM.tif.
2. Open *ARC Tool Box* and Select *Spatial Analyst Tools*, *Surface* and *Slope* tool.

3. Select *DEM.tif* as Input Raster, *Slope_per.tif* as Output Raster, *PERCENT_RISE* Output measurement (optional). Select OK to generate Slope map.
4. As given above the FFPI will change for slope < 30% and > 30%. So convert the slope map into Slope index using the formula given above using Raster Calculator.
5. Select *Spatial Analyst Tools, Map Algebra, Raster Calculator*. In Map Algebra Expression window, write the expression (use the available functional tools) given below.

Con("Slope_per.tif" <= 30,Power(10,"Slope_per.tif"/30),10)



Land Cover/Use (L) and Vegetation Cover/Forest Density (V): The land cover /use dataset includes many different components, including biophysical settings, existing vegetation cover (EVC), existing vegetation height and existing vegetation type. The FFPI uses solely the EVC component because it was overall the most applicable to flash flood threat assessment. EVC essentially combines vegetation cover and land use into one composite dataset, using the percentage of canopy cover for tree, shrub and herbaceous canopy cover.

The land cover data set used is derived from the original raster based Globcover regional (Africa) archive. It has been post-processed to generate a vector version at national extent with the LCCS regional legend (46 classes). This database provides a user-friendly interface and advanced functionalities to breakdown the LCCS classes in their classifiers for further aggregations and analysis. More details are available at <http://www.fao.org/geonetwork/srv/en/main.home>. The shape file's

attributes contain the following fields: -Area (sqm) -ID -Gridcode (Globcover cell value) -LCCCode (unique LCCS code). The land use data is assigned appropriate FFPI values based on the literature review (Zogg and Deitsch, 2013) and given in table 1. The values were subjectively assigned because it would be extremely difficult to scientifically document the contributions of vegetation to water runoff. Some of these values were simply assigned based on tree, shrub and herb cover categories.

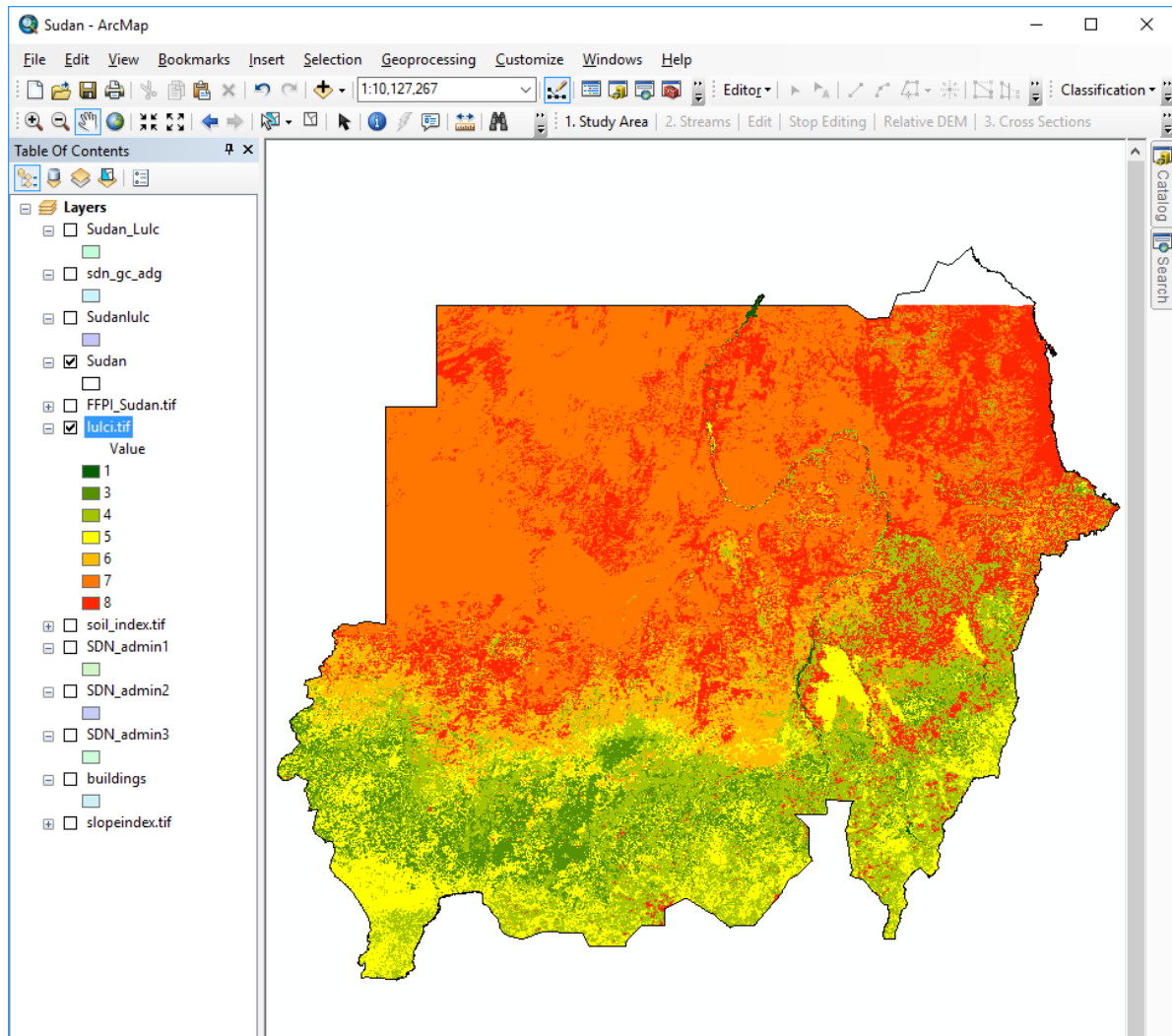
Table 1: Flash Flood Potential Index value for Land Cover/Use (L) and Vegetation Cover/Forest Density (V)

Landsue Category (FAO LCCS Categories)	FFPI
Post-flooding or irrigated croplands (or aquatic)	5
Post-flooding or irrigated shrub or tree crops	5.5
Post-flooding or irrigated herbaceous crops	5
Rainfed croplands	5
Rainfed herbaceous crops	6
Rainfed shrub or tree crops (cash crops, vineyards, olive tree, orchards...)	5.5
Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	5
Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	3
Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)	4
Open (15-40%) broadleaved deciduous forest/woodland (>5m)	3.5
Open (15-40%) need leaved deciduous or evergreen forest (>5m)	3.5
Mosaic forest or shrubland (50-70%) / grassland (20-50%)	4
Mosaic grassland (50-70%) / forest or shrubland (20-50%)	6
Closed to open (>15%) (broad leaved or need leaved, evergreen or deciduous) shrubland (<5m)	5
Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	6
Open Grassland	5
Sparse (<15%) vegetation	4
Closed to open broadleaved forest on temporarily flooded land - Fresh water	5
Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water	4
Closed to open (>15%) grassland on regularly flooded or waterlogged soil - Fresh or brackish water	6
Artificial surfaces and associated areas (Urban areas >50%)	8.5

Bare areas	8
Consolidated bare areas (hardpans, gravels, bare rock, stones, boulders)	7
Non-consolidated bare areas (sandy desert)	7
Water bodies	1

Note: FFPI values are assigned to each land use category using Table 1: FFPI values used for EVC classifications from Zogg and Deitsch (2013). An index value of 1 indicates a minimum flash flood threat and an index of 10 indicates a maximum flash flood threat.

- Add *Sudan_lulc.shp* map to the ARC map window.
- Select Arc Tool Box Feature to Raster from *Conversion Tools, To Raster*. Use *Sudan_lulc* as *Input Features*, select *LINDEX* (FFPI value for each land use category) as *Value Field*, provide *lulcIndex.tif* as *Output Raster Dataset* and select *slopeindex.tif* as *cellsize* (option). Select OK to create a Land Cover/Use (L) and Vegetation Cover/Forest Density (V) index map of Sudan.



Soil Type/Texture (S): Sand and clay are very important components of soils when assessing runoff potential. A soil type consisting of 100% sand will lend very little surface runoff, while 100% clay soils will maximize runoff. The soil type raster was reclassified according to the equations below into two new indexed rasters, one for percent clay and one for percent sand. These values were then averaged to come up with an accurate FFPI.

Below are the equations used to determine the soil type index values for both percent clay and for percent sand, as well as the equation to determine the FFPI based on those values.

$$\text{Clay soil type index} = 0.5\left\{\left(1 + \frac{n}{100}\right) (9)\right\} \quad (3)$$

Where n = percent clay.

$$\text{Sand soil type index} = 0.5\left\{\left(1 + \frac{(100 - n)}{100}\right) (9)\right\} \quad (4)$$

Where n = percent sand.

$$S = 0.5(\text{Clay soil type index} + \text{Sand soil type index}) \quad (5)$$

8. Add Soilmap.tif to the Arcmap window.
9. Open Attribute table of *Soilmap.tif* and identify the attributes which represent the clay (*T_Clay*) and sand (*T_Sand*) percentages?
10. Open *ARC Tool Box* and select *Spatial Analyst Tools, Reclass* and *Lookup* tool. Use clay percentage attribute to create raster map *clay.tif* and sand percentage attribute to create raster map *sand.tif*.
11. Use the *clay.tif* map to calculate *clayindex* using the above formula.

$$0.5 * ((1 + ("clay.tif" / 100.0)) * 9.0)$$

12. Use the *sand.tif* map to calculate *sandindex* using the above formula.

$$0.5 * ((1 + ((100.0 - "sand.tif") / 100.0)) * 9.0)$$

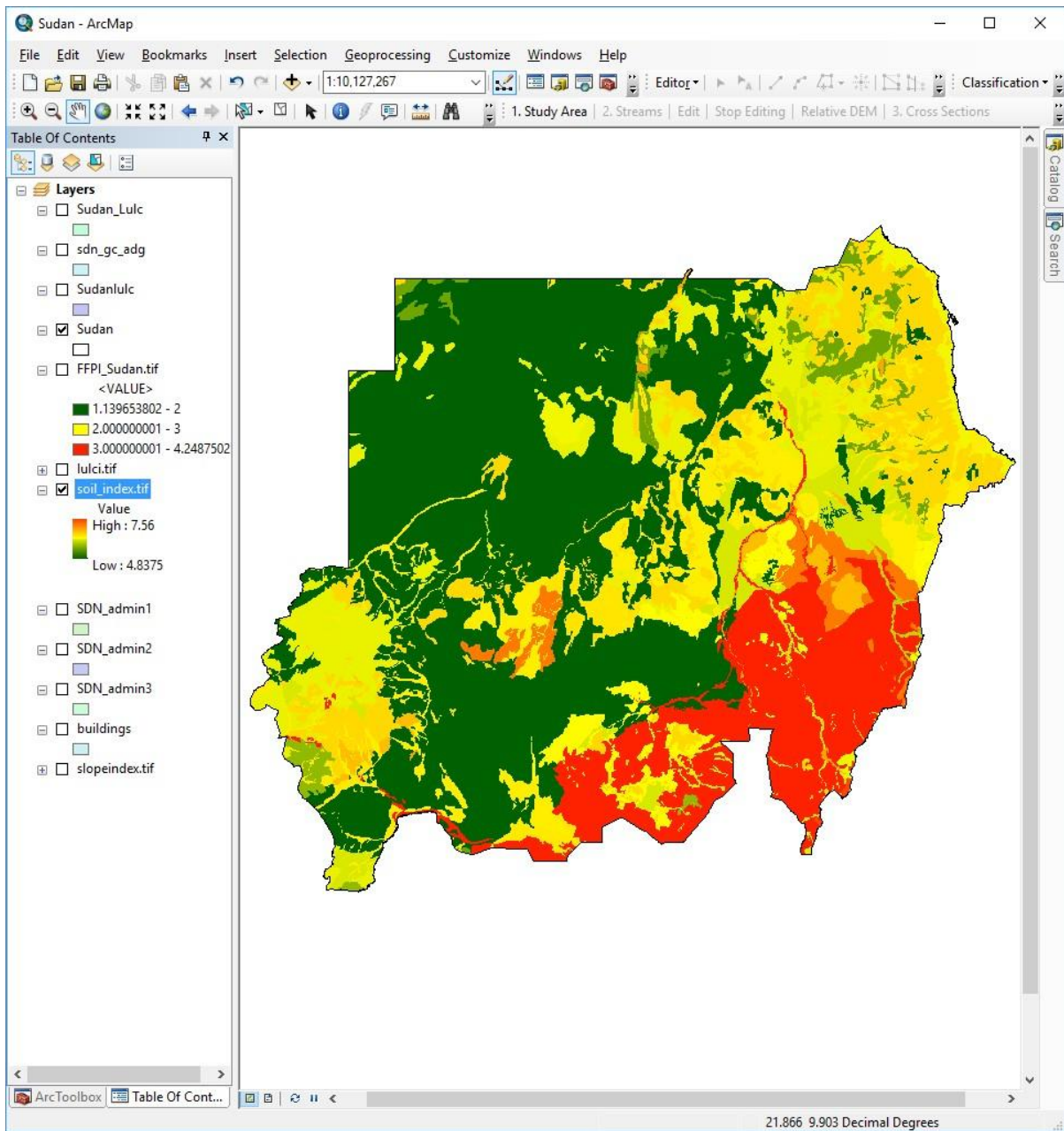
11. *Soilindex.tif* is calculated using formula,

$$0.5 * ("clayindex.tif" + "sandindex.tif")$$

Since soil index map is having a resolution of 1 Km, it is necessary to resample this data to same pixel size i.e. 90 m, same as other datasets i.e. *slopeindex* and *landuse and vegetation index*.

12. Select *Resample* tool from *Data Management Tools, Raster and Raster Processing Arc ToolBox*. Select *Soil_index.tif* as Input Raster, output raster may be *soilindex.tif* and select *slopeindex.tif* as Output *Cell Size* (option). Select Ok to resample the *soilindex* map. The *soilindex* map is given below.

Note: You will notice that the cell size has changed from 908.5 m to 90.85 m.



13. Now using the *slopeindex.tif*, *soilindex.tif* and *lulcIndex.tif* maps to create Flash Flood Potential Index for Sudan, using atc Tool raster calculator.

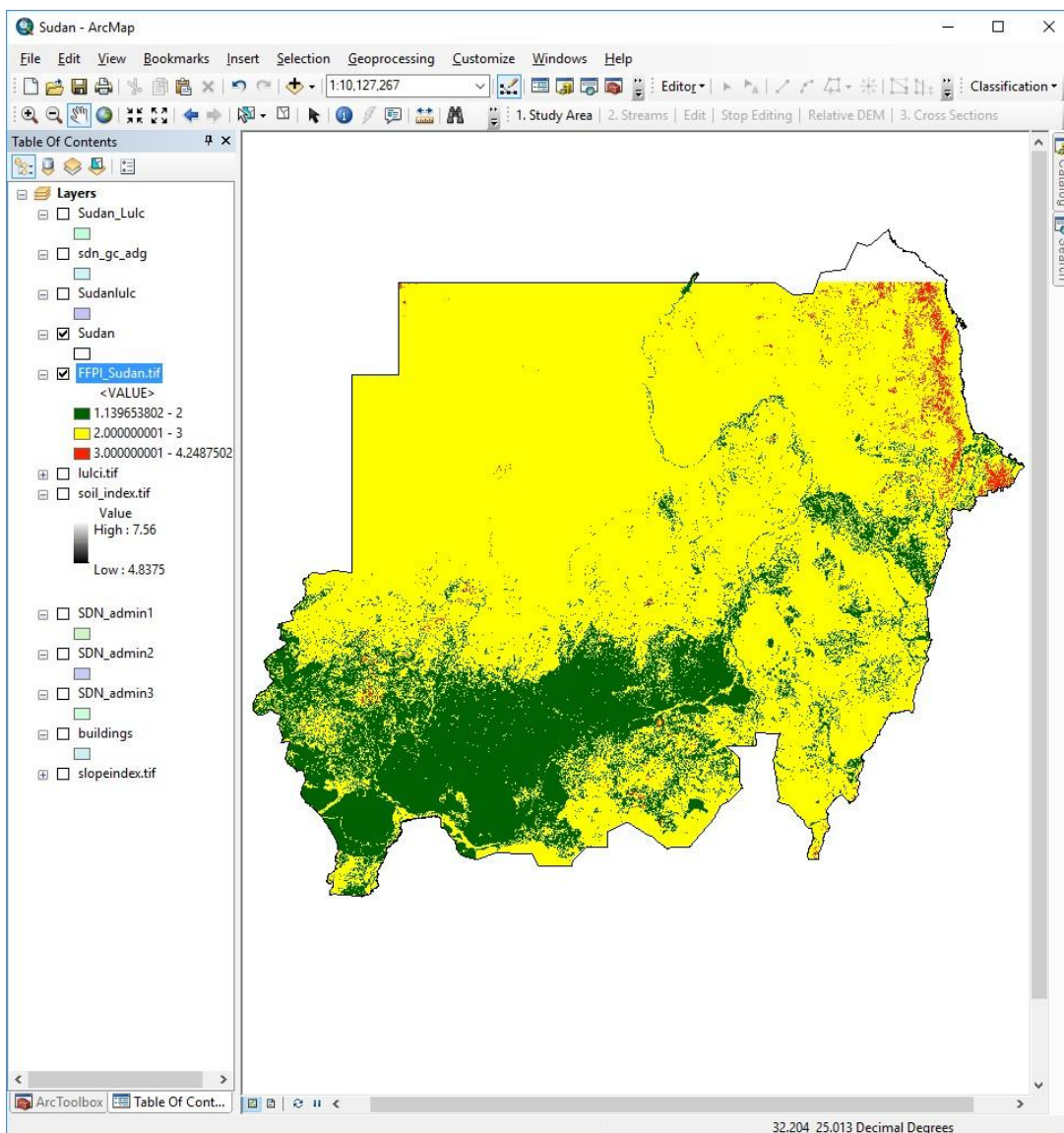
$$\text{FFPI} = 0.5 * (\text{slopeindex.tif} + \text{soilindex.tif} + \text{lulcIndex.tif}) / 3$$

14. As you observed the minimum and maximum range of FFPI is 1.14 and 4.25. For better visualization, let us reclassify it into 3 classes (low, moderate and high) using the limits given below.

FFPI Class	FFPI Min. Range	FFPI Max. Range
High	3.0	4.25
Moderate	2.0	3.0
Low	1.14	2.0

Note: The classification ranges are subjective. Share your field experience in deciding them.

15. Use the above range of values to classify the FFPI map of Sudan. FFPI map of Sudan with above classes is given below.





Exercise 3.4: Flood Hazard Assessment (river flood) using GIS Flood Tool (GFT)

3.3.1 Introduction

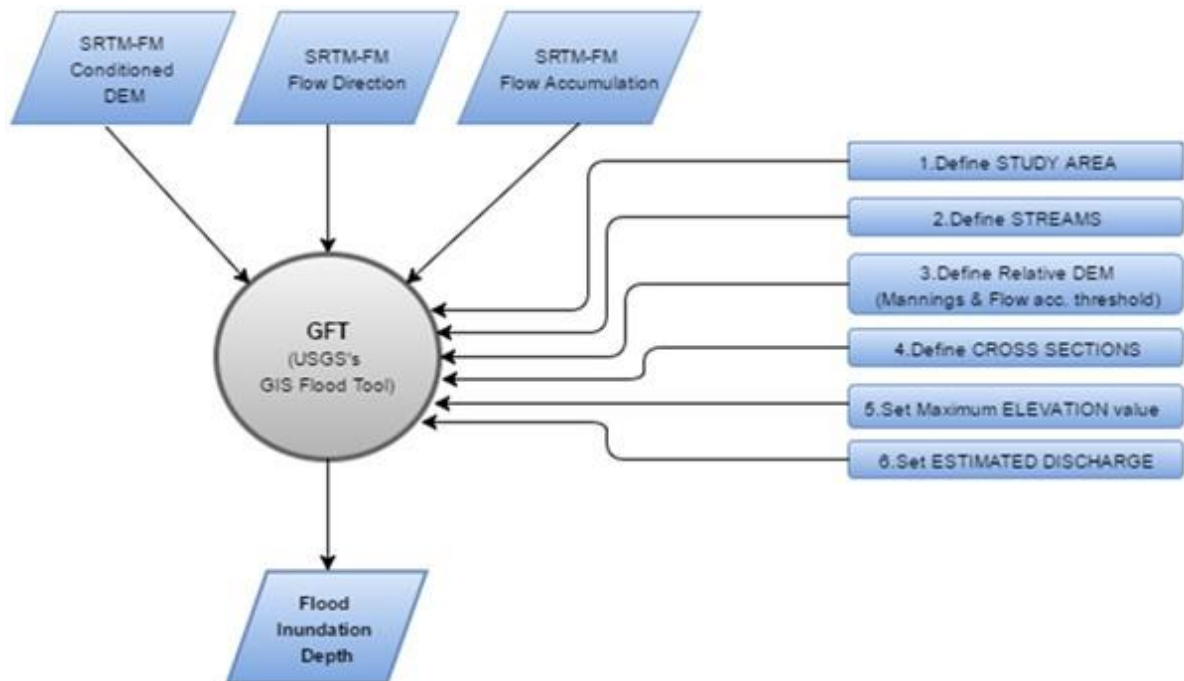
The immediate effects of a flood event include loss of life, displacement of large numbers of people, damaged and destroyed properties and infrastructure. Longer term, the floods lead to outbreaks of disease, and the destruction of crops causing food insecurity. Displaced residents and the local authorities must rebuild after every flood event and children are disrupted from schooling as the schools and other critical infrastructure such as roads and health centers are either inundated or used as relief centers. Hence it is of high importance for national governments as well as humanitarian actors from international organizations to be aware of flood prone areas.

The Nile River Basin in Sudan is subjected to regular flooding, especially near the confluence of blue and white Nile. In August 2013, heavy rains in the region led to a massive flood, the worst in the past 25 years causing significant damages in the country. In this practical exercise, you will be running the GIS Flood Tool (GFT) over the Nile River Basin 90 km downstream from the Blue and White Nile confluence in Khartoum (Please note that river Nile flows South to North), in order to extract a series of modeled flood extents. In this exercise, we will use a flood model to simulate the 2013 Khartoum floods and compare the results with satellite-based data obtained during the flood event.



Source: Bertramz

3.3.2 Road Map



3.3.3 About GFT and SRTM-FM dataset:

The GIS Flood Tool (GFT) is a GIS based flood model made by USGS. The implementation of this flood inundation tools is developed to work with the USGS/UNOSAT's SRTM-FM dataset. The "SRTM-FM" is an extracted hydrological dataset from the CGIAR-CSI's global data v. 4.1 of the NASA's SRTM DEM. All the data processing is accomplished using several tools available in ESRI's ArcGIS that were mostly automated with coding in Python language (Arcorace M., Rusack E. and Verdin K.). The SRTM-FM dataset includes: **Conditioned DEM** for flood modelling, **Flow Direction** and **Flow Accumulation DEM**, Streamlines with Pfafstetter coding, and Catchment areas at 90 m resolution.

Data Inputs

X:\Sudan_Data\Module 3\Floods\GFT\Input

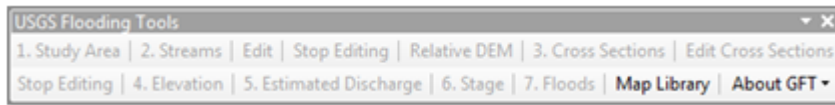
3.3.4 Setting up the USGS's GFT tool:

- Navigate to the following folder and unzip the file "GFT_Arc10v2.zip".

X:\Sudan Training\Sudan_Data\Module 3\Floods\GFT\Software

Follow the instructions in the document "GFT for Version 10 Installation Instructions.docx" to install the GFT on your computer. [This document explains how to install the tool and enable it in ArcMap.](#)

If you have successfully completed the process, you should see the *USGS Flooding Tools* toolbar when you open ArcMap. All of the options are currently greyed out.



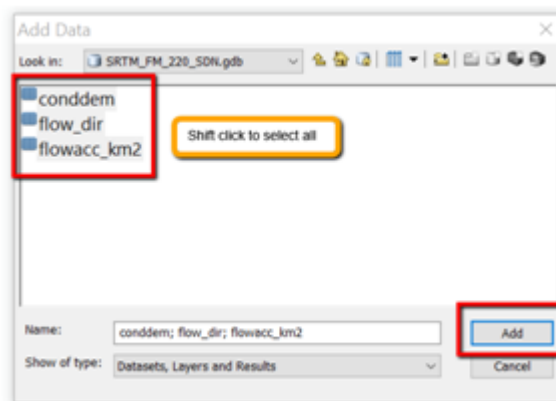
3.3.5 Loading Data into the mxd:

Open a new ArcMap document and save it as “*ModA5_s2_GFT.mxd*” under the following location:
X:\Module3\Floods\GFT\Workspace

- **Click** add data button and **browse** to the following directory

X:\Module3\Floods\GFT\Input\Raster

- **Select** the following datasets from “*SRTM_FM_220_SDN.gdb*” and **click Add**.
- *cond_dem* (Hydrologically conditioned Digital Elevation Model)
- *flow_dir* (Coded representation of the direction of flow over the landscape)
- *flowacc_km2* (Flow accumulation in the landscape in square kilometers)



• Once the three raster layers have been added, the first step in the GFT will be active. Uncheck all the layers except “*cond_dem*”.

- **Add** layers “*AOI.shp*” and “*Gauge_stations_Nile_Khartoum.shp*” from

X:\Module3\Floods\GFT\Input\Vector

- **Right click** the layer “*AOI.shp*” and **choose** *Zoom to Layer*.

- **Double click** the “AOI” layer’s symbol and choose an appropriate symbology (e.g. *Fill color:No color; Outline width:1;Outline color:Red*). Repeat the same procedure for the Gauge stations layer (e.g. Orange triangle).

In this exercise, we are going to make a simple flood modelling simulation using the GFT over this area of Interest (AOI). The AOI includes a portion of Nile River Basin in the states of Khartoum and River Nile. As explained in the following pages, we will assume for this AOI that the flow conditions of the Nile River downstream at the Northern station of the AOI (first gauge station after the Sabaloka Game Reserve, located in the city of Wad Hamed in Al Matammah province) are the result of the open waters over the entire drainage areas above the gauge.

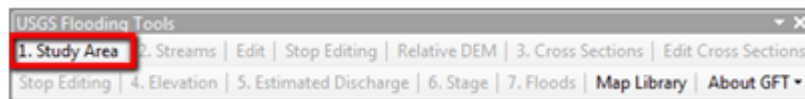


STEP (14)

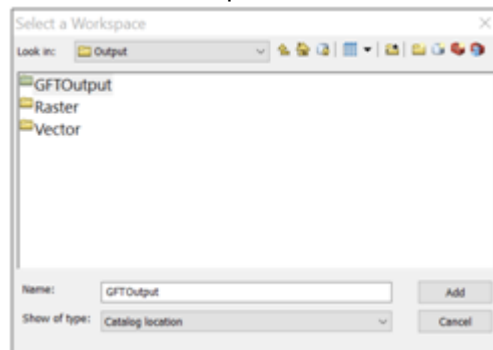
3.3.6 Running the GFT:

Step 1: Define the study area

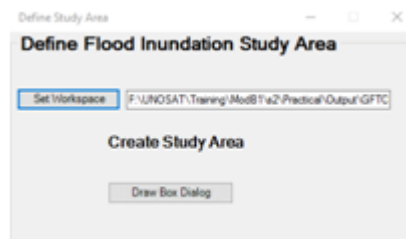
- Click on *1.Study Area* in the GFT toolbar.



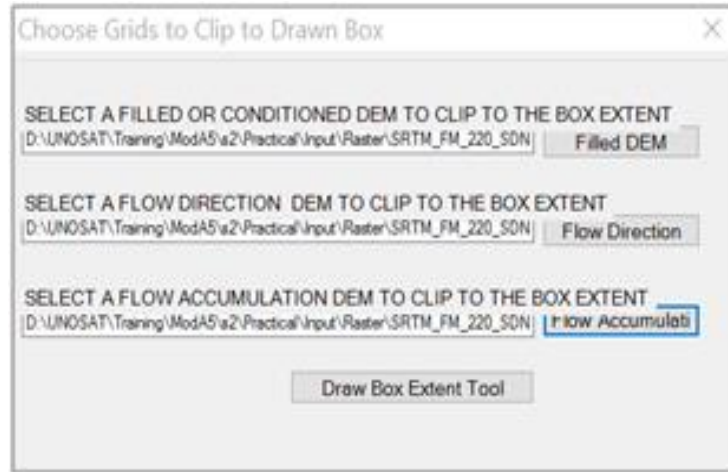
- Click OK on the pop-up window about the python toolbox
- A window will appear asking you to select your workspace.
- Navigate to the folder *X:\Module3\Floods\GFT\Output*, and select the folder “GFTOutput” as your workspace, click Add. All of the outputs from the model will be stored in this folder.



The *Define Flood Inundation Study Area* will then appear. **Click on Draw Box Dialog**



A pop up window will appear asking you to select the *conditioned DEM*, the *Flow Direction*, and the *Flow Accumulation*.

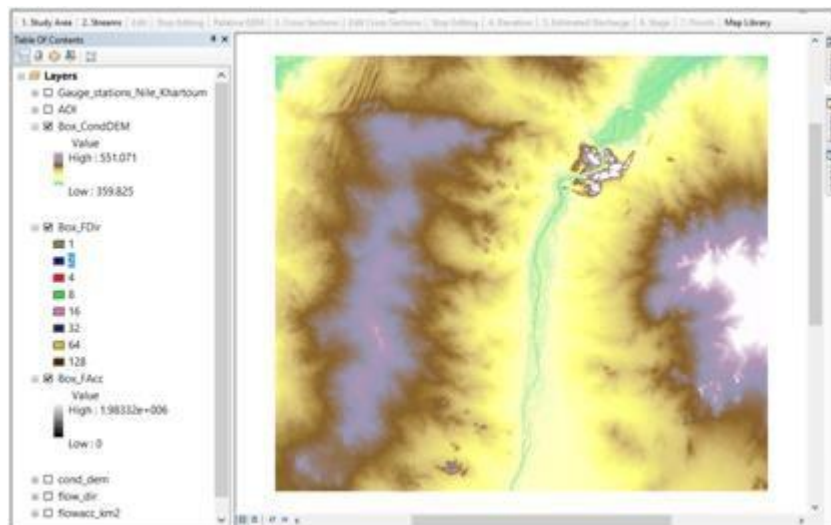


- Click on Filled DEM, navigate to “cond_dem” in the following GDB and **click Add**

X:\Module3\Floods\GFT\Input\Raster\SRTM_FM_220_SDN.gdb

- Click on Flow direction and add “flow_dir” in the same GDB.
- Click on Flow Accumulation and add “flowacc_km2” in the same GDB.
- Click on Draw Box Extent Tool and draw a box around the AO” (Click on the top left-hand corner, holding the mouse button down, and drag the crosshairs down to the bottom right-hand corner of the square).
- Let go of the mouse when you are at the bottom right-hand corner and the program should begin clipping the datasets. Clipping the datasets can take few minutes.

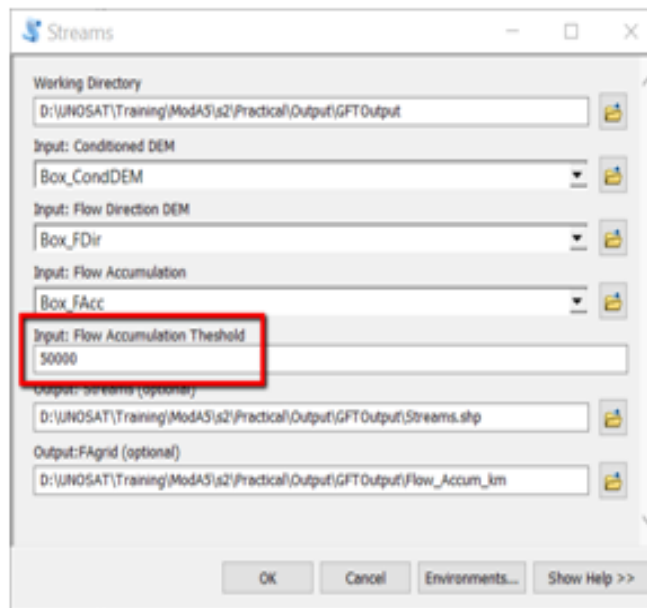
Once it is finished you will see three new rasters in your Table of Contents: “Box_CondDEM”, “Box_FDir”, and “BOX_FAcc”. Uncheck all the other layers. Your screen should look like this:



3.3.7 Step 2a: Extract the streams

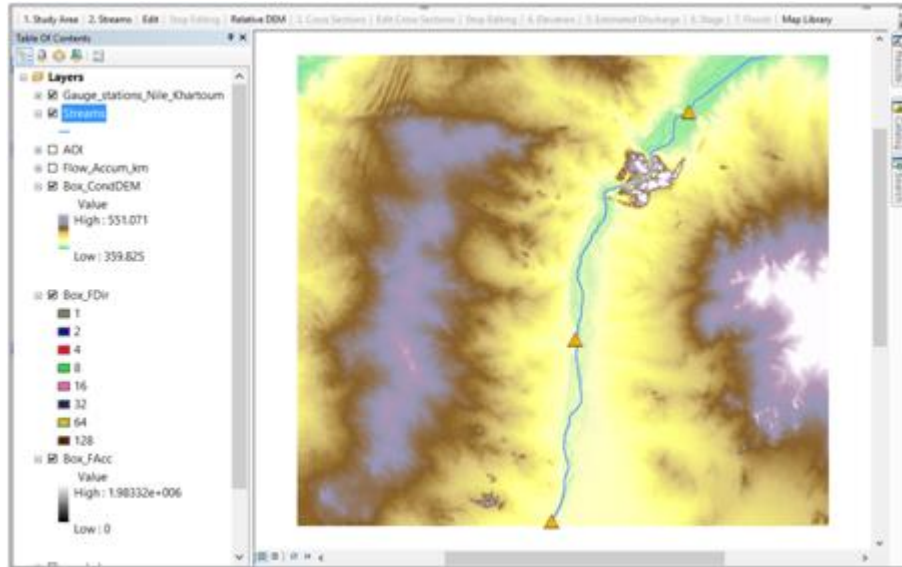
Flow accumulation is calculated using the flow direction raster. The output is a raster with the value of each pixel signifying the number of upslope cells flowing into it. The flow accumulation threshold defines the number of how many pixels, or area in kilometers squared, should be flowing into a given pixel before it is extracted as a stream. The “Streams” step extracts the streams from the Flow Accumulation raster according to the flow accumulation threshold that you set as input.

- **Click** on 2. *Streams* in the USGS Flood Tools Toolbar which should now be active.
- The *Streams* dialog box will appear. Under *Input: Flow Accumulation Threshold* **enter** the value of *50000*. Leave everything else as default and **click OK**



The threshold above is in Square Kilometers. What you are telling the program to do is to look at the flow accumulation raster and extract as streams all of the pixels that have a value of more than 50000 (or in other words: an area of more than 50000 square kilometers flowing into them).

Once the streams tool has stopped running the dialog box will say completed. **Click** on *close* and your screen should look like the picture below when you zoom in a little bit. **Switch on** the gauge stations, if it is off.



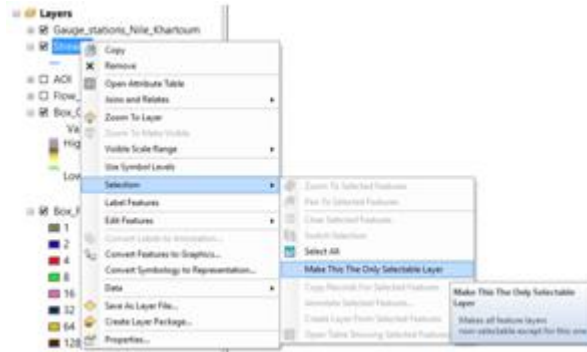
Our objective is to model the flood conditions over the AOI based on the river flow conditions at the gauge located at the outflow point of the modelled river basin. For doing that, we will consider only the river next to the gauge and we will trigger the simulation using the input data at the Northern gauge station. For this exercise, we assume that the Nile River at this point is collecting the water flow derived from open waters over the entire drainage areas above the gauge. Before we can run the model we need to edit the stream segments according to the objective of our simulation by deleting parts of the streamlines that we are not interested in.

- *In the USGS Flood Tools Toolbar, **click** on **Edit**, Do not use the “Start Editing” button of the Arcmap “editor” toolbar!!*




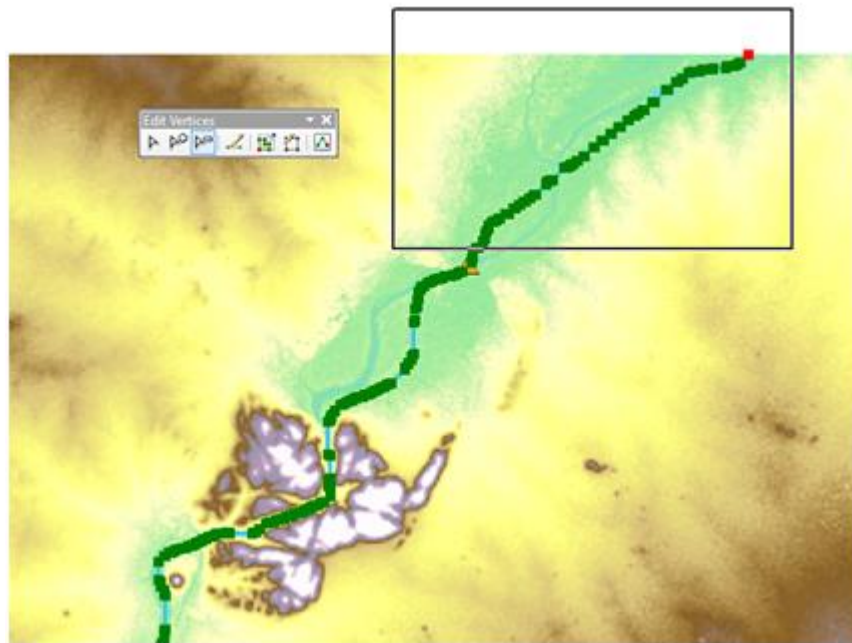
USE ONLY the USGS Flood Tools Toolbar for starting and finishing the streams editing. You can only delete or split the streams using the ArcMap tools of the “Editor” Toolbox. Do not move them.

- **Click** Yes to the pop up window.
- You only have to edit the “Streams” layer. Make this layer the only selectable layer.



The goal of this preliminary flood modeling is to obtain a flood extent estimation of the Nile River Basin within the assigned AOI. As input data for the GFT model, we will use the discharge value at the Northern gauge. In order to do that, we will simulate a flood scenario between the confluence of the Blue and White Nile rivers and the gauge station located 90Km downstream. In particular, we will not consider all the tributaries upstream and we will delete all segments of the resulted river branch after downstream the gauge.

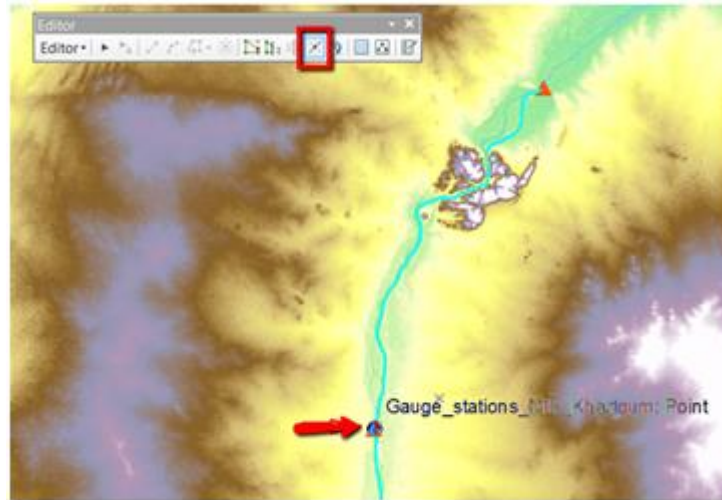
- According to this, **select** the river branch using the *Edit tool*.
- Once the river has been selected, **right click** and **choose** *Edit Vertices* from the pop up window. From a single blue line, it should change into a line with several green dots. Make sure to switch on the gauging station layers, if it is off.
- **Delete** all existing vertices of the selected line using the *Delete Vertex* tool  found in the small window that appears. As shown in the picture below, you can delete all the points downstream the Node 2 by holding the mouse button down and drawing a square that encompasses all the points.



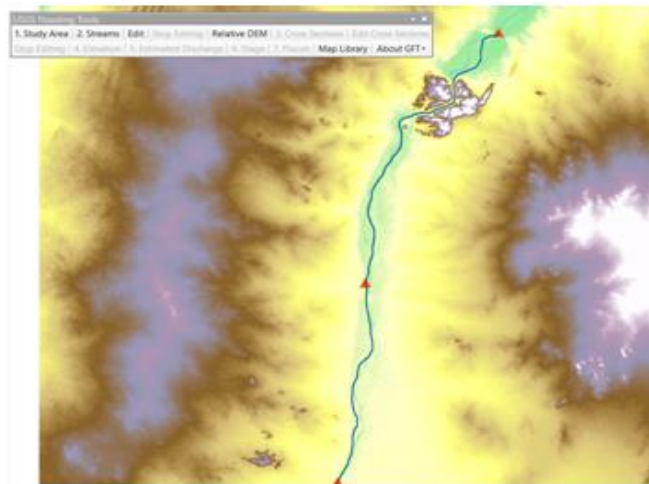


OPTIONAL STEP:

After deleting the vertices downstream the Northern gauge, proceed to **split** the remaining stream (This is due to substantial changes in the cross section of the two resulting streams). The splitting point is the gauge station located in the middle of the stream.



- **Click** on *Stop Editing* in the USGS Flood Tools toolbar, then **click** Yesto save the changes. Do not use "stop editing" button of editor toolbar!!
- Your screen should end up looking like this:



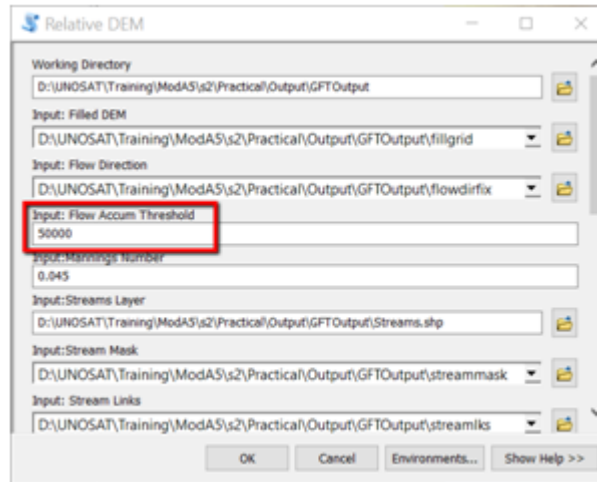
Step 2c: Create the relative DEM

The next step in the GFT is to create the *Relative DEM* on which the flood modeling will be based. The *relative DEM* is essentially a Digital Elevation Model in which the streams have been set to have zero meters elevation and the elevation of all other pixels is set relative to the stream pixel into which it flows. The result is a Digital Elevation Model in which all elevation is relative to the stream, hence the name, Relative DEM.

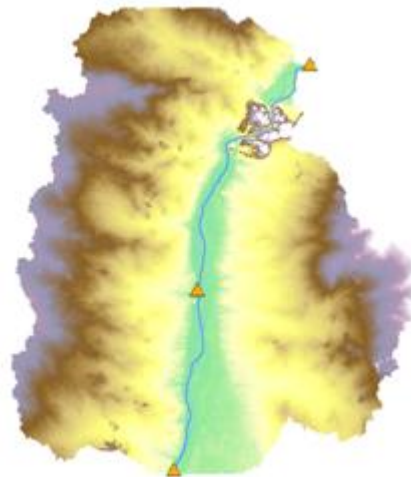
- **Click** on *Relative DEM* in the USGS Flood Tools Toolbar.



- Under *Input: Flow Accum Threshold* enter **50000**. Leave everything else as default.



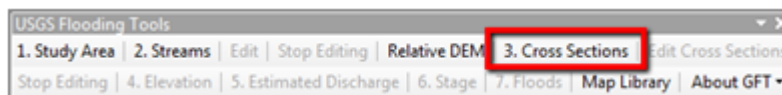
- **Click OK** and this might take few minutes. When the tool finishes running, **click Close**
- **Uncheck** all the other raster layers. Your result should now look similar to the one below. The new DEM is the relative DEM and step 2 is now accomplished.



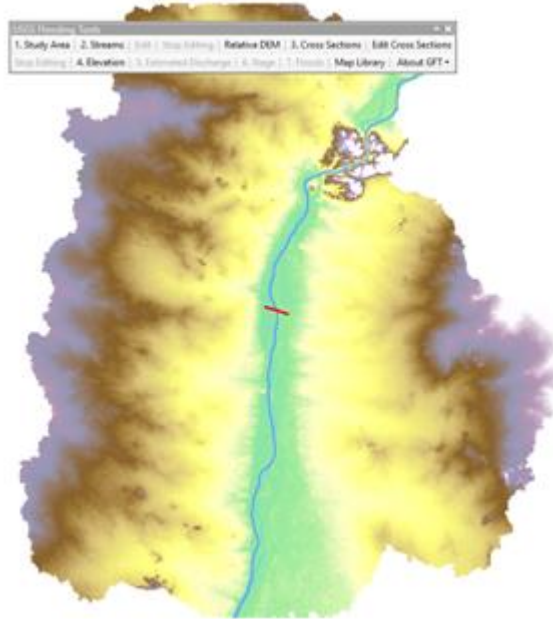
Step 3: Creating and editing the cross sections

The following step after the creation of the relative DEM is the creation of the river *cross section* for each segment of the stream network that we made.

In the *USGS Flood Tools Toolbar*, **click** on *Cross Sections* and **enter** the length of the cross section.



Note that the default value of 20 means a cross-sections of approximately 1,800 meters on either side of the stream segments (*the SRTM-FM data has a pixel size of 3-arc-seconds or approximately 90 meters*). One cross section will be assigned to each stream. At this step your screen should end up looking like this:



Following these guidelines you can rotate, move and edit the vertices of each cross section using the ArcMap Editor Toolbar.

- **Click** on *Edit Cross Sections*.



- **Make** this layer the only selectable layer and edit the cross section layer and **zoom to** the southern cross section.
- **Select** *Edit Cross Section* **Click** *OK* when the *Elevation* button advert appears) and increase as necessary.
- **Click** *Stop Editing* on the *USGS Flooding Tools* toolbar and **click** *Yes* to save the edits.

Step 4: Elevation

After the creation of the cross section the tool will ask you to insert a value for setting the maximum stage that will be considered for creating the *Stage-Discharge* relationship over each cross section. *Stage-discharge curves are generated using Manning's equations.*

- **Click** on *4. Elevation* in the *USGS Flood Tools* toolbar.



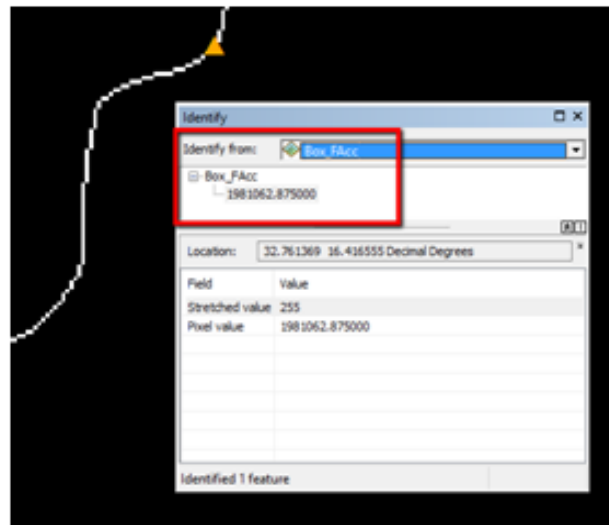
- Set **25** as a default value to the windows that appears asking to set a value in meters. **Click OK** to the pop up window that appears.

Step 5: Estimated Discharge

In this step you are going to insert the flow data acquired from the field to the GFT flood modeling. In general, at this step you should insert the value of discharge values measured during the flood event at the location of the river gauging station. For this simulation, discharge data at the Northern gauge station during the August 2013 Sudan floods is not available, thus the discharge value introduced has been estimated considering average and peak discharge values obtained from various sources (Around 11,000 CMS). The location of this gauge will be used for this exercise as the location point of the GFT input flow data in order to trigger the simulation.

This value is for training purposes only

- **Identify** flow accumulation threshold at gauging station:
 - a) **Turn off** all the layer in the table of contents except the gauging station and the “Box_FAcc” layer.
 - b) **Right click** the layer “Gauging_station_Nile_Khartoum” and **click Zoom to Layer**.
 - c) **Zoom in** around the location of the northernmost gauging station (i.e. at 1:50,000 scale).The map document should look similar to the picture below
 - d) **Click** on *Identify* button in the *Tools toolbar*. **Query** the flow accumulation grid (“Box_FAcc” layer) near the Northern gauge station using the identify tool by clicking on the closest white pixel to the gauge. Make sure to choose the right layer in the identify window. Under *Identify from: Box_FAcc*
 - e) **Take note** of the identified pixel value (1,981,062 sq km). This is the drainage area in square kilometers above the gauge. This value will be used as input parameter (*flow accumulation threshold*) for the following steps.



- **Click** on **5. Estimated Discharge** in the *USGS Flood Tools toolbar*.



- **Insert** the 11,000 CMS, which is the estimated discharge at this gauge station during the 2013 Khartoum floods. *The values used are for training purposes only.*

- **Insert** the *flow accumulation* value of 1,981,062 sq. km and **click** OK in the information pop up window that appears.

Step 6: Stage

Step 6 is the calculation of all the stages at each cross section.

- **Click** on 6. Stage in the *USGS Flood Tools toolbar* and launch the process (it will take few seconds). **Click** OK in the information pop up window that appears



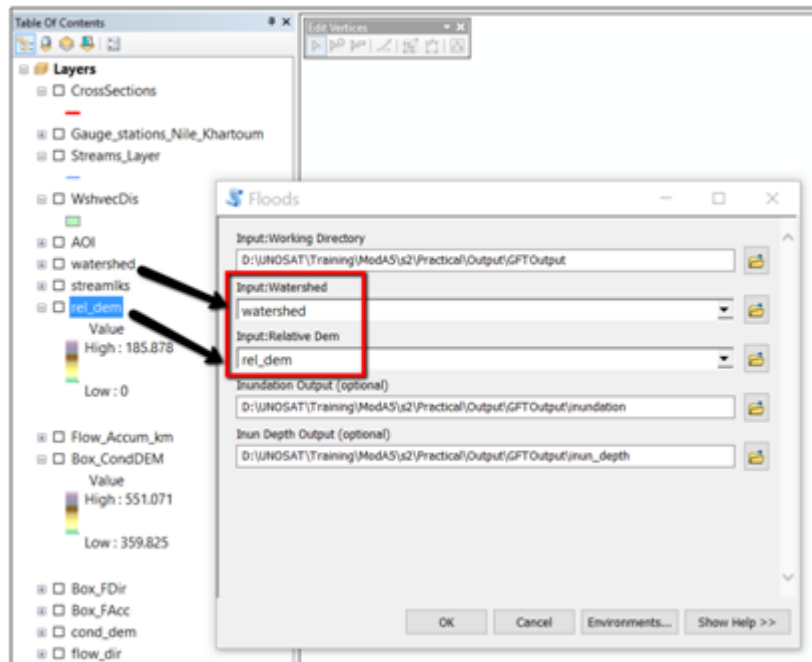
Step 7: Floods

The final step no. 7 is the calculation of the flood inundation extent based on the relative DEM.

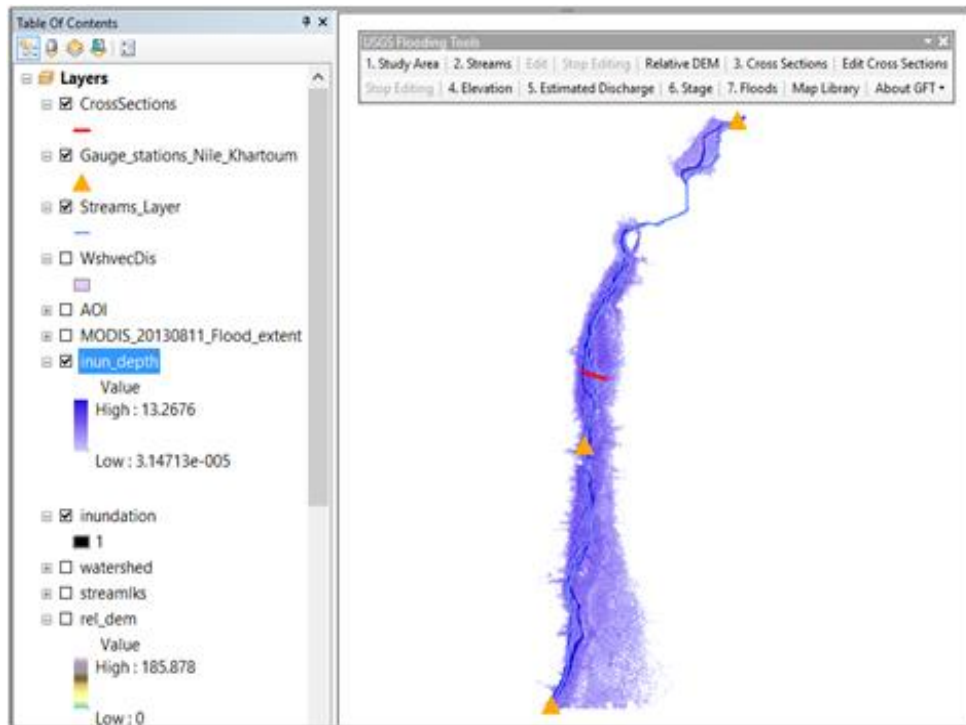
- **Click** on 7. Floods in the *USGS Flood Tools toolbar*.



- **Insert** the parameters as following and **click** OK. This process can take few minutes.



- When the inundation depth raster have loaded, look at the result. Output layers “*inun_depth*” (raster of modeled water depth) and “*inundation*” (raster of inundation extent) will appear in the *Table of Contents*.
- **Right click** on “*inun_depth*” and **choose** *Zoom to layer*.



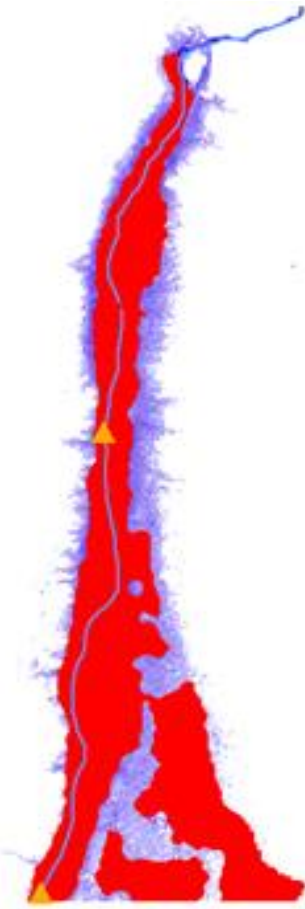
3.3.8 Compare modelled extent with flood observation

Once we get the result from the GFT we need to identify the good fit between model and satellite-based observation.

- **Activate** the layer “MODIS_20130811_Flood_extent.shp”.
- **Compare** “inun_depth” (modelled) with “MODIS_20130811_Flood_extent.shp” (observation) and **check** the accuracy of the model. [Use Swipe tool from the Effects toolbar](#)

If the final results are not satisfactory, repeat the process modifying the estimated values introduced: Number and length of the Streams, Flow Accumulation Threshold and Elevation (the values chosen are appropriate for this case study and do not need to be modified as the results will not vary, unless extreme values are assigned), Manning’s Number, Cross Sections geometry and Discharge.

**Note that Discharge and flow accumulation values can be modified in the present project by just clicking and introducing new values, nevertheless GFT does not allow changes to values previous to step 5. If this is the case, close the ArcMap project and start again.*



DISCUSSION

GFT model lets the user to derive flood inundation data in the most simplistic and efficient way. The results from the model can be utilized to identify the flood risk zones, and potentially contribute towards better decision making at national and community levels. For instance, there is increasing evidence that humanitarian actors such as Red Cross and Red Crescent Climate Center and Save the Children, to name a few, are utilizing flood models to understand the risk and prepare for the impending hazard.

But like all other mathematical and hydrologic models, it is not without limitations. The accuracy greatly depends on the identified cross section, resolution of the DEM used, threshold values and ground knowledge of the user.

In what case would the modelled flood extents be useful? Can you think of any cases where they should not be applied?

What do you think are the advantages and disadvantages of a model such as the GFT?

 Can you think of any other ways to improve the accuracy of this model? Will using a higher resolution DEM help?

In your country, what is the highest resolution of DEM available? Can you identify any possibilities to acquire new data?




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,

- Add "Post_20160529.tif" data into Arcmap ToC. (**This is data from Exercise 3.4 output**)
- 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?

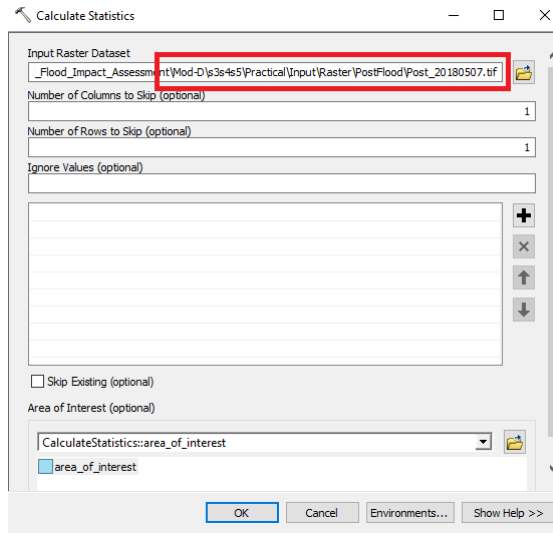
Identification of Optimal threshold value

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 "Post_20160529.tif" :

- **Bring up** Arctoolbox by **clicking** the  button
- **Go to** *Data management tools > Raster > Raster properties > Calculate Statistics*
- **Select** the raster dataset "Post_20160529.tif" from the following location:

X:\Module2\Sentinel-1\Input

- **Click OK**



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

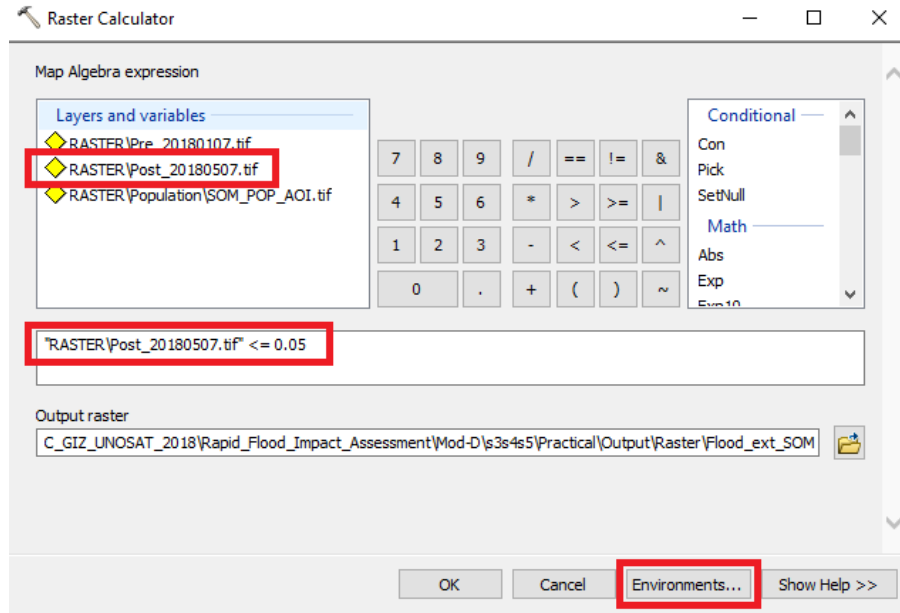
Now that you have identified a suitable threshold of pixel values corresponding to water, you can start to proceed with the pixel-based classification process using a raster calculator:

- Using the *Search* toolbox, **open Raster Calculator**
- In the *Raster Calculator* tab, **double click** on the raster layer “*Post_20160529.tif*” and **insert** the following mathematical expression using the most suitable identified pixel value threshold:

“*Raster Layer*” \leq *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.tif*” and **save** it in the output raster folder:

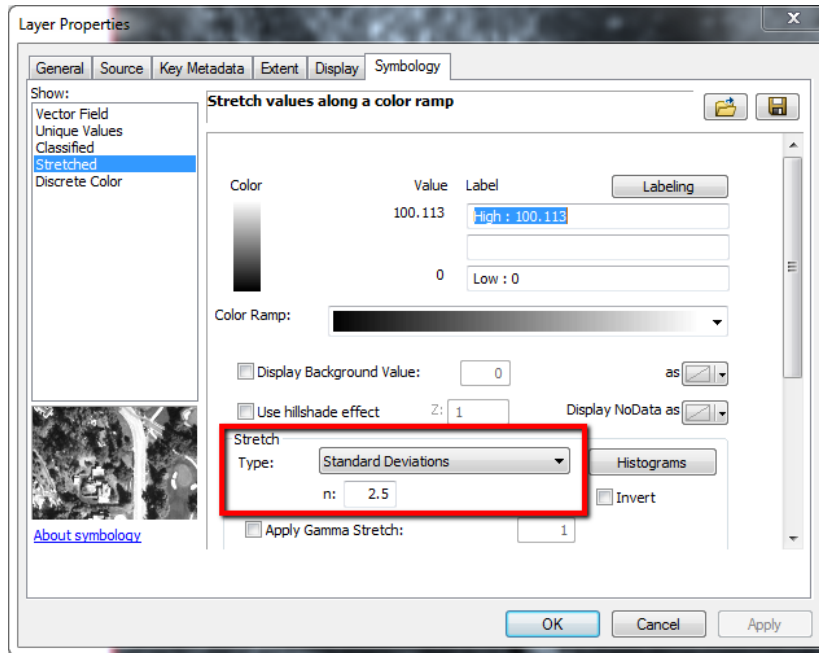
X:\Module2\Sentinel-1\Output

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.

If at any point, your raster image is appearing to be completely black:

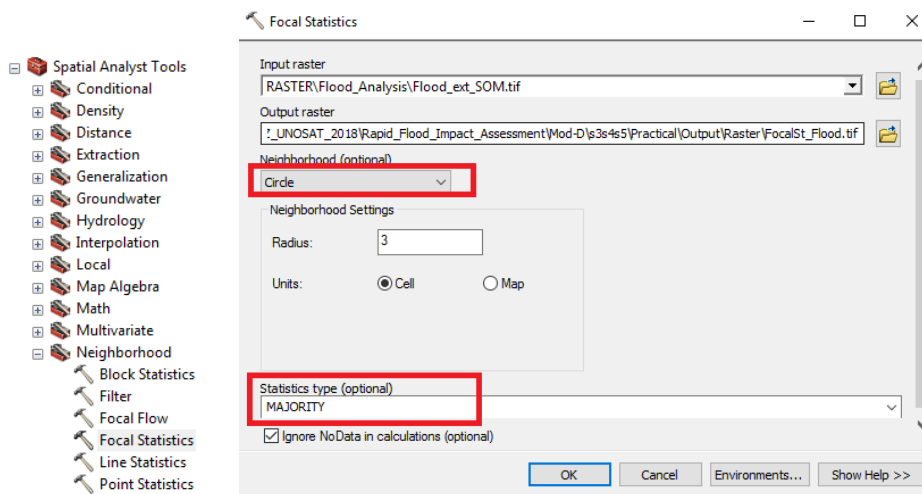
- **Right click** on that layer >*Properties* > *Symbology* >Under *Stretch* >**Type: Standard Deviation**



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.tif*” as input raster and **apply** the filter parameters as below:

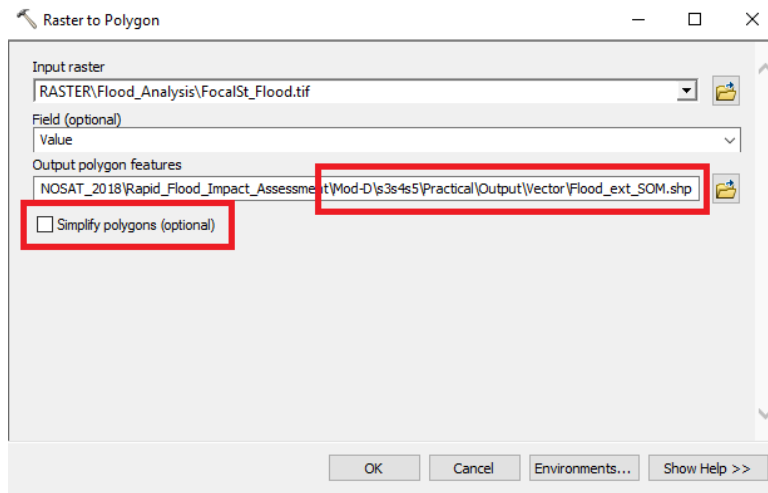



- **Name** the output raster layer as “*FocalSt_Flood.tif*” and **save** it in the output raster folder:

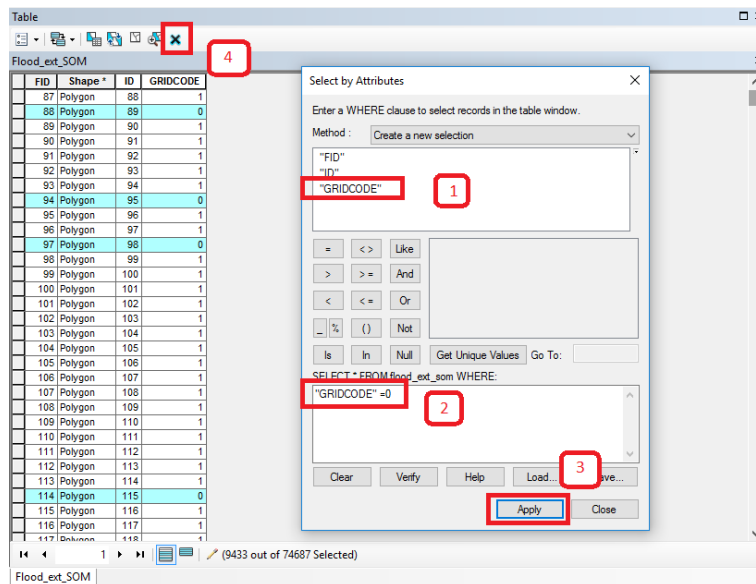
X:\Module2\Sentinel-1\Output


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

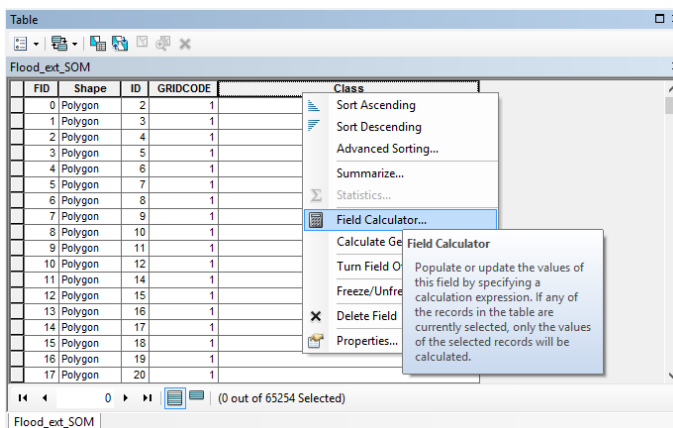
- **Search** for the tool *Raster to Polygon*
- **Add** the raster layer from the previous step (“*FocalSt_Flood.tif*”) and **name** the vector file to export as “*Flood_ext.shp*”
- **Choose** as output location:
X:\Module2\Sentinel-1\Output
- **Uncheck** the option *Simplify polygons*

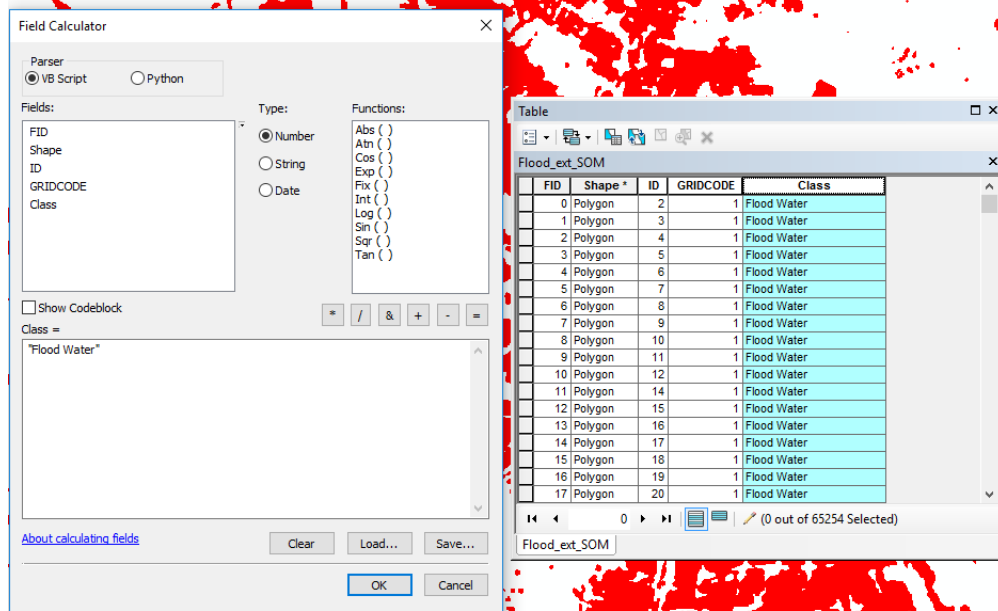


- **Add** the exported vector layer to your ArcMap project.
- **Right click** on “*Flood_ext.shp*” > *Edit Feature* > *Start Editing*
- **Right click** on the vector layer “*Flood_ext.shp*” > *Open Attribute Table*
- From the bottom on the *Attribute Table Dialog Box*, **click** *Table Options*  > *Select by Attributes*
- **Double click** on *GRIDCODE* and type in the following query expression:



- 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 quotations marks as well):



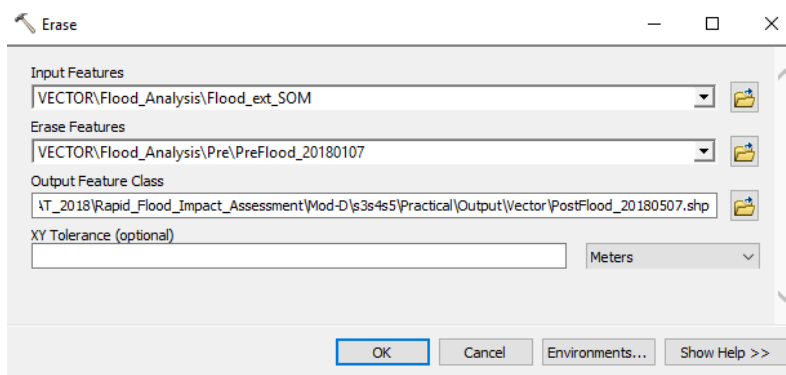


Subtracting Pre flood layer from Post flood Layer

The post flood water also includes the pre flood water such as rivers and lakes. So before calculating statistics, it is important to subtract the pre-water from post-water. For your convenience, using the steps above, pre-flood water has been extracted and clipped to the AOI. (You will find the shapefile in **X:\Module2\Sentinel-1\Input**).

- Use the tool *Erase (Analysis)* to **remove** the *pre-flood extent* from the *post-flood extent*, selecting "*Flood_ext.shp*" as Input Features and "*PreFlood_ext.shp*" as Erase Features
- **Name** the output feature class as "*PostFlood_20160529.shp*" and **save** it in the output vector folder:

X:\Module2\Sentinel-1\Input

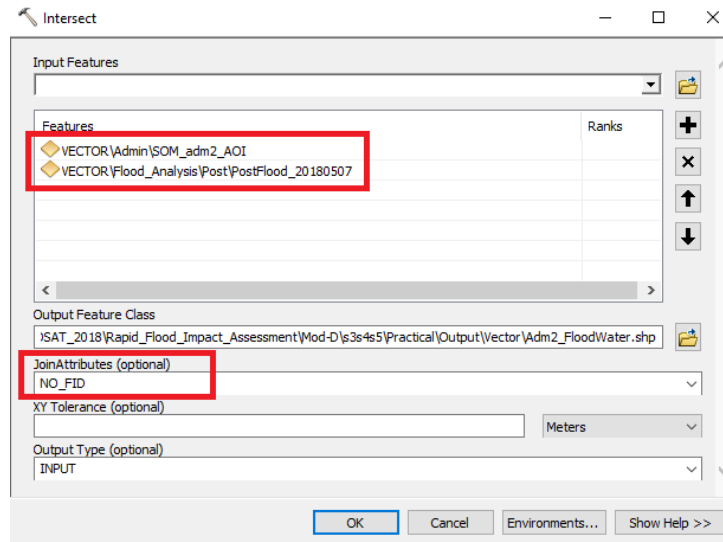


Satellite Analysis: estimated flood water extent by affected administrative units

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 (“*PostFlood_20160529.shp*” and “*SDN_adm3_AOI.shp*”) and “*NO_FID*” as *JoinAttributes*
- **Name** the output layer file “*Adm3_FloodWater*” and **choose** as output location:


X:\Module2\Sentinel-1\Output



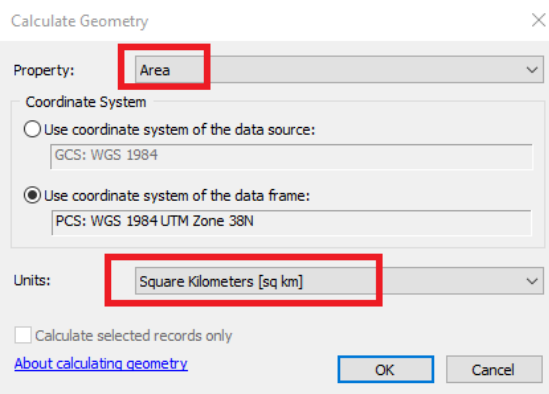
The output file “*Adm3_FloodWater*” will be automatically added to the ToC:

- **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):

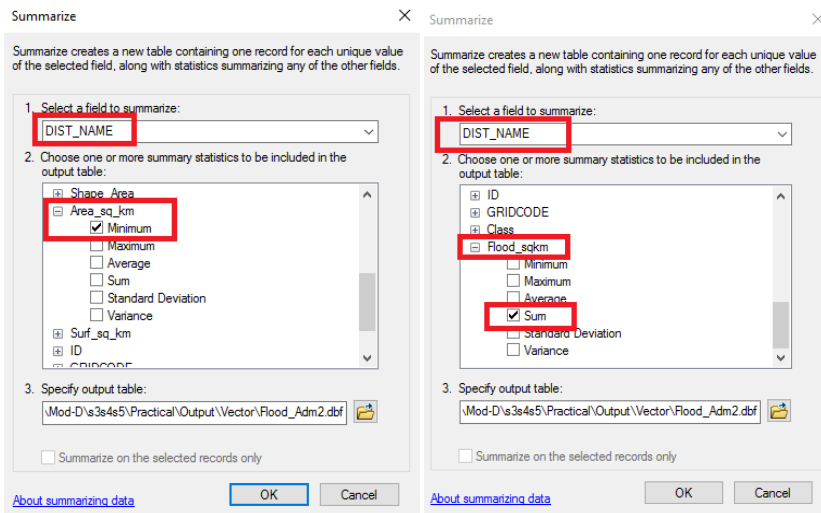
- From the *Attribute Table*, **click** *Table Options*  > *Add Field...* **Enter** “*Flood_sqkm*” as *Name* and **select** *Double* as *Field Type*
- **Right click** on the field “*Flood_sqkm*” > *Calculate Geometry*
- From the *Calculate Geometry Dialog Box*, **select** the following parameters:

- **Click OK**



Each record of the attribute table “Admin3_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 Admin2_Namefield (which in this case is Name_2) 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.



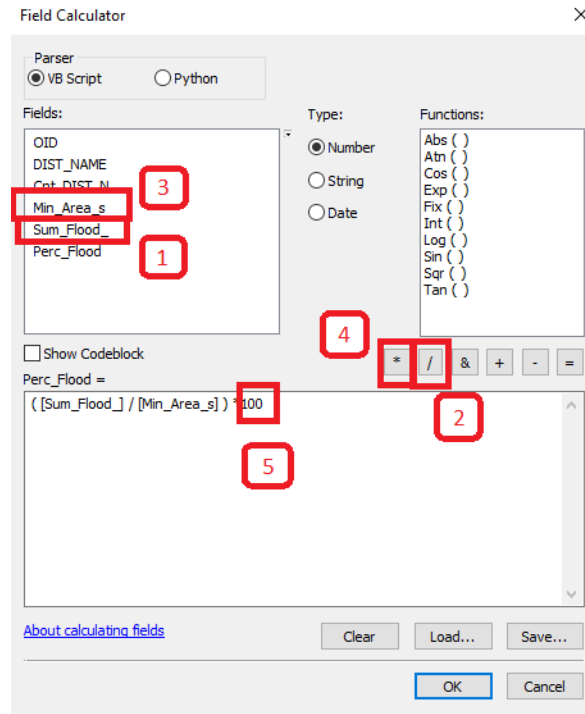
- **Name** the output .dbf table as “Flood_Adm2” and **choose** as output location:

X:\Module2\Sentinel-1\Output

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):

$$“(Sum_Flood_sqkm”/”Min_Area_sq_km”) *100”$$



3.4 Exposure assessment of elements at Flood Risk

3.4.1 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 pre-flood areas.
2. Understand the geographical extent of post-flood areas.
3. Assess the actual flood extent.

4. 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	X:\Module3\Floods\Exposure	Vector (polygon)	TX_2060811_Khartoum_Analysis_Extent.shp
Pre-Flood Area	X:\Module3\Floods\Exposure	Vector (polygon)	TX_2060811_Khartoum_PreFlood.shp
Post Flood Area	X:\Module3\Floods\Exposure	Vector (polygon)	TX_2060811_PostFlood_Khartoum.shp
Road Network	X:\Module3\Floods\Exposure	Vector (polyline)	Roads_Sudan.shp
Settlements	X:\Module3\Floods\Exposure	Vector (point)	Settlements_Sudan.shp
Land use	X:\Module3\Floods\Exposure	Vector (polygon)	Landuse_Landcover.shp
Population (Grid) data	X:\Module3\Floods\Exposure	Raster	Sudan_Population_WP.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

Understanding the elements at risk

- Open ARC GIS software and add all the data given and view the data given.
- Open the Flood Inundation data and view the data and answer the question.
- Calculate the area of the flood extent in sq. Km within the Area of Interest?

Hint: Erase the pre-flood area from post-flood area.



STEP (15)

Assessment of elements at risk exposed to flood

- 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

Road Type	Length of the Road Exposed to Flood (Km)
Total	

- 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 à Overlay à Intersect

3.4.2 Flood vulnerability and risk assessment

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

$$\text{Flood risk} = \text{Likelihood of flooding} \times \text{Consequences of flooding}$$

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.

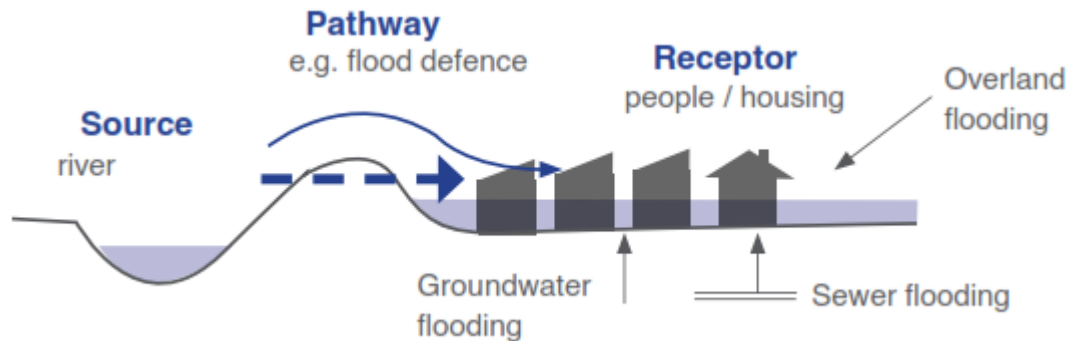


Figure: Source-Pathway-Receptor Model

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.

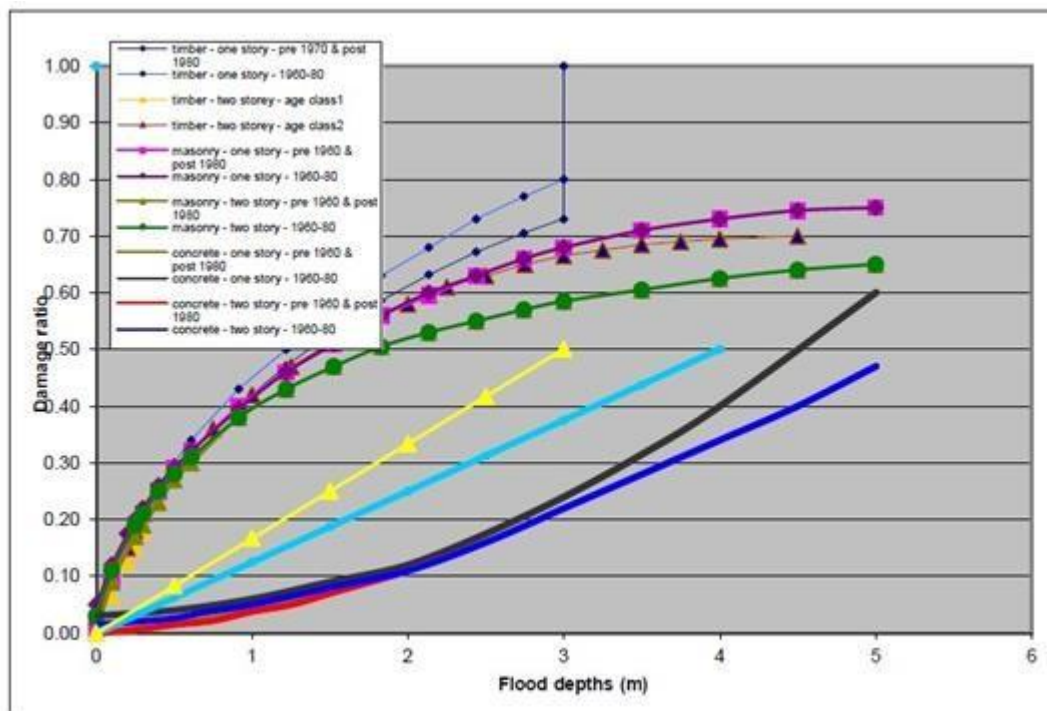
Flood vulnerability is one of the significant components in risk management and flood damage assessment. Vulnerability measurement is a complex process because it is influenced by several environmental, economic, and social or even political elements in local scale. In other words, vulnerability is affected 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 area being exposed to the flood impacts as a subject to potential losses. Susceptibility is considered status of people, environment and infrastructure tendency to influence by a hazard because of 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 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.

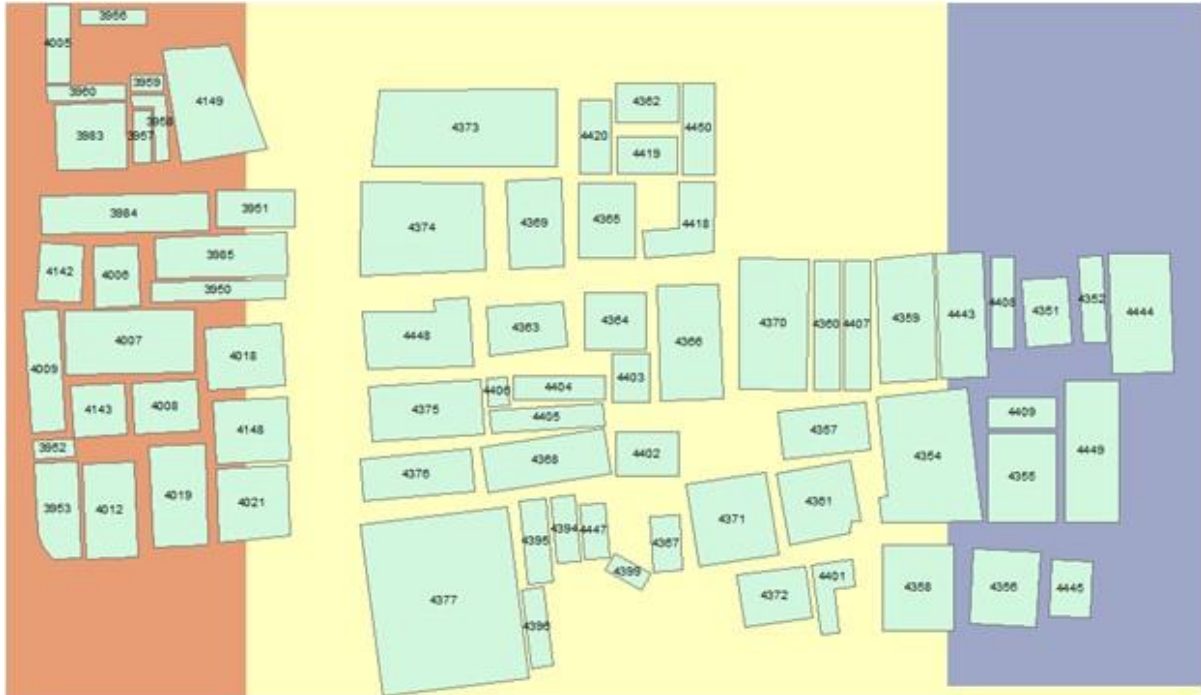
An example vulnerability curve is shown here, which indicates the relationship between flood depth (m) and percentage of the damage for different types of buildings.

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



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

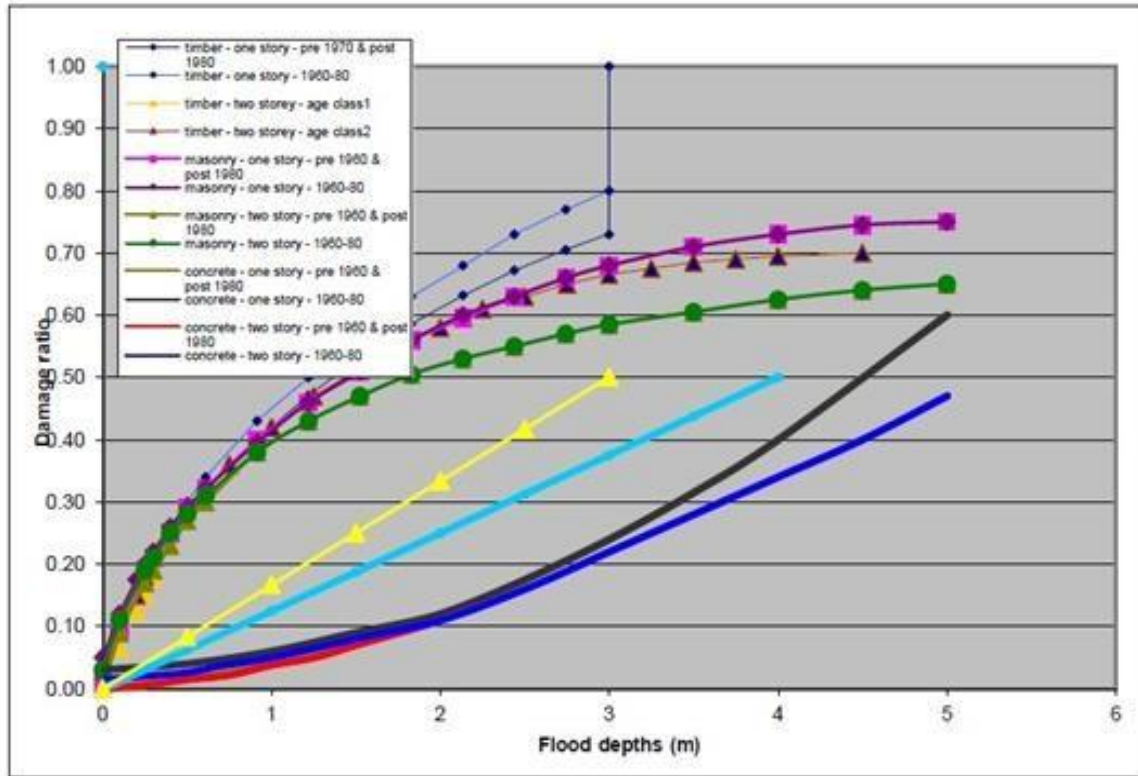
- Attribute Table for Buildings with details of material, age class and cost of the building

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.



	Flood Depth (m)	Damage Ratio	Cost of the Building (\$)	Damage (\$)
			1000	
			1600	
			7000	
			10000	
			7000	
			6000	
			6000	
			3500	
			3500	
			10000	

Conclusions based on the analysis:

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

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



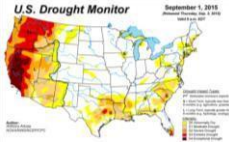

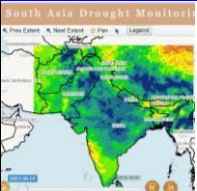

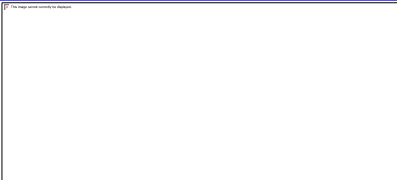
3.5 Hazard Monitoring and Multi-hazard Early Warning Systems

The topics, concepts, and techniques covered under module three above are very important inputs to hazard monitoring. Some of the major disasters in the Greater Horn of Africa region are slow onset disasters like drought and some others have rapid onset like earthquake and to some extent floods. If DRM institutions have the capacity to identify major disasters, put in place key indicators and set thresholds and finally monitor indicators at a certain time interval, this definitely contribute to a significant reduction in loss of life and damage to property. The opportune time to put in place all the preparedness, mitigation and response plans is the time before a disaster strikes. It is far cheaper to invest in preparedness, mitigation and resilience building as compared to investment required to respond to and rebuild after a disaster. From the historical disaster data and experience of the region, disaster is *'a matter of when and not if'* indicating the need to put in place functional mechanisms to disaster risk reduction. One of such an important mechanisms to DRR is to put in place hazard monitoring and early warning systems. Under this section we will be discussing a GIS based techniques for monitoring two of the major disasters in the region, droughts and floods at a different time scale.

3.5.1 Drought Monitoring for Early Warning

Key indicators and thresholds for drought monitoring

There are several indicators and indices to drought monitoring and a reading material from World Meteorological Organization (WMO) is provided for your reference under **C/DATA/Module3/DRM readings** folder. For this training very relevant global experiences on drought monitoring will be presented and we will limit ourselves to selected few, leaving the option for you to explore further. The following table summarizes some selected examples of drought hazard indicators and monitoring from different parts of the world.

Type of Drought	Key indicator(s)	Institution	Web page
Combined Drought	SPI, VHI, Water level, temp., soil moisture, field data	National Drought Mitigation Center (USA)	 http://drought.unl.edu/Home.aspx
Combined Drought Indicator (CDI)	SPI, Soil moisture, vegetation anomaly, snow pack, river discharge	European Drought Observatory - Joint Research Center	 edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000
Meteorological, agricultural	SPI, soil moisture, drought severity index	The South Asia Drought Monitoring System (SADMS)	 http://dms.iwmi.org/app/
Meteorological, agricultural, hydrological	SPI, stream flow, vegetation, and many others	Princeton University: African drought & flood monitor	 http://stream.princeton.edu/AWCM/WEBPAGE/interface.php?locale=en
Meteorological, agricultural	SPI, vegetation anomaly/condition	ICPAC: Drought Watch	 https://icpac.maps.arcgis.com/apps/CompareAnalysis/index.html?appid=622cfedde5304661bf606eacaa65d7dc

Seasonal and Monthly Drought Monitoring

One of the key point in hazard monitoring is to decide the time scale which depends on nature of the hazard, temporal resolution required, objectives of the monitoring, in addition to many other factors. For drought monitoring for instance the common time scales are dekadal (10 days), monthly and seasonal. For our case we will limit our exercises to monthly and seasonal monitoring of drought for selected seasons in 2017. In hazard monitoring a threshold value or a reference year/ state/layer is compared with the season under consideration. The anomaly or difference of these two values can be calculated in one of the three ways. These are absolute difference (current – reference), relative difference (current – reference/reference) and standardized difference (current-reference/standard deviation).

For the purpose of demonstration and exercise, we run seasonal anomaly based drought monitoring

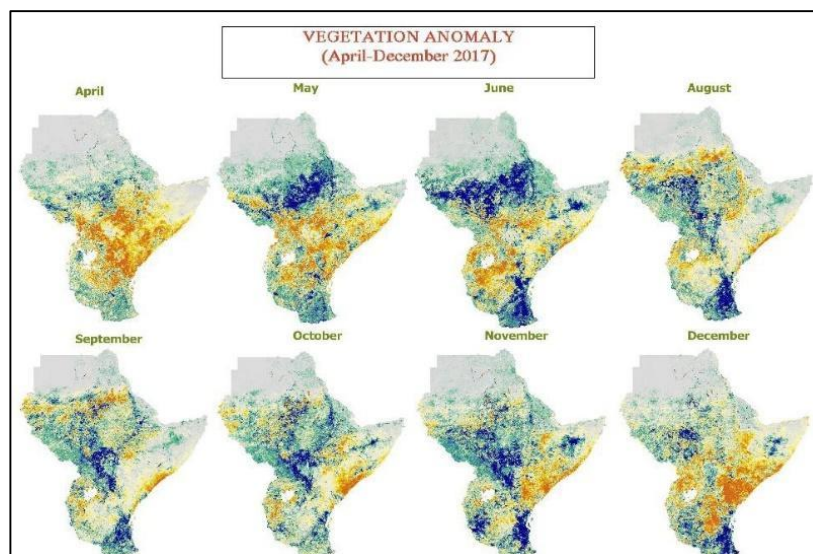
(meteorological drought). For that we will follow these procedures:

- Choose your season for your country
- Prepare seasonal total rainfall data for climatological years (1981-2010) WMO
- Calculate Long Term Average (LTA) of your data
- Subtract the Long term average from March to May 2017 data (MAM2017 – LTA) =Absolute difference
- Set the result in to reasonable classes to see the areas receiving excess and deficit for the season as compared to long term average or a reference year.

NOTICE:

- For monthly monitoring you need to calculate monthly long term average for all the twelve months and calculate the anomaly.
- For monitoring rainfall and vegetation anomaly you can also consider calculating standardized difference ($Current - Long\ term\ average / Standard\ Deviation$)
- Monitoring of drought requires monitoring anomaly at decadal, monthly, seasonal scales depending on your needs

This is monthly vegetation anomaly map produced in the same way as rainfall anomaly.



3.5.2 Multi-hazard Early Warning Systems

Early Warning Systems (EWS) is defined as:

“The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.” (UNISDR, 2009)

Traditionally, many countries have been reactive to disasters experiencing significant losses in lives and livelihoods of their citizens. Adoption of the Hyogo Framework for Action (HFA) 2005–2015 by 168 countries has led to a paradigm shift in disaster risk management from emergency response to a comprehensive approach which also includes preparedness and preventive strategies to reduce risk, according to WMO. The current Sendai framework (2015-2030) also stressed the need for multi-hazard early warning system by placing it as one of the seven goals for an effective disaster risk reduction.

The first of the four priority of the Sendai Framework is understanding risk which by implication is about hazard assessment, monitoring and early warning to an effective understanding of risk and put all the necessary mechanisms to prepare, prevent, mitigate and effectively responded to disaster risks.

Early Warning Systems (EWS) are well recognized as a critical life-saving tool for floods, droughts, storms, bush fires, and other hazards. The recorded economic losses linked to extreme hydro-meteorological events have increased nearly 50 times over the past five decades, but the global loss of life has decreased significantly, by a factor of about 10, thus saving millions of lives over this period. This has been attributed to better monitoring and forecasting of hydro-meteorological hazards and more effective emergency preparedness, according to WMO report.

From their practice and experience, WMO identified ten common principles that have led to the success of Early warning systems, irrespective of the political, social, institutional, and economic factors in each country.

Political recognition. There is a strong political recognition of the benefits of early warning systems, reflected in harmonized national and local disaster risk management policies, planning, legislation and budgeting

Common operational components. Each effective system is built upon four components: hazard detection, monitoring and forecasting; risk analysis and incorporation of risk information in emergency planning and warnings; dissemination of timely and authoritative warnings; and community planning and preparedness with the ability to activate emergency plans to prepare and respond, coordinated across agencies at national to local levels.

Role clarification. Stakeholders are identified, their roles and responsibilities and coordination mechanisms are clearly defined and then they are documented within national and local plans, legislation, directives and memoranda of understanding, including those of technical agencies such as National Meteorological and Hydrological Services.

Resource allocation. EWS capacities are supported by adequate resources (human, financial, equipment, etc.) across national and local levels, and the system is designed and implemented for long-term sustainability.

Risk assessment. Hazard, exposure and vulnerability information are used to carry out risk assessments at different levels, as critical input into emergency planning and development of warning messages.

Appropriate warnings. Warning messages are: clear, consistent and include risk information; designed to link threat levels to emergency preparedness and response actions (using color, flags, etc.); understood by authorities and the population; and issued from a single (or unified), recognized and authoritative source.

Timely dissemination. Warning dissemination mechanisms are able to reach the authorities, other stakeholders and the population at risk in a timely and reliable fashion.

Integration into response planning. Emergency response plans are developed with consideration for hazard/risk levels, characteristics of the exposed communities (urban, rural, ethnic populations, tourists and particularly vulnerable groups such as children, the elderly and the hospitalized), coordination mechanisms and various stakeholders.

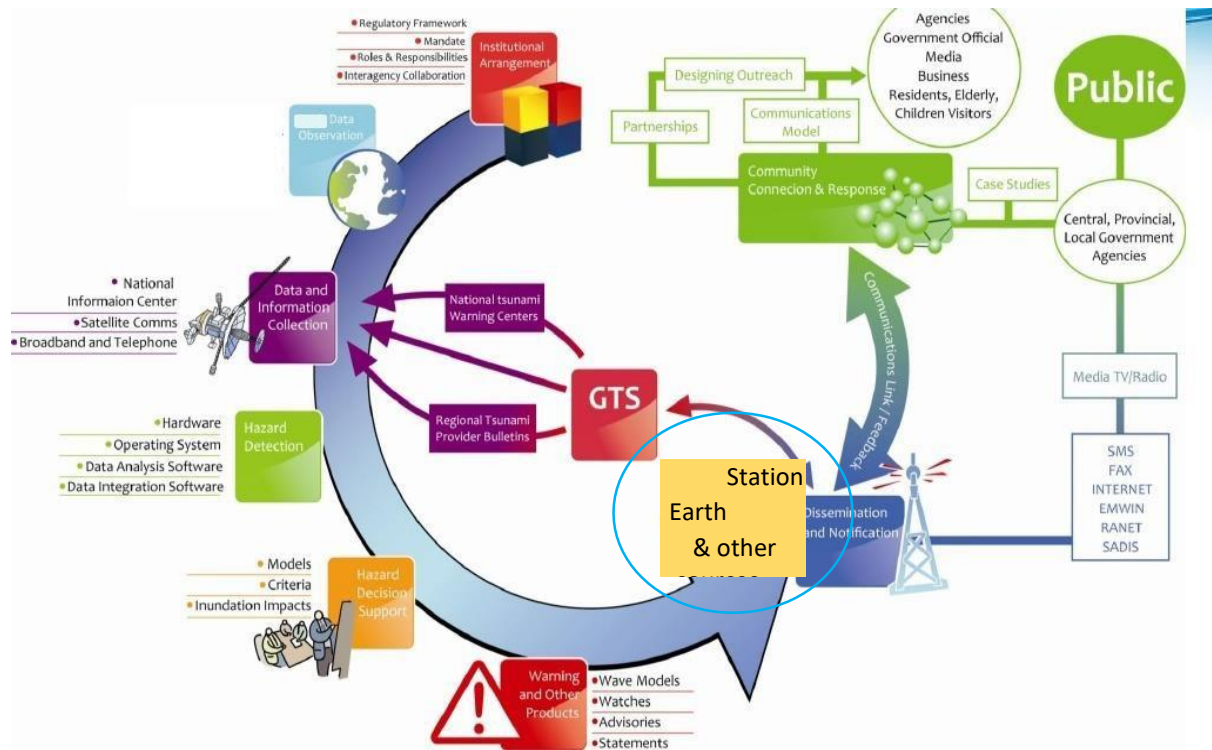
Integration in relevant educational programme. Training in risk awareness, hazard recognition and

related emergency response actions is integrated in various formal and informal educational programme and linked to regularly conducted drills and tests across the system to ensure operational readiness at any time.

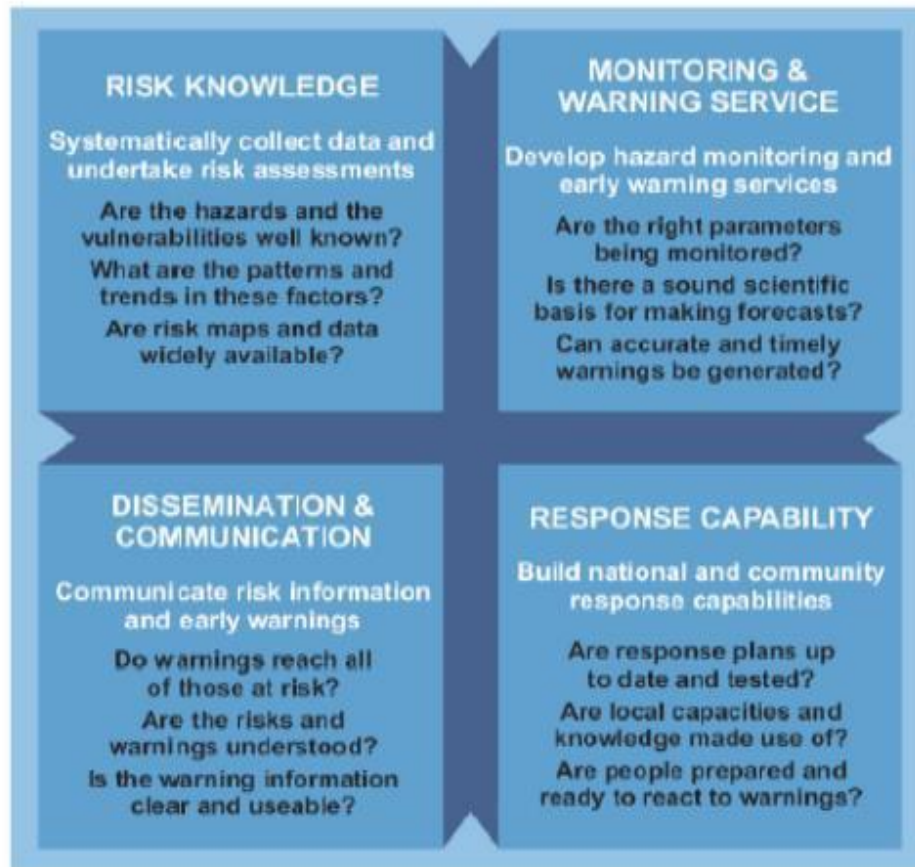
Feedback. Effective feedback and improvement mechanisms are in place at all levels to provide systematic evaluation and ensure system improvement over time.

A concept note document by UNISDR also recognized early warning as an effective approach for reducing disaster risk and the loss of life. There has been a paradigm shift from single hazard to multi-hazard early warning and from providing hazard information to providing risk and impact information. However, there are gaps in effective implementation of people-centered, multi-hazard warning systems. In addition, risk knowledge and impact information are often not at all, or insufficiently, integrated into multi-hazard early warning systems.

The development and hosting of a multi-hazard early warning system for your institution requires all the technical skills covered under the previous modules of this training, in addition to other capacities like hardware, resources and so on. However, it is very important to stress the importance of key issues to a successful early warning system like institutions in disaster governance, multi-sector working group(s), community participation, selection of appropriate methodology/technology, mainstreaming to major sectors, partnerships (Government, Non-Governmental actors, Private sector, and Research and Higher learning institutions. ...etc.) and others.



A functional and end-to-end early warning system requires addressing the following four key components according to a training material obtained from ADPC. Each of these blocks require detailed planning and expertise.



However, do not forget to start with what you already have in place. One of the good practices in developing early warning is to understand the major hazards in your country, compiling data from earth observation and data from the different sectoral ministries and non-governmental offices relevant and related to hazards and risk.

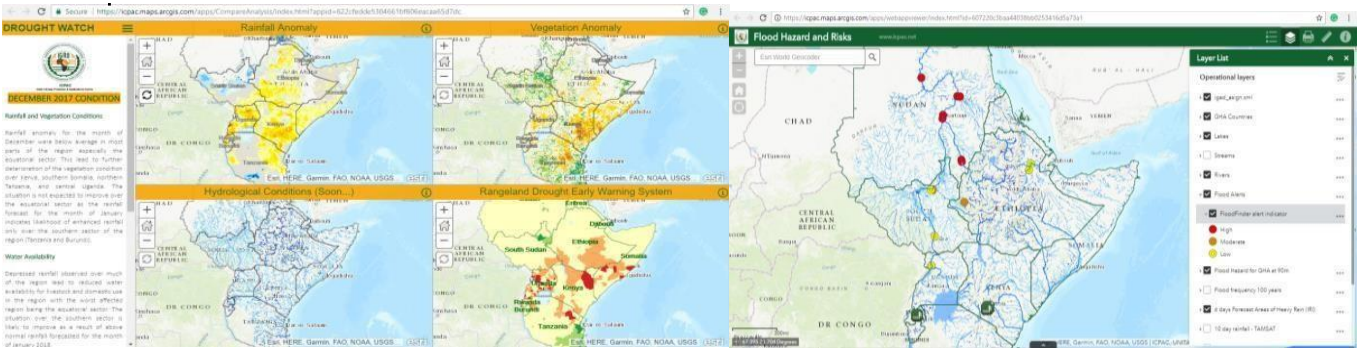
3.5.3 Components of Early Warning System

There are four components needed for an effective early warning: **Detection, monitoring and forecasting the hazards; Analyses of risks involved; Dissemination of timely warnings - which should carry the authority of government; Activation of emergency plans to prepare and respond.** These four components need to be coordinated across many agencies at national to local levels for the system to work. Failure in one component or lack of coordination across them could lead to the failure of the whole system. The issuance of warnings is a national responsibility; thus, roles and responsibilities of various public and private sector stakeholders for implementation of EWS should be clarified and reflected in the national to local regulatory frameworks, planning, budgetary, coordination, and operational mechanisms.

Component 1: Detection, monitoring and forecasting the hazards

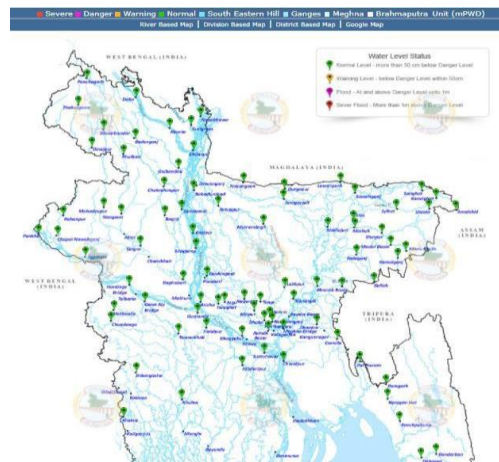
The first part of Module 3 of this training material covers detailed techniques, concepts and steps in hazard assessment which is meant to detect and identify the hazards. It is this assessment and baseline data that will constitute the monitoring of hazards based on indicators and thresholds we set for certain geographical area, as discussed under module 3. Forecasting parameters like rainfall helps to give

good lead time for preparedness and mitigation of the impending disaster but also helps to mobilize resource for response.



Monitoring based Drought early warning warning

Model based flood early warning



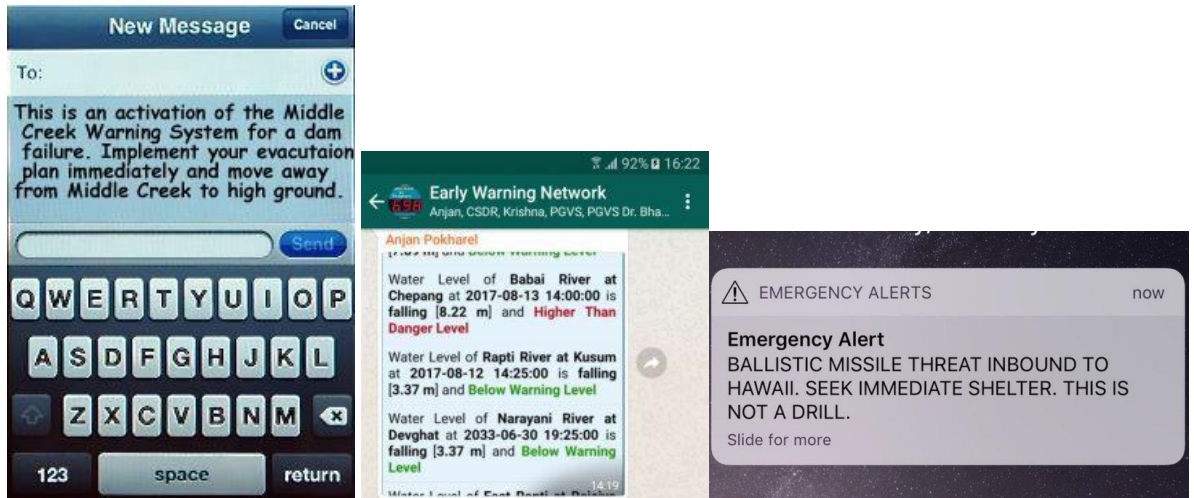
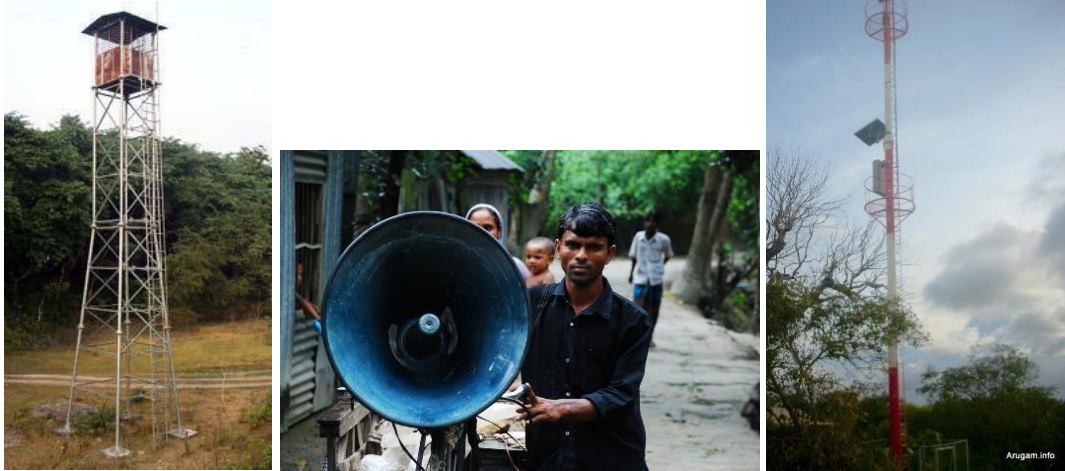
Measurement/model based flood early warning (Bangladesh, <http://www.ffwc.gov.bd/?id=river>)

Component 2: Analysis of risks involved

Detailed data on what we call “*elements at risk*” is used to map the scope and extents of the risk involved during a disaster. In flood hazard and risk assessment, for instance, once all the extent and severity of the flood is identified the next step is to overlay elements at risk which includes settlement areas, key infrastructure, crop fields, key grazing areas...etc. The choice of the elements at risk depends on the nature and magnitude of the hazard, objective of your risk assessment, data availability and other factors to mapping risk. Once you are able to produce risk maps and able to validate the final product you should clearly see the elements at risk and level of risks involved. Based on this information, you should be able to produce early warning information aimed at taking actions that would reduce the risk, mitigate the impacts, or build the resilience capacity of the communities at risk. Your early warning information contains several layers of information but needs to be clear on the type and level of risks involved (to life, property...etc) with coverage/location information, guideline on *what to do* for the responders (the community is the first responder), and so on. The experiences from early warning systems and practices reveals the strong need for people centered early warning systems.

Component 3: Dissemination of timely warnings

One of the main features of early warning is timeliness. The more time we give the warning the better for planning and preparation. The dissemination of early warning information can use different stages and platforms. Some of these platforms can be summarized as follows; automatic or manual alarms, text messages, email groups, activation of emergency systems, high level meetings...etc. depending on the nature (quick onset or slow onset) of the disaster.



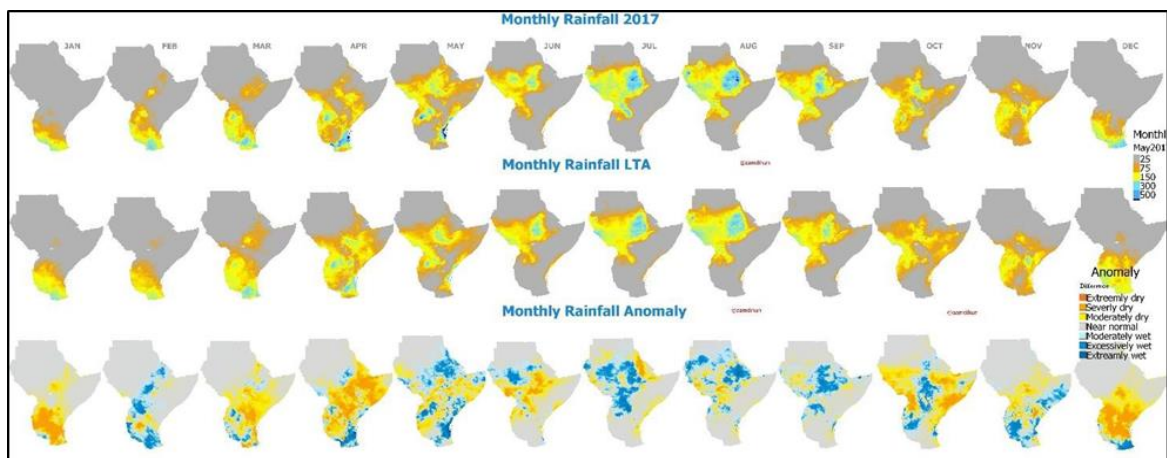
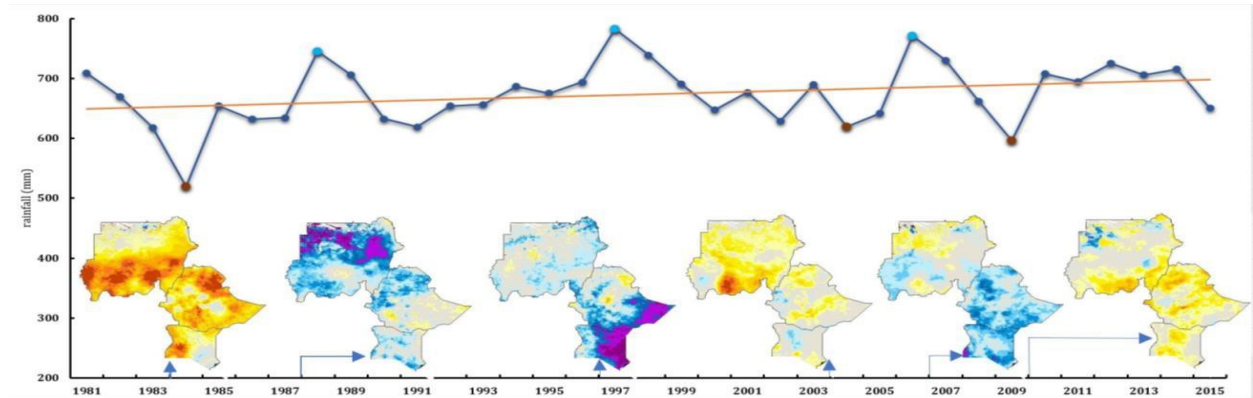
Component 4: Activation of emergency plans to prepare and respond

This is the critical stage of the early warning system where inaction or delayed action in the faces of looming hazard would result in loss of life and damage to property. Timely early warning system helps to activate an emergency plan well in time which in turn allows for sufficient time to prepare and effectively respond to a disaster.

3.5.4 Monitoring and Forecast Based Early Warning Systems

Monitoring based early warning systems

The advantage of monitoring based early warning system (EWS), as compared to forecast based EWS is its higher level of confidence and lesser uncertainty. However, monitoring requires continuous follow up of the situation starting with historical records.

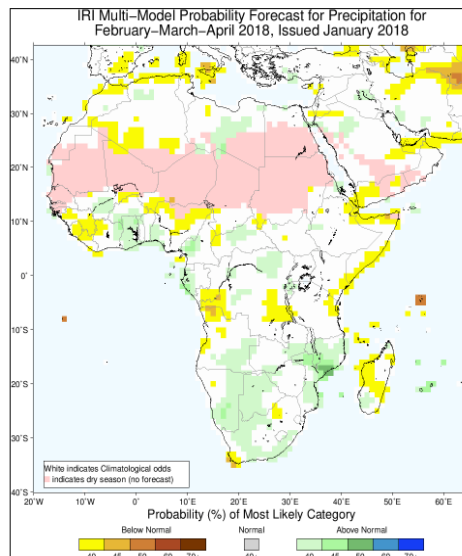
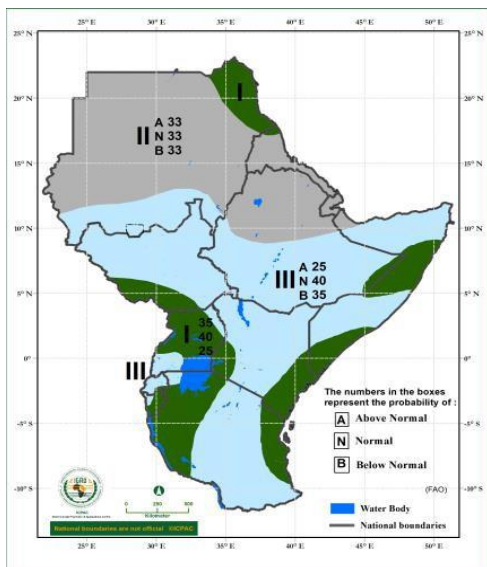


Source: Saifeldin Abdulrahman and Ahmed Amdihun, 2017

3.5.5 Forecast based early warning systems

The forecast based early warning system, in this context refers to a situation where daily, decadal, monthly or seasonal forecast of input parameter is used to deduce about a future situation or develop a future scenario. For instance, ICPAC produces seasonal forecast of rainfall and temperature and if a rainfall anomaly is calculated based on this forecast, we can qualify this as forecast based early warning.

However, it is important to note that both monitoring and forecast based early warning might not have clear boundary as both might use models and predictors or indices.

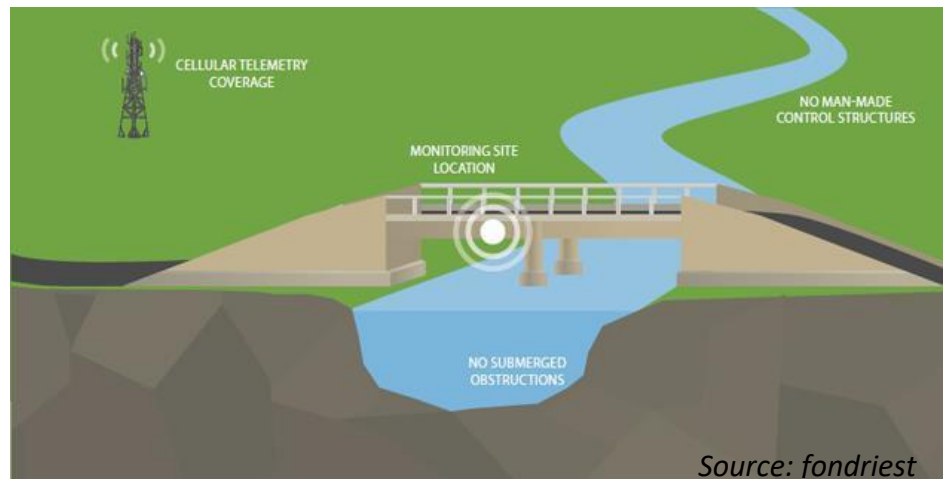


The GHACOF exercise you finalized over the last two days is a forecast based early warning system which mainly bases on expert opinion and consensus on what to expect for the coming season.

STEP (17)

3.6 Flood Monitoring and Early Warning

Many of low land areas are prone to flooding than highlands, the establishment of flood warning systems near any major waterway or body of water provides critical information that can protect property and save lives. Most effective flood warning methods extend beyond the installation of gages and telemetry equipment, and employ qualified staff and carefully designed procedures to provide the earliest warning about whether a flood should be expected, when it will occur, and how severe it will be. This guide offers instruction to individuals, communities, and organizations interested in establishing and operating flood warning systems.



Flood Risk Early Warning

An effective flood warning system is based on the regular collection of rainfall data within the basin, stream level, and stream flow data. This is achieved through routine monitoring using an automated communications process by which measurements and other data are collected at remote or inaccessible points and transmitted to receiving equipment for monitoring, and then disseminating the warning.

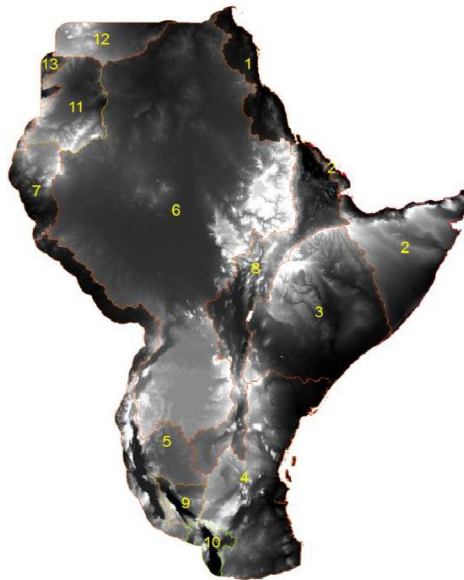
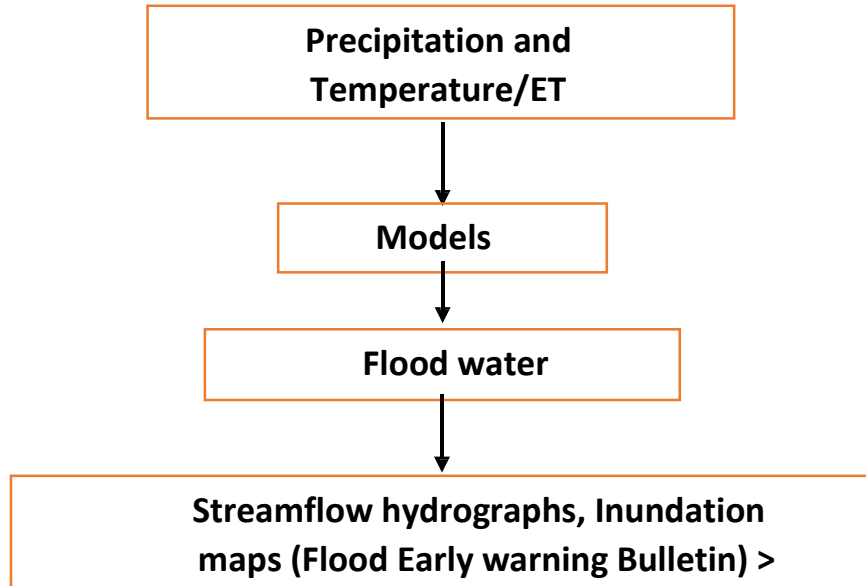
Automated flood warning systems may utilize radio, mobile phones, or satellite telemetry to communicate with a host computer or network. Most used methods to disseminate the warning are Global System for Mobile Communications (GSM) and web-based flood monitoring system.

Web-based flood monitoring system

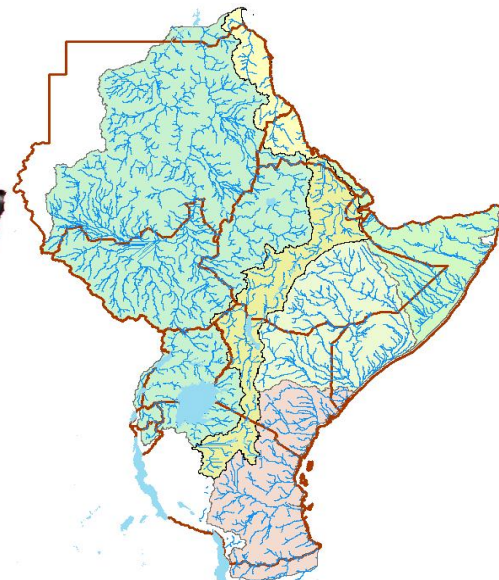
This section will highlight what ICPAC does at regional level in terms of flood early warning. Flood warning should be location based, specific in time and give the extent of coverage to assist timely actions to save lives and properties.



The approach used at ICPAC

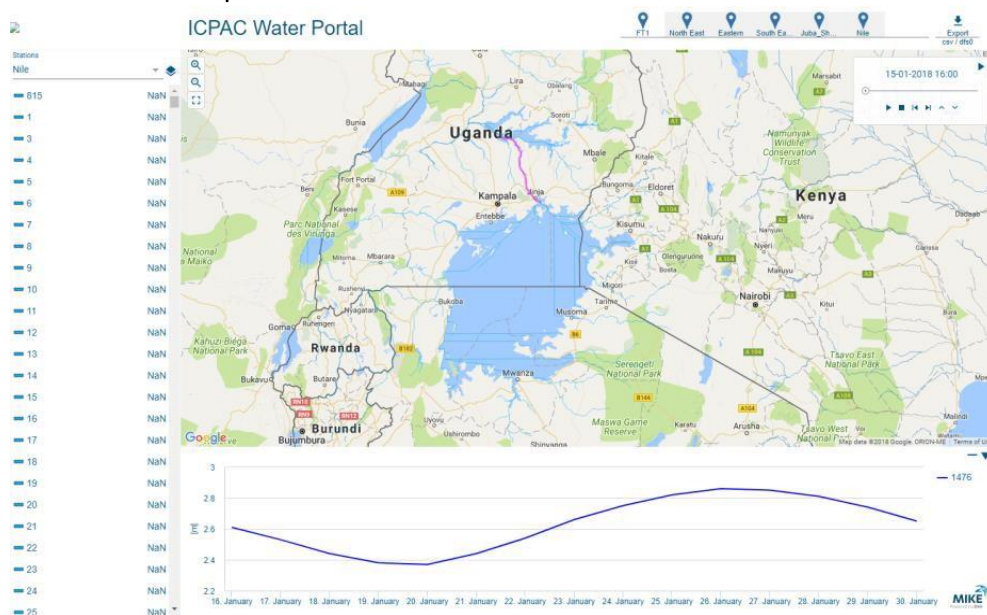
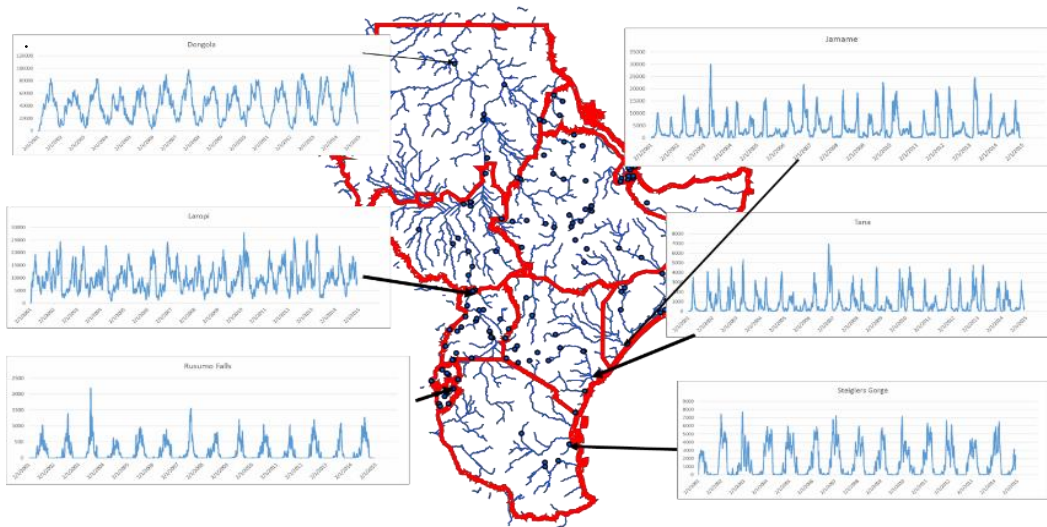


Catchment delineation based on 90m resolution DEM.



Delineated streams of catchment area > 1,000km² using GeoSFM model

Interaction with ICPAC web-based platform (underdevelopment)



You can interact with the portal from the link: 41.215.21.156

Dissemination portal – Mike operations (Underdevelopment)

Reference:

Zogg Jeffrey and Kevin Deitsch, 2013. The Flash Flood Potential Index at WFO Des Moines, Iowa, NOAA and National Weather Service Report.

4 Final Group Exercises (Floods and Droughts)

4.1.1 Group Exercise on Flood / Drought:

Task: Design and Implementation of Flood / Drought Risk using EO Data

The participants in each group should discuss among themselves and come out of with answers / make a presentation for the following questions.

1. Keeping in view of the flood/drought issues in Sudan, design a Flood/Drought Risk Assessment plan using EO Data and other database.
2. Develop a work plan to access / download the freely available and required data (satellite and GIS database) for Sudan.
3. Generate a work plan for analysis of satellite data for flood / drought hazard assessment
4. Develop a work plan for exposure assessment due to flood / drought hazard
5. Develop strategy for vulnerability and risk assessment of exposed elements for flood / drought.
6. Identify the suitable national institutions/departments/ organizations who can support the government in defor various components of risk assessment.
7. Do you see any additional support / requirement to develop a national strategy for flood and drought risk assessment in Sudan?



DRAFT PROGRAMME OF THE TRAINING

In-Country Technical Training on Hazard Assessment Using Earth Observation and GIS for Sudan, 21-25 October 2018, Khartoum, Sudan

Day One: Sunday, 21st October 2018

TIME	ACTIVITY	Responsible
08:30 - 09:00	Arrival and Registration	ICPAC
09:00 - 09:30	Welcoming Remarks Introductions Training workshop objectives and Expected Outcomes Programme of Work	HAC/IGAD Dr. Ahmed Amdihun Dr. Hari Prasad
09:45-10:30	MODULE-1: Introduction to Earth Observation and GIS (Theories and Concepts)	Dr. Hari Prasad Mr. Jully Ouma
10:30 - 10:45	Health Break (Group Photo)	
11:00 - 13:00	Applications of Geospatial Technology in Disaster Risk Reduction (Flood and Drought) HAC Presentation	Dr. Ahmed Amdihun Ms. Rispa Gicheha HAC-Representative
13:00 - 14:00	Lunch Break	
14:15 - 15:30	Introduction to ArcGIS	Mr. Jully Ouma Ms. Rispa Gicheha
15:30 - 15:45	Health Break	
15:45 - 17:00	Working with Baseline Data in GIS	Mr. Jully Ouma Ms. Rispa Gicheha

Day Two: Monday, 22nd October 2018

TIME	ACTIVITY	Responsible
08:30 - 09:00	Recap of day 1	Volunteer
09:00 -10:30	Basic Geoprocessing and spatial analysis tools	Dr. Ahmed Amdihun Dr. Hari Prasad
10:30 - 11:00	Health Break	
11:00 - 13:00	Basic Geoprocessing and spatial analysis tools	Dr. Ahmed Amdihun Dr. Hari Prasad
13:00 - 14:00	Lunch Break	



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14:00 - 15:30	MODULE-2: Earth Observation Products and Processing Satellite Image Pre-processing (Download, Composing, Mosaicing and Clipping)	Ms. Rispa Gicheha Mr. Jully Ouma
15:30 - 15:45	Health Break	
15:45 - 17:00	Satellite Image Pre-processing (Download, Composing, Mosaicing and Clipping)	Ms. Rispa Gicheha Mr. Jully Ouma

Day Three: Tuesday, 23rd October 2018

TIME	ACTIVITY	Responsible
09:00 - 09:15	Recap of day 2	Volunteer
09.15 -10:30	Image Processing (Unsupervised and Supervised Classifications)	Ms. Rispa Gicheha Mr. Jully Ouma
10:30 - 11:00	Health Break	
11:00 - 13:00	Exercise 2.1: GIS Exercise 2.2: Remote Sensing	Ms. Rispa Gicheha Mr. Jully Ouma
13:00 - 14:00	Lunch Break	
14:00 - 15:30	MODULE-3: Concepts and Terminologies in Disaster Risk Management Hazard Assessment (Drought)	Dr. Ahmed Amdihun Mr. Jully Ouma
15:30 - 15:45	Health Break	
15:45 - 17:00	Hazard Assessment (Drought)	Dr. Ahmed Amdihun Mr. Jully Ouma

Day Four: Wednesday, 24th October 2018

TIME	ACTIVITY	Responsible
09:00 - 09:15	Recap of day 3	Volunteer
09.15 -10:30	Drought Vulnerability and Risk Mapping	Dr. Ahmed Amdihun Mr. Jully Ouma
10:30 - 11:00	Health Break	
11:00 - 13:00	Drought Vulnerability and Risk Mapping	Dr. Ahmed Amdihun Mr. Jully Ouma
13:00 - 14:00	Lunch Break	
14:00 - 15:30	Hazard Assessment (Floods)	Dr. Hari Prasad Ms. Rispa Gicheha
15:30 - 15:45	Health Break	
15:45 - 17:00	Flood Hazard Assessment	Dr. Hari Prasad Ms. Rispa Gicheha



ACP-EU Natural Disaster Risk Reduction Program

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Day Five: Thursday, 25th October 2018

TIME	ACTIVITY	Responsible
09:00 - 09:15	Recap of day 4	Volunteer
09:15 - 10:30	Flood Vulnerability and Risk Assessment	Dr. Hari Prasad
10:30 - 11:00	Health Break	
11:00 - 12:15	Flood Vulnerability and Risk Assessment (Theory and Exercises)	Dr. Hari Prasad
12:15 - 13:00	Hazard Monitoring and Multi-hazard Early Warning Systems (Presentation and Discussion)	Dr. Ahmed Amdihun
13:00 - 14:00	Lunch Break	
14:00 - 15:30	Final Group Exercise (Droughts and Floods using real life examples – Remote sensing, GIS, Hazard/Risk Assessment)	Dr. Ahmed Amdihun Dr. Hari Prasad Mr. Jully Ouma Ms. Rispa Gicheha
15:30 - 15:45	Health Break	
15:45 - 17:00	Discussion and Way forward <i>Closing Remark</i>	HAC IGAD Participants

