



**GFDRR**  
Global Facility for Disaster Reduction and Recovery

ACP-EU Natural Disaster Risk Reduction Program



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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 South 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 Adaptation, 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 South Sudan

26 – 30 November, 2018

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





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



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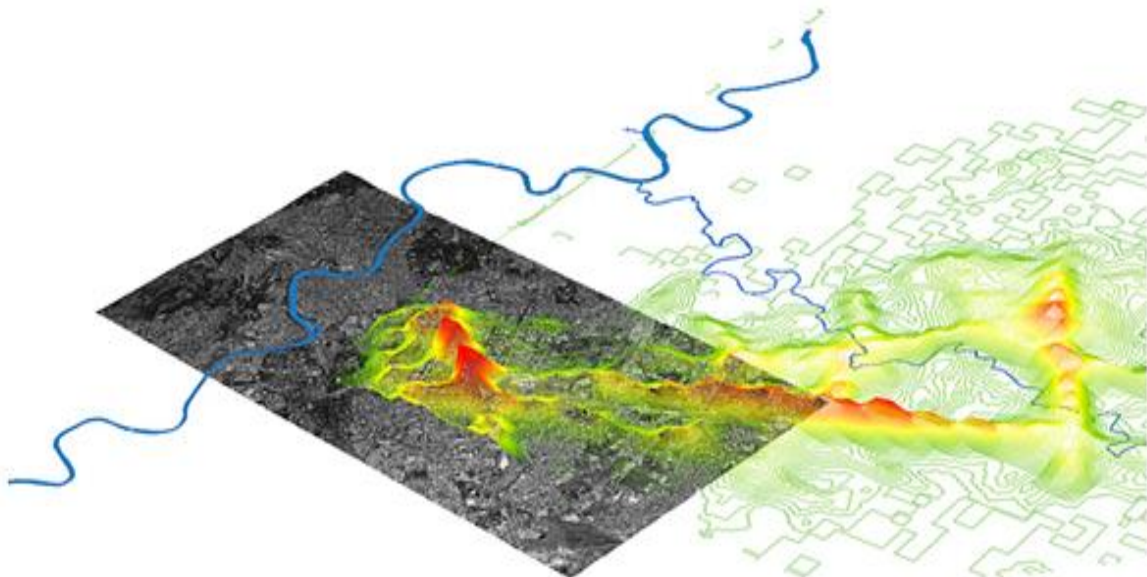
# 1 Theories and Concepts of GIS

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

1. Understand the theory and concepts of GIS
2. Get familiar with ARCGIS software along with geo-processing tools and spatial analysis
3. Identify main open GIS data sources in relation to Disaster Risk Management(DRM)
4. 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

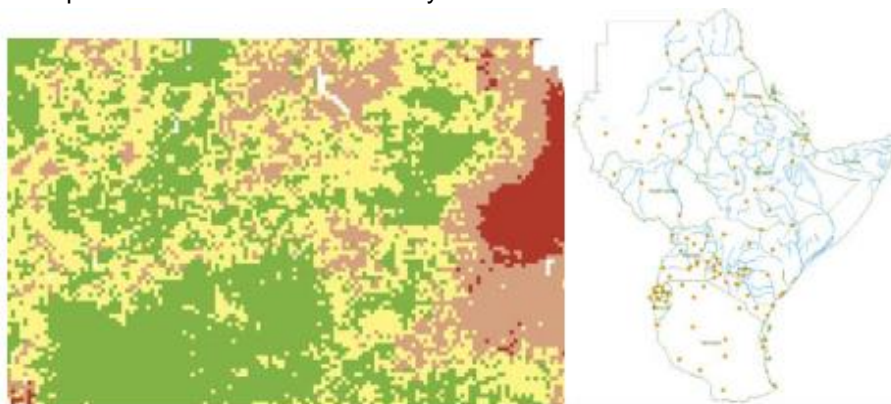
## 1.1.2 Source and Nature of Spatial Data

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

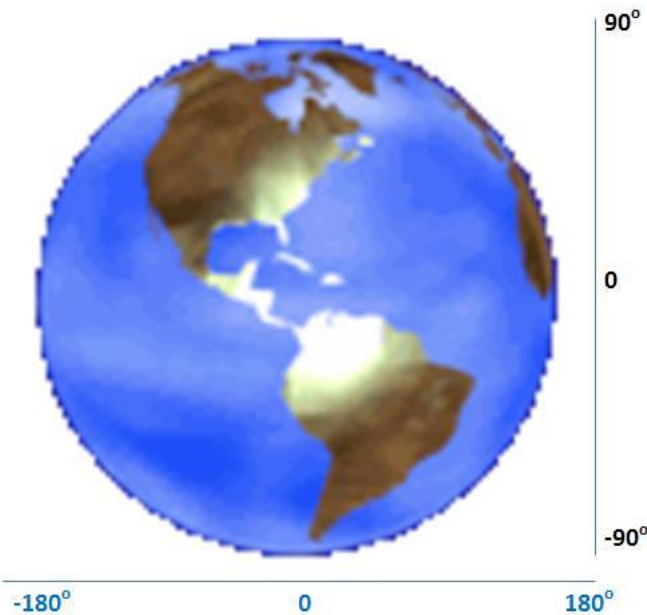


Attributes shows characteristics of a feature; any additional information that are associated with each vector feature such as land cover class or area or administrative division. So every field (column) in an attribute table refers to the attributes. Raster consists on only of a cell value associated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





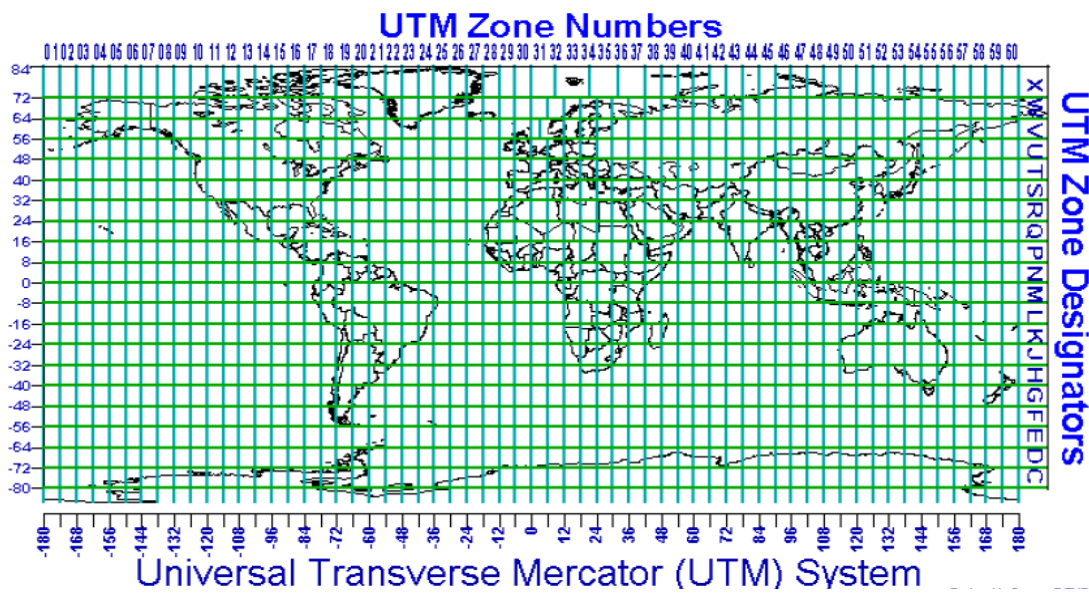
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## 1.2 Introduction to ARCGIS

### 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

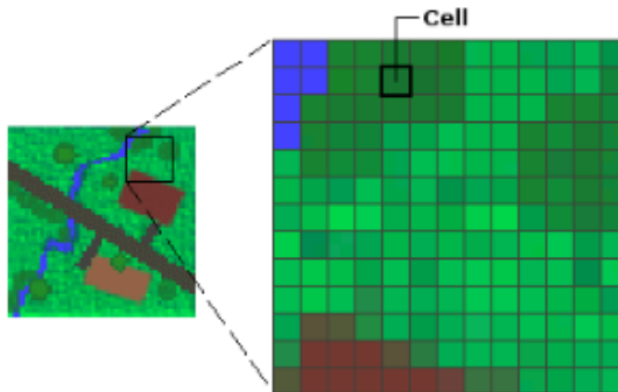
By going through this exercise you will become familiarized with some basic tools and functionalities of ArcMap and you will be able to:

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

### 1.3 GLOSSARY

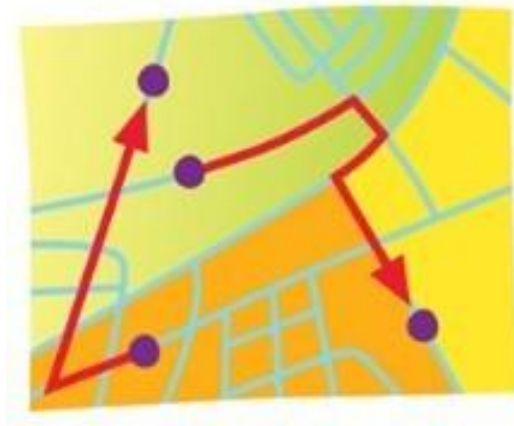
**Geographic Information System (GIS):** A system for capturing, storing, checking and displaying data related to positions on Earth's surface. GIS can handle data as several layers, in two predominant data models.

**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

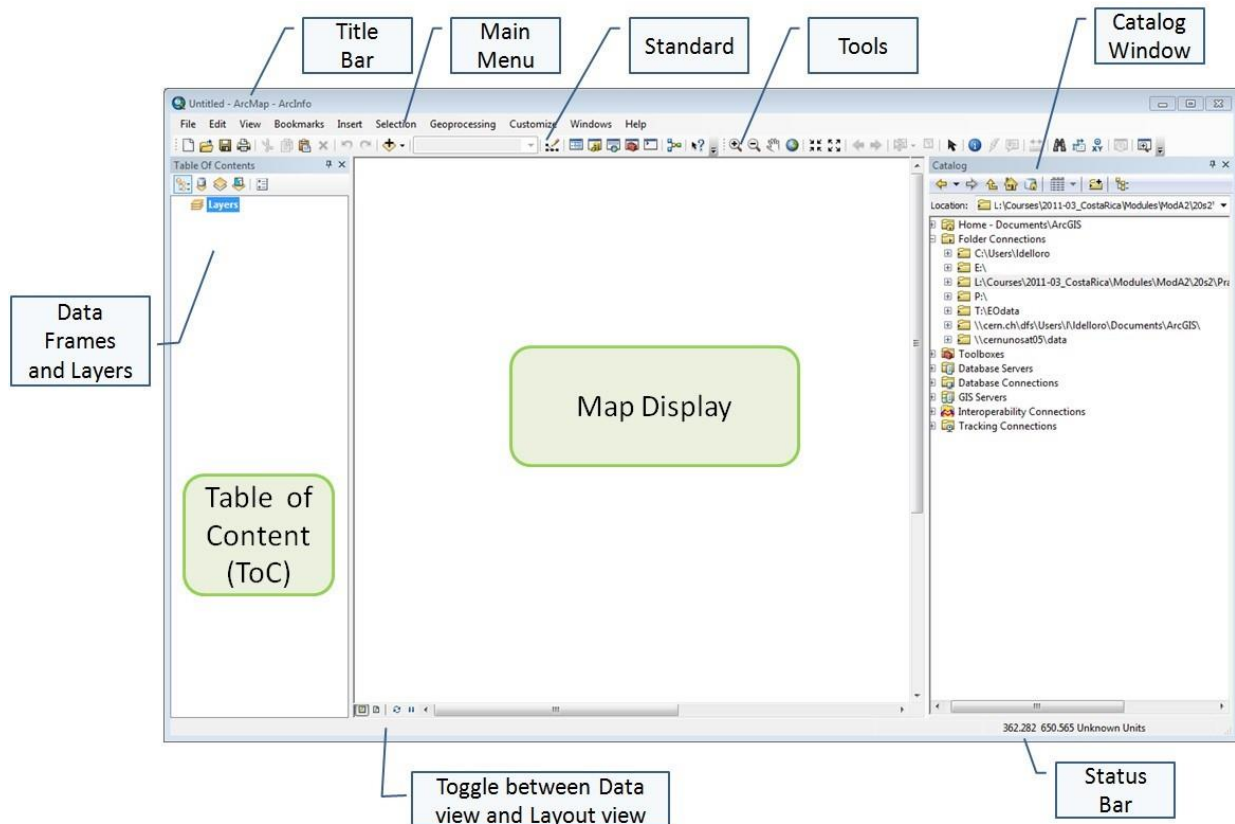
1. **Start** ArcMap by double-clicking on the ArcMap icon on your desktop . If an icon is not present, you can use the Start Menu: *Programs > ArcGIS > ArcMap*.
2. You can specify, whether or not to start with a new empty map, a template or an existing map

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

1. **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.

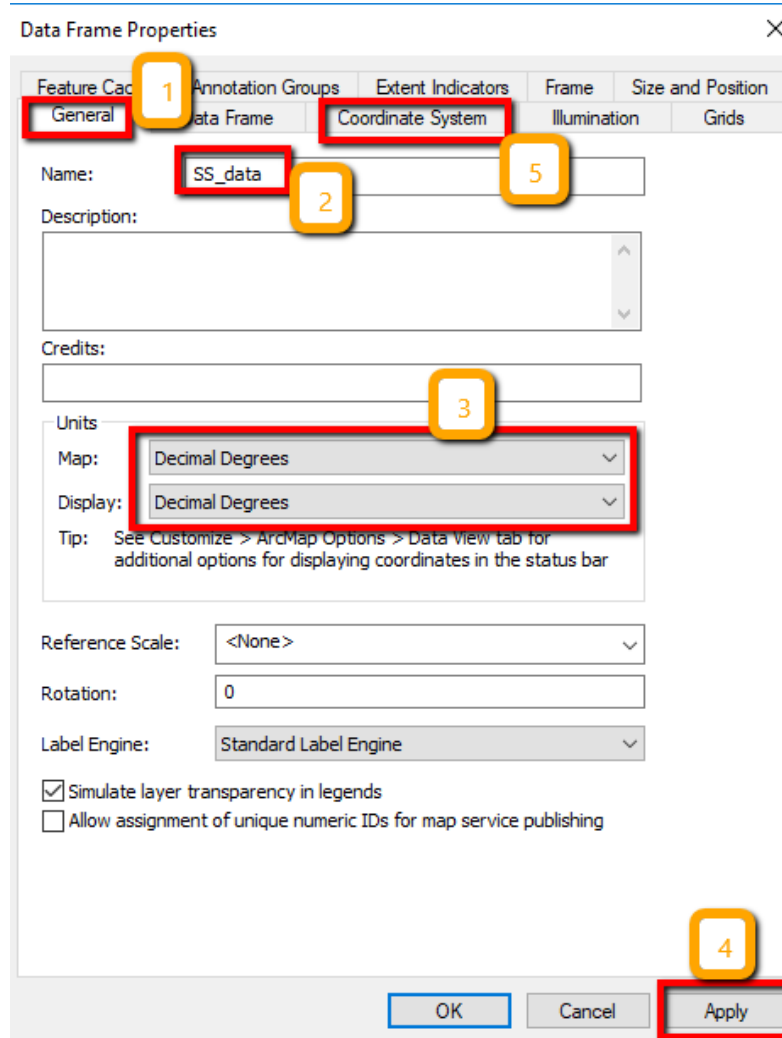


#### 1.4.3 Set Data Frame Properties

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.



1. From table of contents, **right click** on the data frame name “Layers”
2. **Select Properties > General tab**
3. In the Name section, **type “SS\_data”**
4. In the Units section, **select Decimal Degrees** for both Map and Display Units and **click Apply**



1. **Select the Coordinate System** tab and notice that no projection is selected
2. **Expand the Geographic Coordinate Systems > World > WGS 1984**
3. **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.

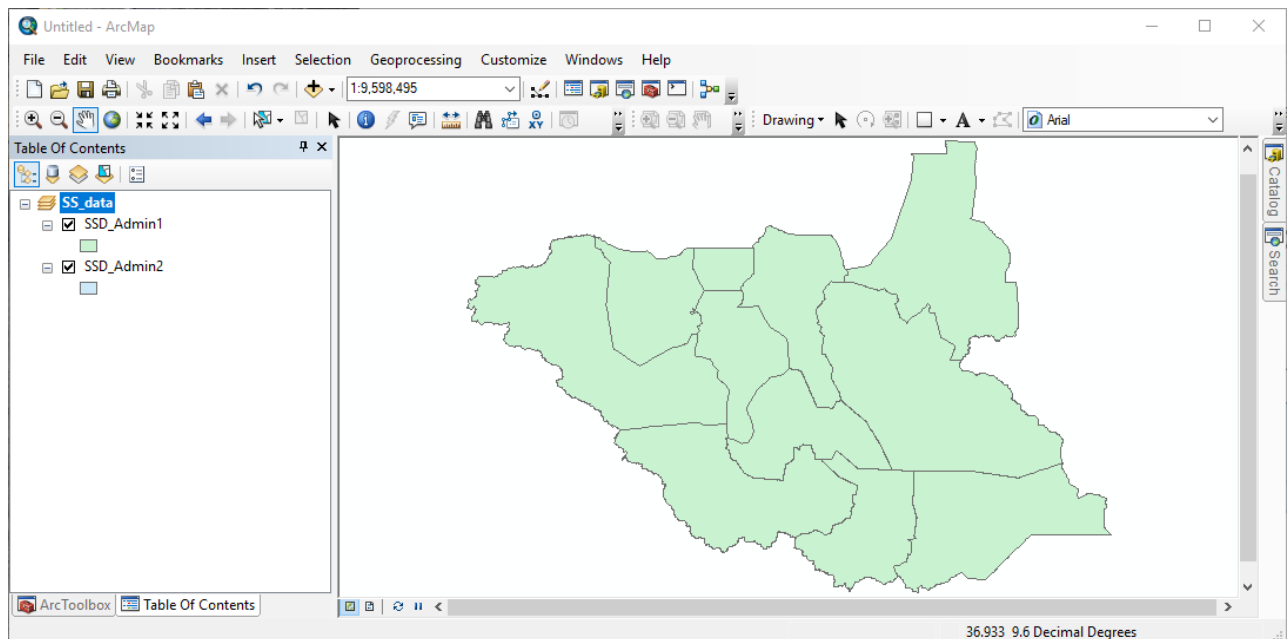


## STEP (2)

### 1.5 Working with Baseline data

#### 1.5.1 Add data into ArcMAP

1. From the standard toolbar, **click** the *Add Data* button 
2. Browse to: **X:\SSD\_data\Module1\Admin**
3. 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 
4. From Admin Folder, select *SSD\_Admin1.shp* and *SSD\_Admin2.shp*. You can select multiple files by **pressing** “Ctrl” key while selecting the files.

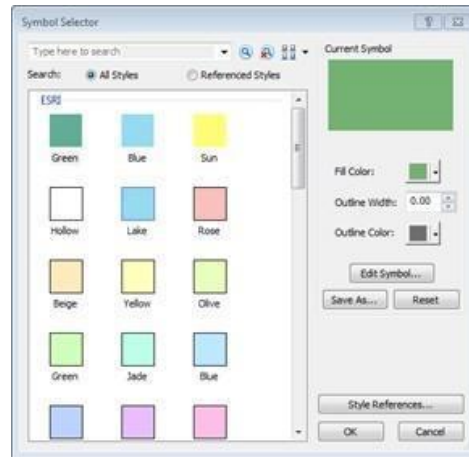


The selected layers are added to the *Table of Contents* and displayed (if checked) in the *Data View*. Layers are displayed with random colors and can always be changed.

#### 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:

1. **Double click** on the symbol(s) below the layer name.
2. From the dialog box that appears, **select** your preferred color.
3. 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.

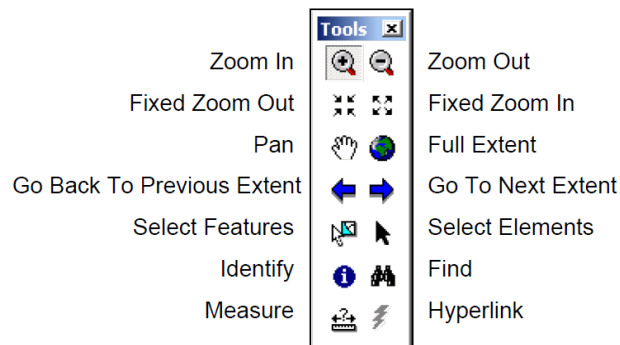
### 1.5.4 Creating a Group Layer

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:

1. **Right click** on the *Data Frame* > *New Group Layer*
2. **Right click** on the new group layer and select *Properties*
3. **Enter** “*Administrative Boundaries*” as Layer Name. You can change the name of the new group layer by single left click
4. **Select** “*Show layer at all scales*” and **Click OK**
5. **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.



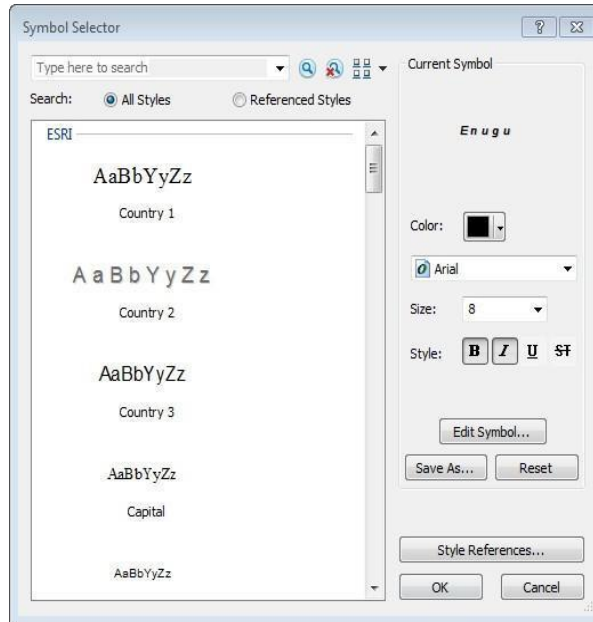


**Notice** that as you move the cursor around the map, the cursor position displayed at the bottom left of ArcMap window changes respectively.

### 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.

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



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



Layer Properties

General Source Selection Display Symbology Fields Definition Query Labels Points & Relates Time HTML Popup

Label features in this layer

Method: Label all the features the same way.

All features will be labeled using the options specified.

Text String

Label Field: STATE

Text Symbol

AaBbYyZz Arial 8 Symbol...

Other Options

Placement Properties... Scale Range... Pre-defined Label Style

Label Styles...


OK Cancel Apply





### 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.

1. **Zoom to** one place of interest (**choose** any region(s) from *SSD\_Admin1.shp*)
2. From the main menu toolbar, **click** *Bookmarks > Create*
3. In the *Spatial Bookmarks* dialog box, **type** the name of the place you have chosen
4. Zoom to full extent  and then **click** *Bookmarks > "placename"*




#### STEP (3)

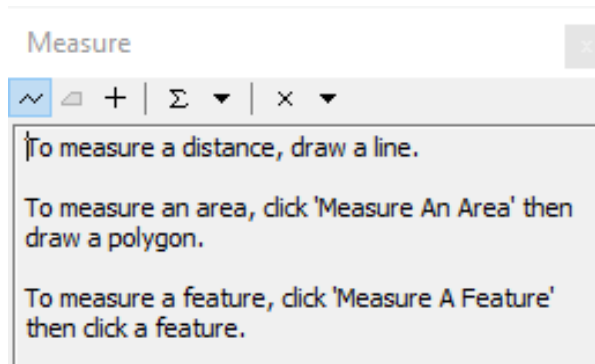
## 1.6 Information Extraction

### 1.6.1 Measure Distances

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

1. **Add** "*places.shp*" data to ArcMAP from *X:\SSD\_data\Module1\Baseline data*
2. We want to measure distance between two points.
3. From the ArcMap toolbar, **click** the Measure button 

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

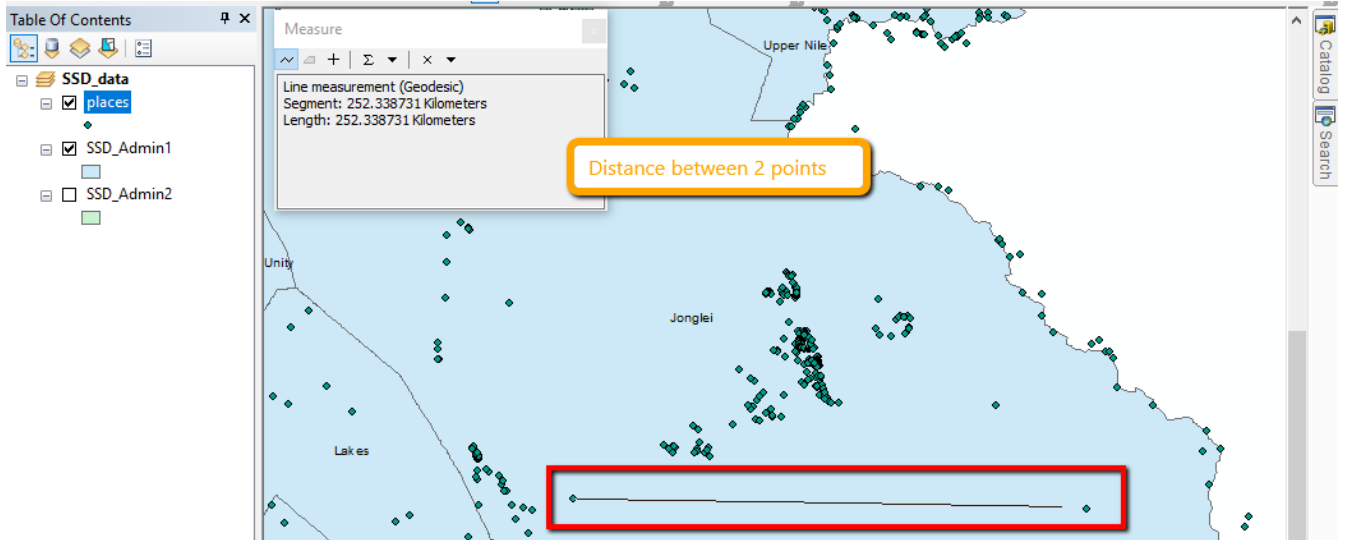


1. **Click** the *Choose Units* button and **choose** *Kilometers* for distances
2. Identify two points in **Jonglei** region that you want to measure their distance
3. **Click once** to fix the line's starting point and **move** your mouse to the desired ending point
4. You can see the distance automatically appearing in the Measure toolbar




**What is the Distance between Point 1 and Point 2 in Kilometers?** \_\_\_\_\_

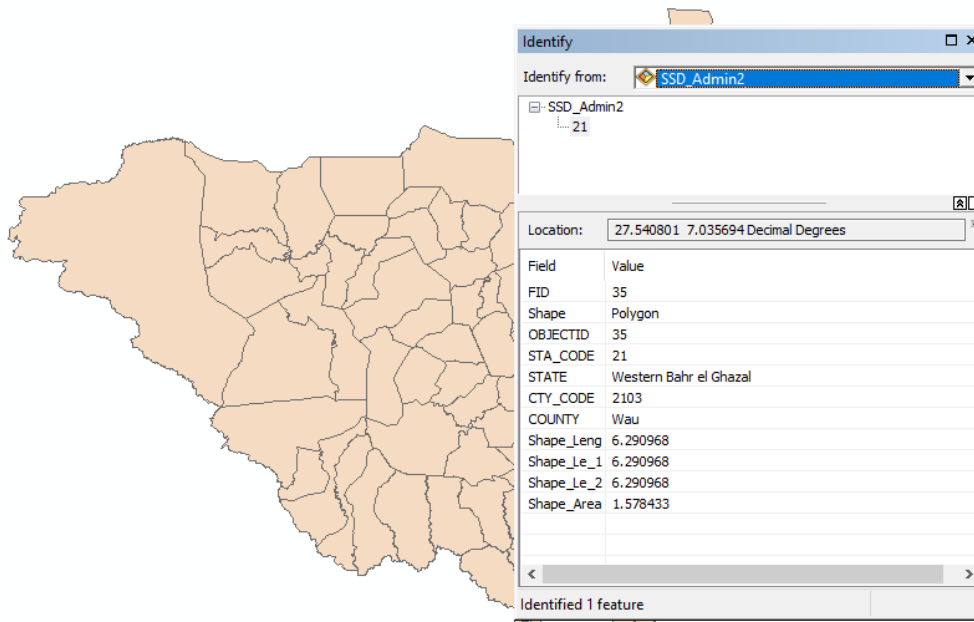




### 1.6.2 Identify Features

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

1. **Zoom** to full extent
2. From the ArcMap toolbar, **click** the *Identify* button 
3. **Click** inside any boundary




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

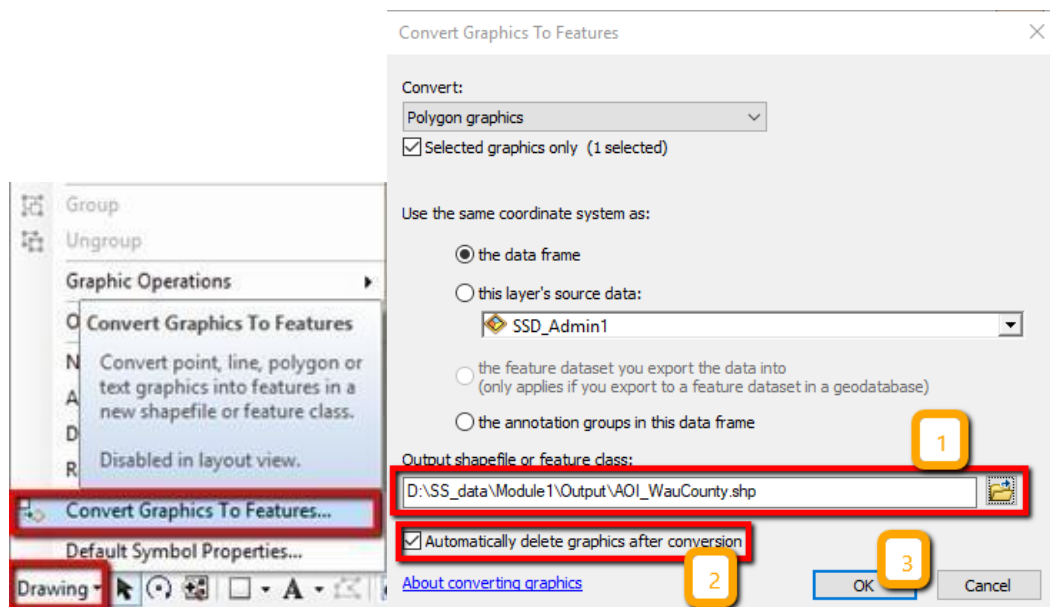
1. **Right click** on the layer in the Identify window and **click** “Zoom to”
2. **Choose** the *Identify from:* to be the layer that you want to work with
3. **Create an Area of Interest (AOI)**





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.

1. **Click** on *Customize* menu > *Toolbars* > Make sure *Draw* tool is checked
2. By using the drawing tool, **Click** on  and **draw** a new rectangle so that *Wau County* (SSD\_Admin2.shp) falls inside the rectangle (**Click** on the top-left vertex and **drag** to the vertex in bottom-right corner)
3. From the *Drawing* toolbar **click** *Drawing* > *Convert Graphics to Features*, **activate** “*Automatically delete graphics after conversion*”. Name the output layer as “*AOI\_WauCounty.shp*” and save it on: **X:\SSD\_data\Module1\Output**



1. **Click** Yes in the next dialog box to export the layer.
2. 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?**

### 1.6.3 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).




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**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*



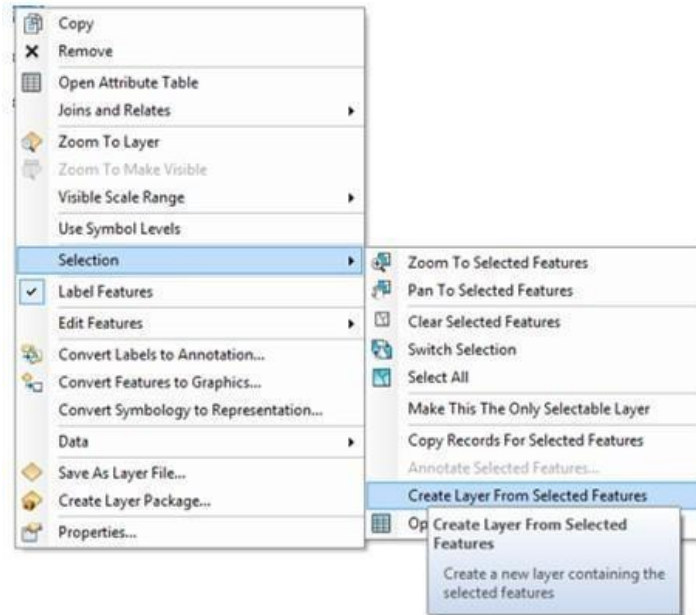
**unitar**


1. From the ArcMap toolbar, **click** on the *Select Features* button 
2. **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.

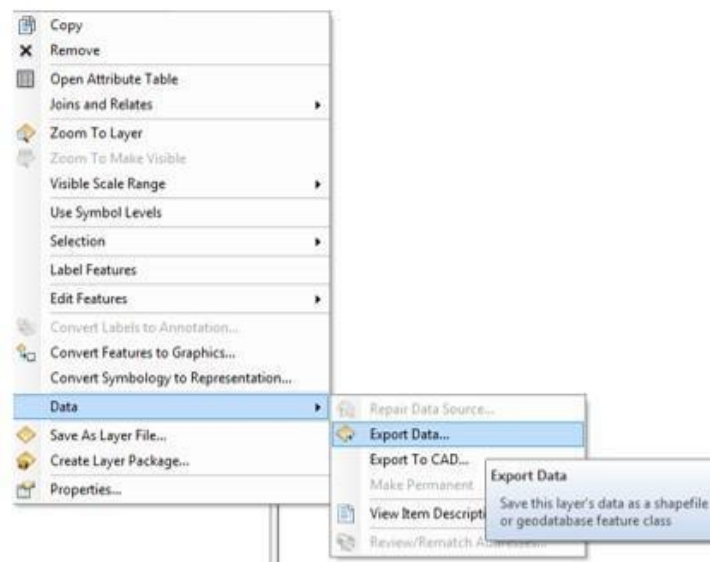
1. From the *Table of Contents*, **right click** on the feature of interest
2. **Go to** *Selection* > *Create a Layer from Selected Features*



1. Click on the *Clear Selection* button 
2. **Uncheck** the *Administrative Boundaries* group layer
3. **Right click** on the layer created from selection
4. Click on *Zoom to layer*

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

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



2. In the dialog box, under the title, 'Use the same coordinate system as' **choose** "this layer's source data"
3. **Save** the file in the following location: **X:\SSD\_data\Module1\Output**



4. **Name** the feature class to export as “ *Practice\_Selection* ”
5. **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

1. **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

1. **Right click** on the layer > *Remove*
2. **Check/activate**  the *Administrative Boundaries* group layer
3. **Right click** > *Zoom to layer*

### 1.6.4 Working with Attribute Tables

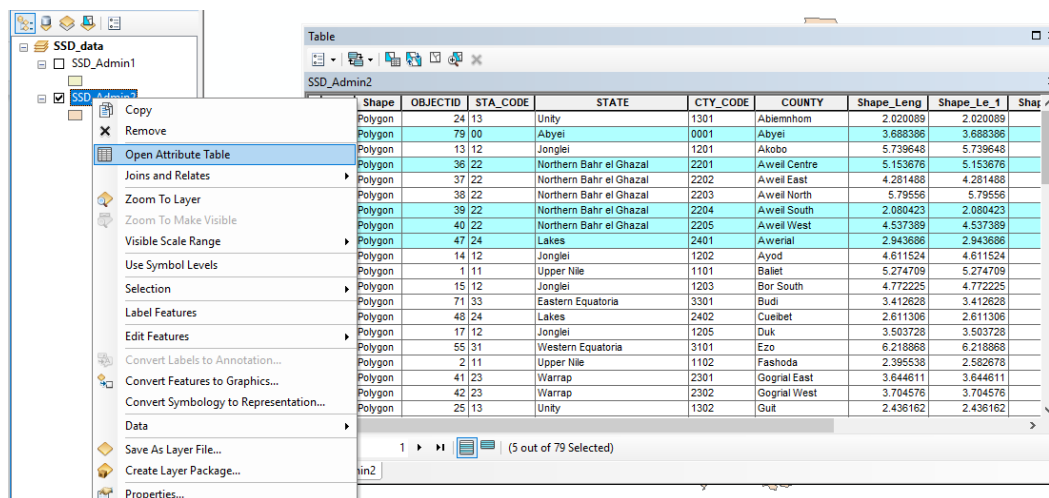
In GIS, a feature on a map may be associated with lot of information (attribute values) stored in a table. A layer’s attribute table contains a row (or record) for each feature and a column (or field) for each attribute or category (attribute field).

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

1. **Right click** on “*SSD\_Admin2*” administrative layer
2. **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).

1. **Right click** on the selected record from the table
2. **Click on Zoom to selected** or Click on this icon

To sort attribute values stored in the table:



1. **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.

### 1.6.5 Advance Selection

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

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

The Select by Attributes dialog box appears

2. **Select** "SSD\_Admin2" under *Layer*
3. **Select** *Create a new selection*
4. **Select** the attribute field "COUNTY" and
5. **Double click** on "COUNTY", **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. 'Juba'.

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

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

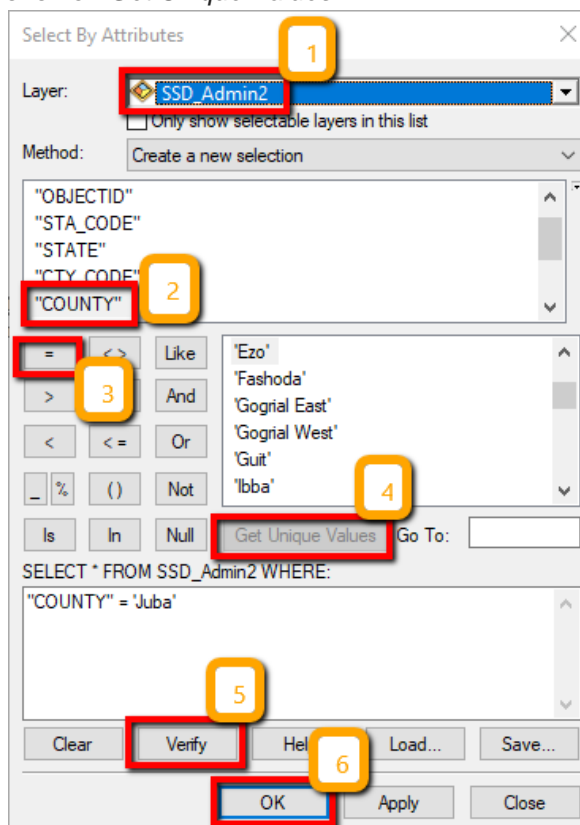
NOTE: You can select more than one region using the *IN* function as shown below:

"COUNTY" IN ( 'Guit', 'Ibba' )

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 *places* that are located inside our boundary.

10. From the standard toolbar, **click** the *Add Data* button. Alternately you can also drag and drop using the Catalog Window.
11. **Select** the *Places.shp* from Baseline data in Module1 folder (same as above).
12. Using either the selection tool or the *Select by Attributes* dialog box, **select** a feature (in this case, any region e.g. *Lakes*) from the *SSD\_Admin1.shp* layer.





13. From the *Main Menu* toolbar, **click** *Selection > Select by Locations*

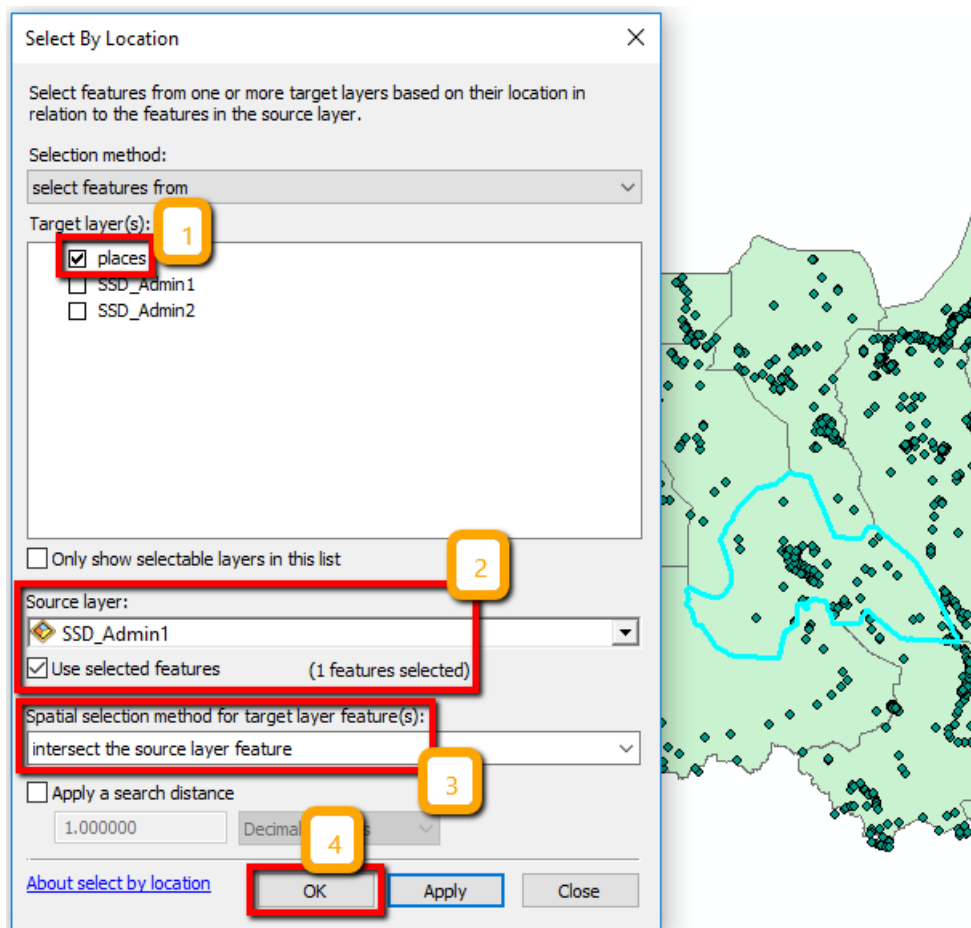
The *Select by Locations* dialog box appears:

14. **Select** features from “*places*” data layer, **choose** *Source Layer* as *SSD\_Admin1*.

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

15. **Under** *Spatial selection method for target layer feature(s)* **choose** “*intersect the source layer feature*”

16. **Click** *OK*



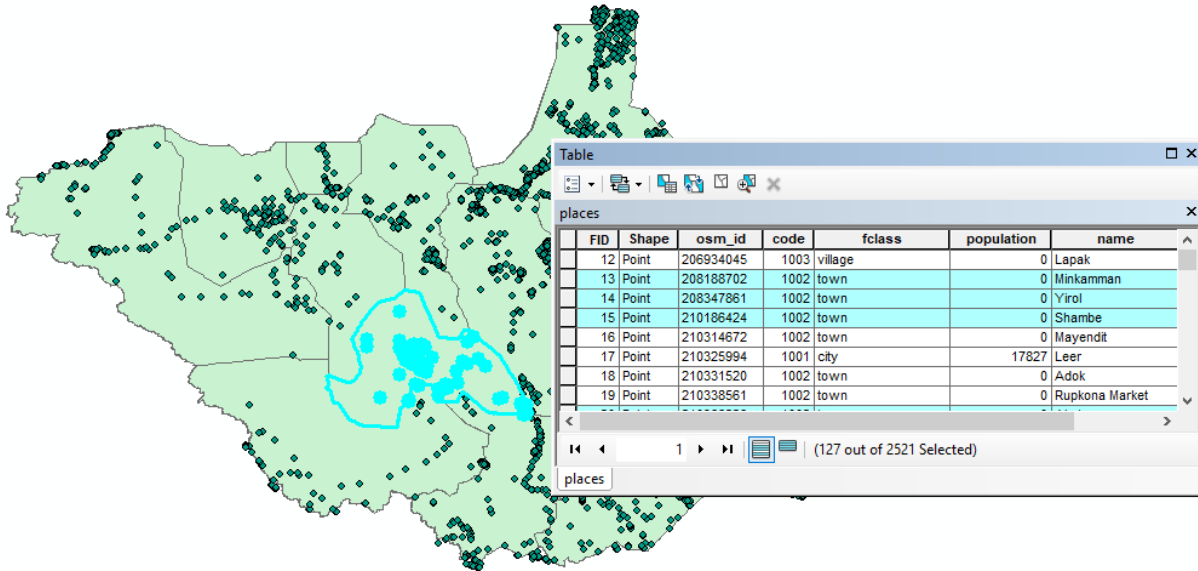
17. **Click** *Selection > Zoom to Selected Features*

18. **Right click** on *places* > *Open Attribute Table*

19. **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):





15. Click *Clear Selection* button and then zoom to *full extent*

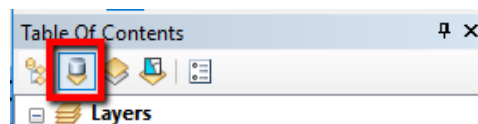
## 1.7 Joining Tables

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 shapefile.

In this exercise you will be joining the rainfall mean of the 2nd dekad of March 2017 data to the level 1 (SSD\_Admin1) administration boundary polygons.

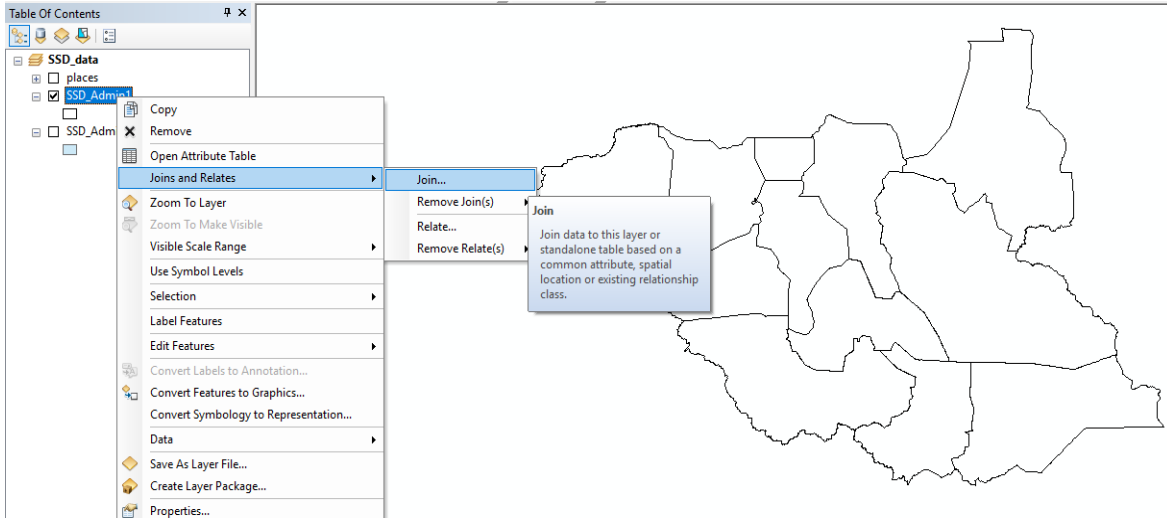
1. Add “SSD\_Admin1.shp” and “Rainfall2.3.2017.txt” data to ArcMap from this location;  
X:\SSD\_data\Module1\Baseline data

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



Join the attributes of the “Rainfall2.3.2017” table to the Attribute table of “SSD\_Admin1”.

2. **Right-click** the layer or table you want to join (SSD\_Admin1), **point** to *Joins and Relates* > **click** *Join*.



2. **Click** the first drop-down arrow and **click** *Join attributes from a table*.
3. **Click** the second drop-down arrow and **click** the field name in the layer “STATE” on which the join will be based.
4. **Click** the third drop-down arrow to **choose** the table to join to the layer “Rainfall2.3.2017.txt”.
5. **Click** the fourth drop-down arrow and **click** the field in the table on which to base the join “STATE”.
6. **Click** OK





Join Data

Join lets you append additional data to this layer's attribute table so you can, for example, symbolize the layer's features using this data.

What do you want to join to this layer? **1**

Join attributes from a table

1. Choose the field in this layer that the join will be based on: **2**

STATE

2. Choose the table to join to this layer, or load the table from disk:

Rainfall2.3.2017.txt **3**

Show the attribute tables of layers in this list

3. Choose the field in the table to base the join on: **4**

STATE

Join Options

Keep all records

All records in the target table are shown in the resulting table. Unmatched records will contain null values for all fields being appended into the target table from the join table.

Keep only matching records

If a record in the target table doesn't have a match in the join table, that record is removed from the resulting target table.

Validate Join

**5**

OK Cancel

[About joining data](#)

Open the attribute table of "SSD\_Admin1". The attributes of the table are appended to the layer's attribute table.

Table

SSD\_Admin1

Shape_Le_1	Shape_Le_2	Shape_Area	Lat	LAT_1	OID	STATE	MEAN
3.688386	3.688386	0.86525	0	0	<Null>	Abyei	0.877079
0	15.050708	7.136404	0	0	<Null>	Upper Nile	1.185293
0	15.682004	9.997347	0	0	<Null>	Jonglei	5.671798
0	10.597308	3.774714	0	0	<Null>	Unity	1.529947
0	18.522545	8.512203	0	0	<Null>	Western Bahr el Ghazal	2.818569
0	8.591027	3.397506	0	0	<Null>	Northern Bahr el Ghazal	1.208664
0	9.009811	2.948308	0	0	<Null>	Warrap	2.534482
0	10.498765	3.535979	0	0	<Null>	Lakes	9.623569
0	15.504564	6.447208	0	0	<Null>	Western Equatoria	20.65036
0	10.964873	3.513336	0	0	<Null>	Central Equatoria	18.964023
0	12.727294	6.057537	0	0	<Null>	Eastern Equatoria	13.356752

(0 out of 11 Selected)

SSD\_Admin1



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

Shape_Le_1	Shape_Le_2	Shape_Area	Lat	LAT_1	OID	STATE	MEAN
3.688386	3.688386	0.86525	0	0	0 <Null>	Abyei	0.8770
0	15.050708	7.136404	0	0	0 <Null>	Upper Nile	1.1852
0	15.682004	9.997347	0	0	0 <Null>	Jonglei	5.6717
0	10.597308	3.774714	0	0	0 <Null>	Unity	1.5299
0	18.522545	8.512203	0	0	0 <Null>	Western Bahr el Ghazal	2.8185
0	8.591027	3.397506	0	0	0 <Null>	Northern Bahr el Ghazal	1.2086
0	9.009811	2.948308	0	0	0 <Null>	Warrap	2.5344
0	10.498765	3.535979	0	0	0 <Null>	Lakes	9.6235

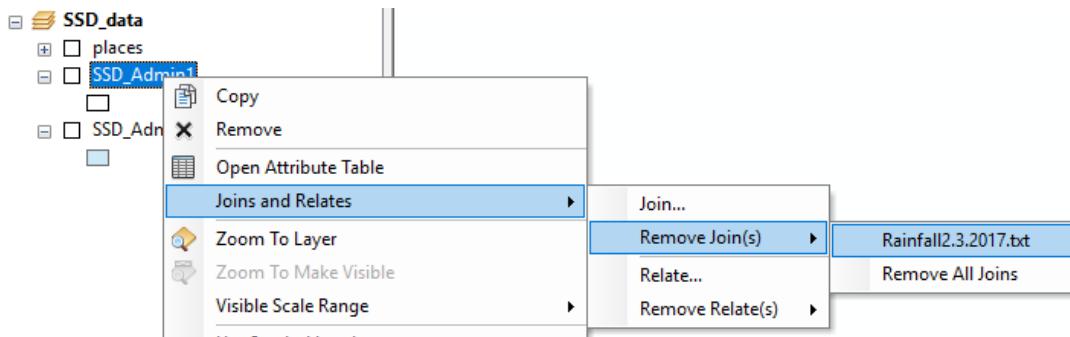


Which State has the highest amount of mean rainfall for the Dekada? \_\_\_\_\_

Which State has the least amount of mean rainfall for the Dekada? \_\_\_\_\_

**NOTE:** You may want to remove the current join from “SSD\_Admin1” to do so, here is the procedure;

2. **Right-click** the layer containing a join you want to remove and point to *Joins and Relates*.
3. **Point to Remove Join(s)** and **click** the join you want to remove “Rainfall2.3.2017.txt”.



## 1.8 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 ArcGIS to handle the various chores of a day to day GIS activities.

### 1.8.1 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.

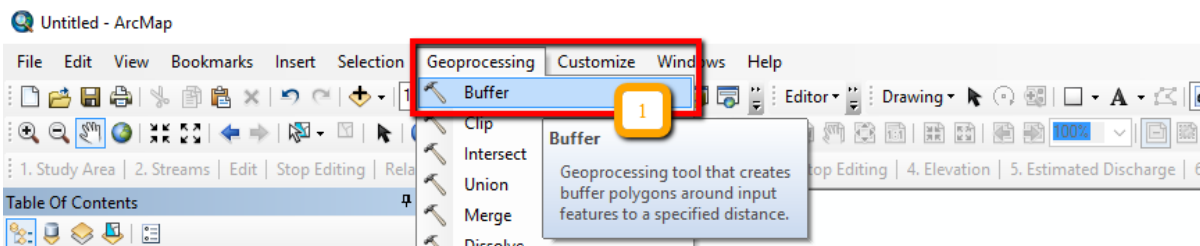


#### STEP (4)

### 1.8.2 Buffer Analysis

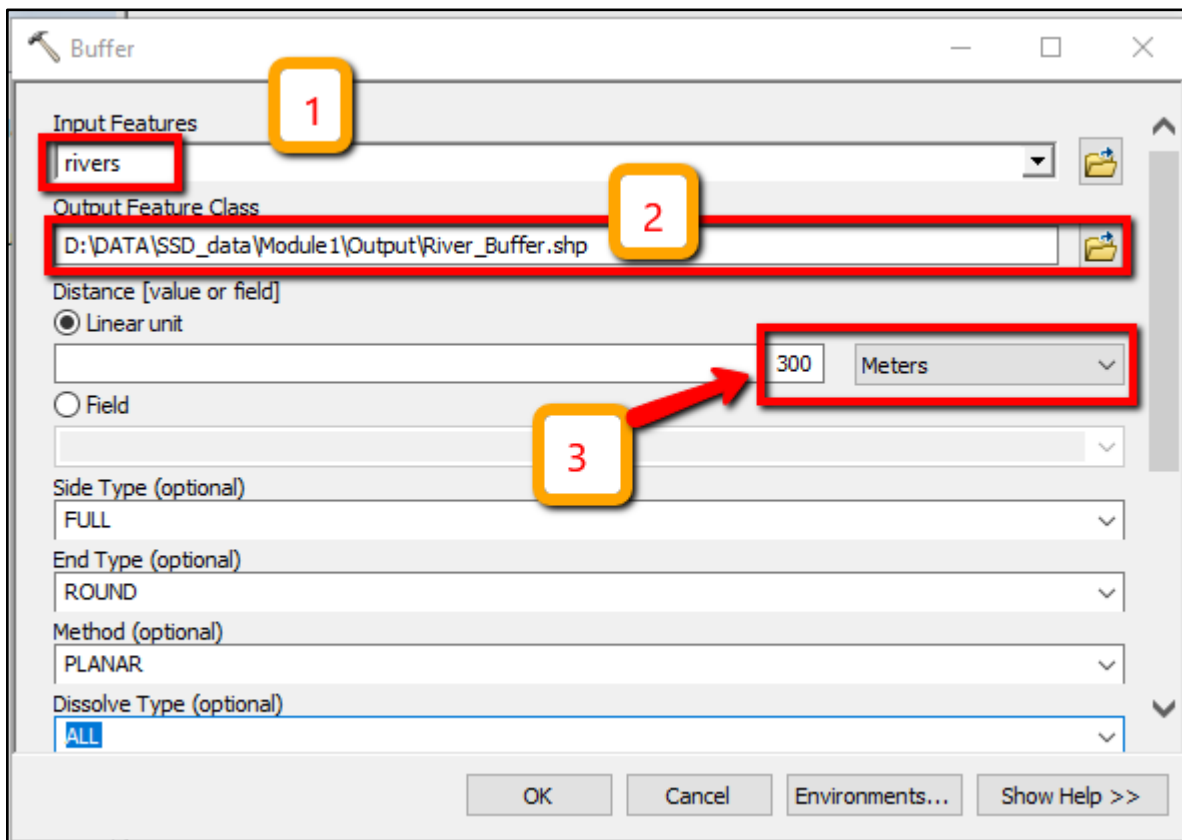
Buffer analysis is one of the most important **Geoprocessing** tools that help to identify proximity of places from a reference layer. For instance, if you wish to identify road networks within 3km of water points you can easily identify them. Let’s create a buffer of 300m from a **Major rivers** and see how far people should build of farm from the river.

1. **Open ArcMap and add** the layer for *Rivers* from *X:\SSD\_data\Module1\Baseline* data folder
2. **Click on Geoprocessing** from the Menu Bar > then **Click on Buffer**



3. Under *Input Features* **select “Rivers”**
4. **Save Out Feature Class as River\_Buffer.shp** *X:\SSD\_data\Module1\Output*

5. *Linear Unit* should be 300 meters > **Click OK**
6. **Zoom in** to one river line to see the buffer area of 300m.



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

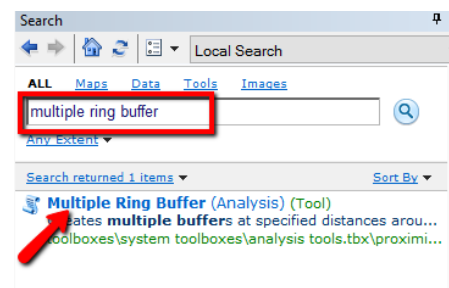


What if we want different buffer distance like 1km, 5km, and 10km to show from most to least areas at risk of flood hazard?

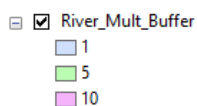
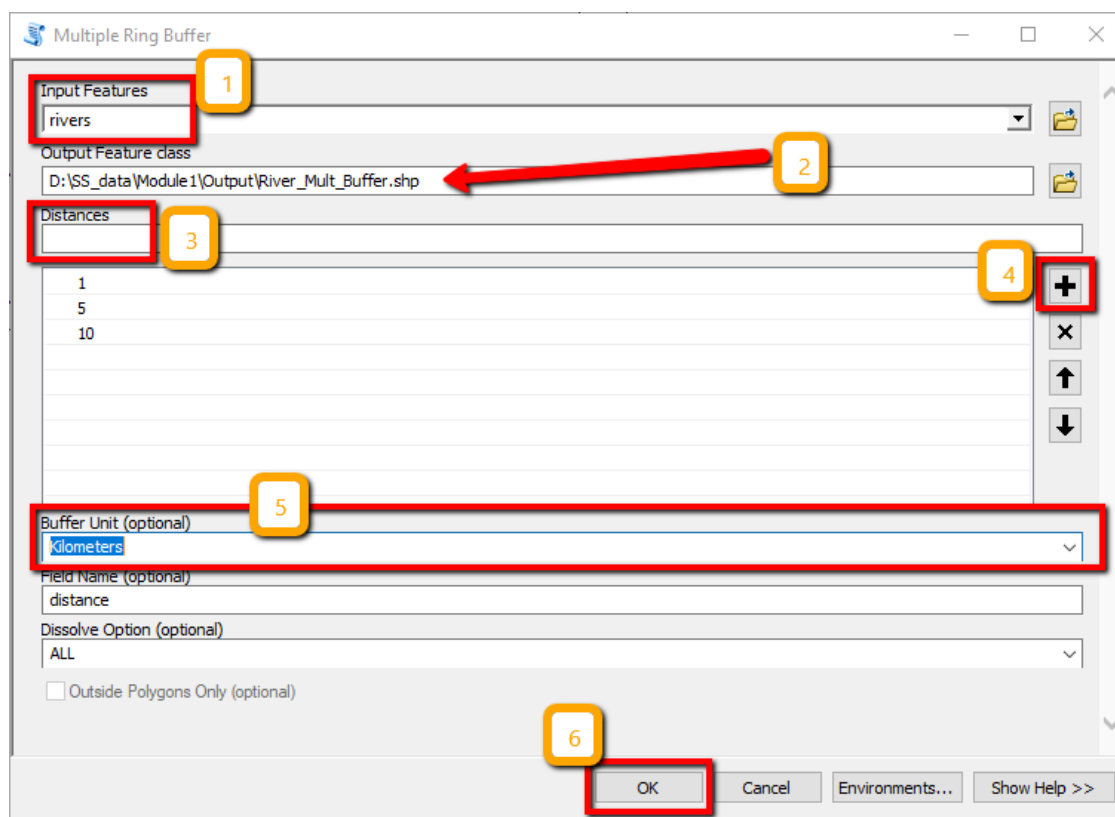
### 1.8.3 Multiple Ring Buffer

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:\SSD\_data\Module1\Output**
- 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.



### 1.8.4 Intersect

This is an important geoprocessing tool to find the intersection between two or more layers. It has a practical application, for instance if you wish to calculate the Primary road coverage across the different Counties of South Sudan you can intersect primary roads with admin2 layer.

- Open ArcMap and **Add** roads layer and *SSD\_Admin2* from *X:\SSD\_data\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 *roads* layer and *SSD\_Admin2* as intersect features
- **Save** the Output feature class to *X:\SSD\_data\Module1\Output* folder with the name *Primaryroads\_districts.shp* and **click** *Ok*.



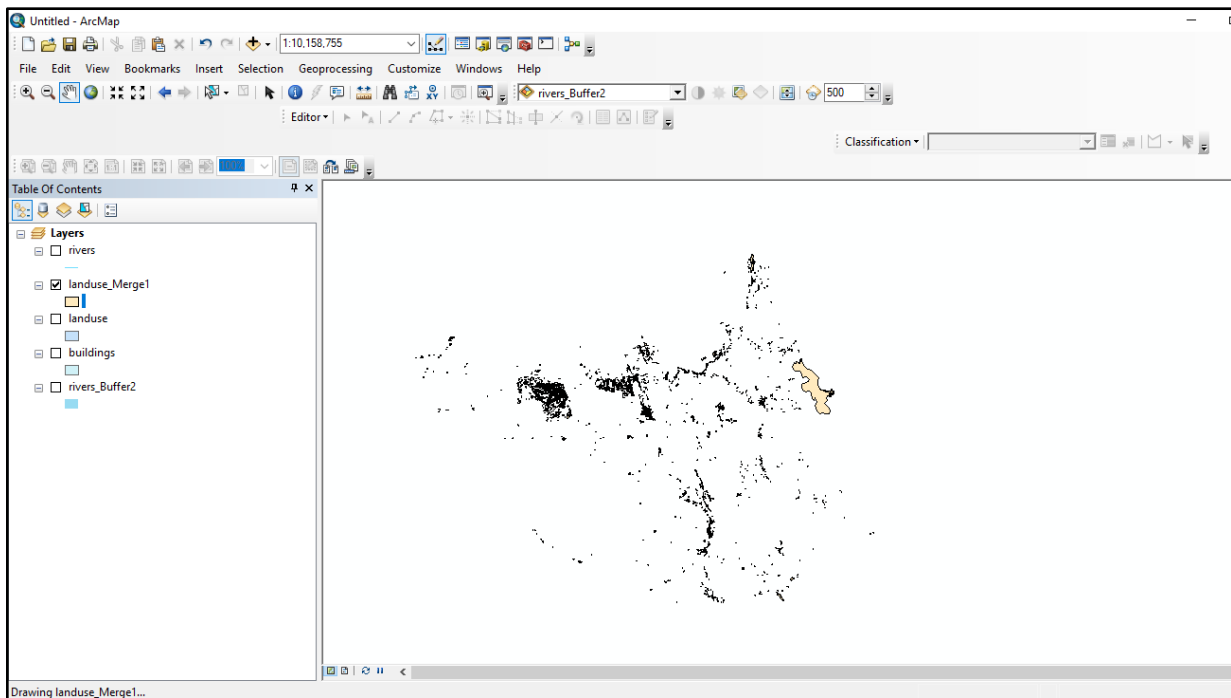
- Now you can open the attribute table of the **Primaryroads\_districts.shp** to see that the district names are attached to the roads table. This means that you can also calculate the distance of roads in each of the region. You can classify the **Primaryroads\_districts.shp** to see the road map in each region.

### 1.8.5 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 you want to merge land use layer with buildings layer for certain analysis purposes.

Let's **merge** the *buildings* and *land use* layers in South Sudan for further analysis.

- **Add** the *buildings* and *landuse* layers from **X:\SSD\_data\Module1\Baseline\_data**
- **Search** for a tool *Merge* and **open**. Set the *buildings* and *landuse* as inputs layers
- **Save** the *Output feature class* to **X:\SSD\_data\Module1\Output** folder with the name *Building\_landuse.shp* and **click OK**
- If you open the layer, you will notice that the two layers and their attribute tables are combined.



### 1.8.6 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.

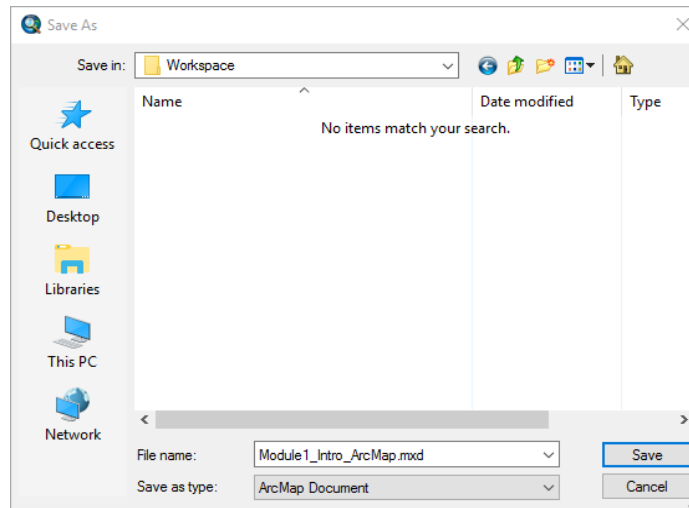
If you haven't saved the map project before and you want to save it into a desired folder location:





7. Click **File > Save As**.

8. Enter the name "*Module1\_Intro\_ArcMap.mxd*" and **save** it on: **X:\SSD\_data\Module1\Output**



### STEP (5)

## 1.9 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.

### 1.9.1 Baseline Geospatial Data for Disaster Risk Assessment

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

Web Portal	Web Link	Data Description	Data Type
ICPAC-Geoportal	<a href="http://geoportal.icpac.net/">http://geoportal.icpac.net/</a>	Free regional data	Vector/Raster
Drought Wathc	<a href="https://icpac.maps.arcgis.com/apps/CompareAnalysis/index.html?appid=622cfedde5304661bf606eaca65d7dc">https://icpac.maps.arcgis.com/apps/CompareAnalysis/index.html?appid=622cfedde5304661bf606eaca65d7dc</a>	Free	Web-Map



**GFDRR**  
Global Facility for Disaster Reduction and Recovery

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



**unitar**  
United Nations Institute for Training and Research

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



**MODULE: 2**  
**INTRODUCTION TO EARTH OBSERVATION (REMOTE SENSING)**

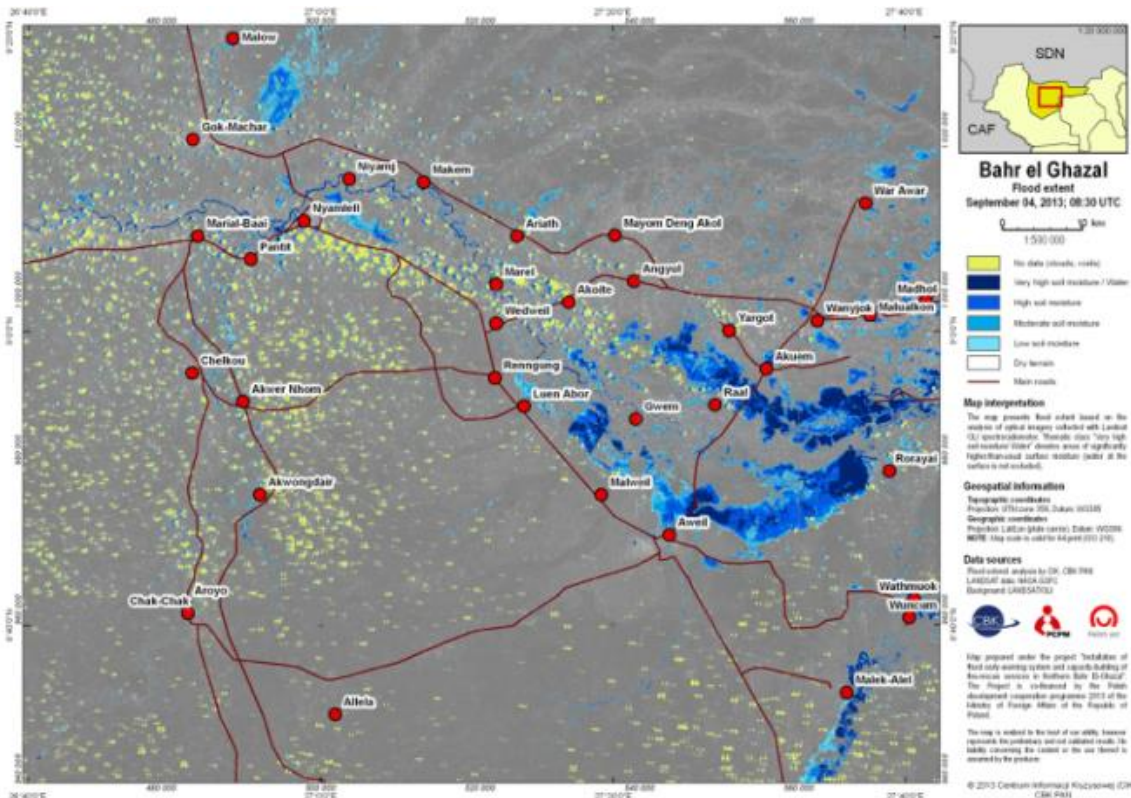


## 2 Theories and Concepts on Earth Observation/Remote Sensing

### 2.1 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.



South Sudan: Bahr El-Ghazal flooding extent - September 04, 2013. Image Source: reliefweb.

### 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:

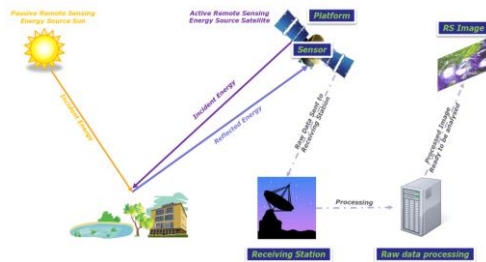
1. Understand the concept of Remote Sensing.
2. Download Sentinel-2 data from the Web.
3. Load satellite imageries into ArcMap.
4. Perform band combinations (Composing).



5. Mosaicing for different screens.
6. Clip raster data with using AOI.
7. 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.



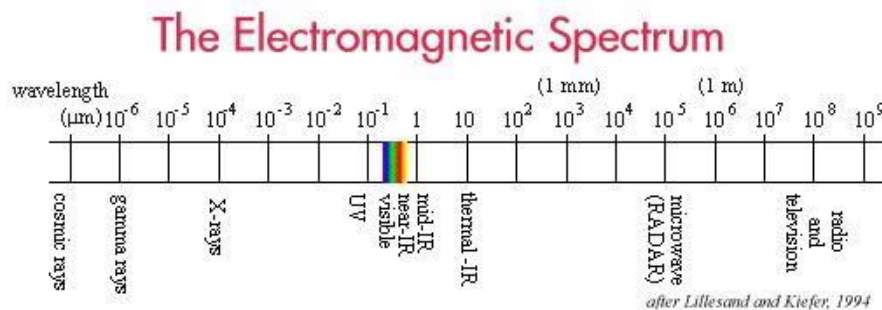
**Platform** is the structure or vehicle on which the remote sensing instrument (sensor) is mounted.

**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).



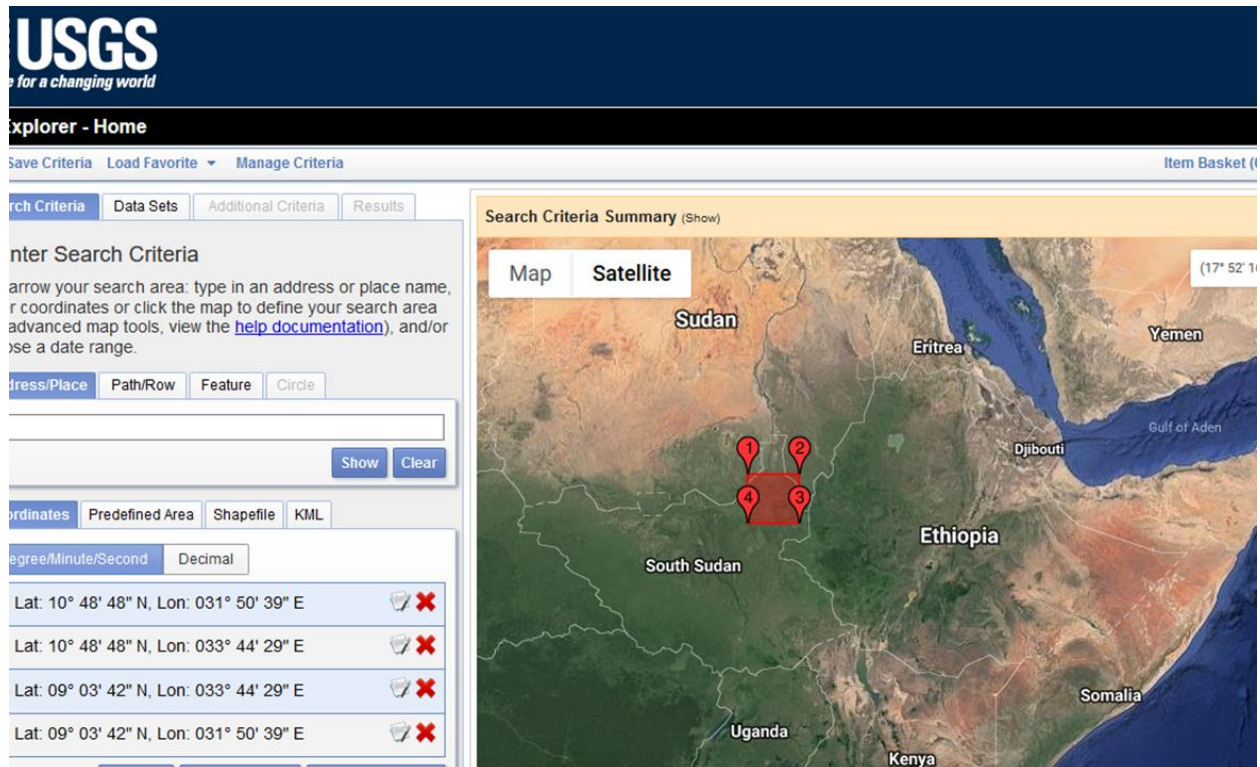
### STEP (6)

## 2.3 Image Pre-processing

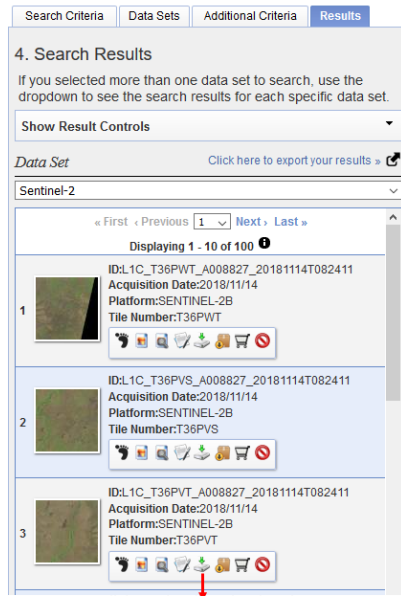
Image Pre-processing is done prior to data analysis, it's carried out to correct for any distortions. These procedures include radiometric correction to correct for uneven sensor response, Geometric correction to correct for geometric distortion due to Earth's rotation or to conform to a specific map 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

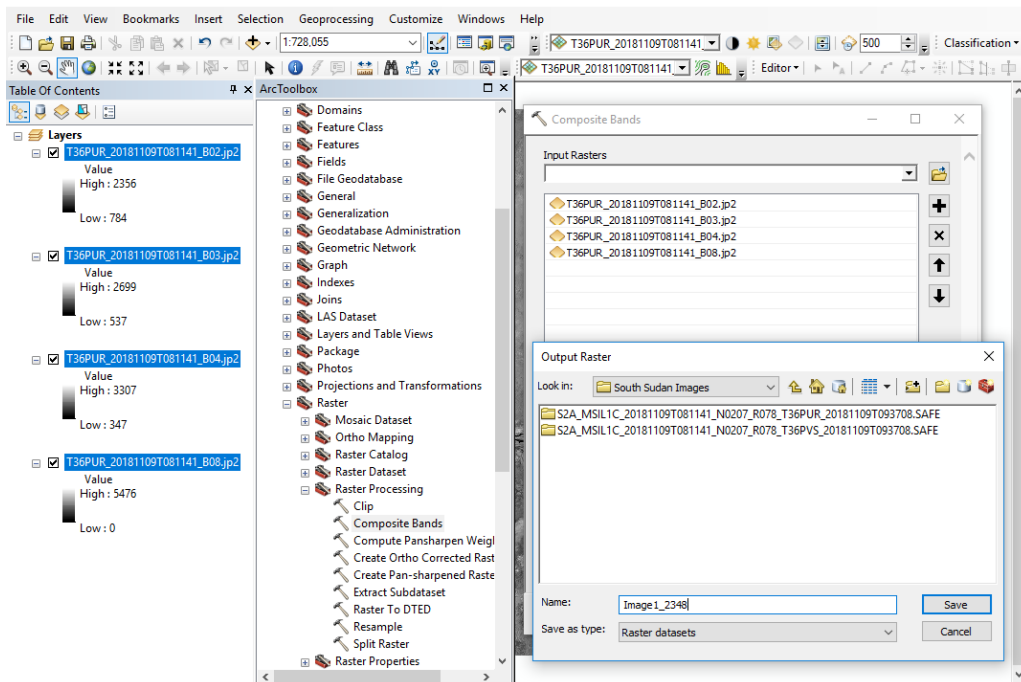
- 1) Enter Search Criteria
- 2) Define area of interest
- 3) Set the date range
- 4) Select the data Sets  
i.e. Sentinel-2 or Landsat 8
- 5) Additional Criteria, select cloud cover %
- 6) Results – Display the available images as per the set parameters

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

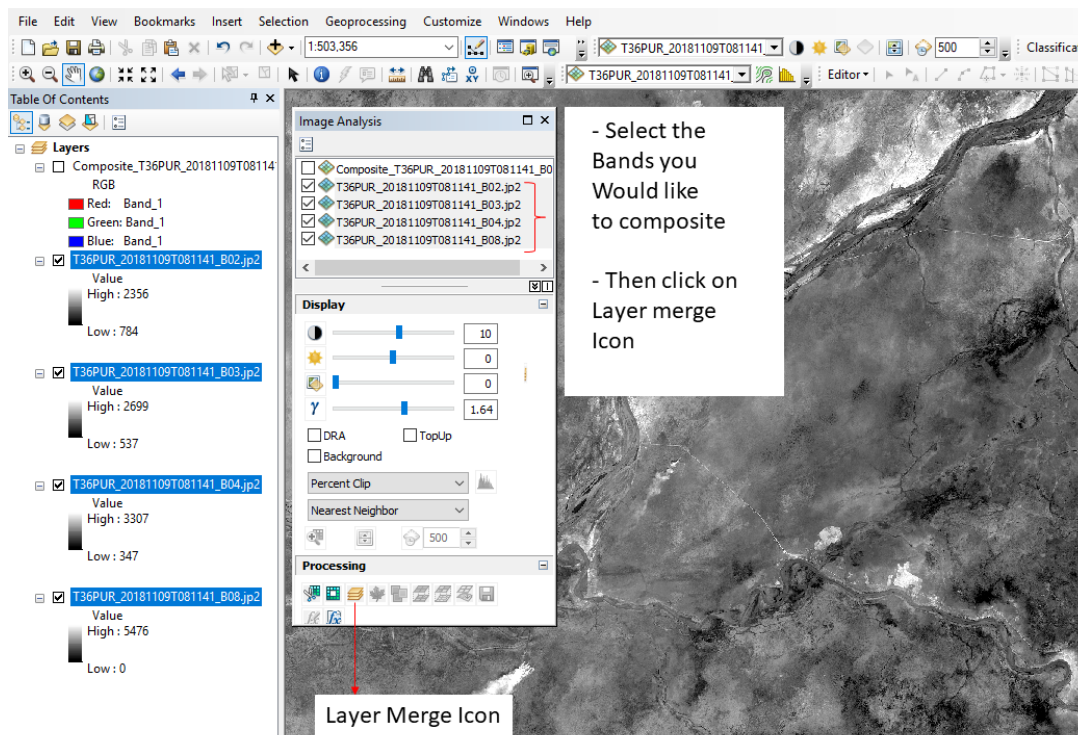
Image Compositing allows you to combine raster bands to create various RGB band combinations.

1. In ArcMap, navigate to **Geoprocessing > ArcToolbox > Data Management Tools > Raster > Raster Processing > Composite Bands**.
2. **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,

1. Load the different bands in ArcMap in our case **bands 2348** > **Navigate to Windows > Images Analysis**







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. Save the 2 images as Image 1 and Image 2. To combine them you need to do a mosaic.

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

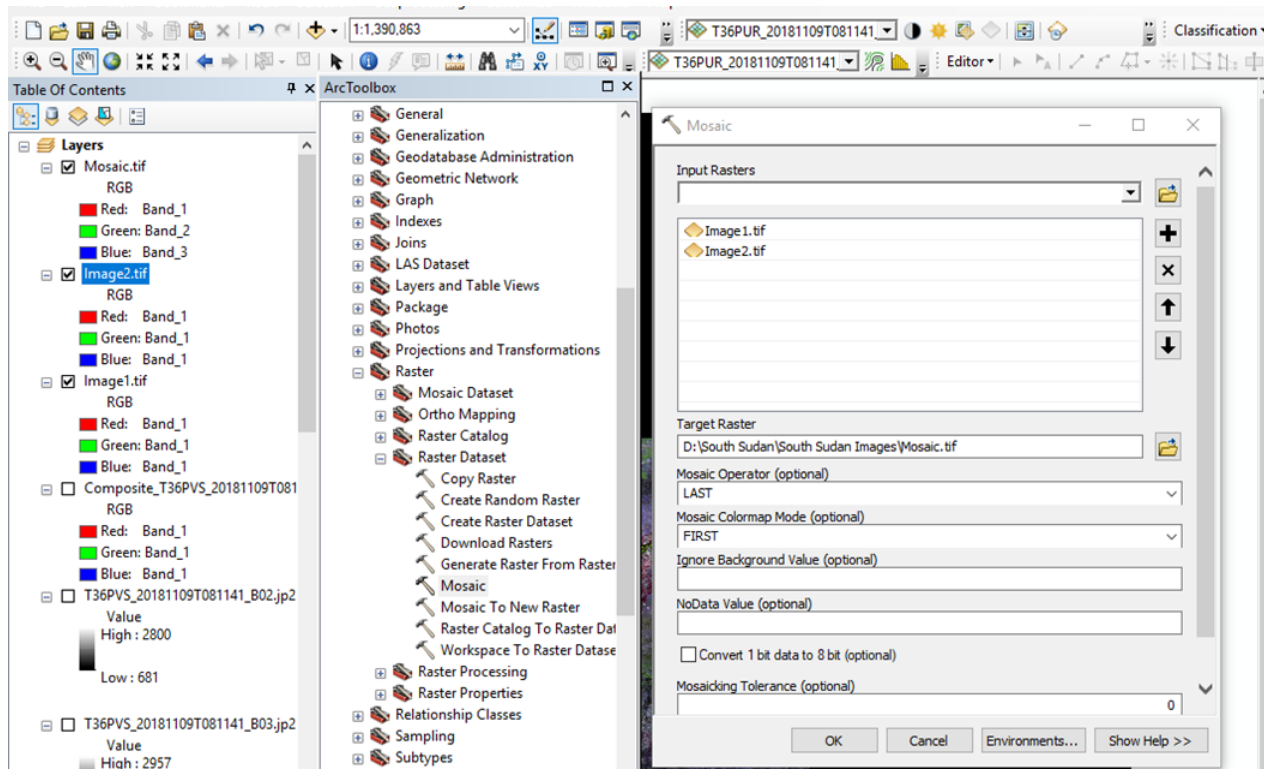


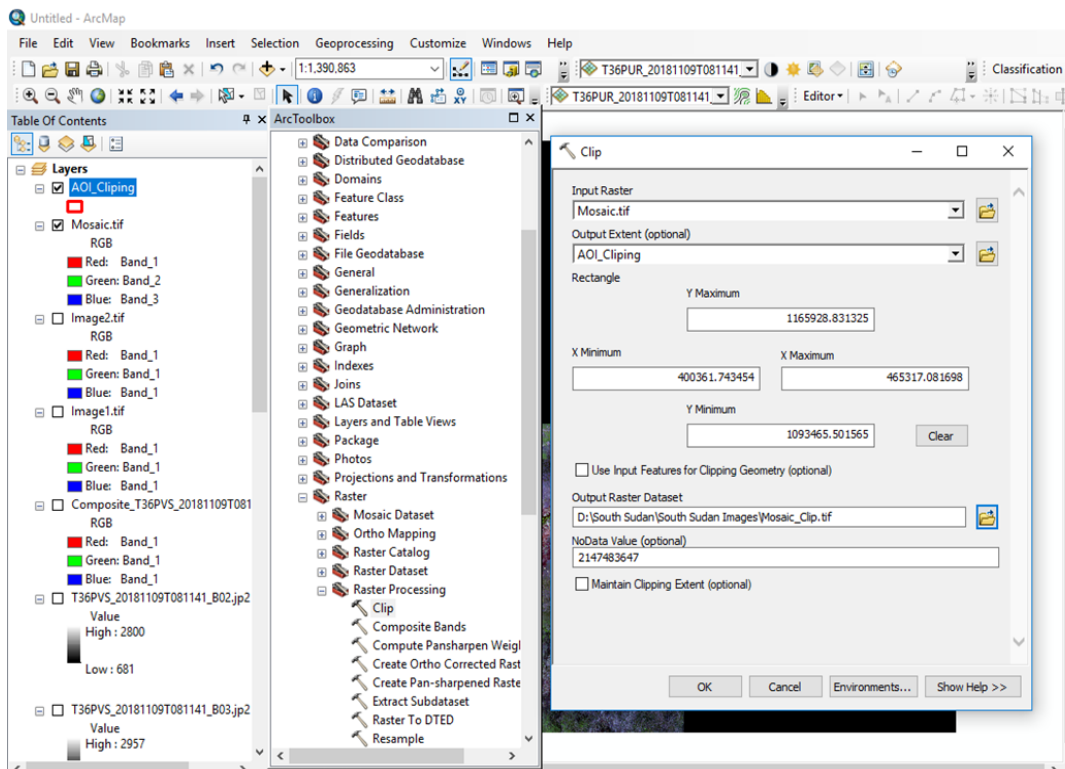
Image Clipping allows you to clip a smaller area of interest from a bigger Image.

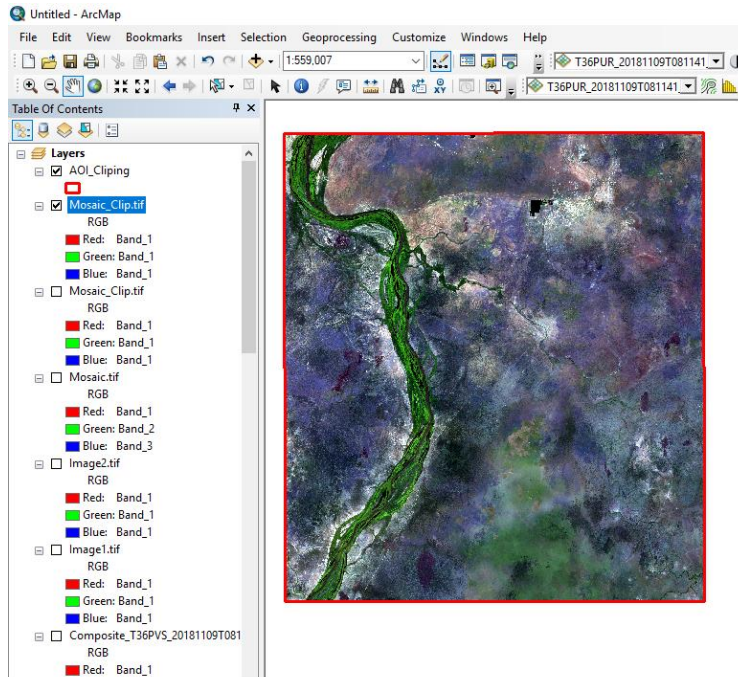
1. **Create** an Area Of Interest (AOI) by drawing a polygon shapefile, An AOI has been provided for you, use it to clip the image you have just mosaicked.
2. **Navigate** to *Geoprocessing > ArcToolbox > Data Management Tools > Raster > Raster Processing > Clip*

The area of interest falls between 2 images



To clip the Area Of Interest; go to **Arc Tool box> Data Management Tools> Raster> Raster Processing> Clip**. Output Extent - input the AOI Shapefile.





Display the image you have just clipped - **Mosaic\_Clip.tif** and use it to do both supervised and Unsupervised classification.



### STEP (7)

## 2.4 Image Classification

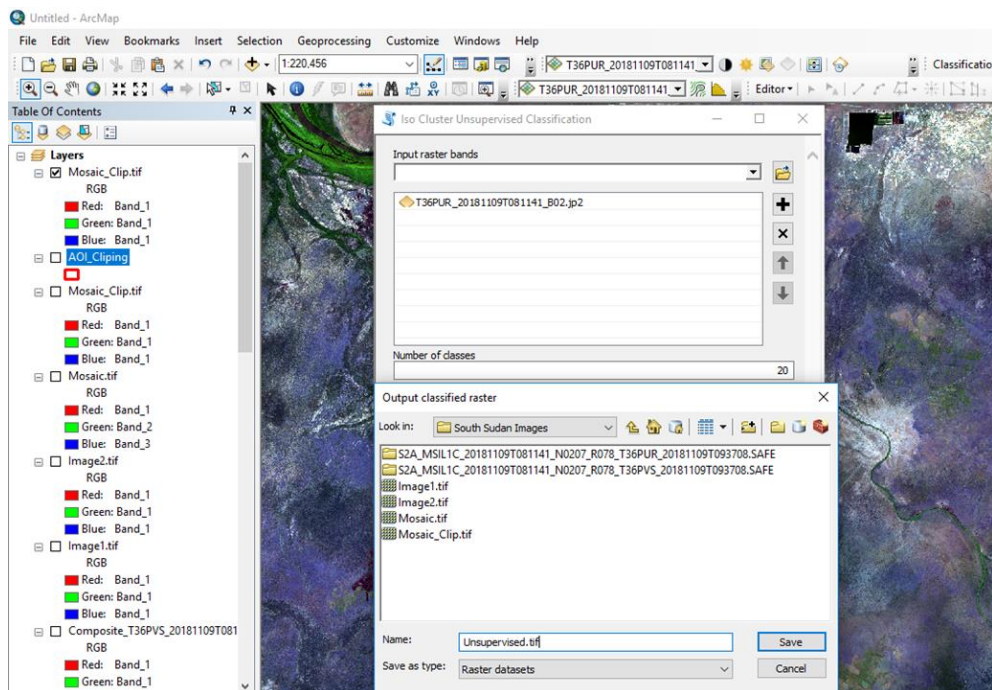
Image classification refers to extracting information from multiband raster. The resulting raster from image classification can be used to create thematic maps.

### 2.4.1 Unsupervised Classification

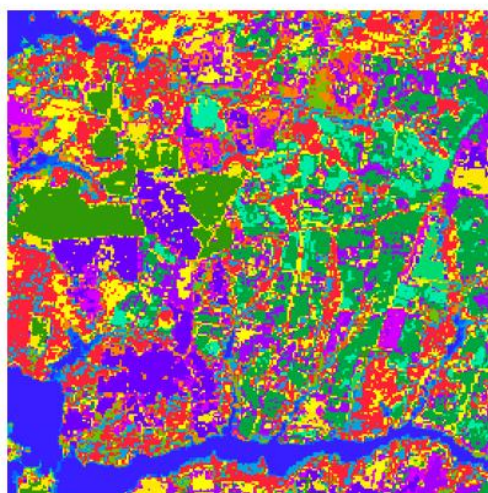
Unsupervised classification works well when the user doesn't know how many classes are present in the image. The computer uses the spectral signature to determine which class to place the pixel in.

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

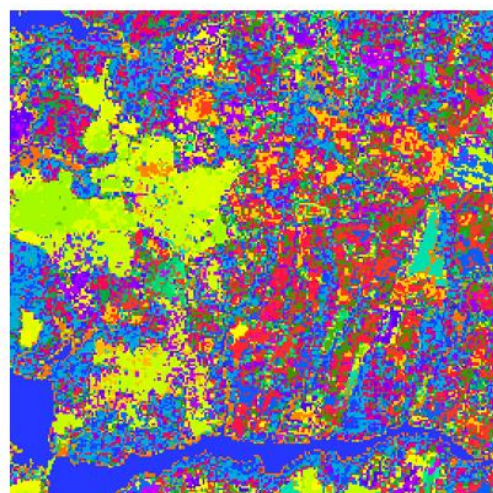




- Output of an unsupervised classification is shown below:



20 SPECTRAL CLASSES



100 SPECTRAL CLASSES

### 2.4.2 Supervised Classification

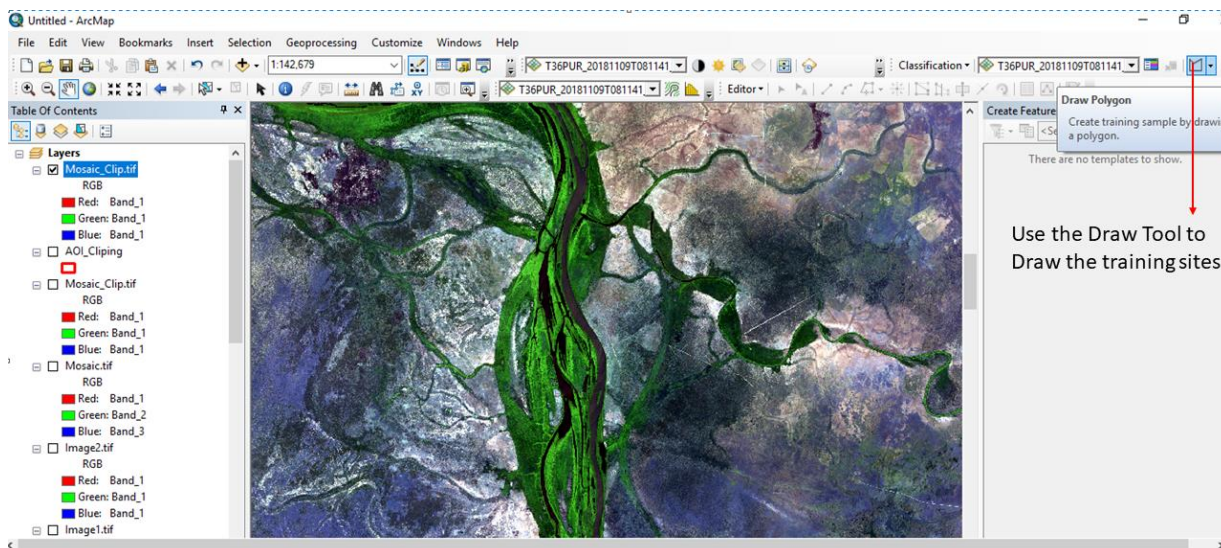
Supervised classification uses the spectral signatures obtained from training samples to classify an image. The image interpreter determines the classes and identifies the training samples for different land cover types. The process involves

- ✓ Creating training areas
- ✓ Creating signature file
- ✓ Classifying the image

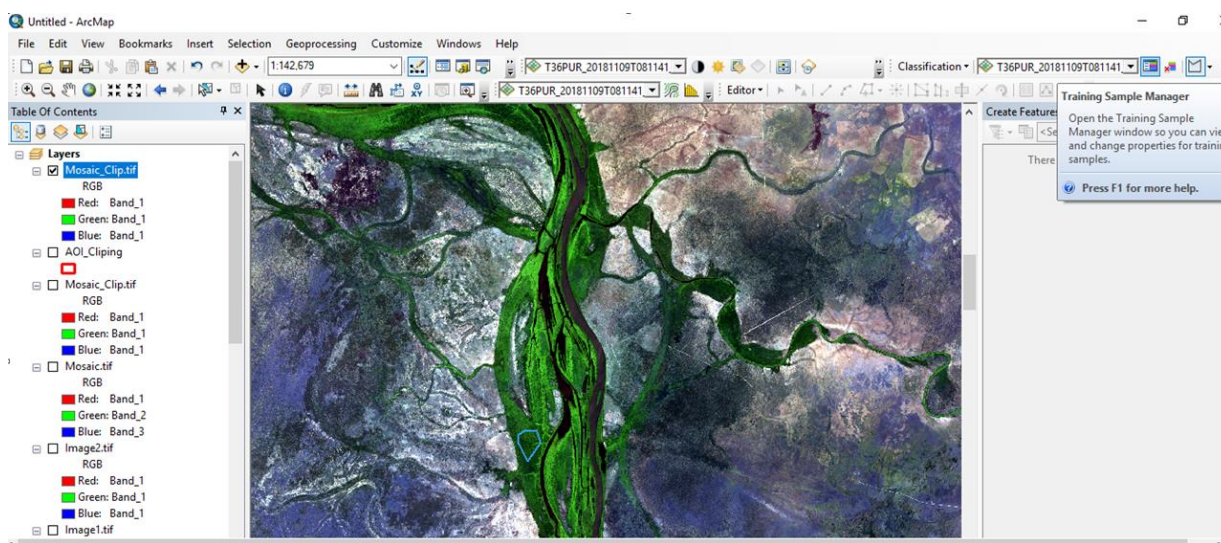




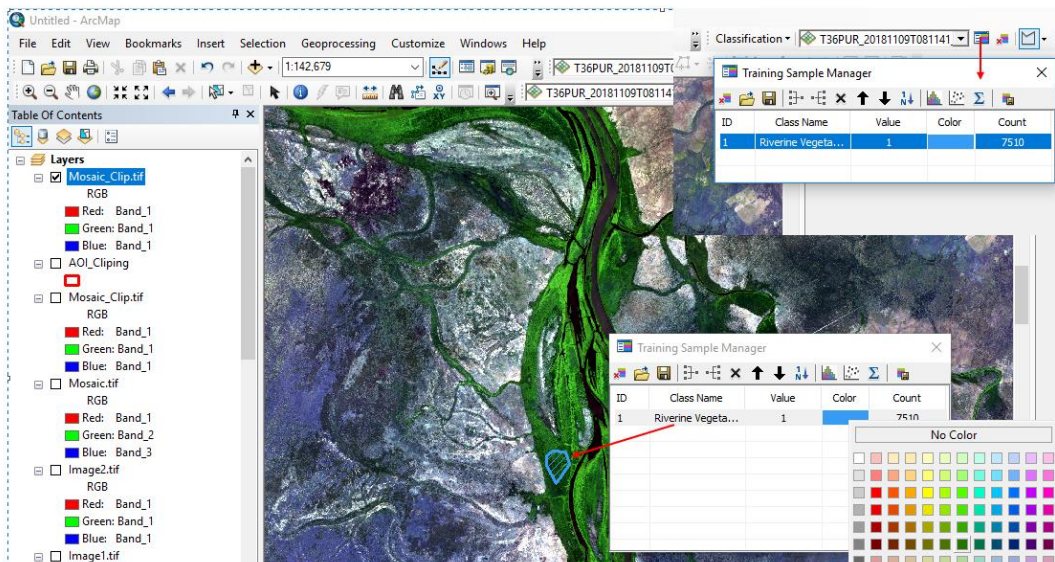
1. **Go to** Customize > Extensions > Make sure the spatial analyst box is checked.
2. On the tool bar, make sure the *Image Classification* is checked.
3. **Create** training areas of the following classes
  - 1) Riverine Vegetation
  - 2) Shrub Grass
  - 3) Bare
  - 4) Farms
  - 5) Built Up



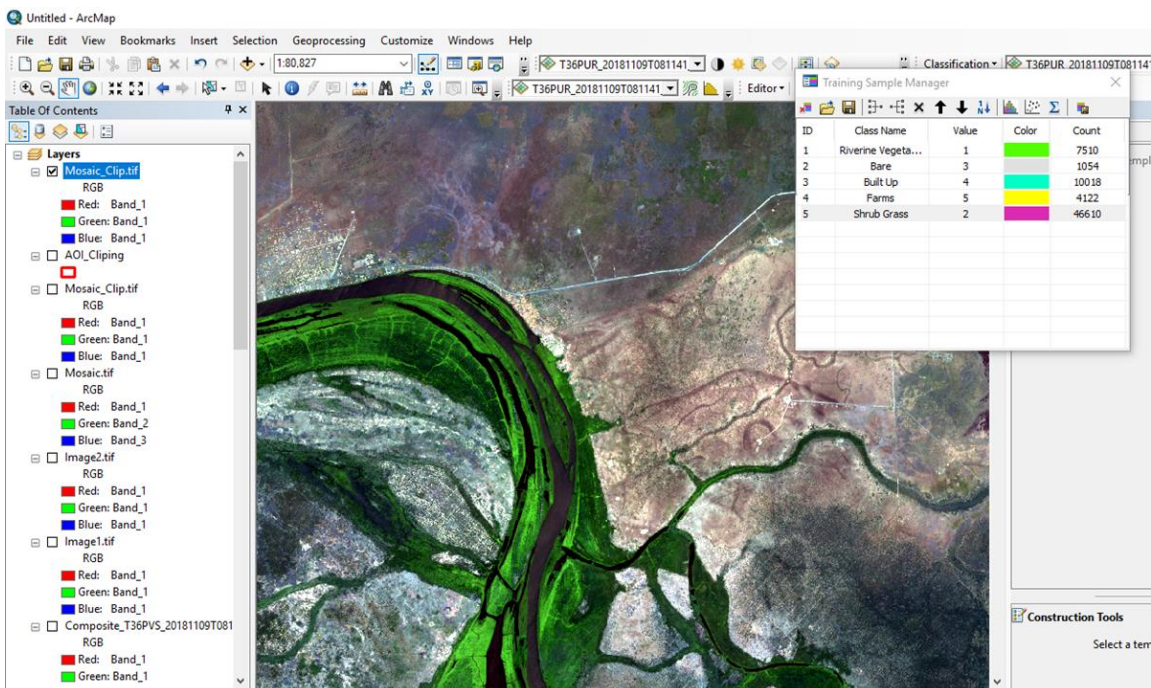
Once you draw the training site, open the training sample manager and give class name and value.







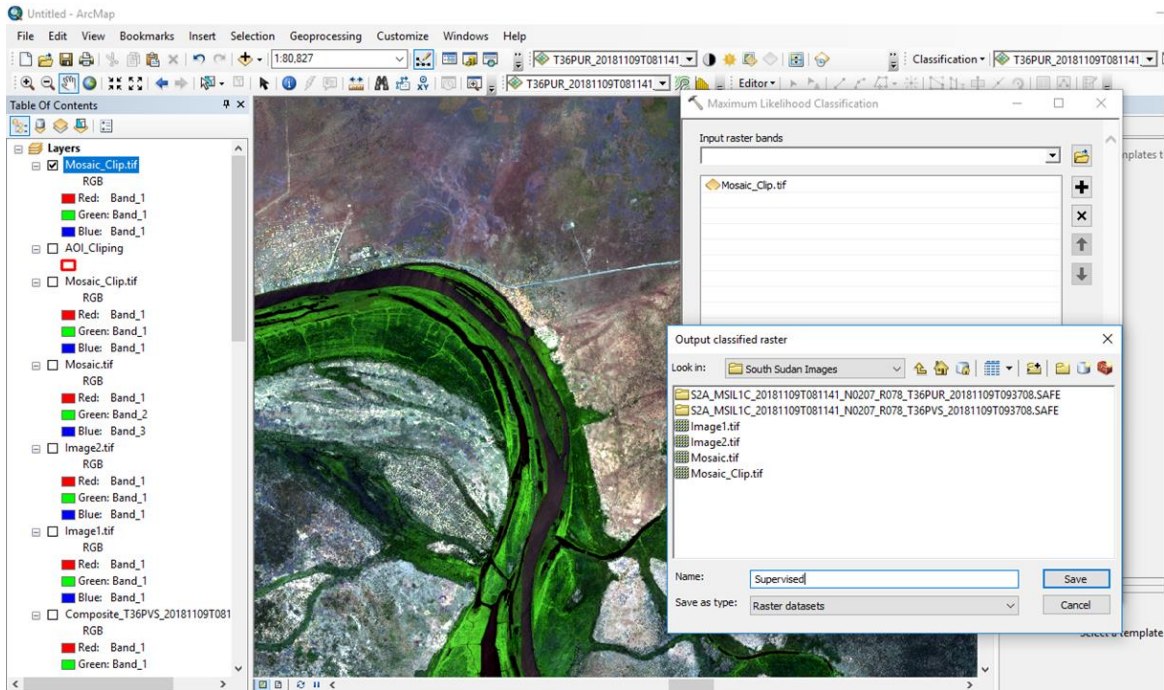
Draw all the other training sites and give class names and values.



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

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





2. *Input Raster Bands* -Input the Image you would like to classify (The Mosaic\_Clip) and Input the signature file.
3. Give an output name - **Supervised.tif**
4. An Image will be classified with 5 classes.



## 2.5 Exercise 2.1: Analysis of Elements at Risk

### 2.5.1 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 i.e. Upper Nile State.

1. Understand the geographical extent of Upper Nile state.
2. Understand the elements at risk database given.
3. Quantitative assessment of the exposed elements at risk within area Upper Nile State.

#### Data Input

The input data used in this module is,

Description	Data path	Data Type	File Name
Area of Interest Boundary	\\SSD_Data\Module2\Elements_AT_Risk\	Vector (polygon)	Upper_Nile_State.shp
Road Network	\\SSD_Data\Module2\Elements_AT_Risk\	Vector (polyline)	Roads_Nile_State.shp
Settlements	\\SSD_Data\Module2\Elements_AT_Risk\	Vector (point)	Places_Nile_State.shp
Land use	\\SSD_Data\Module2\Elements_AT_Risk\	Vector (polygon)	Lulc_Nile_State.shp
Population (Grid) data	\\SSD_Data\Module2\Elements_AT_Risk\	Raster	SSD_Pop_WP.tif

#### Output

Output expected in this session is,

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

#### Understanding the elements at risk

Open the *Elements\_At\_Risk.mxd* in ARC GIS software.

*Hint: Use Attribute Table tool to answer.*

1. 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?



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2. How many settlements exist within the Area of Interest?

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

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



**GFDRR**  
Global Facility for Disaster Reduction and Recovery

**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*



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



### 3 Introduction to Disaster Risk Management (DRM)

#### Learning objectives

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

1. Elaborate basic terminologies and concepts in DRM together with Global and Continental DRM frameworks
2. Demonstrate how to undertake hazard assessment and derive some of the indicators and thresholds on drought and flood hazards
3. 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 = Hazard x Vulnerability  
Capacity
5. Disaster risk reduction includes all measures, which reduce disaster-related losses of life, property or assets by either reducing the hazard or vulnerability of the elements at risk or by increasing the capacity of at risk communities.
6. DRM is multi sectoral and Multi-hazard by its very nature

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







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

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

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

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

## DISASTER

A 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:

1. Establish the context and build partnerships and rapport based on the mandates and context;
2. Identify the hazards (Hazard Assessment);
3. Determine the elements at risk (people and health, property, livelihoods, Community structures, critical facilities, environment etc.) (Exposure Assessment);
4. Determine conditions and factors of vulnerability. Why can the elements at risk be damaged? (physical, economic, social, motivational reasons) (Vulnerability Assessment);
5. Identify existing coping strategies and capacities/resources (material, human, institutional/organizational, motivational etc.) (Capacity Assessment);
6. Assess risks (based on the Hazard, Vulnerability and Capacity Assessment);
7. 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?
8. Prioritize risk reduction measures to undertake: immediate, short-term, medium-term, long-term;
9. Implement the risk reduction measures as planned;
10. 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:\SSD\_data\Module3\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**





**GFDRR**

Global Facility for Disaster Reduction and Recovery

**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



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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.***

## **3.2 Hazard, Vulnerability and Risk Assessment**

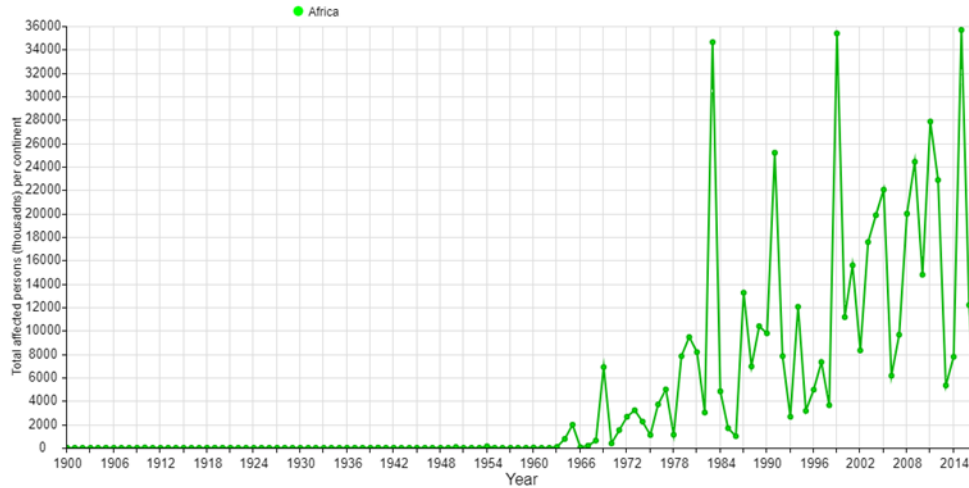
### **3.2.1 Introduction to Hazard Assessment**

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 South 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;



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Global Facility for Disaster Reduction and Recovery

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

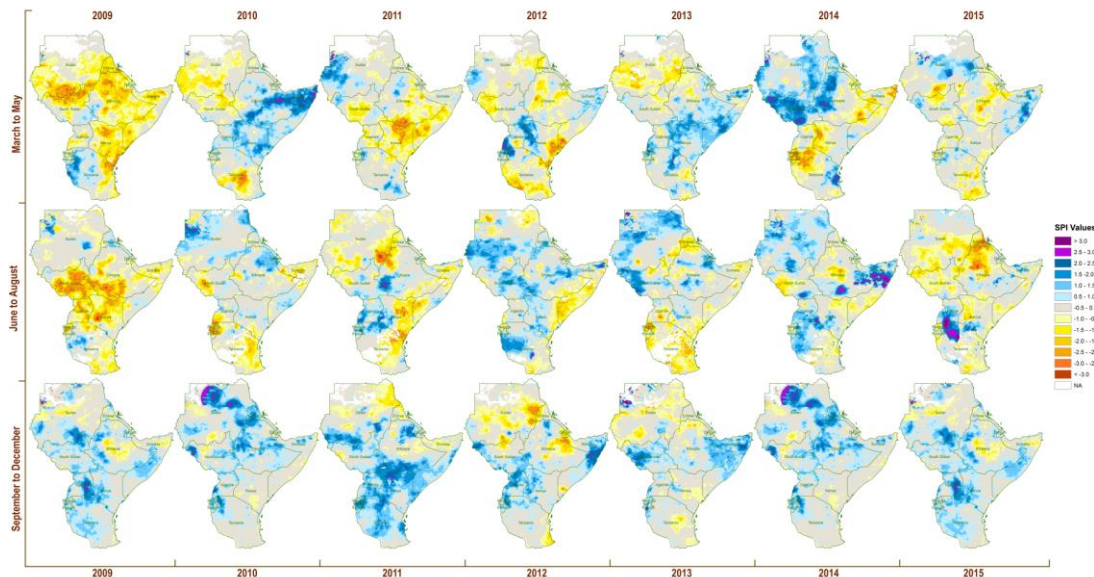


**unitar**

**Table 1. SPI values**

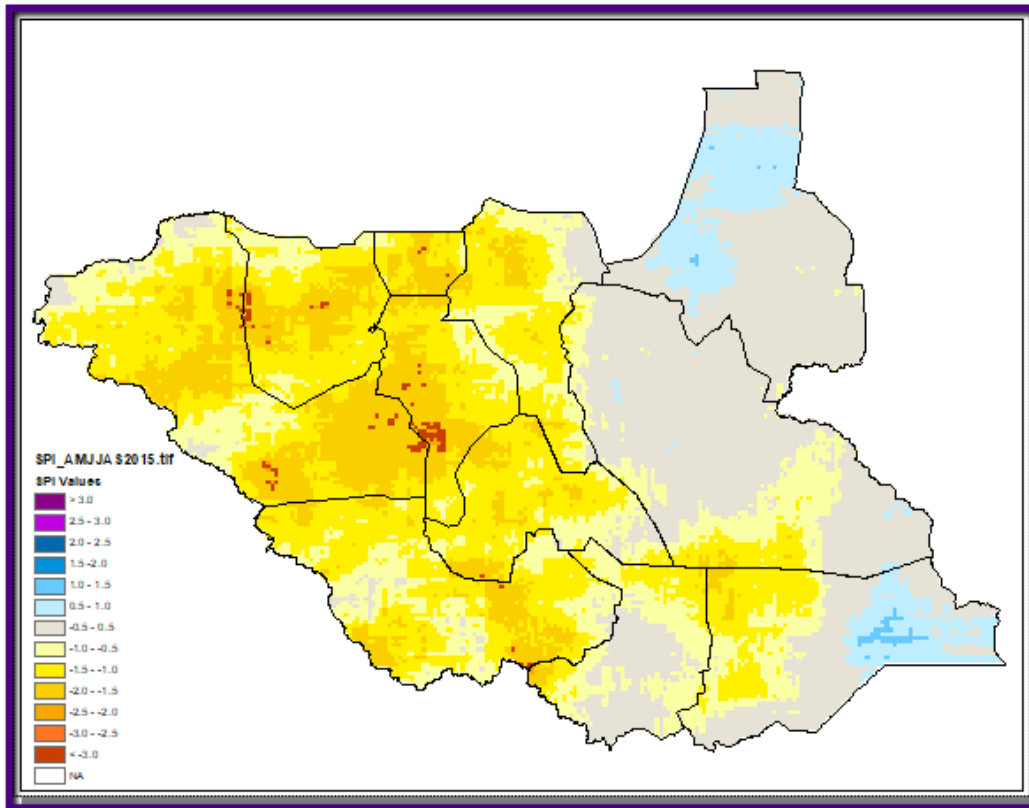
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

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 South Sudan for April to September 2015 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 calculated through 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.



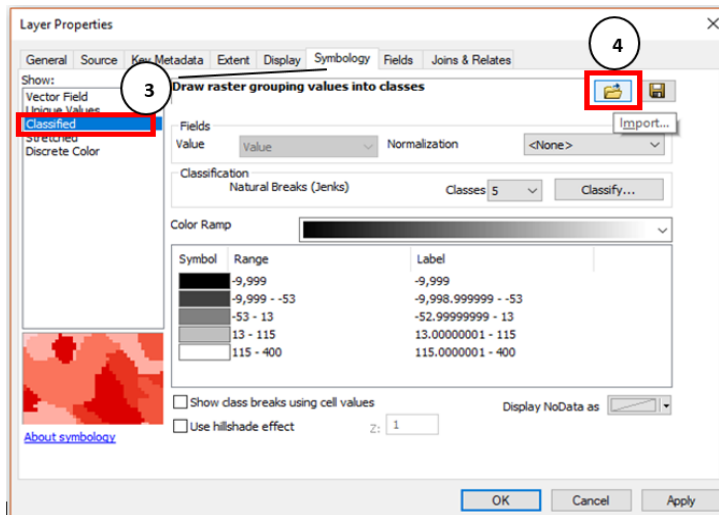
#### STEPS (8): Working with SPI

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

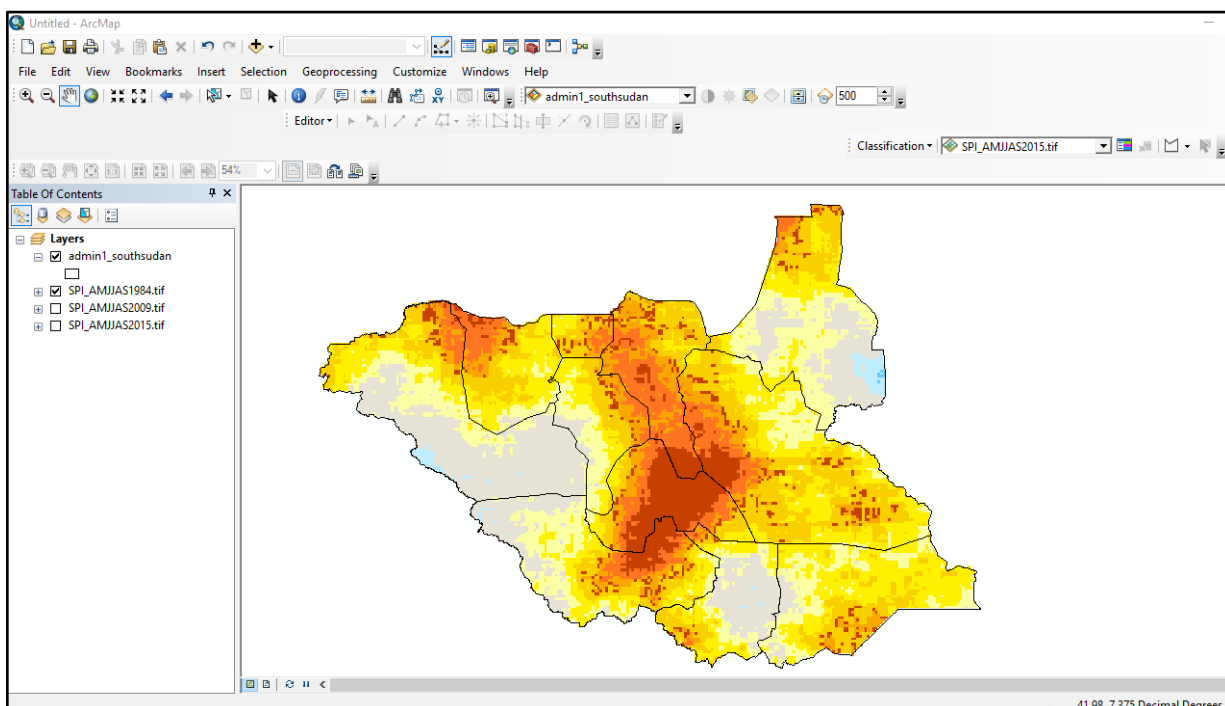
1. Open ArcMap and **add** the following layers from **X:\SSD\_data\Module3\Drought\SPI folder**
  - **SPI\_AMJJAS\_1984.tif**
  - **SPI\_AMJJAS\_2009.tif**
  - **SPI\_AMJJAS\_2015.tif**
2. The black and white images has got values and the symbology can be set manually or import from the existing \*.lyr file. For this exercise we will import a symbology.



3. Double click on **SPI\_AMJJAS\_1984.tif** and go to **symbology** and under show click **classified**.
4. Now click on **import** and go to **X:\SSD\_data\Module3\Drought\SPI** folder and select **SPI\_symbology.lyr** file

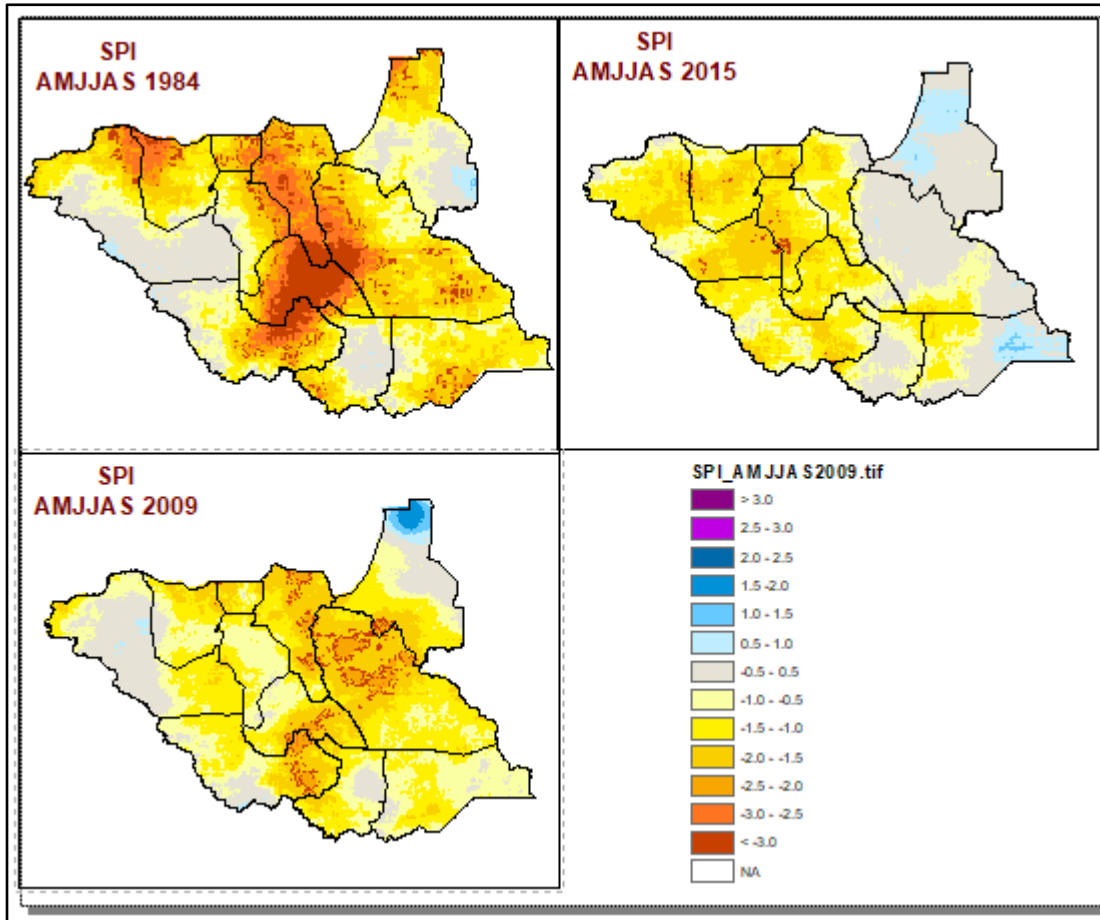


5. Click Ok and now your map view should look something similar to this.



6. Follow similar steps to change the symbology for 1984, 2009 and 2015 SPI data layers.

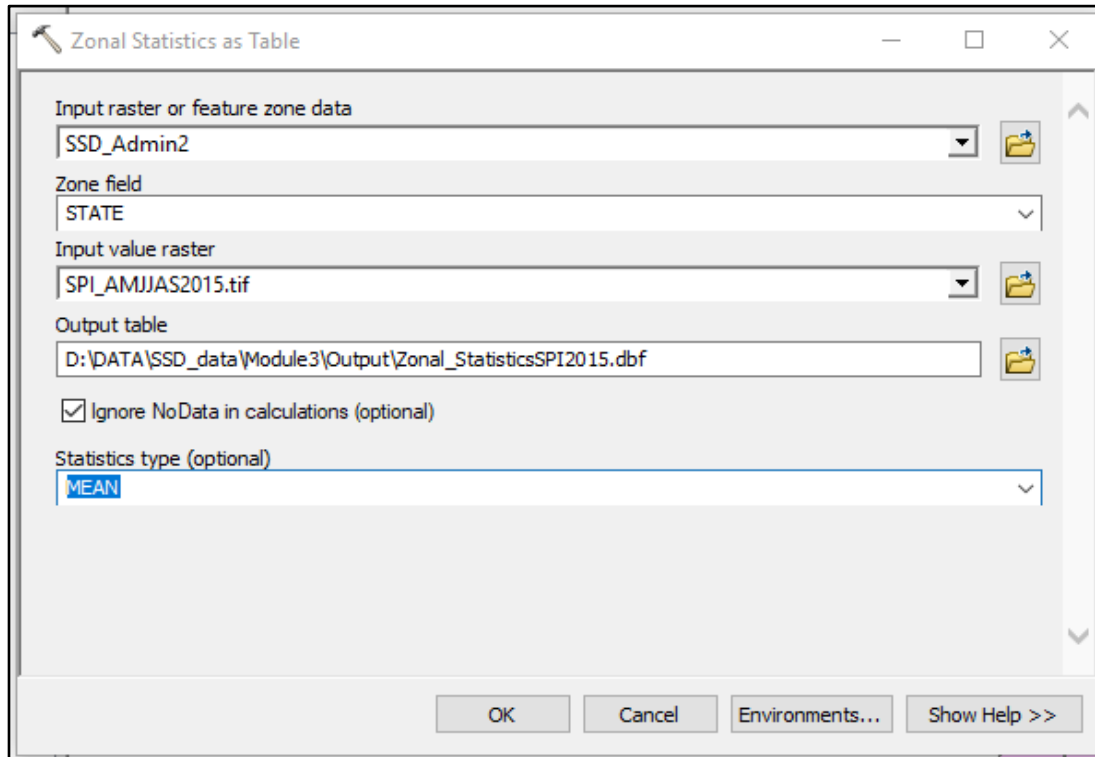




### STEPS (9):

Calculate Zonal Statistics to produce seasonal meteorological drought hazard map for South Sudan districts (Admin2)

1. Add the **SS\_Admin2** layer from **X:\SSD\_data\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 **SSD\_Admin2** as input raster or feature zone data and **STATE** as zone field.
4. Select **SPI\_AMJJAS\_2015.tif** file as input value raster and save the output table under **X:\SSD\_data\Module3\Output** folder by the name **Zonal\_StatisticsSPI2015.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 **SSD\_Admin2** and Zonal statistics\_SPI2015 using the common field "STATE"

6. Right click on **SSD\_Admin2** layer and click on **Join and relate >> Join**
7. Select **STATE** in the first drop down field and **Zonal statistics table** in the second and **STATE** under the third dropdown
8. Click **Ok** and you can open attribute table of **SSD\_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 **SSD\_Admin2** and export data. Save it under **X:\SSD\_data\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.



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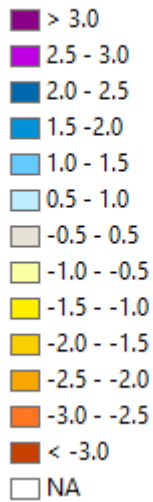
ACP-EU Natural Disaster Risk Reduction Program  
An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRR United Nations Institute for Training and Research



**unitar**  
United Nations Institute for Training and Research

SPI\_AMJJAS 2015

SPI Values

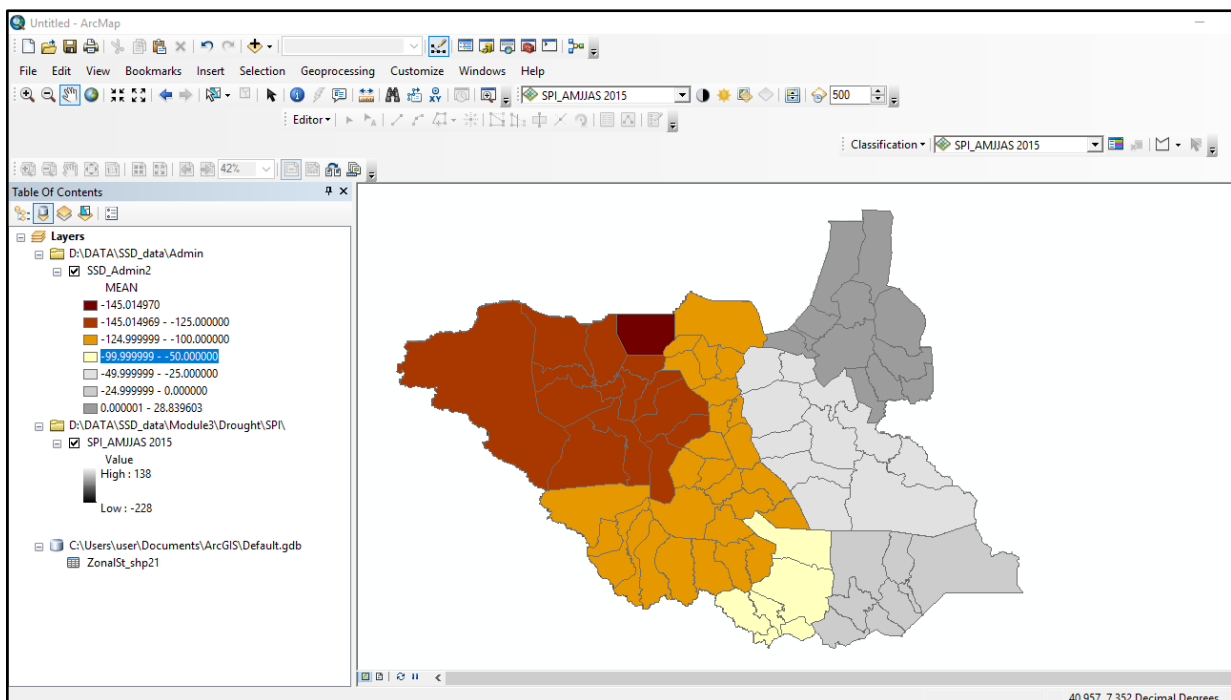


**11.** Double click on the *Drought\_hazard\_severity.shp* layer and go to **symbology**

**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.

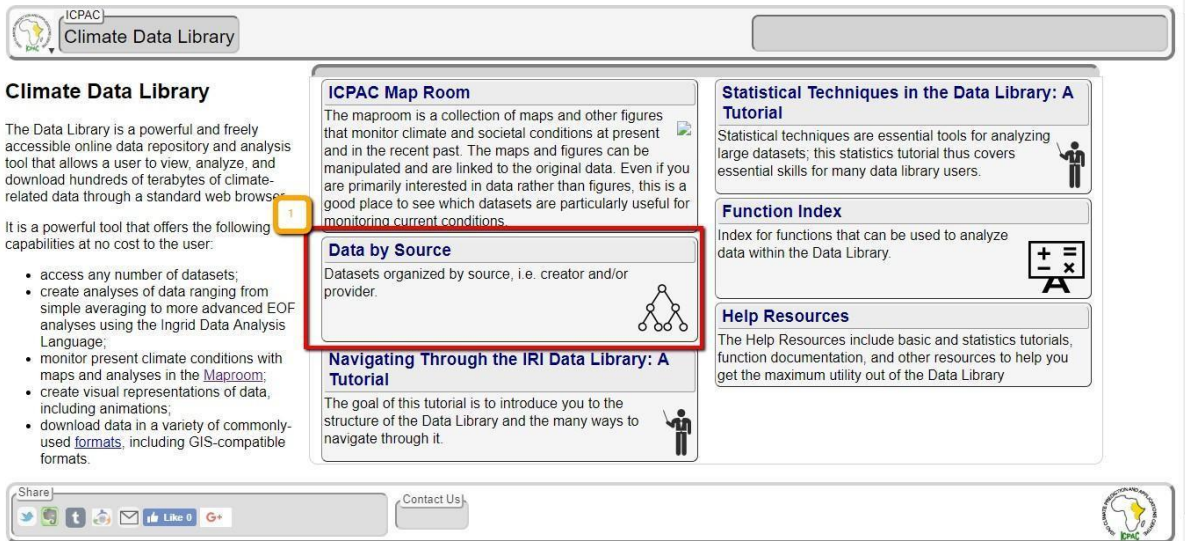




### 3.2.3 Downloading SPI Data

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:

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



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

### Datasets and Variables

<a href="#">ENACTS</a>	Enhancing National Climate Service initiative.	2
<a href="#">Features</a>	Features[Political ]	
<a href="#">ICPAC</a>	ICPAC[Projections CHIRPS-BLENDED Forecasts CHIRP-BLENDED ]	
<a href="#">Indices</a>	Indices[nino ]	
<a href="#">KADI ANI</a>	KADI ANI EXTENDED 1	

### Datasets and Variables

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



## 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

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

6

3. Change Time, Longitude and Latitude as shown below
4. Then Restrict Ranges > Stop Selecting

## Datasets and Variables

4

[dekadal](#) ICPAC CHIRPS-BLENDED dekadal[rainfall]

[monthly](#) ICPAC CHIRPS-BLENDED monthly[rainfall WASP]

[seasonal](#) ICPAC CHIRPS-BLENDED seasonal[rainfall]

## 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

5. Click on Data Files > then Click on GeoTIFF Image as shown below





6. **Once** you are sure of the month, Click on e.g. 200908 GeoTiff for GIS
7. 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.	
<a href="#">2-Dimensional Table</a>	A 2-dimensional ascii file that includes an ArcInfo Header.
<a href="#">IDA Image</a>	File(s) in the Image Display and Analysis format. Typically used with WinDisp.
<a href="#">LAN Image</a>	File(s) in the ERDAS LAN format. Typically used with various GIS programs, including ArcView and H Mapper.
<a href="#">GeoTIFF Image</a>	File in GeoTIFF format. Typically used with various GIS programs, including ArcView and ENVI.

### GeoTIFF Image Format Downloads

#### ICPAC CHIRPS-BLENDED monthly rainfall spi

Time: Aug 2009 Jul 2009 Sep 2009

23.15N

Latitude 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**

### 3.2.4 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, NDVImax and NDVImin 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):

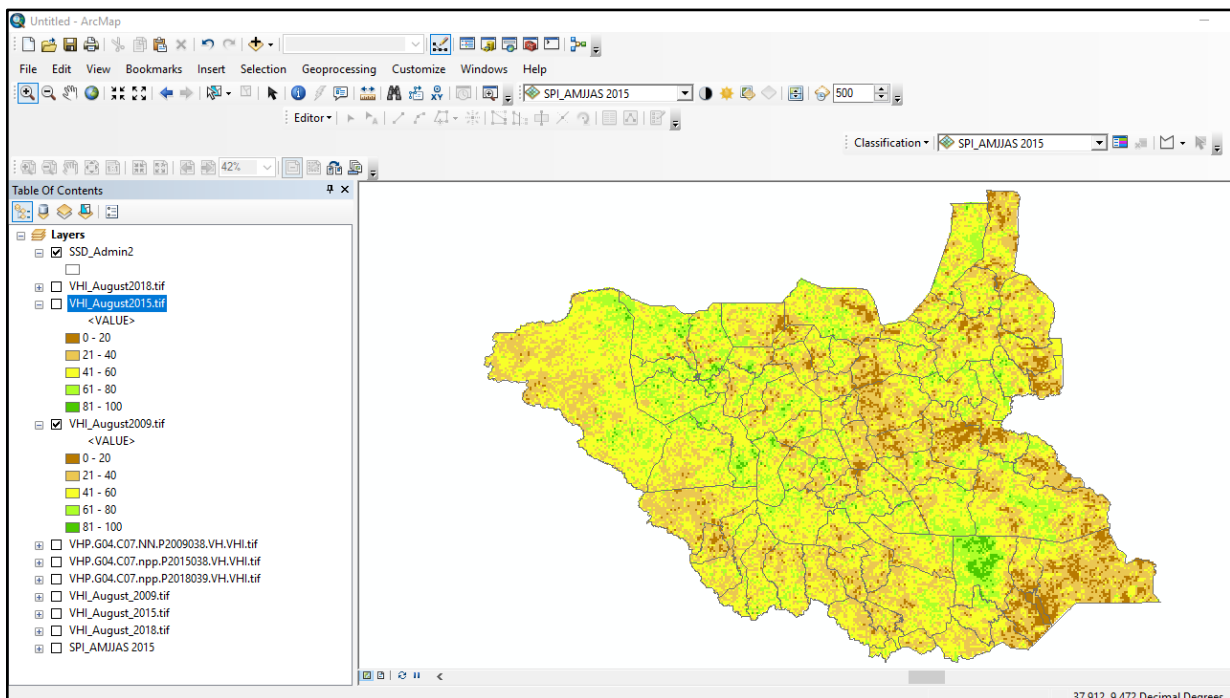
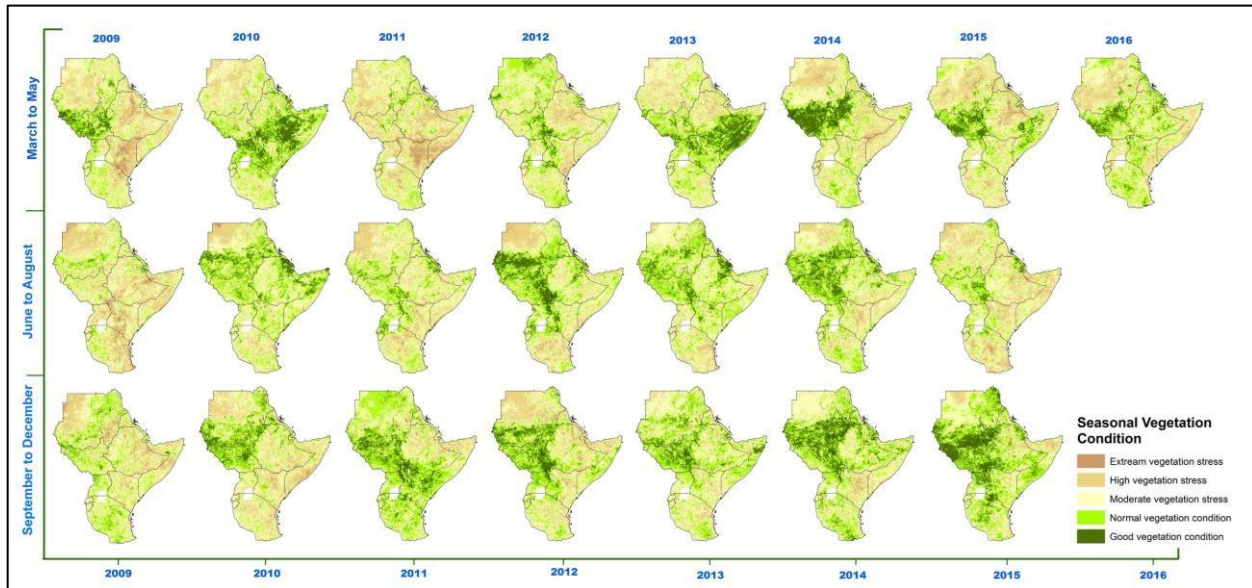
#### Classify VHI values to standard classes

1. Open ArcMap and add the following VHI layers from X:\Module3\Drought\VHI folder
  - **VHI\_August2009.tif**
  - **VHI\_August2015.tif**
  - **VHI\_August2018.tif**
2. Now classify the layers. Right click on the **VHI\_August2009.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.



3. Set the class interval 20,40,60,80,100 and click **Ok**
4. Now import symbology from X:\SSD\_data\Module3\Drought\VHI folder and click **Ok** choose the color range from the color ramp and click **Ok**.

Your map looks similar to the one below.





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



### Exercise 3.1

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

#### 3.2.4.1 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.

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

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

2. 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
3. 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

#### 3.2.5 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):

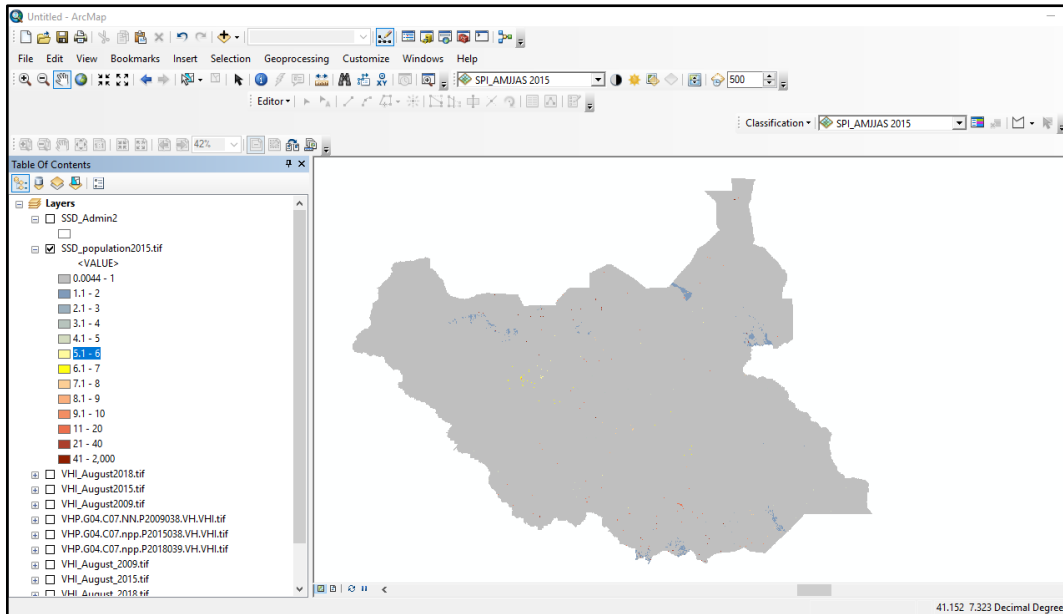
Human Population Counts from Worldpop Data Layer (100 meter resolution)

1. Load the SSD\_population2015.tif layer from X:ISSD\_data\Module1\Population folder





2. Double click on **SSD\_population2015** and go to **classified** and import a **symbology\_hpopulation** from **X:\SSD\_data\Module1\Population folder**
3. Now your district population map should look something like this



4. Now load the **Drought\_hazard\_severity.shp** layer you produced earlier under **Step 9**
5. 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 generate the total population from the population raster above.
6. Go to **Windows >> Search** and keyin **zonal statistics as a table** and click to open the tool
7. Set the **Drought\_hazard\_severity.shp** as input layer and **STATE** as zone field. Set **SSD\_Population2015** as input value raster
8. Save the output under **X:\SSD\_data\Module3\Output** folder with file name **SSD\_population2015\_table** and Set the statistics to **SUM** and click Ok
9. Now we need to join the two table (**SSD\_population2015\_table** and **Drought\_hazard\_severity.shp**)
10. Right click on **Drought\_hazard\_severity.shp** layer and **Join and Relate >> Join**
11. Set **STATE** as common field and **SSD\_population2015\_table** as a table to join with.
12. Click Ok and now open the attribute table of **Drought\_hazard\_severity.shp** and right click on the field **MEAN** and **Sort Ascending** and select all records with **SPI value < -100**
13. Now go to the **SUM** field and right click and click on **statistics** to see the total population of districts with SPI value at less than -100. (Total population under drought is \_\_\_\_\_Million)



### Exercise 3.2

- 1) What is the total population under drought condition at less than -140?



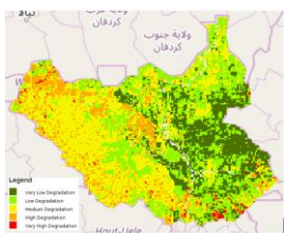
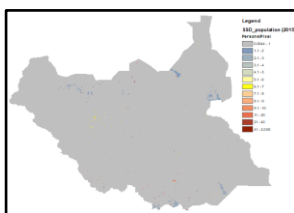
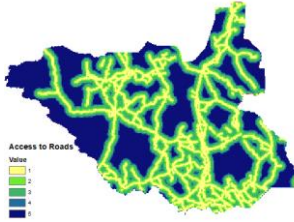


- 2) For an emergency response planning there is a need to identify districts that are “Very Dry” and “Extremely Dry” for this season based on SPI grades. How many people are in need of humanitarian assistance assuming that 60% of the population are vulnerable in each of the districts? Hint: Select target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

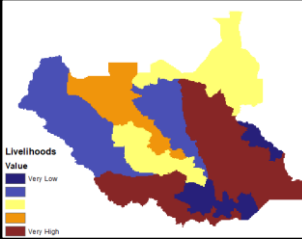
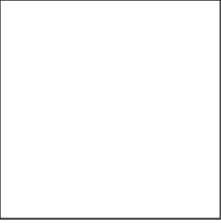
### Vulnerability

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, cultural...etc factors. The east Africa region, for instance is vulnerable due to over dependence on natural resources and primary activity, over reliance on rain- fed agriculture, low level of development, inadequate institutional and economic capabilities among many others. .

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

Factor	Indicator	Range/threshold/criteria	Remark
ENVIRONMENTAL	Land degradation (data source: MESA)	Severe, High, Medium, Low, none/minimal	
PHYSICAL	Population Density (data source: Worldpop)	Very High, high, moderate, low very low	
	Access to major Roads (Primary, Secondary and tertiary roads only) (data source: Roads/HDX)	- very poor (>25km) - Poor Access(20-25km > 4/5hrs) - Medium Access(15-20km 3/4hrs), - Good Access(10-15km-2hrs) - Very Good Access (<10km) 1 ½ hrs	



ECONOMIC	<p>Livelihoods (data source: FEWSNET)</p> <p>Level of Poverty</p>	<p>Very highly, High low Very low Null</p> <p>Extreme Very high (&gt;50) High (40-50%), Medium (20-40%) Low (&lt;20%) Very low</p>	 
----------	---	--	---

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



**STEPS (12):**

**3.2.6 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.



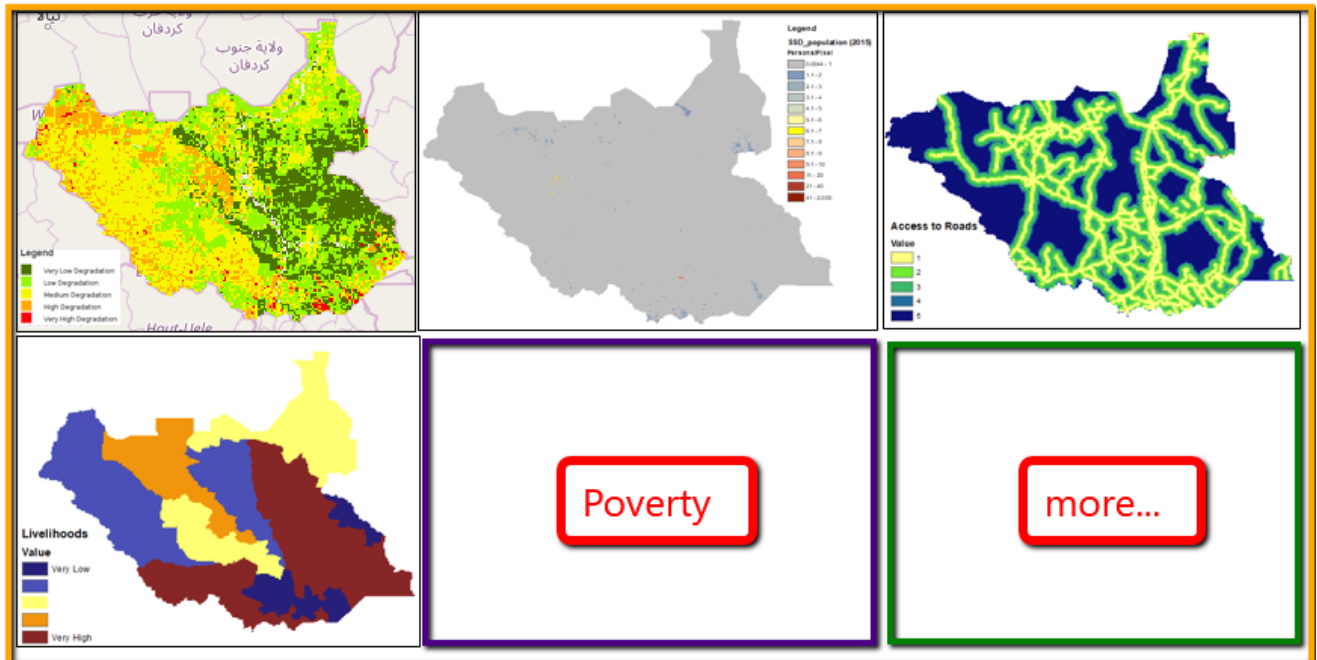
GFDRL

ACP-EU Natural Disaster Risk Reduction Program

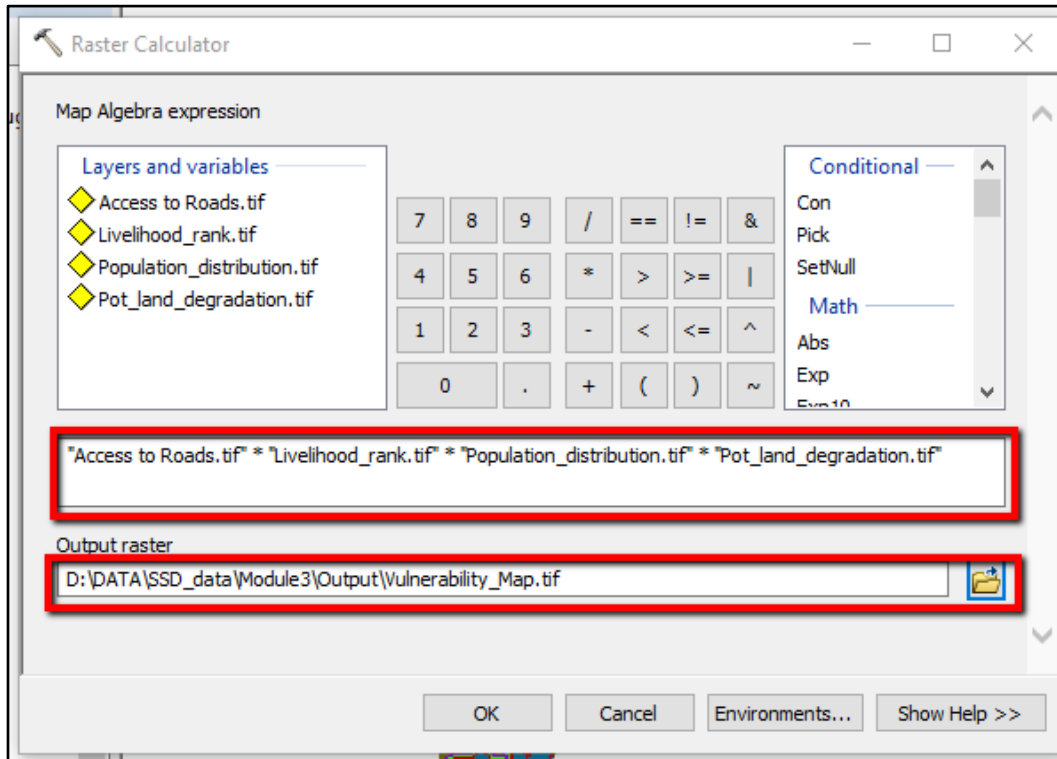
An initiative of the African, Caribbean and Pacific Group, funded by the European Union and managed by GFDRL United Nations Institute for Training and Research



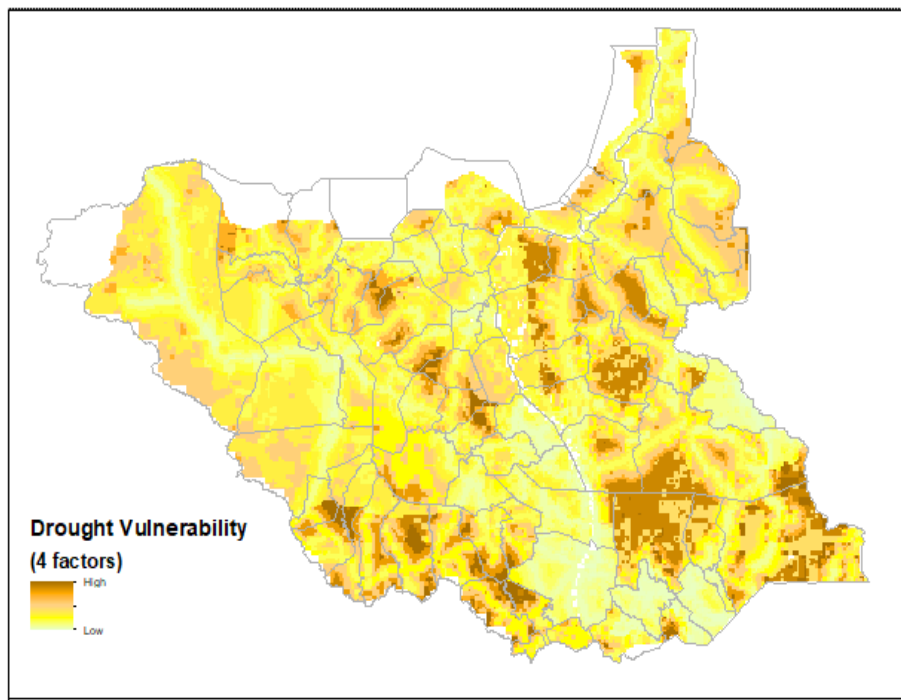
unitar



1. Load the following five layers from **X:\SSD\_data\Module3\Drought\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:\ISSD\_data\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 AMJJAS 2009 to produce Drought risk map for South Sudan. The poverty and related layers can stand to depict the lack of capacity indicated in the risk equation.

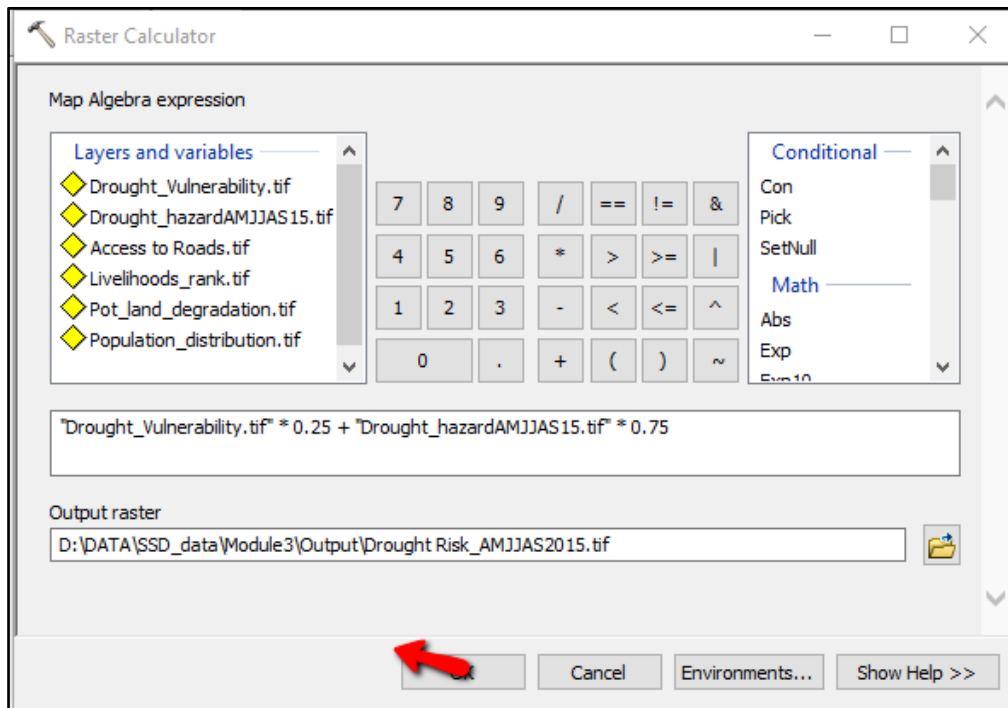


### STEPS (13):

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

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

1. Open the drought\_hazardAMJJAS15.tif and Drought vulnerability.tif layers from X:\SSD\_data\Module3\Risk folder
2. As you can notice the two layers are standardized and classified into five classes. Now go to **Windows >> Search** for **Raster calculator** and open it
3. In the **Raster calculator** double click on **drought 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 (3/4<sup>th</sup>) 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\_AMJJAS2015.tif** and save it under X:\SSD\_data\Module3\Outputs folder and click **Ok** to run the operation





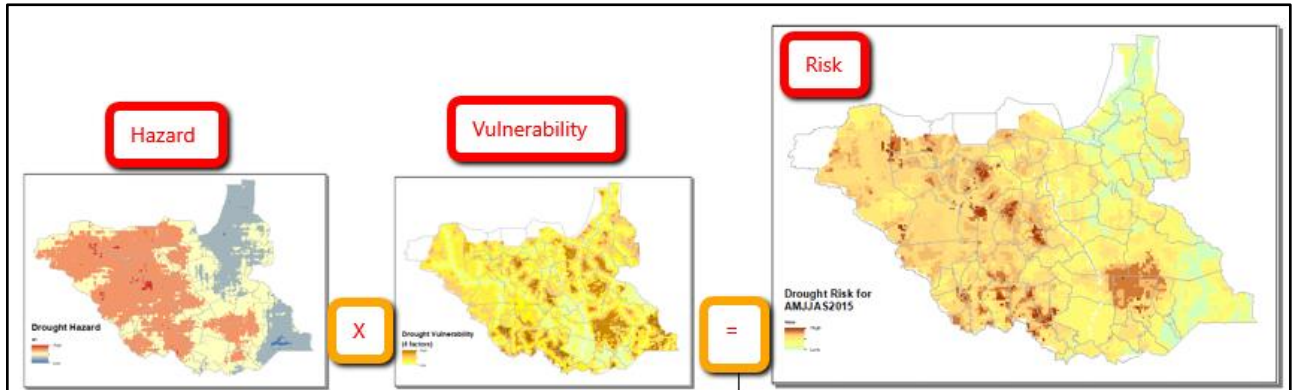
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Now you can open the drought risk layer and stretch it from high to low grades for example to show low, medium and high risk areas for the AMJJAS 2015 season.



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

### 3.3 Flood Hazard Assessment

#### Learning Objectives:

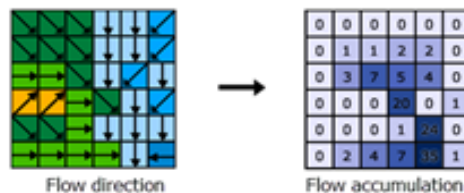
1. Causes of Floods?
2. What is a Flood Hazard?
3. Flood Hazard Assessment Methods
  - Use of Historical data (the past flood approach)
  - Hydrological and hydraulic approach (flood modelling)
  - Temporal Satellite Data Analysis
4. Understand Flash Flood hazard assessment using using Flash Flood Potential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

### 3.4 GLOSSARY

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

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

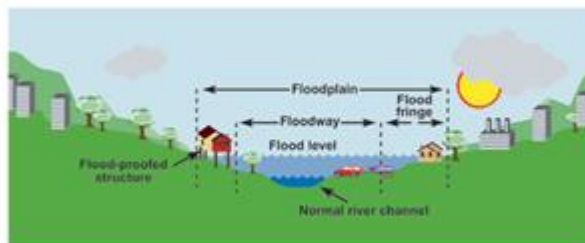
**Flow Accumulation** tool calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into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



Source: ESRI

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

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



Source: Environment and Climate Change Canada



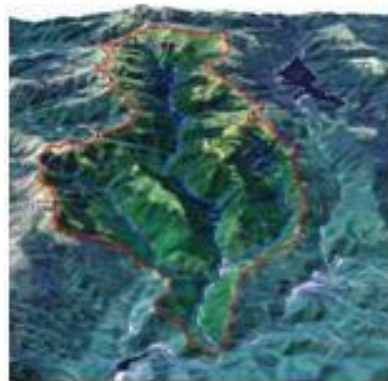
**Floodplain** is the land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood event.

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

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

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

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



Source: NASA

### Causes of Floods?

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

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

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

### Climate Change Effect.

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

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

### What is a Flood Hazard?

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

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

Source: UNISDR, 2004.



### 3.4.1 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

1. Identifying the probability of flood occurrence
2. Flood Modelling (Hydrological and Hydraulic) approach
3. Temporal Satellite Data Analysis

#### 3.4.1.1 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

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

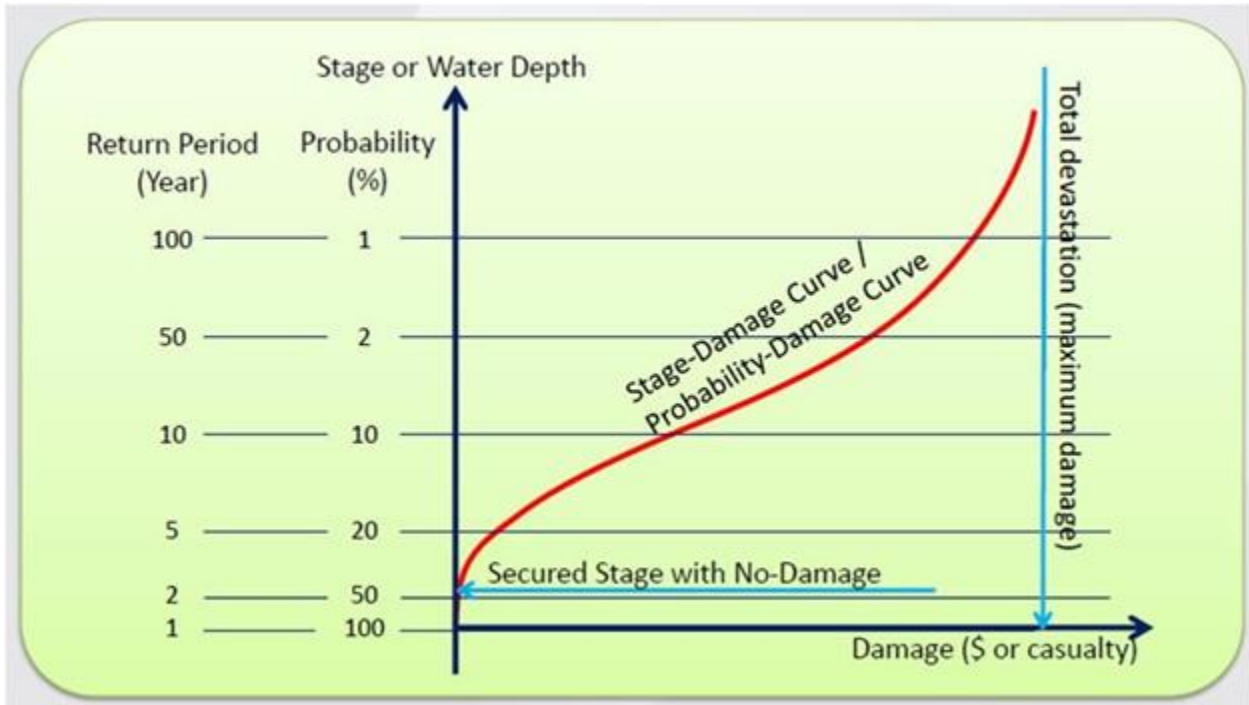
To determine the probability use the formula:  $P = 1 / Tr$

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 Category	Hazard	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.

### Exercise 3.3: Flood Frequency Analysis

#### 3.4.2 Introduction

The return interval or return period, places magnitude of floods in terms of their expected frequency giving a probability of a particular flood occurrence. The method that is used to calculate or determine return periods based on the available data i.e. historical data of flood events, is popularly known as flood frequency analysis.



A 100-year flood is a common design flood use delineates 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 Flood Frequency Analysis is the probability of flood occurrence for different flood gauge heights. 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.

### Learning Objectives

1. Analyze historical data of flood events and calculate the return period or probability of occurrences for different flood gauge heights.

### Data Inputs

Annual Peak Flood discharge (Q) at a particular gauging station as long as possible along with date / year of occurrence.

### Methodology

2. Arrange the Annual Peak Flood discharge data in descending order (highest to lowest) and rank the largest as 1, second largest as 2, etc.
3. Compute the recurrence interval (or return period) of each flood using the formula:

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

N = Total number of years of flood discharge data available

M = Rank of the flood discharge considered for analysis

T = Return period of flood discharge considered for analysis

4. Calculate the probability of occurrence,  $P = 1 / T$
5. Probability that a given flood will occur at least once in 'N' years =

### Exercise

1. Annual Peak Flood discharge data is given below and arrange it in descending order and rank them.
2. Calculate the return period and also probability of occurrence.





2001	24.6				
2002	56.8				
2003	23.2				
2004	17.12				
2005	9.9				
2006	3.46				
2007	50.6				
2008	116.6				
2009	20.2				

1. What is the return period and probability of occurrence of a flood discharge of 50.6 m<sup>3</sup>/s.

2. Return period = \_\_\_\_\_ Probability of occurrence = \_\_\_\_\_

3. Calculate the probability of a flood discharge of 50.6 m<sup>3</sup>/s will occur at least once in,

5 years:  $1 - (1 - 1/ \quad )^5 =$

10 years:  $1 - (1 - 1/ \quad )^{10} =$

25 years:  $1 - (1 - 1/ \quad )^{25} =$

4. What is the return period and probability of occurrence of a flood discharge of 111.8 m<sup>3</sup>/s.

5. Return period = \_\_\_\_\_ Probability of occurrence = \_\_\_\_\_

6. Calculate the probability of a flood discharge of 111.8 m<sup>3</sup>/s will occur at least once in,

5 years:  $1 - (1 - 1/ \quad )^5 =$

10 years:  $1 - (1 - 1/ \quad )^{10} =$

25 years:  $1 - (1 - 1/ \quad )^{25} =$

**Conclusion:**

As the return period ....., probability of occurrence .....

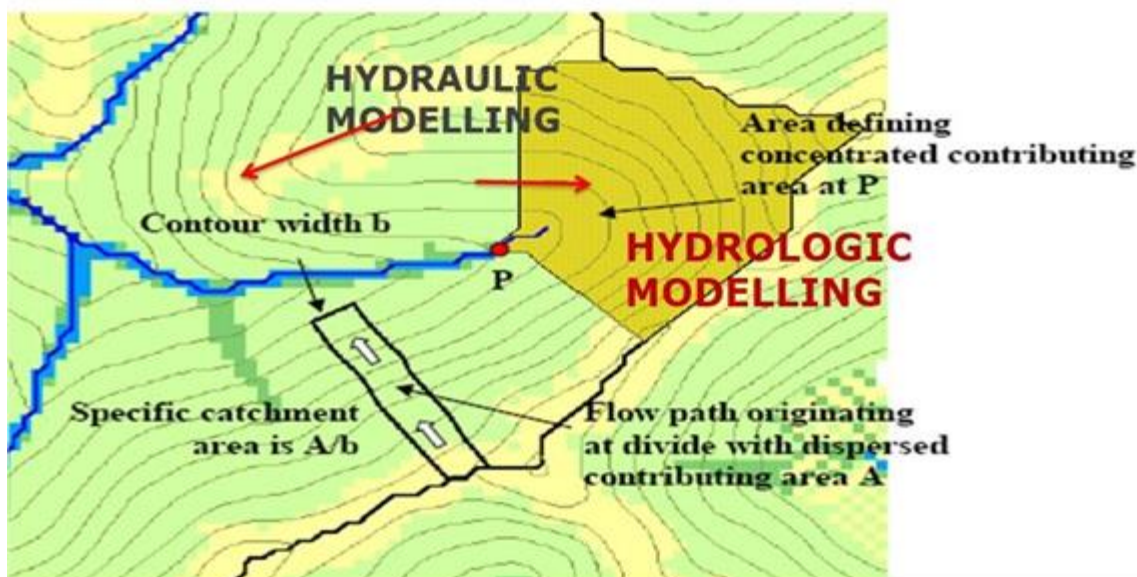
**Own Observations from this exercise:**

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

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



#### Hydrologic and Hydraulic Modelling

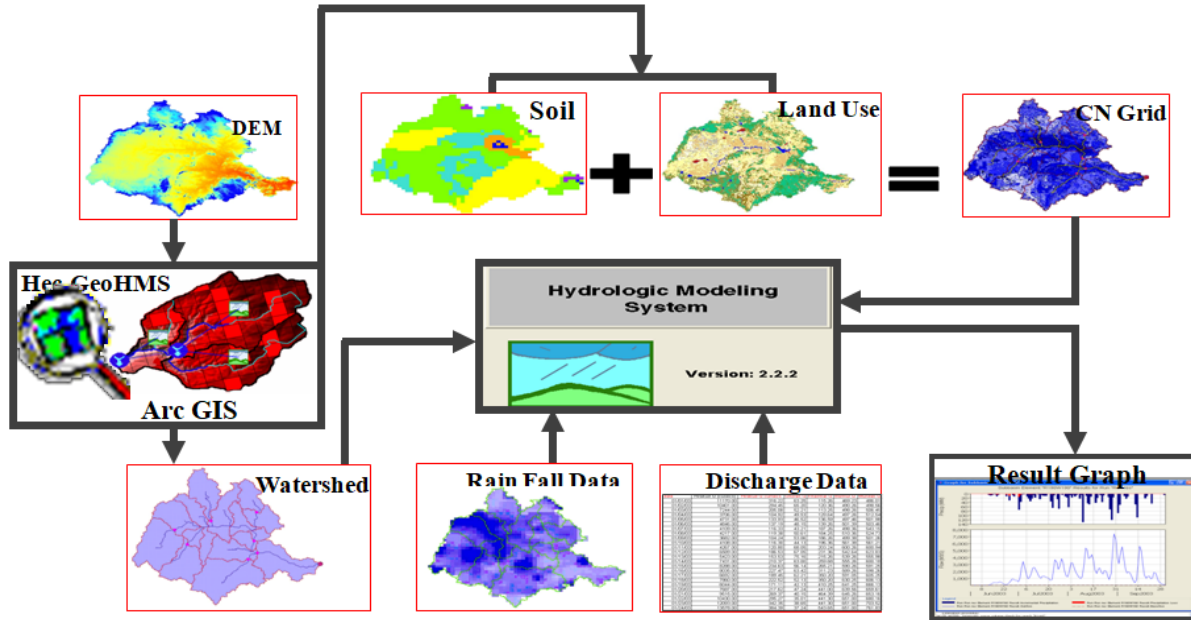
Many hydrologic models exist in literature, however most popularly used models are given here.

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

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

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



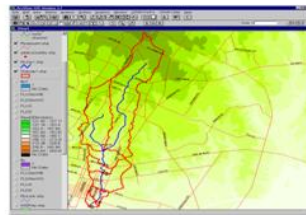


### Components of Hydrological Model

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

### Pre Processing

Arc GIS  
Input Data  
DEM



### Post Processing

Arc GIS  
Flood Inundation Maps



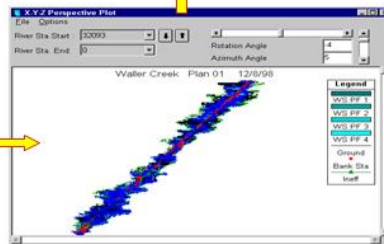
### HEC-HMS

Flood  
discharge



### HEC-RAS

Water  
surface  
profiles



### Components of Hydraulic Model

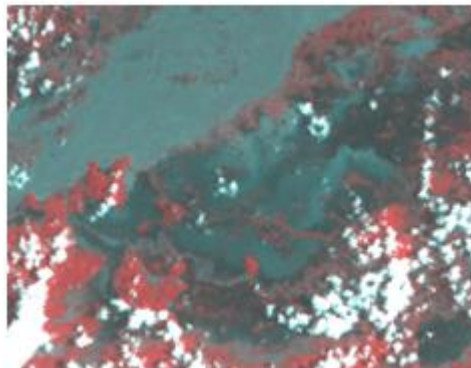
### Temporal Satellite Data Analysis:

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.

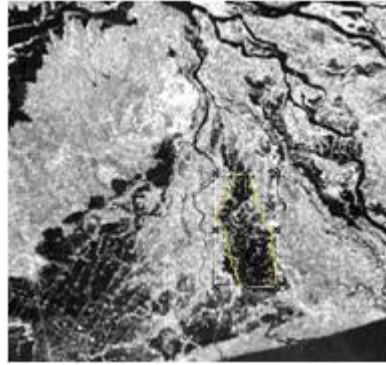


*Flood area represented in optical satellite data*

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 3.4: 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.

#### **Learning Objectives**

1. Understand the concepts of FFPI
2. Input geo-spatial data requirement and data availability
3. Development and Analysis of FFPI



## Data Inputs

Data	Type of Data / File Format	Specifications	Source	File Name	Data Path
Digital Elevation Model (DEM)	Raster / Tif	Resolution: 90 m	SRTM	DEM.tif	\\SSD_Data\Module3\Flood\FFPI\Input\Raster\
Land Cover/Use	Vector / Shapefile	-	<a href="http://www.fao.org/geonetwork/srv/en/main.home">http://www.fao.org/geonetwork/srv/en/main.home</a>	SSD_Lulc.shp	\\SSD_Data\Module3\Flood\FFPI\Input\Vector
Soil Type/Texture	Raster / Tif	Resolution: 1 Km	FAO Harmonized World Soil Database V 1.21	SSD_Soil.tif	\\SSD_Data\Module3\Flood\FFPI\Input\Raster\
South Sudan Admin 3 (level 3)	Vector / Shapefile	-	ICPAC	SSD_Admin3.shp	\\SSD_Data\Module3\Flood\FFPI\Input\Vector
Watershed boundary	Vector / Shapefile	-	Hydrosheds	SSD_Wshed.s.shp	\\SSD_Data\Module3\Flood\FFPI\Input\Vector

## Methodology

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. 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 weights

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. An index value of 1 indicates a minimum flash flood threat and an index of 10 indicates a maximum flash flood threat. 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.

### Exercise

The datasets required for FFPI represent the physiographic characteristics of the terrain i.e. Slope, Soil and Land Cover/Use (L) and Vegetation Cover/Forest Density (V) index.

**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** the existing ArcMap project (workspace) "SSD\_FFPI.mxd" stored on:

X:\SSD\_Data\Module3\Flood\FFPI\Workspace\

2. Check the input data given above, in Table of Contents (TOC).
3. **Bring up** Arctoolbox by **clicking** the  button
4. **Go to** *Spatial Analyst Tools > Surface > Slope*
5. **Select** the *Input Raster "DEM.tif"* from the following location:

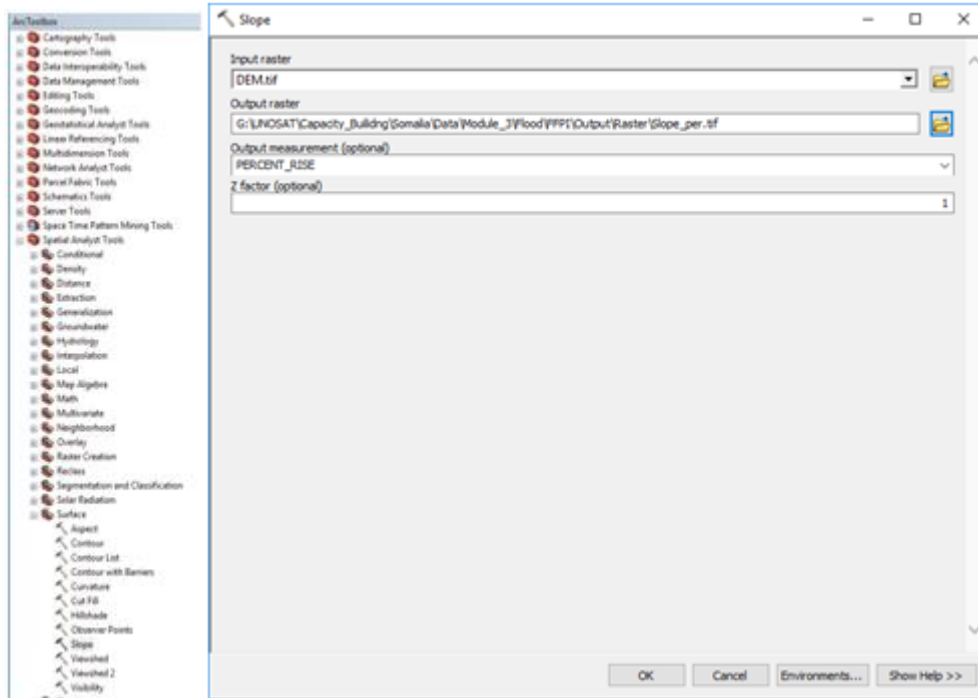
X:\SSD\_data\Module3\Flood\FFPI\Input\Raster\

6. **Select** the *Output Raster "Slope\_per.tif"* in the following location:

X:\SSD\_data\Module3\Flood\FFPI\Output\Raster\

7. **Select** the "PERCENT\_RISE" for Output measurement (optional)
8. **Click OK**






10. Slope Index will change for slope < 30%,

$$\text{Slope index} = 10^{n/30}$$

If slope is > 30%, Slope Index = 10.

Convert the slope map into Slope Index using the above formula, using Raster Calculator.

11. **Bring up** Arctoolbox by **clicking** the  button
12. **Go to** *Spatial Analyst Tools > Map Algebra > Raster Calculator.*
13. In Raster Calculator Expression window, write the expression (use the available functional tools) given below.

**Con("Slope\_per.tif" <= 30.0,Power(10.0,"Slope\_per.tif"/30.0),10.0)**

14. **Select** the *Output Raster "SlopeIndex.tif"* in the following location

**X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\**

15. *SlopeIndex* map should look like as given below.



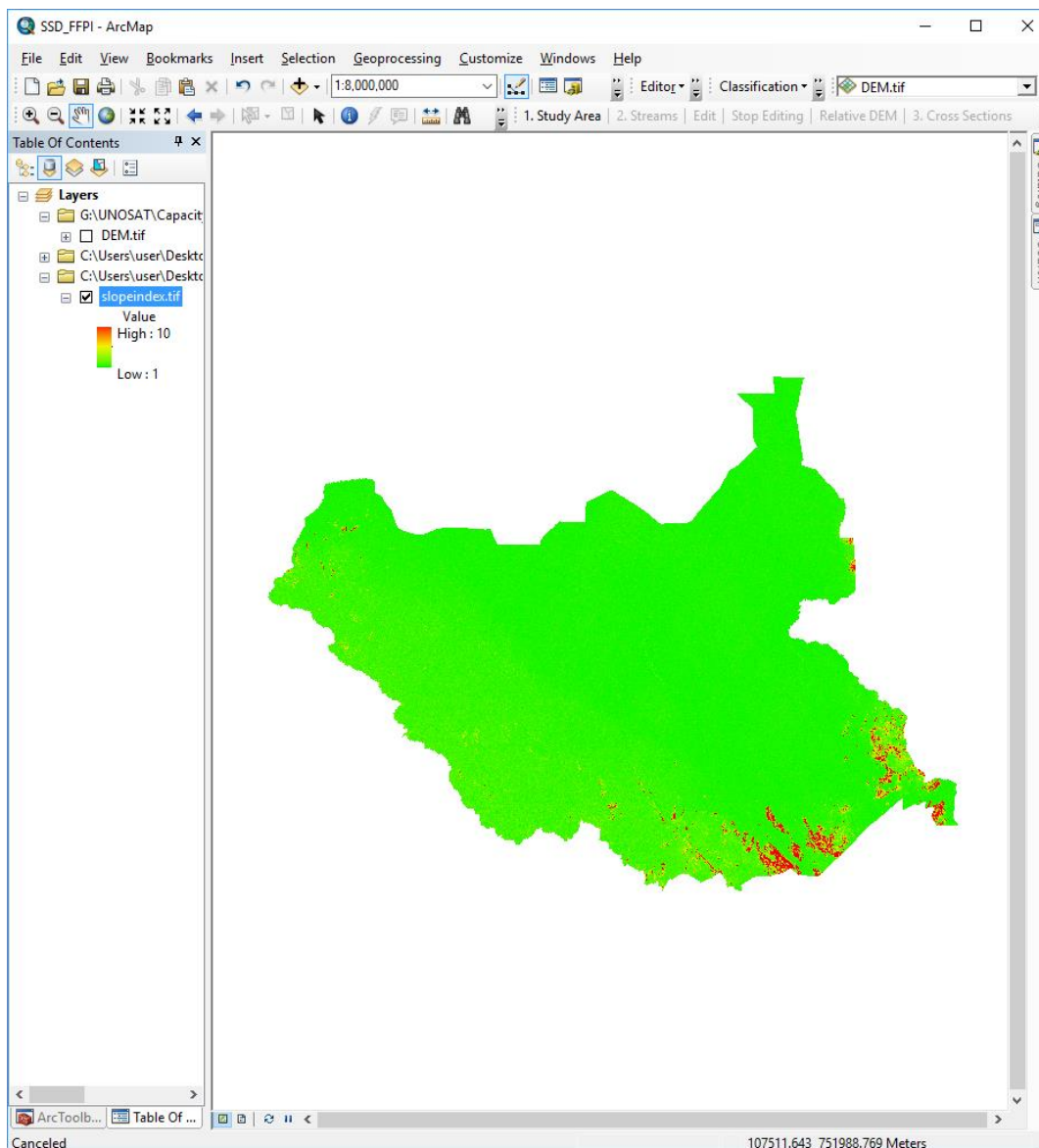
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**Land Cover/Use (L) and Vegetation Cover/Forest Density (V):** The land cover /use dataset includes many different components, including biophysical settings, existing vegetation cover (EVC), existing vegetation height and existing vegetation type. 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 extracted from the regional (Africa) archive of Global land cover (raster). It has been post-processed to generate a vector version at national extent with the LCCS regional legend (46 classes), aggregated to 6 classes: Agriculture (AG), Barren Area (BA), Natural Vegetation Terrestrial (NVT), Natural Vegetation Aquatic (NVW), Urban Areas (UR) and Water Bodies (WAT). More details are available at



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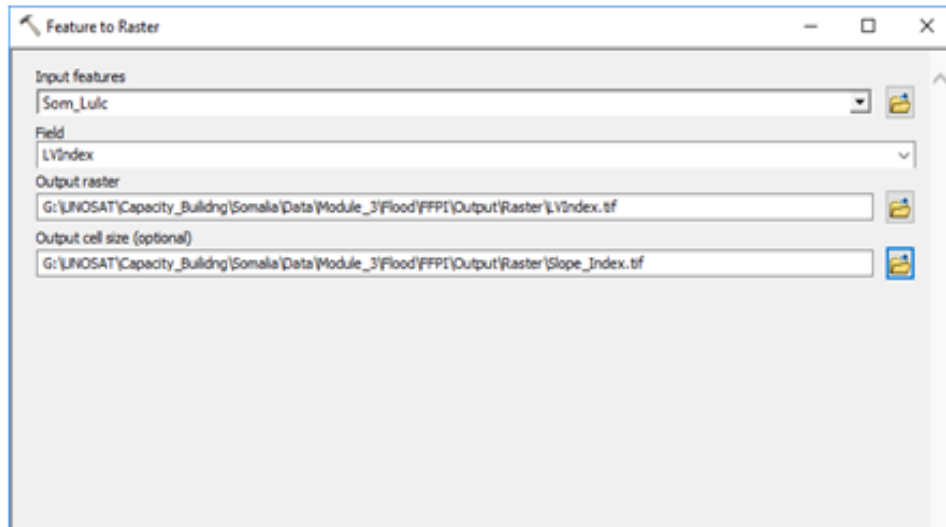
<http://www.fao.org/geonetwork/srv/en/metadata.show?currTab=simple&id=38184>. The above mentioned land use categories are assigned appropriate FFPI values based on the literature (Zogg and Deitsch, 2013) and given in Table 1. The values were subjectively assigned because it would be extremely difficult 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)

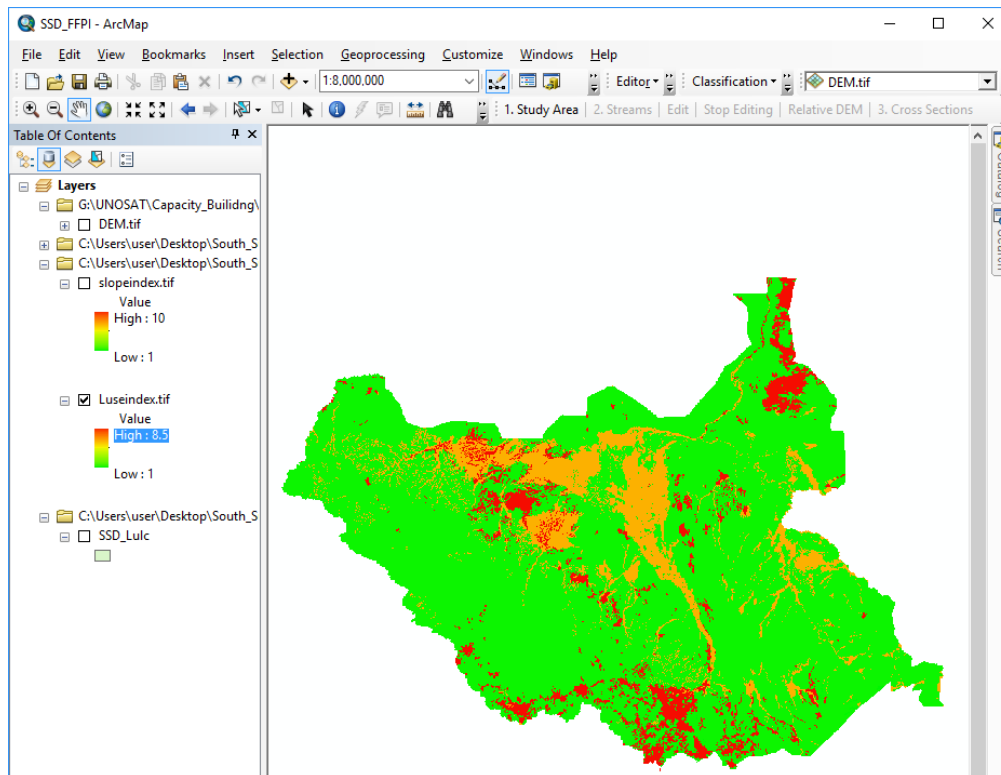
Aggregated Land use Category (FAO LCCS Categories)	FFPI
Agriculture (AG)	5.5
Barren Area (BA)	8
Natural Vegetation Terrestrial (NVT)	4
Natural Vegetation Aquatic (NVW)	5
Urban Areas (UR)	8.5
Water Bodies (WAT)	1

Note: An index value of 1 indicates a minimum flash flood threat and an index of 10 indicates a maximum flash flood threat.

1. Select "Sudan\_lulc" map in the ARC map window.
2. **Bring up** Arctoolbox by **clicking** the  button
3. **Go to** Conversion Tools > To Raster > Feature to Raster.
4. **Select** the Input Features "SSD\_Lulc" from the following location:
  - o X:\SSD\_data\Module3\Flood\FFPI\Input\Vector\
5. **Select** Field "Luse\_Index.tif" (FFPI value for each land use category).
6. **Select** Output Raster "LuseIndex.tif" in the following location
  - o X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\
7. **Select** Output Cell size (optional) "SlopeIndex.tif"
8. **Click** OK



- “LVIndex.tif” map should look like as given below.



**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 calculate Soil Index.

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



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Where  $n$  = percent clay.

1. Select "SSD\_Soil.tif" in the ARC map window.
2. Right Click and Open Attribute table of "SSD\_Soil.tif" and identify the attributes which represent the Clay ( $T\_CLAY$ ) and Sand ( $T\_SAND$ ) percentages?
3. **Bring up** Arctoolbox by **clicking** the  button
4. **Go to** *Spatial Analyst Tools > Reclass > Lookup.*
5. **Select** the *Input Raster* "SSD\_Soil.tif" from the following location:

X:\SSD\_data\Module3\Flood\FFPI\Input\Raster\

6. Select *Lookup field* "T\_CLAY"
7. **Select** the *Output Raster* "Clay.tif" in the following location:

X:\SSD\_data\Module3\Flood\FFPI\Output\Raster\

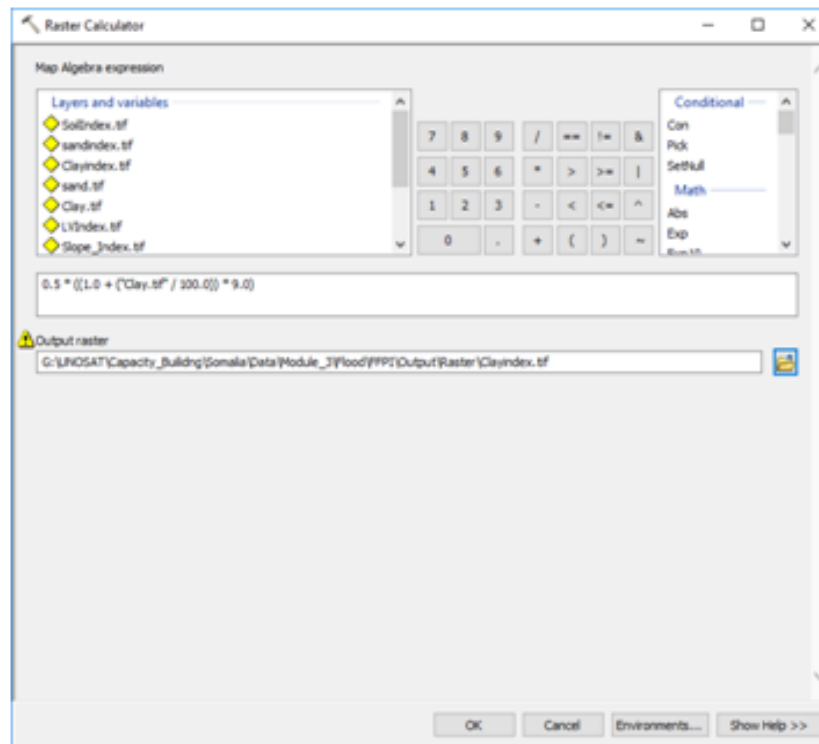
8. **Click** *OK.*
9. **Bring up** Arctoolbox by **clicking** the  button
10. **Go to** *Spatial Analyst Tools > Map Algebra > Raster Calculator.*
11. In Raster Calculator Expression window, write the expression (use the available functional tools) given below.

$$0.5 * ((1.0 + ("clay.tif" / 100.0)) * 9.0)$$

12. **Select** *Output Raster* "ClayIndex.tif" in the following location

X:\SSD\_data\Module3\Flood\FFPI\Output\Raster\

13. **Click** *OK.*







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

Where  $n$  = percent sand.


1. **Bring up** Arctoolbox by **clicking** the  button
2. **Go to** *Spatial Analyst Tools > Reclass > Lookup.*
3. **Select** the *Input Raster* “SSD\_Soil.tif” from the following location:

X:\SSD\_Data\Module3\Flood\FFPI\Input\Raster\

4. Select *Lookup field* “T\_SAND”
5. **Select** the *Output Raster* “Sand.tif” in the following location:

X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\

6. **Click** *OK.*

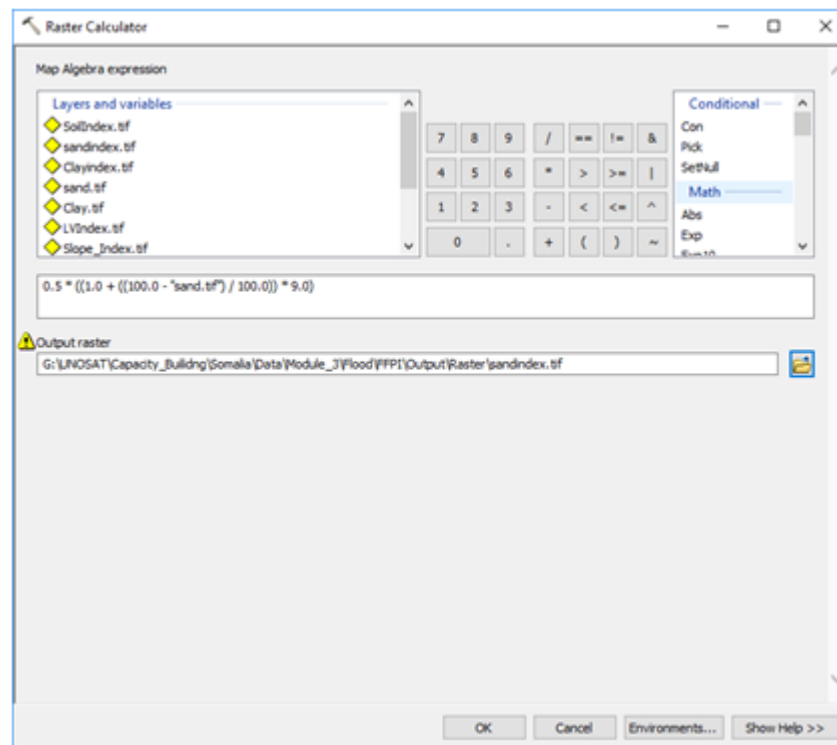
7. **Bring up** Arctoolbox by **clicking** the  button
8. **Go to** *Spatial Analyst Tools > Map Algebra > Raster Calculator.*
9. In Raster Calculator Expression window, write the expression (use the available functional tools) given below.

$$0.5 * ((1.0 + ((100.0 - "sand.tif") / 100.0)) * 9.0)$$

10. **Select** *Output Raster* “SandIndex.tif” in the following location


X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\

11. **Click** *OK.*





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

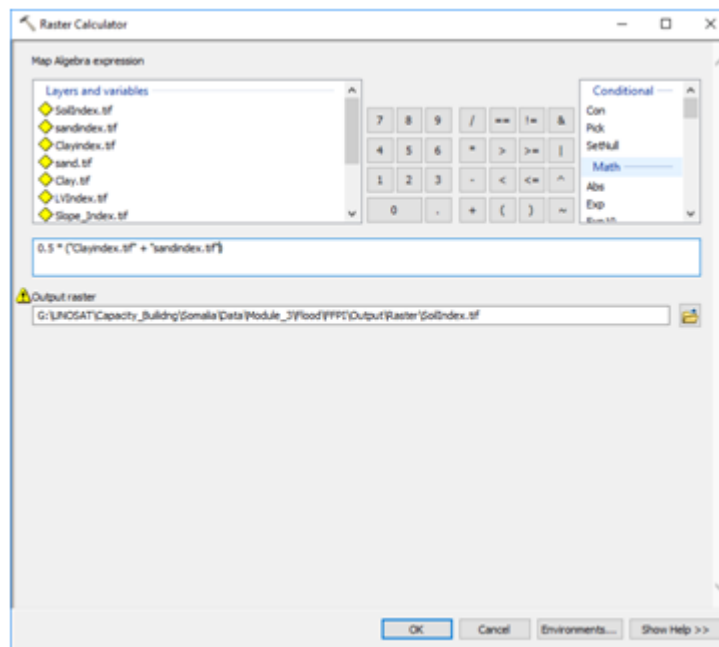
1. **Bring up** Arctoolbox by **clicking** the  button
2. **Go to** *Spatial Analyst Tools > Map Algebra > Raster Calculator.*
3. In Raster Calculator Expression window, write the expression (use the available functional tools) given below.

**0.5 \* ("ClayIndex.tif" + "SandIndex.tif")**

4. **Select** *Output Raster "SoilIndex.tif"* in the following location

X:\SSD\_Data\Module3\Flood\FPI\Output\Raster\

5. **Click** *OK.*



6. *SoilIndex.tif* map should look like as given below.



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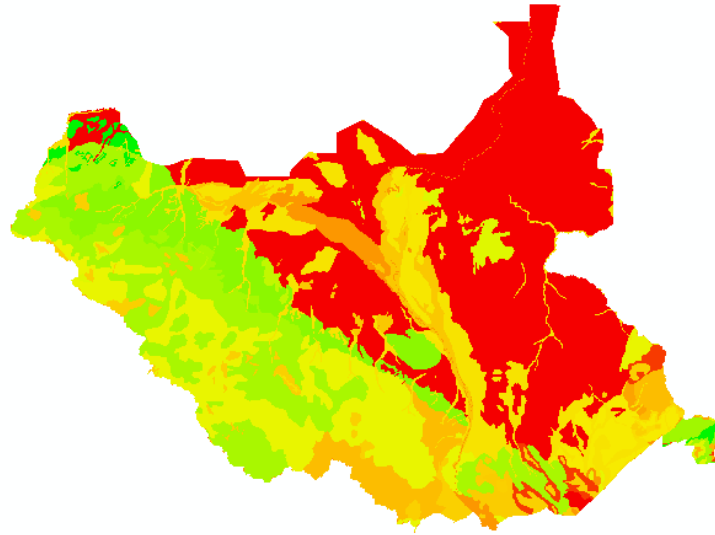
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- FFP\_SSD.tif
- SoilIndex.tif
  - Value
  - High : 7.56
  - Low : 4.545
- Luseindex.tif
- C:\Users\user\Desktop\South\_S
- SSD\_Lulc



7. Now using the *Slopeindex.tif*, *SoilIndex.tif* and *LVIndex.tif* maps calculate Flash Flood Potential Index for Solmalia, using *Spatial Analyst Tools > Map Algebra > Raster Calculator*.

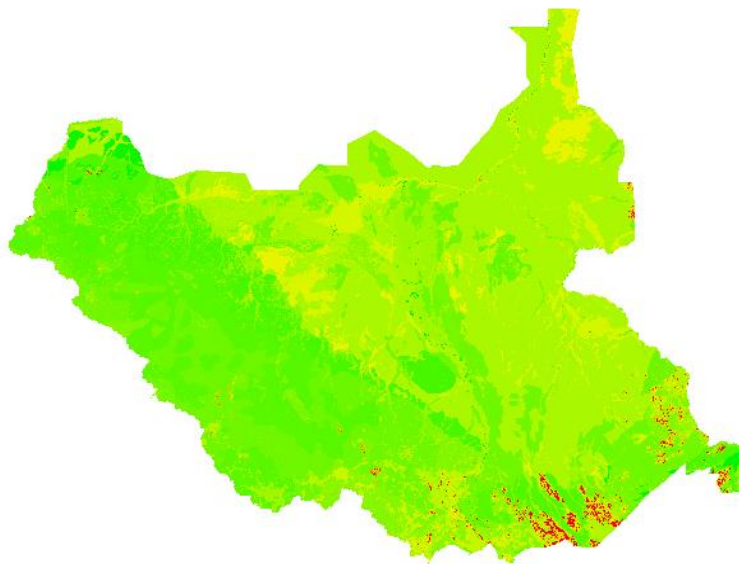
$$FFPI = 0.5 * (\text{slopeindex.tif} + \text{soilindex.tif} + \text{lulcIndex.tif}) / 3$$

8. **Select Output Raster** "FFPI\_SSD.tif" in the following location

X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\

9. **Click OK.**

- slopeindex.tif
- FFPI\_SSD.tif
  - Value
  - High : 4.06875
  - Low : 1.24458
- SoilIndex.tif
  - Value
  - High : 7.56
  - Low : 4.545
- Luseindex.tif
- C:\Users\user\Desktop\South\_S
- SSD\_Lulc






10. As you observed the minimum and maximum range of FFPI is 1.245 and 4.069. 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	Class Code
High	3.0	4.069	3
Moderate	2.0	3.0	2
Low	1.245	2.0	1

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

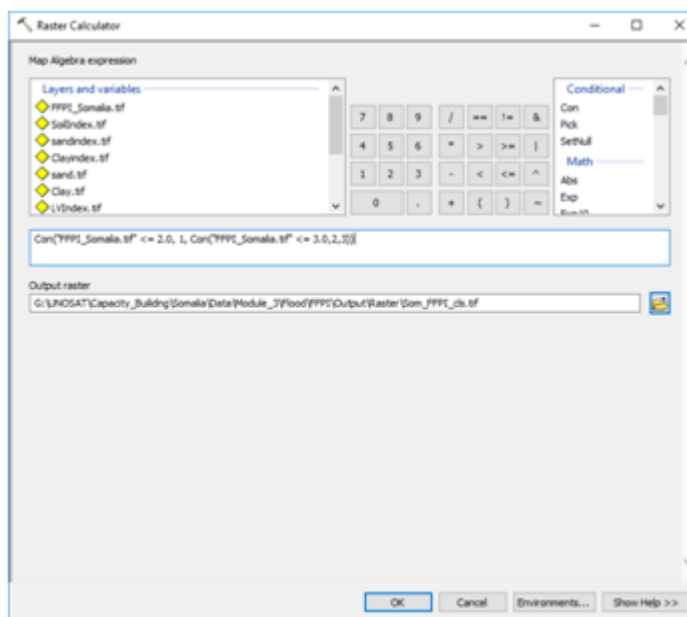
1. Use the above range of FFPI values to classify the FFPI map of South Sudan using *Raster Calculator*.
2. **Bring up** Arctoolbox by **clicking** the  button
3. **Go to** *Spatial Analyst Tools > Map Algebra > Raster Calculator*.
4. In Raster Calculator Expression window, write the expression (use the available functional tools) given below.

**Con("FFPI\_SSD.tif" <= 2.0, 1, Con("FFPI\_SSD.tif" <= 3.0, 2,3))**

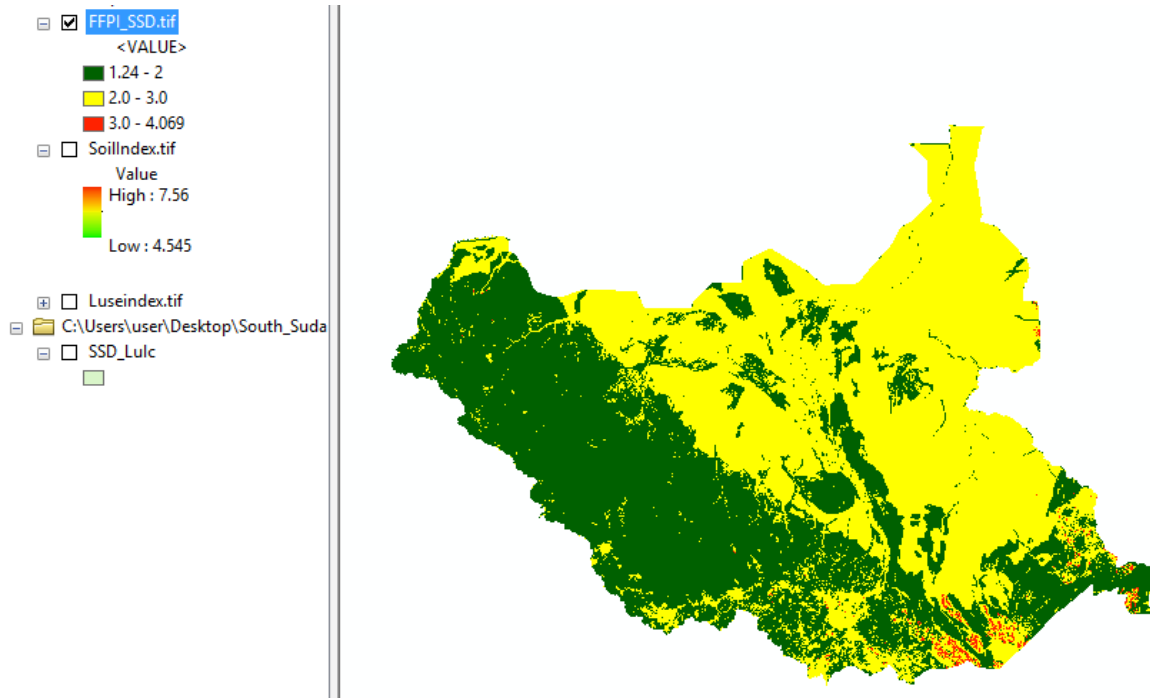
5. **Select Output Raster** "*FFPI\_SSD\_cls.tif*" in the following location

**X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\**


6. **Click OK.**



- The classified FFPI map of South Sudan is given below.



### Which sub-District in South Sudan has highest Flash Flood Potential?

1. Let us now assess the mean FFPI within each sub-district (Admin 3).
2. **Bring up** Arctoolbox by **clicking** the  button
3. **Go to** *Spatial Analyst Tools > Zonal > Zonal Statistics as Table.*
4. **Select** the *Input Raster or Feature Zone Data* “SSD\_Admin3” from the following location:

X:\SSD\_Data\Module3\Flood\FFPI\Input\Vector\

5. **Select** Zone Field “NAME\_3”
6. **Select** the *Input Value Raster* “FFPI\_SSD.tif” in the following location:

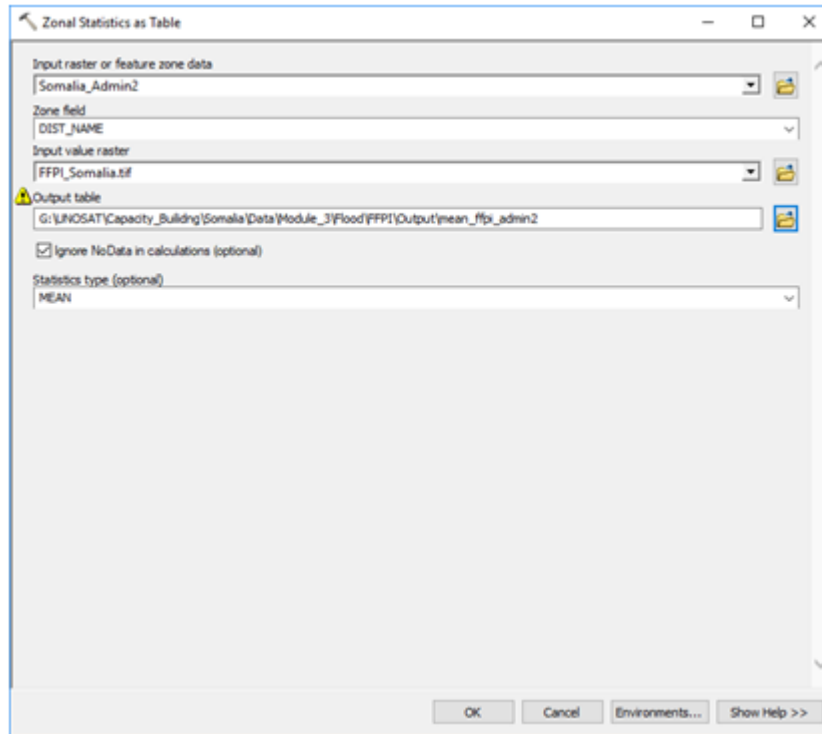
X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\

7. **Select** the *Output Table* “Mean\_FFPI\_Admin3” in the following location:

X:\SSD\_Data\Module3\Flood\FFPI\Output\

8. Select Statistics Type (optional) “MEAN”
9. **Click** *OK.*





1. Open the Table “*Mean\_FFPI\_Admin3*” to see the Mean FFPI value for each sub-district in the field “*MEAN*”.
2. Analyse the table “*Mean\_FFPI\_Admin3*” and answer the following questions.

### Questions


1. In which sub-district the mean FFPI is highest?

---

2. In how many sub-districts the mean FFPI is more than 2.0?

---

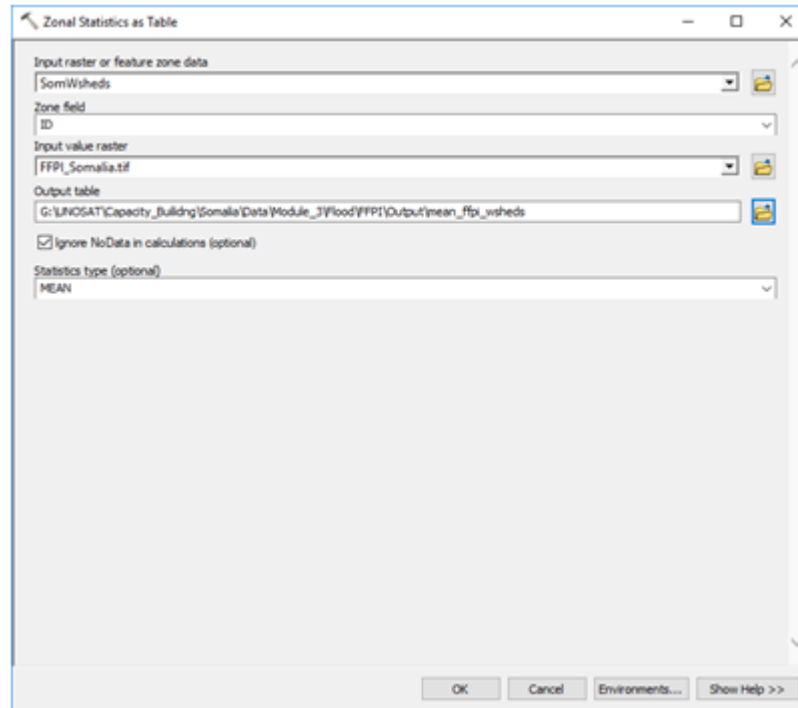
### How many watersheds in South Sudan have highest Flash Flood Potential?

1. Let us now assess the mean FFPI within each watershed.
2. **Bring up** ArcToolbox by **clicking** the  button
3. **Go to** *Spatial Analyst Tools > Zonal > Zonal Statistics as Table.*
4. **Select** the *Input Raster or Feature Zone Data* “*SSD\_Wsheds*” from the following location:

X:\SSD\_Data\Module3\Flood\FFPI\Input\Vector\



5. **Select** Zone Field “ID”
6. **Select** the *Input Value Raster* “FFPI\_SSD.tif” in the following location:  
X:\SSD\_Data\Module3\Flood\FFPI\Output\Raster\
7. **Select** the *Output Table* “Mean\_FFPI\_Wsheds” in the following location:  
X:\SSD\_Data\Module3\Flood\FFPI\Output\
8. Select Statistics Type (optional) “MEAN”
9. **Click OK.**



- Analyse the table “Mean\_FFPI\_Wsheds” and answer the following question.

### Questions

1. In how many watersheds the mean FFPI is more than 3.0?

---

### Own Observations from this exercise:

---



### 3.4.4 UNDERSTANDING FLOOD HAZARD MAP (GAR 2015) OF UPPER NILE STATE

#### 3.4.4.1 Flood Hazard mapping methodology adopted in Global Assessment Report

The methodology used for the flood hazard maps derivation encompasses several steps. Hazard maps were developed for the “present climate”, using stream-flow data from a global database of stream-flow data has been compiled, merging different sources gathering more than 8000 stations over the globe with time series long enough in order to perform an extreme value statistical analysis. Where observed data is not available, a regression relationship of the geomorphological and climatological variables was used to derive “index discharge”. A continuous, distributed and physically based hydrologic model, CONTINNUM was used to improve this regression and estimate river discharge at selected locations in the river network.

Once the discharge is determined (Figure 1 (a)), results are the input of a simplified hydraulic flood model. The model draws hydraulic cross-sections (Figure 1 (b)) where the flood level is computed from the stream-flow value resolving the manning equation. Levels are then interpolated on the basis of the local relative morphology.



Figure 1:(a) Locations of discharge estimate (b) Hydraulic cross-sections at discharge locations

Source: GAR,2011

A flow chart below depicts the methodology adopted for hydrologic and hydraulic modeling along with final flood hazard preparation in GIS environment.



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Figure 2 : Scheme illustrating the full workflow to obtain flood hazard maps for different return periods  
Source: GAR,2011

Flood Hazard map of 25 year return period for Upper Nile state in South Sudan is extracted from global flood map. Flood depth in Nile state varies from 0 to 438.6 cm. The flood depth is re-classified into 5 depth classes (0 - 25 cm, 25 - 50 cm, 50 - 100 cm, 100 - 200 cm, > 200 cm) and shown in Figure 3.

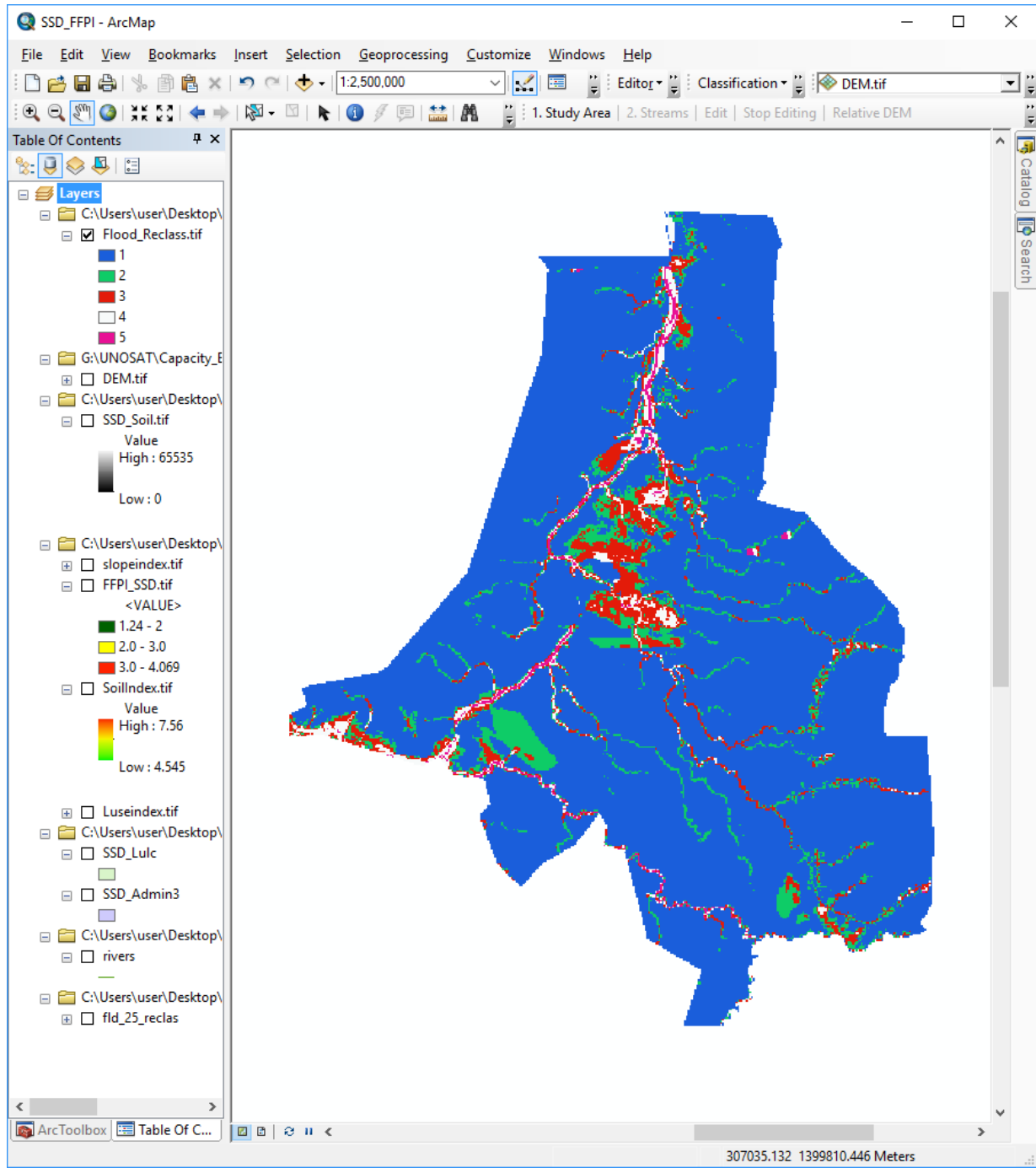


Figure 3: Flood Hazard map (25 year Return Period) of Upper Nile state in South Sudan  
Source: GAR, 2011.

### Exercise 3.5 EXPOSURE ASSESSMENT OF ELEMENTS AT FLOOD RISK

#### Introduction

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





## Learning Objectives

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

1. Understand the geographical extent of 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\Flood\Exposure\Input\Vector	Vector (polygon)	<i>Upper_Nile_State.shp</i>
Flood Extent Area	X:\Module3\Flood\Exposure\Input\Vector	Vector (polygon)	<i>fld_25_reclas.shp</i>
Road Network	X:\Module3\Flood\Exposure\Input\Vector	Vector (polyline)	Roads_Nile_State.zip
Settlements	X:\Module3\Flood\Exposure\Input\Vector	Vector (point)	Places_Nile_State.shp
Land use	X:\Module3\Flood\Exposure\Input\Vector	Vector (polygon)	Lulc_Nile_State.shp
Population (Grid) data	X:\Module3\Flood\Exposure\Input\Raster	Raster	SSD_Pop_WP.tif



## Output

Output expected in this session is,


1. Area of Flood Extent
2. Length of the road types inundated due to Flood
3. Land use categories inundated due to Flood
4. Settlements located in Flood area
5. Population affected due to flood



### STEP (16)

#### Assessment of elements at risk exposed to flood

1. Open *Exposure\_Flood.mxd* at *X:/SSD\_Data/Module3/Flood/Exposure/Workspace/*
2. 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*

1. Length of the road types exposed to Flood

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



<b>Total</b>	

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*

---

- Overlay Flood extent and land use map to assess the land use categories exposed to flood. Calculate percentage of total land use categories exposed to flood.

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

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

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



## DISCUSSION

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

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

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

-----  
-----

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

-----  
-----

Can you identify the potential problems in using Optical data?

-----  
-----

What are the advantages/disadvantages of using WorldPop data?

-----  
-----

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

-----  
-----

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

-----

-----

### 3.4.5 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.

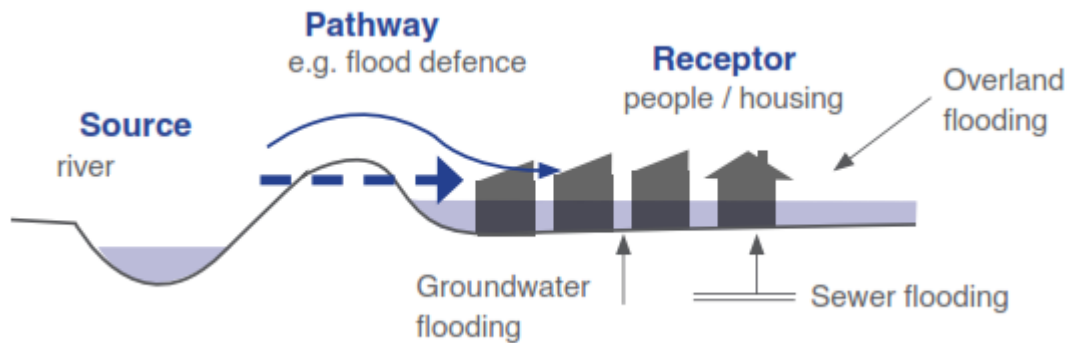


Figure: Source-Pathway-Receptor Model

**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.



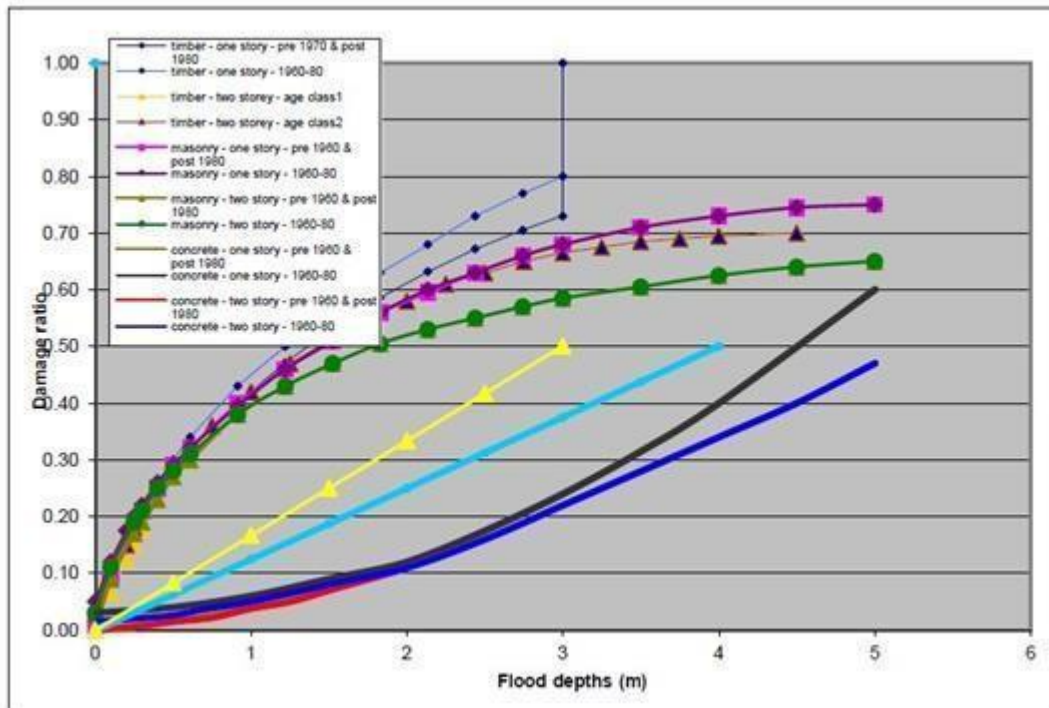


Flood vulnerability is one of the significant components in risk management and flood damage assessment. Vulnerability measurement is a complex process because it influenced by several environmental, economic, and social or even political elements in local scale. In other words vulnerability is affected 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 circumstance.

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.





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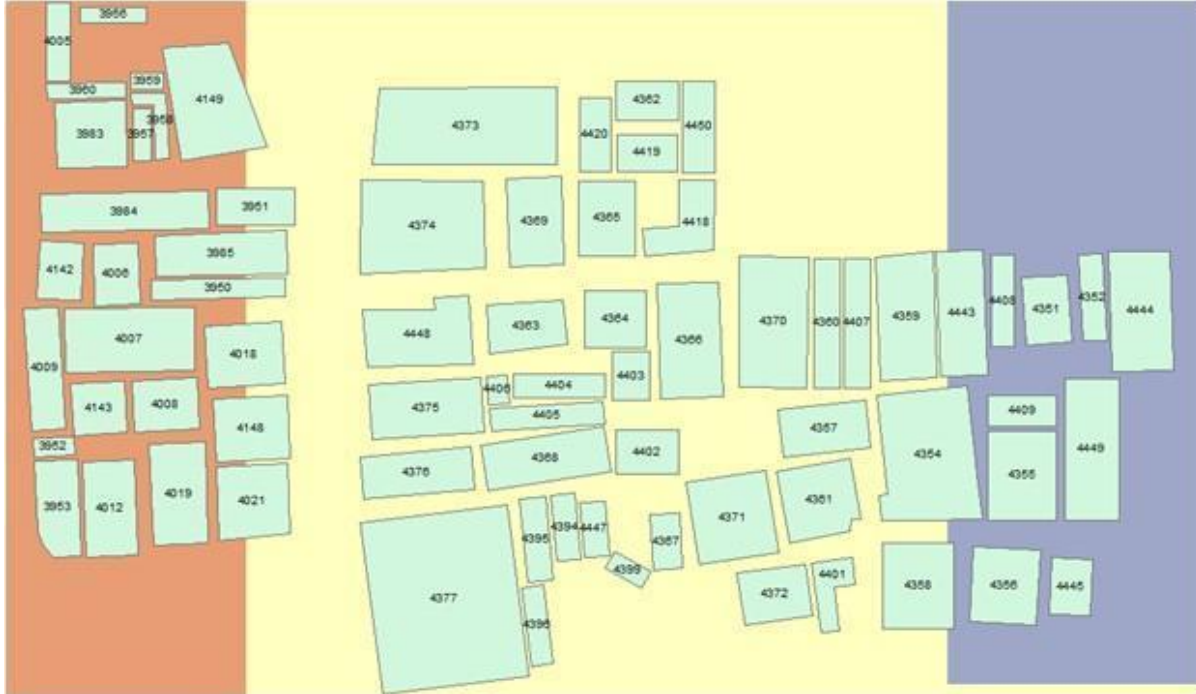
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## Flood Risk Assessment Exercise

**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:

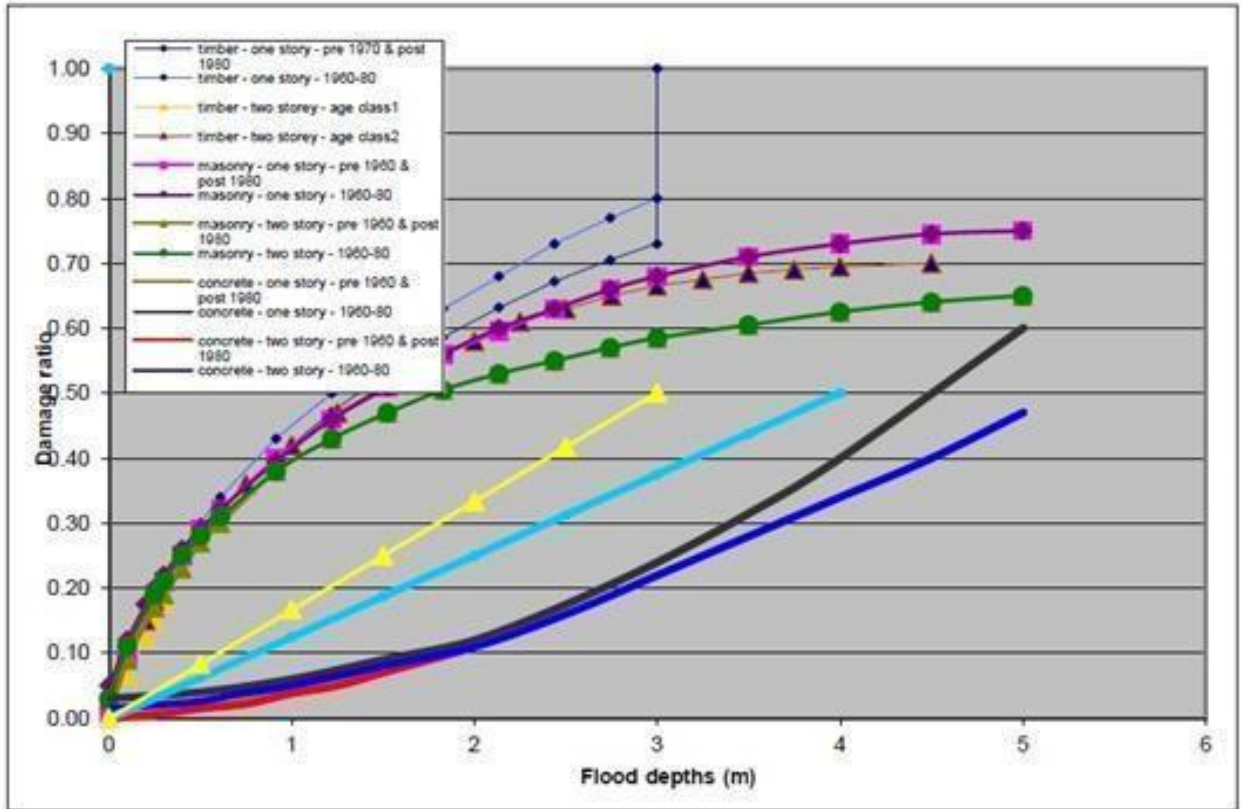
Flood Depth (m)	Color Code in the flood depth map
1.0	
1.5	
2.0	

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



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

- **Depth - Damage Ratio Curves**



### Methodology

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

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



ID	Flood Depth (m)	Damage Ratio	Cost of the Building (\$)	Damage (\$)
39 51			1000	
39 59			1600	
39 83			7000	
39 85			10000	
43 55			7000	
43 59			6000	
43 66			6000	
43 73			3500	
44 43			3500	
44 49			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?

-----  
-----



**STEP (17)**

### 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.

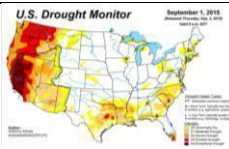

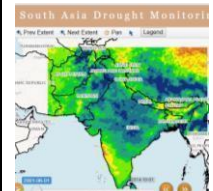


#### 3.5.1 Drought Monitoring for Early Warning

##### 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)	 <a href="http://drought.unl.edu/Home.aspx">http://drought.unl.edu/Home.aspx</a>
Combined Drought Indicator (CDI)	SPI, Soil moisture, vegetation anomaly, snow pack, river discharge	European Drought Observatory - Joint Research Center	 <a href="http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000">edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000</a>
Meteorological, agricultural	SPI, soil moisture, drought severity index	The South Asia Drought Monitoring System (SADMS)	 <a href="http://dms.iwmi.org/app/">http://dms.iwmi.org/app/</a>
Meteorological, agricultural, hydrological	SPI, stream flow, vegetation, and many others	Princeton University: African drought & flood monitor	 <a href="http://stream.princeton.edu/AWCM/WEBPAGE/interface.php?locale=en">http://stream.princeton.edu/AWCM/WEBPAGE/interface.php?locale=en</a>
Meteorological, agricultural	SPI, vegetation anomaly/condition	ICPAC: Drought Watch	 <a href="https://icpac.maps.arcgis.com/apps/CompareAnalysis/index.html?appid=622cfedde5304661bf606eaca65d7dc">https://icpac.maps.arcgis.com/apps/CompareAnalysis/index.html?appid=622cfedde5304661bf606eaca65d7dc</a>

### 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).

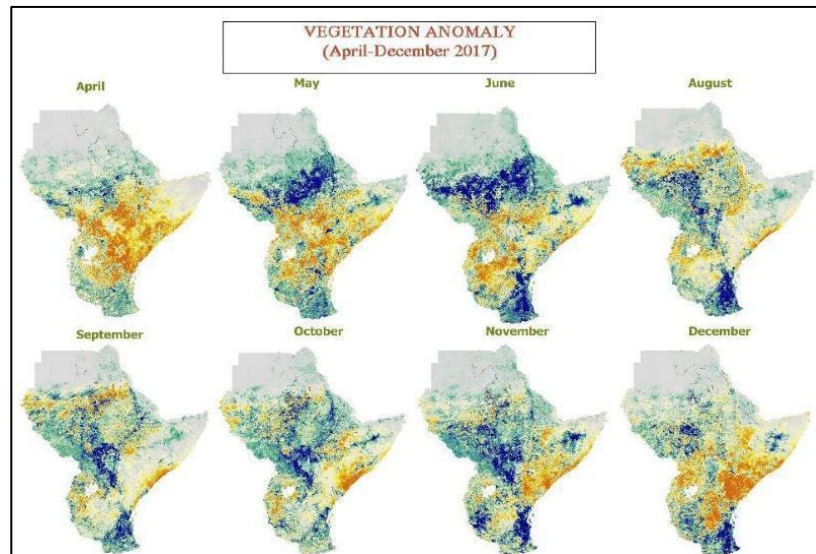
For the purpose of demonstration and exercise, we run seasonal anomaly based drought monitoring (meteorological drought). For that we will follow these procedures:

- 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 May2017 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.

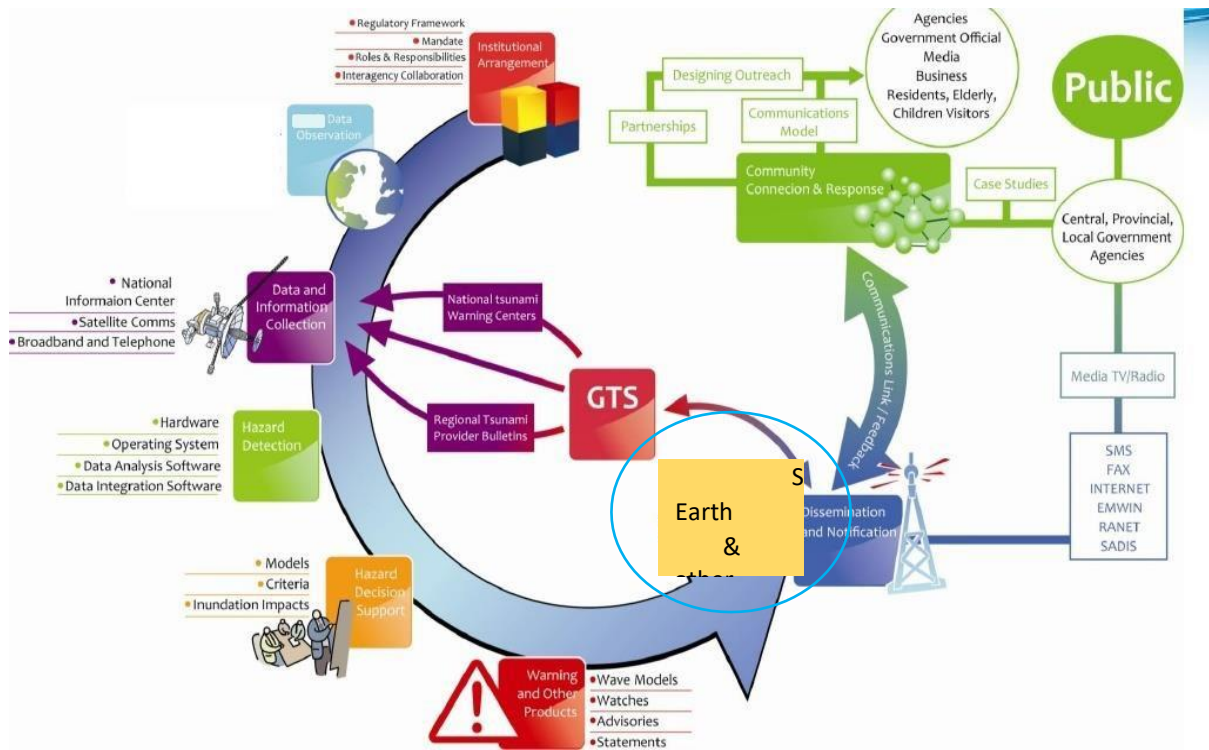
**Integration into response planning.** Emergency response plans are developed with consideration for hazard/risk levels, characteristics of the exposed communities (urban, rural, ethnic populations, tourists and particularly vulnerable groups such as children, the elderly and the hospitalized), coordination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

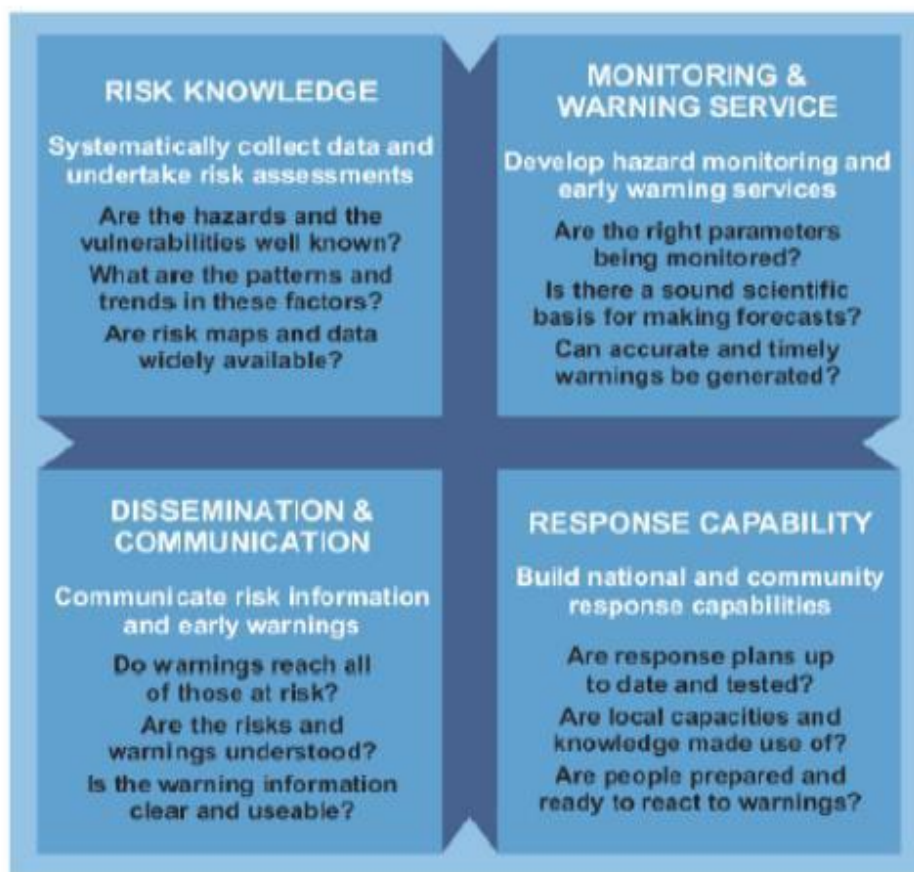
The development and hosting of a multi-hazard early warning system for your institution requires all the technical skills covered under the previous modules of this training, in addition to other capacities like hardware, resources and so on. However, it is very important to stress the importance of 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

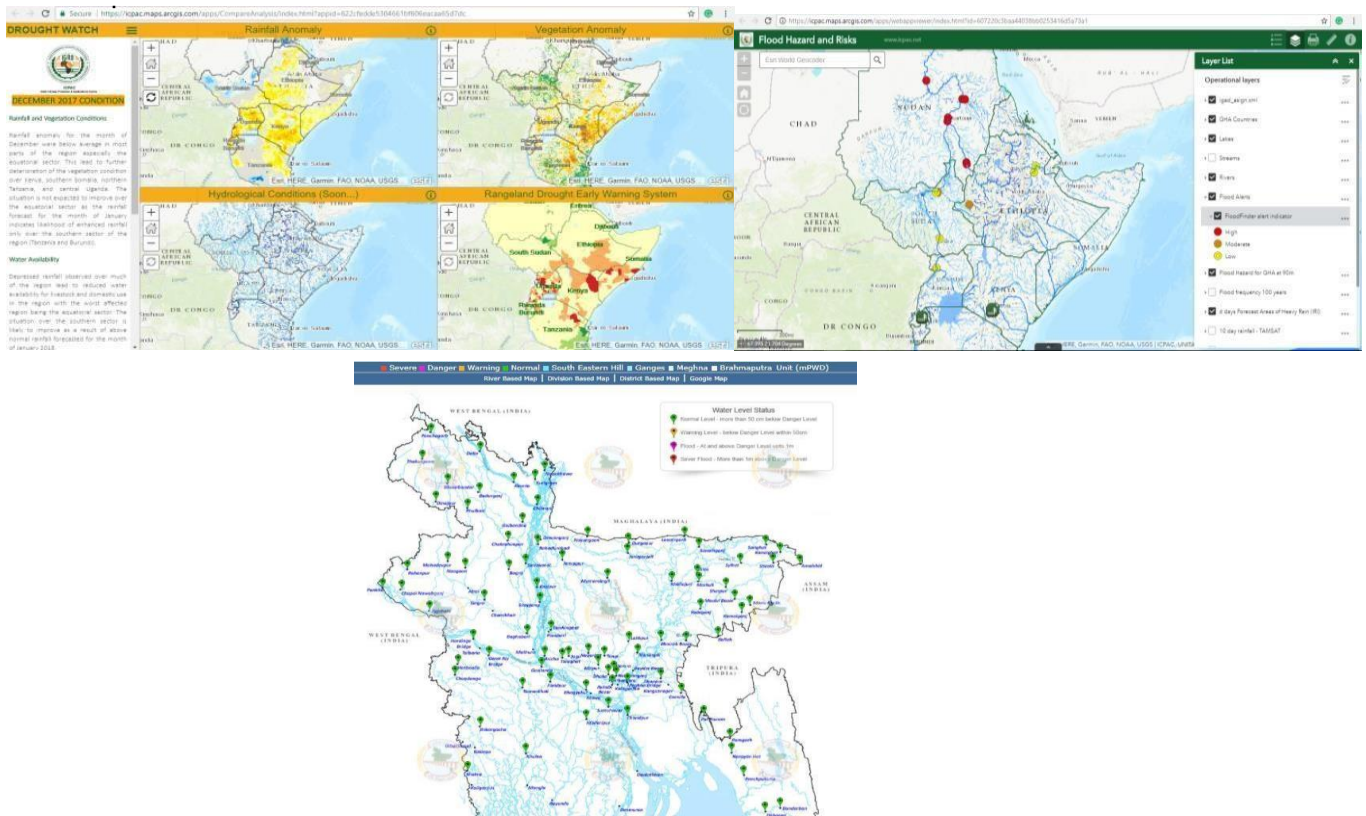
There are four components needed for an effective early warning: **Detection, monitoring and forecasting the hazards; Analyses of risks involved; Dissemination of timely warnings - which should carry the authority of government; Activation of emergency plans to prepare and respond.** These four components 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 Model based flood early warning*



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

## 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

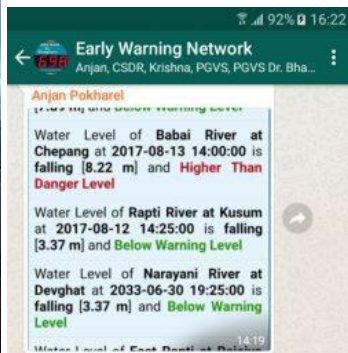




the type and level of risks involved (to life, property...etc) with coverage/location information, guideline on *what to do* for the responders (the community is the first responder), and so on. The experiences from early warning systems and practices reveals the strong need for people centered early 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.



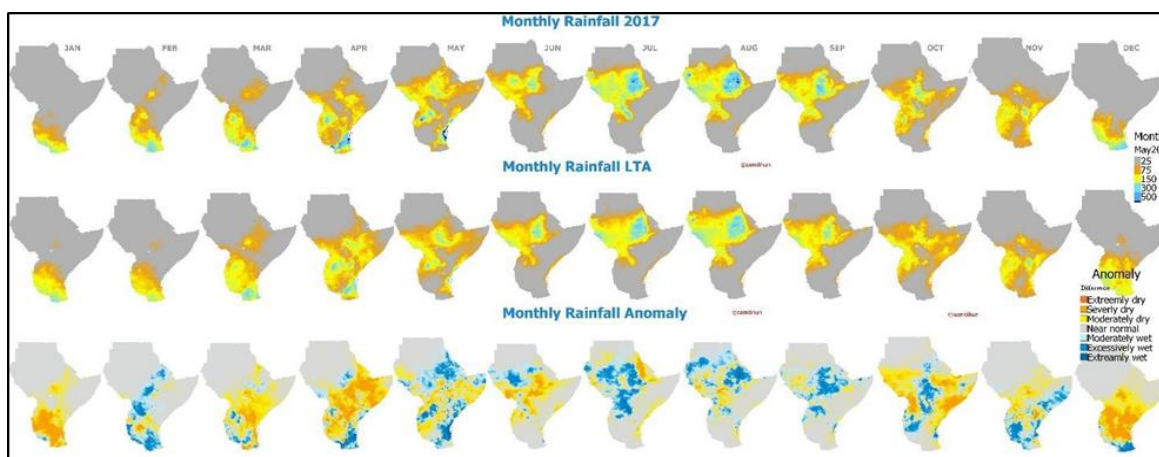
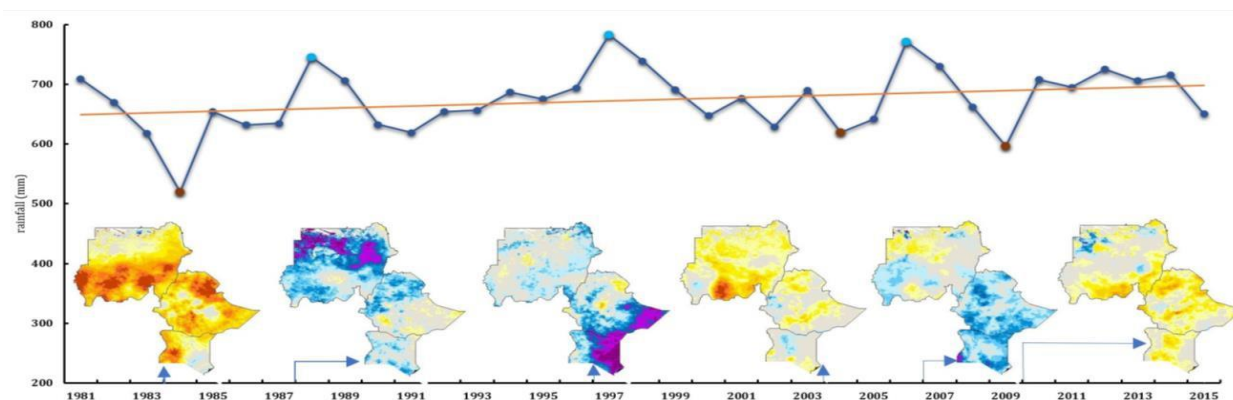
### Component 4: Activation of emergency plans to prepare and respond

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

#### 3.5.4.1 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 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.



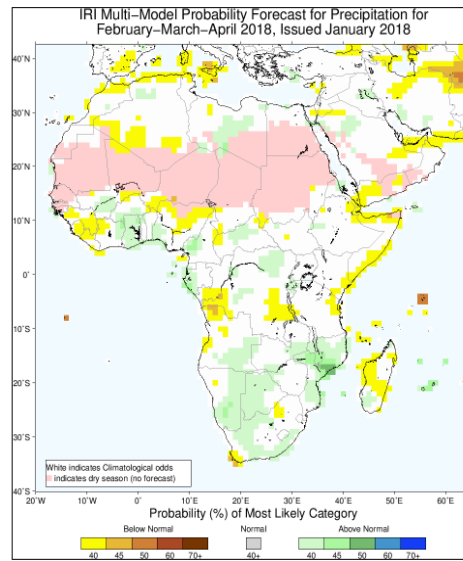
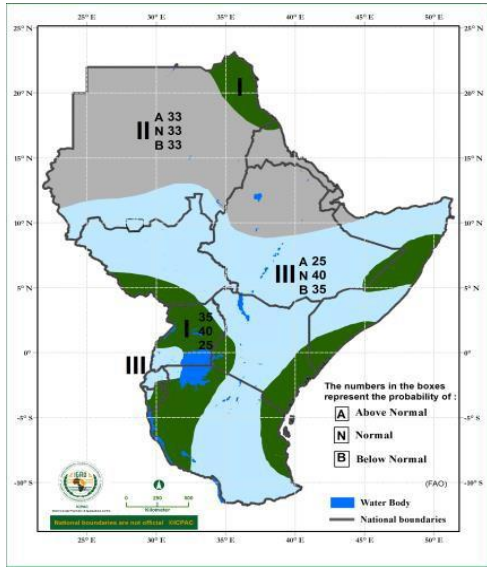
**GFDRR**  
Global Facility for Disaster Reduction and Recovery

**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



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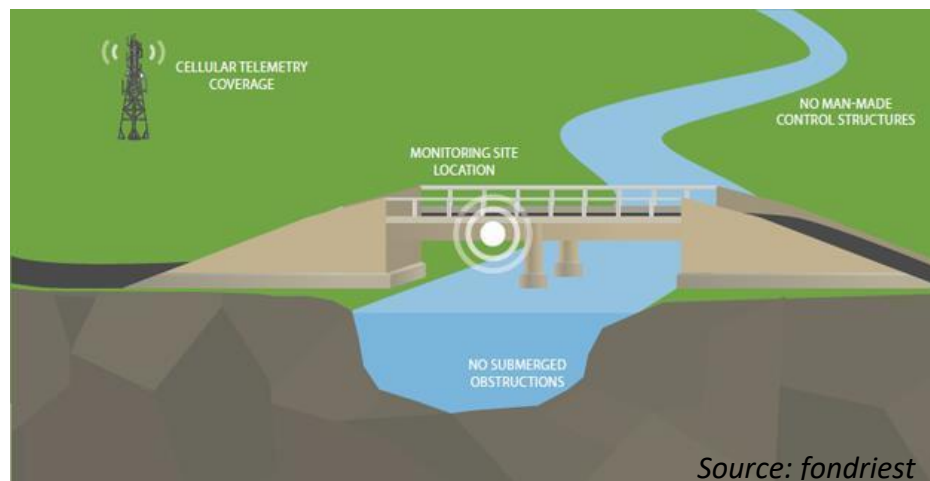
The GHACOF exercise you finalized over the last two days is a forecast based early warning system which mainly bases on expert opinion and consensus on what to expect for the coming season.



## STEP (18)

### 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.



#### 3.6.1 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.

##### 3.6.1.1 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.





**GFDRR**

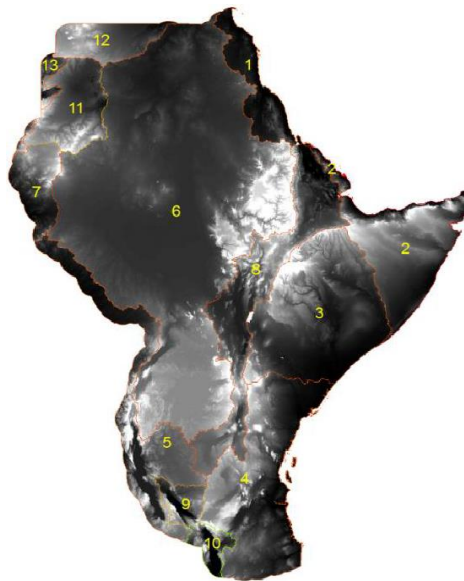
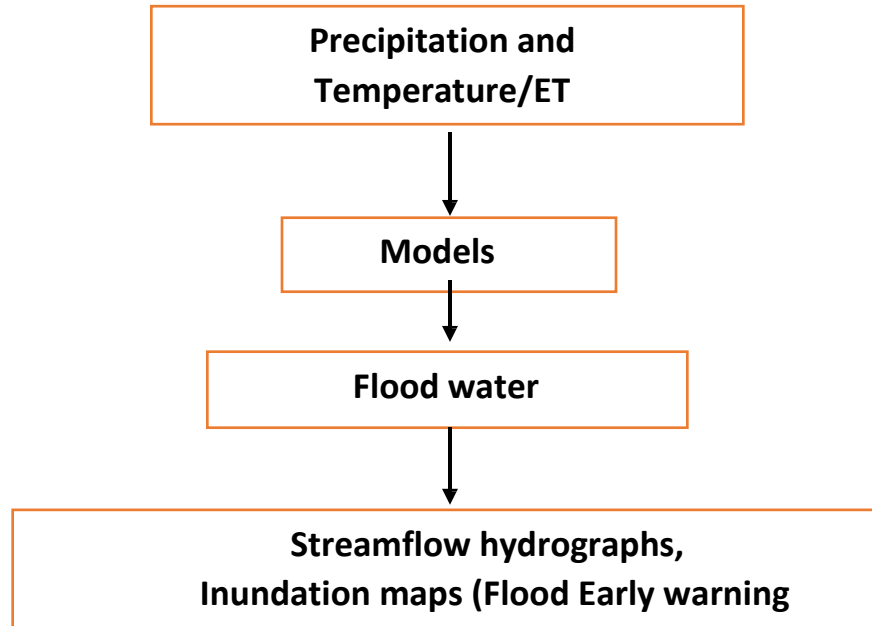
ACP-EU Natural Disaster Risk Reduction Program

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

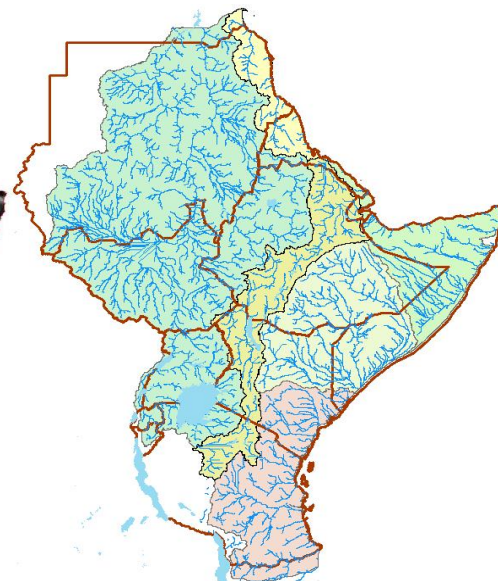


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## The approach used at ICPAC



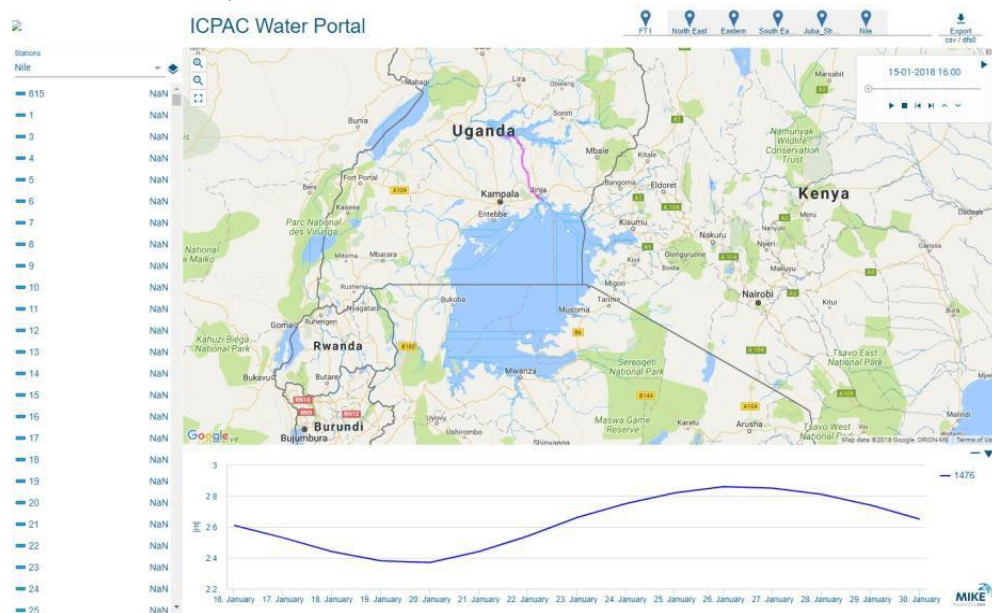
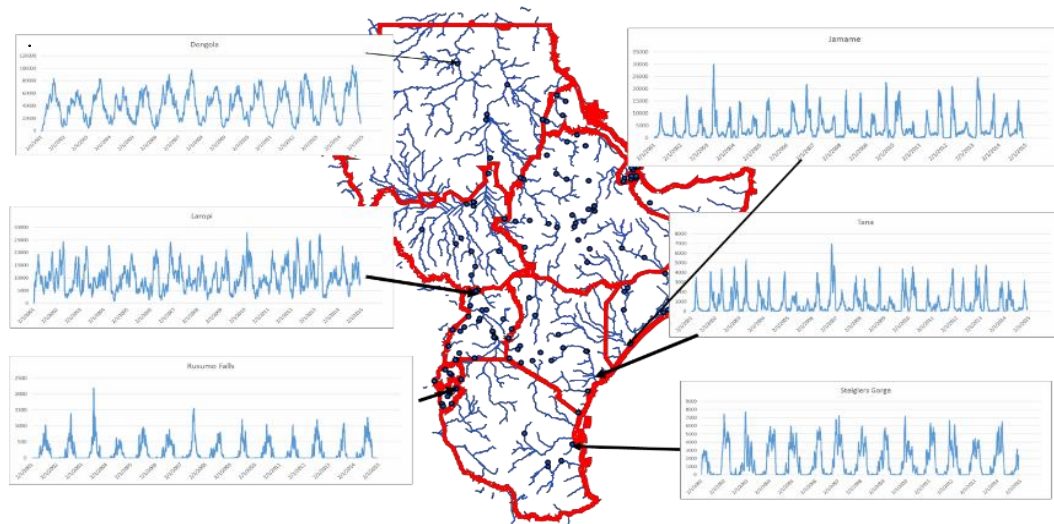
Catchment delineation based on 90m resolution DEM.



Delineated streams of catchment area > 1,000km<sup>2</sup> using GeoSFM model



## Interaction with ICPAC web-based platform (underdevelopment)



You can interact with the portal from the link: [41.215.21.156](http://41.215.21.156)

**Dissemination portal – Mike operations (Underdevelopment)**

### 3.7 Reference:

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

# Final Group Exercises (Floods and Droughts)

## 4 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 South 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 South 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 South Sudan?