United Nations Educational, Scientific and Cultural Organization

Intergovernmental Hydrological Programme

Content for Planned Pilot Courses implemented by Makerere University

Geospatial tools for water systems resilience

Table of Contents

1.0 Introduction

Geospatial techniques offer an opportunity of analysis water resources and enhancing systems and livelihood resilience. Sustainable water resources and climate change adaptation are serious development challenges raising a daunting task in Uganda. yet, the development path of Uganda is premised on sustainable utilization of water resources. Geospatial technology has been rapidly developing and gigabytes of remotely sensed data is provided at high spatial resolutions. However, capacities in the utility of geospatial technology to address resilience issues are still lacking. This was noted in the HCD framework document for the water and sanitation sector of Uganda. This training, was thus envisaged to bridge that capacity gap.

1.1 Objectives

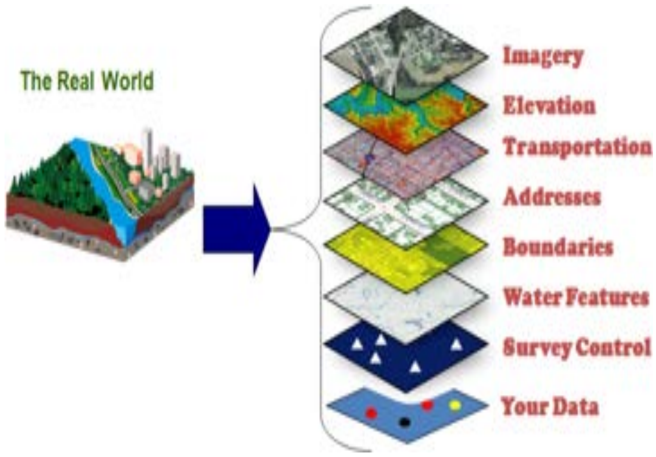
- To provide insight in recent and contemporary spatial technologies for watershed management and climate change adaptation

- To equip participants with advanced GIS based skills for assessing resilience of water resources and dependent livelihoods.

2.0 Content

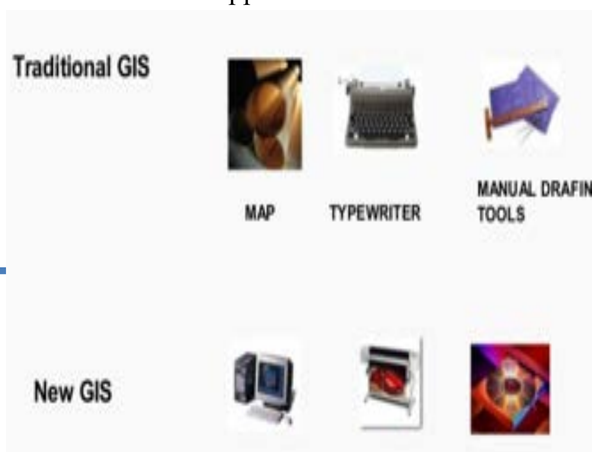
2.1 introduction to GIS

Geographic Information System (GIS) is a computerized tool for capture, storage, retrieval, manipulation, analysis and display of spatial referenced data. With GIS application, you can collect spatial data, enter it into a GIS system, store for future use and carryout spatial analysis to create maps/graphs/tables that can aid spatial decision with the aim to improve agricultural development.



2.2 History of GIS

GIS is a relatively new field - it started in the 1970's. Computerised GIS were only available to companies and universities that had expensive computer equipment. These days, anyone with a personal computer or laptop can use GIS software. Over time GIS Applications have also become easier to use - it used to require a lot of training to use a GIS Application, but now it is much easier to get started in GIS even for amateurs and casual users.



The developments in the field of computer technology have given new direction to handling and using spatial data for assessment, planning and monitoring. The concept of using the computers for making maps and analysing them was initiated with the SYMAP –Synagraphic mapping system, developed by Harvard School of computer graphics in the early 1970. Since then, there has been wide range of automated methods for handling maps using computers.

The history of using computers for mapping and spatial analysis shows that there have been parallel developments in automated data capture, data analysis and presentation in several broadly related fields. All these efforts have been oriented towards the same sort of operation: namely to develop powerful tools for collecting, storing, retrieving at will, transforming, integrating and displaying spatial and non-spatial data from the real world for a particular set of purpose.

The GIS can be used to solve broad range of problems as comparable to any isolated system for spatial and non-spatial data alone. For examples using a GIS:

a) Users can interrogate geographical features displayed on computer map and retrieve associated attribute information for display
b) Maps can be constructed by querying or analysing attribute data
c) New sets of information can be generated by performing spatial operations
d) Different items of attribute data can be associated with one another through a shared location codes

2.3 Data types used in GIS

Broadly, a GIS system use twofold categories of datasets: Spatial data and non-spatial data

1) Spatial data. These are datasets (vector and raster) that have been prepared through field surveys or remote sensed data that is referenced on the earth's surface. The composition of these datasets includes satellite images, coordinates among others that are interpreted to produce thematic maps which can aid agricultural planning towards to the sustainable use of limited resources
2) The non- spatial data are attributes as complimentary to the spatial data and describe what is at a point, along a line or in a polygon and as socio-economic characteristics from other sources. The attributes of a soil category could be the depth of soil, texture, erosion, drainage

2.4 Spatial data structures

2.4.1 Vector model

It represents the geographical feature by a set of coordinates vectors as X, Y -coordinates define points, line and polygons.

The types spatial data in GIS is generally described by X, Y coordinates and descriptive data are best organised in alphanumeric fields. The categories include:

a) Points refer to a single place and usually considered as having no dimension or having dimension which is negligible when compared to the study for example the location of farmers and storage facilities etc

b) Line represents the linear feature and consists of series of X,Y coordinate pairs with discrete beginning and ending point for example rivers and road network
c) Polygons are closed features defined by a set of linked lines enclosing an area. The polygons are character by area and perimeter for example the land use, the size of the farmer's cropped fields

2.4.2 Raster model

It represents the image with help of square grids. The system stores an image by assigning a series of values to each cell identified by its Cartesian coordinates in space.

Raster graphics are digital images created or captured (for example, by scanning in a photo) as a set of samples of a given space. A raster is a grid of x and y coordinates on a display space. A raster image file identifies which of these coordinates to illuminate in monochrome or color values. The raster file is sometimes referred to as a bitmap because it contains information that is directly mapped to the display grid.

2.5 Coordinate Reference System

A coordinate reference system (CRS) then defines, with the help of coordinates, how the two-dimensional, projected map in your GIS is related to real places on the earth. The decision as to which map projection and coordinate reference system to use, depends on the regional extent of the area you want to work in, on the analysis you want to do and the availability of data.

2.5.1 Map Projection in detail

A map projection is one of many methods used to represent the 3-dimensional surface of the earth or other round body on a 2-dimensional plane in cartography (mapmaking). This process is typically, but not necessarily, a mathematical procedure (some methods are graphically based).

2.5.2 Creation of a Map Projection

The creation of a map projection involves three steps in which information is lost in each step:

- ❐ selection of a model for the shape of the earth or round body (choosing between a sphere or ellipsoid)
- ❐ transform geographic coordinates (longitude and latitude) to plane coordinates (eastings and northings).
- ❐ reduce the scale (in manual cartography this step came second, in digital cartography it comes last)

2.5.3 Metric properties of maps

Maps assume that the viewer has an orthogonal view of the map (they are looking straight down on every point). This is also called a perpendicular view or normal view. The metric properties or a map are

- ➲ area
- ➲ shape
- ➲ direction
- ➲ distance
- ➲ scale

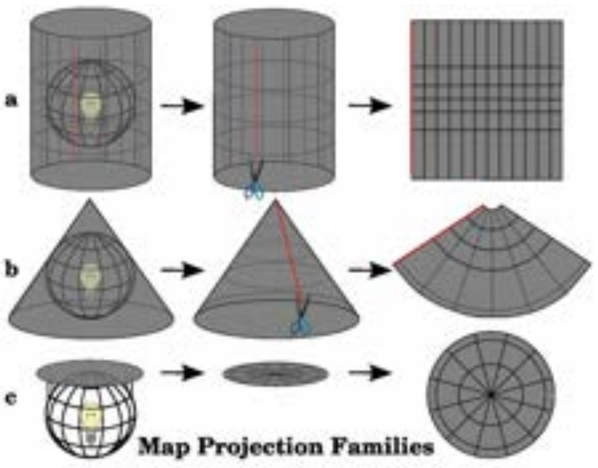
2.5.4 Choosing a projection surface

If a surface can be transformed onto another surface without stretching, tearing, or shrinking, then the surface is said to be an applicable surface. The sphere or ellipsoid are not applicable with a plane surface so any projection that attempts to project them on a flat sheet will have to distort the image (similar to the impossibility of making a flat sheet from an orange peel).

A surface that can be unfolded or unrolled into a flat plane or sheet without stretching, tearing or shrinking is called a ‘developable surface’. The cylinder, cone and of course the plane are all developable surfaces since they can be unfolded into a flat sheet without distorting the projected image (although the original projection of the earth’s surface on the cylinder or cone would be distorted).

2.5.5 The three families of map projections

The process of creating map projections can be visualised by positioning a light source inside a transparent globe on which opaque earth features are placed. Then project the feature outlines onto a two-dimensional flat piece of paper. Different ways of projecting can be produced by surrounding the globe in a cylindrical fashion, as a cone, or even as a flat surface. Each of these methods produces what is called a map projection family. Therefore, there is a family of planar projections, a family of cylindrical projections, and another called conical projections



Three families of map projection

- Cylindrical projection
- Conical projection
- Planar projection

Figure shows classification of map projection

2.6 *Spatial analysis*

Spatial analysis is the process of manipulating spatial information to extract new information and meaning from the original data. Usually spatial analysis is carried out with a Geographic Information System (GIS). A GIS usually provides manipulation and spatial analysis tools for calculating feature statistics and carrying out geoprocessing activities as data interpolation. For example, the tool will facilitate the computation of an area of land under cultivation, proximity of farmed land to the sensitive ecosystems and update layers etc

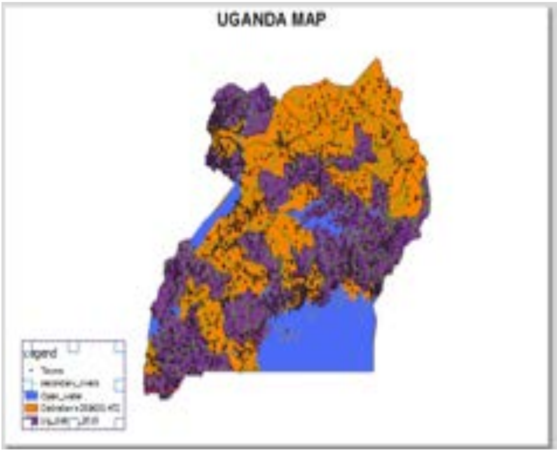
Some of the tools used for spatial analysis include:

a) Buffering. A buffer zone is any area that serves the purpose of keeping real world features distant from one another
b) Clip: Refers to extraction of specific features from the input layer
c) Merge: Refers to the combination of distant features

2.7 Map production

Map production is the process of arranging map elements on a sheet of paper in a way that, even without many words, the average person can understand what it is all about. Maps are usually produced for presentations and reports where the audience or reader is a politician, citizen or a learner with no professional background in GIS.

Because of this, a map has to be effective in communicating spatial information. Common elements of a map are the title, map body, legend, north arrow, scale bar, acknowledgement, and map border.



Map of Uganda created after over lay of GIS layers

3.0 Introduction to GIS software

3.1 Types of GIS software

a) Geographic Information System (GIS) Software is designed to store, retrieve, manage, manipulate, display, and analyze all types of geographic and spatial data.
b) GIS software enables you produce maps and other graphic displays of geographic information for analysis and presentation.
c) We have two types of GIS software: Open source and commercial software

3.2 Open source software

The development of open source GIS software has—in terms of software history—a long tradition with the appearance of a first system in 1978. Numerous systems are available which cover all sectors of geospatial data handling. Eg QGIS, SAGA GIS, uDIG, JUMP GIS etc

Most open source software is available for free and the users can benefit from the availability and transparency of the open source (program) code, which may be adapted for specific consumer needs and can again be shared within the community.

3.3 Commercial software

These are softwares that are purchased prior to usage in carrying out spatial analysis. Some of the notable software include: ArcGIS, ENVI, Erdas imagine, ESRI, Intergraph etc

3.4 Introduction to Esri technology

Esri (Environmental Systems Research Institute, Inc) develops geographic information systems (GIS) that provides a variety of mapping functions that can be integrated into nearly every type of organization. Esri focuses on GIS because of the belief that "geography matters". Geography connects our many cultures and societies. GIS provides additional ways to understand cultures and societies which increases communication and collaboration opportunities.

3.4.1 Key Functionality

- Answer questions, test predictions, and examine relationships
- Create, edit, and ensure the quality of geographic data
- Create professional qualtiy maps
- Manage data more efficiently

3.4.2 History of Software Development

a) Developer – ESRI - Environmental Systems Research Institute, Inc., started in 1969 as a privately held consulting firm that specialized in landuse analysis projects.
  a.1 Software Developers originated at Harvard graphics lab
b) ArcInfo – early version of software
  b.1 Main-frame, unix-based software
  b.2 "arc" refers to line segments of map elements
  b.3 "info" refers to information in database system
  b.4 Command driven software package (analogous to "DOS")
c) ArcView (1990's)– first release of a windows-based, GUI (graphical-user interface) based GIS system for desktop computers; still available but phasing out
d) ArcGIS (2000's) – next generation GIS software merging codes and routines from best of ArcInfo and placed in a GUI-Windows environment of ArcView, compatible with desktop computing

3.4.3 Overview of ArcGIS Software

Software collective referred to as "ArcGIS Desktop"

i. Software Modules
  i.1 ArcMap – software used to display, analyze, and create GIS data
  i.2 ArcView level install – basic level application
  i.3 ArcEditor – step up, includes data editing capabilities
  i.4 ArcInfo – highest level install, with advanced editing and analysis features
  i.5 ArcCatalog- tool for viewing and managing spatial data files (analogous to Windows Explorer)
  i.6 ArcToolbox – set of tools and functions used to convert data formats, manage map projections, perform analysis, modify data.
ii. Extensions
  ii.1 The Extensions dialog allows you to load and unload software capabilities, allowing you to enhance your working environment with additional objects, scripts and customization.
  ii.2 You can use extensions provided by ESRI and you can also create your own.
iii. Data Files in ArcGIS
  iii.1 Shapefiles – developed for ArcView

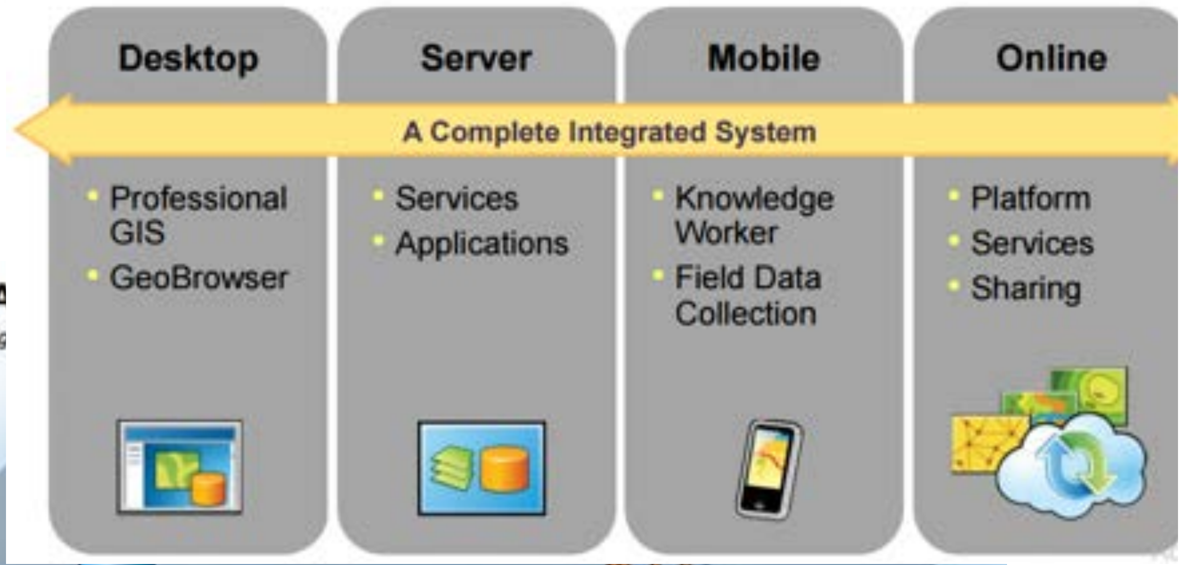
ArcView shapefiles are a simple, non-topological format for storing the geometric location and attribute information of geographic features. A shapefile is one of the spatial data formats that you can work with in ArcView. The shapefile format defines the geometry and attributes of geographically-referenced features in as many as five files with specific file extensions that should be stored in the same project workspace

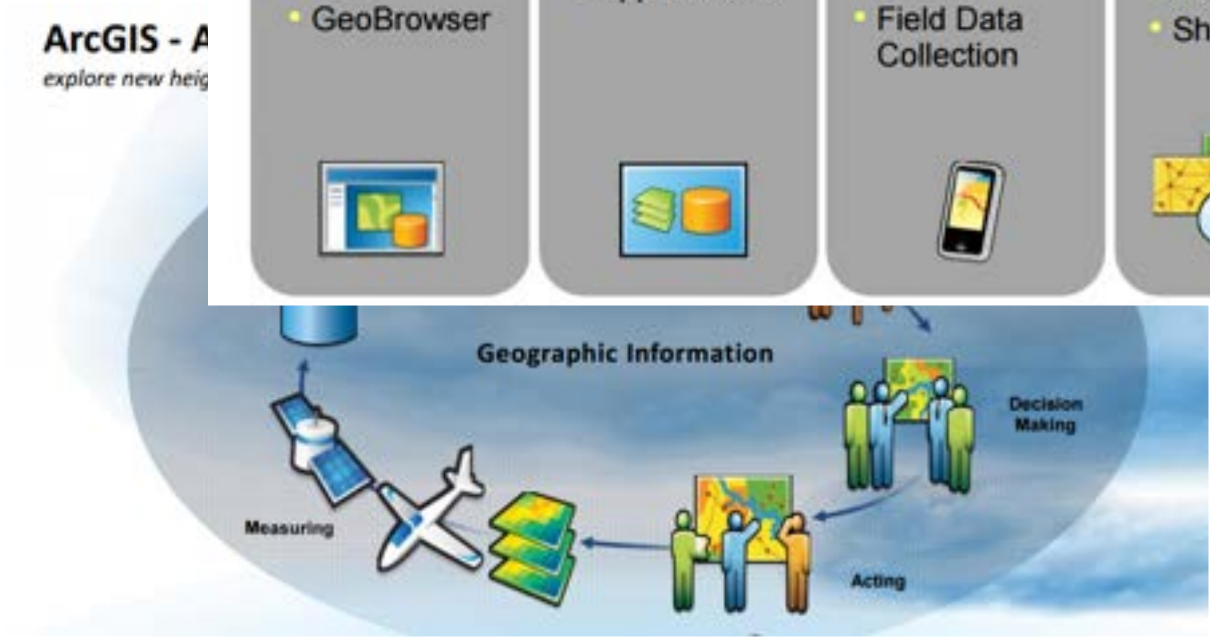
3.4.4 The capabilities of the ArcGIS licences

Map Creation and Interactive Visualization	ArcView	ArcEditor	ArcInfo
Visually model and spatially analyze a process or workflow.	X	X	X
Create interactive maps from file, database, and online sources.	X	X	X
Create street-level maps that incorporate GPS locations.	X	X	X
View CAD data or satellite images.	X	X	X
Generate reports and charts.	X	X	X
Multiuser Editing and Advanced Data Management			
Complete GIS data editing capabilities.		X	X
Edit a multiuser enterprise geodatabase.		X	X
Use disconnected editing in the field.		X	X
Store historical snapshots of your data.		X	X
Automate quality control.		X	X
Create spatial data from scanned maps.		X	X
Use raster-to-vector conversion.		X	X
Advanced Analysis, High-End Cartography, and Extensive Database Management			
Advanced GIS data analysis and modeling			X
Atlas like, publication-quality maps			X
Advanced data translation and creation			X
Advanced feature manipulation and processing			X
Data conversion for CAD, raster, dBASE, and coverage formats			X

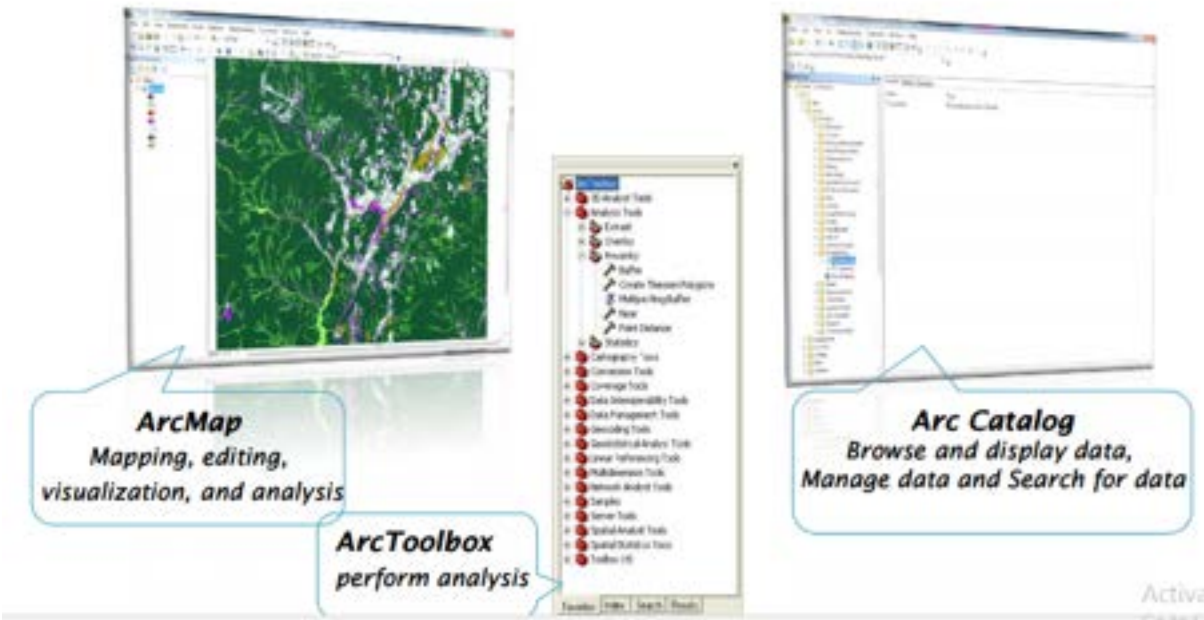
3.4.5 ArcGIS software system


Browser
Basic client
Rich client
Mobile
Windows
iOS
Android
Blackberry
Desktop
• Visualize
• Create
• Collaborate
• Discover
• Manage
• Analyze
Cloud/web services
Enterprise server
Local

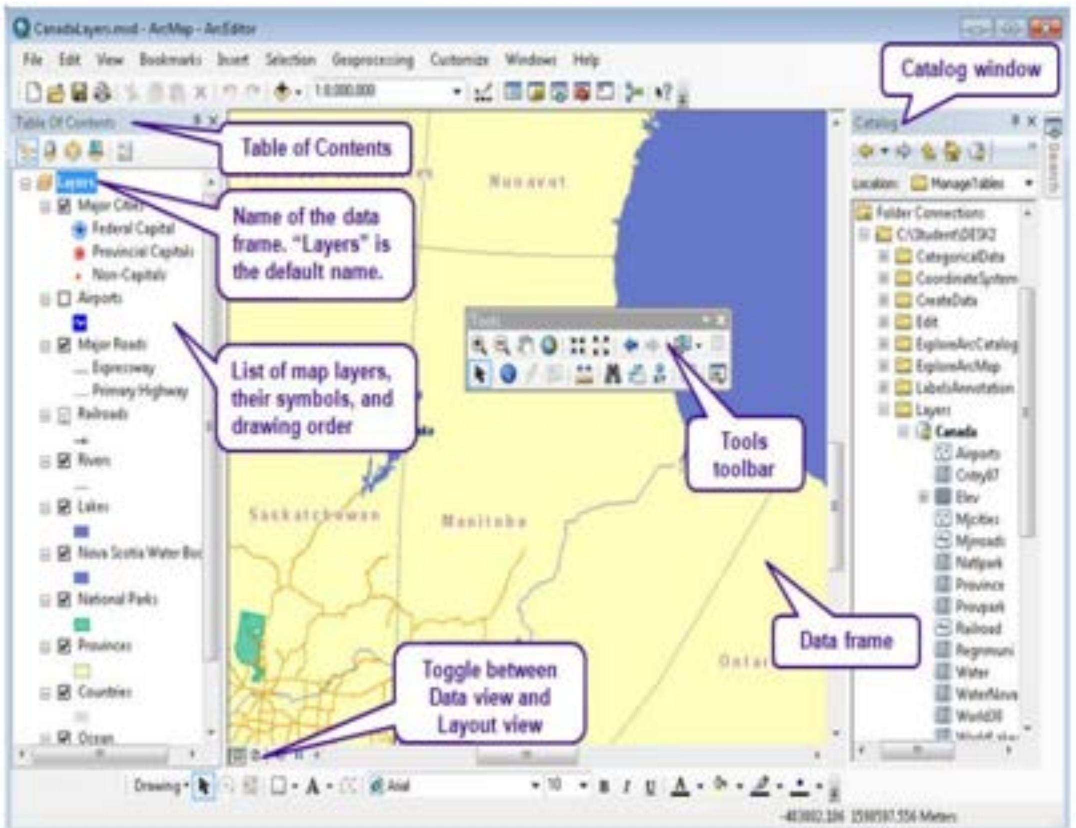

Desktop
Server
Mobile
Online
A Complete Integrated System
Professional GIS
GeoBrowser
Services
Applications
Knowledge Worker
Field Data Collection
Platform
Services
Sharing


Geographic Information
Decision Making
Measuring
Acting

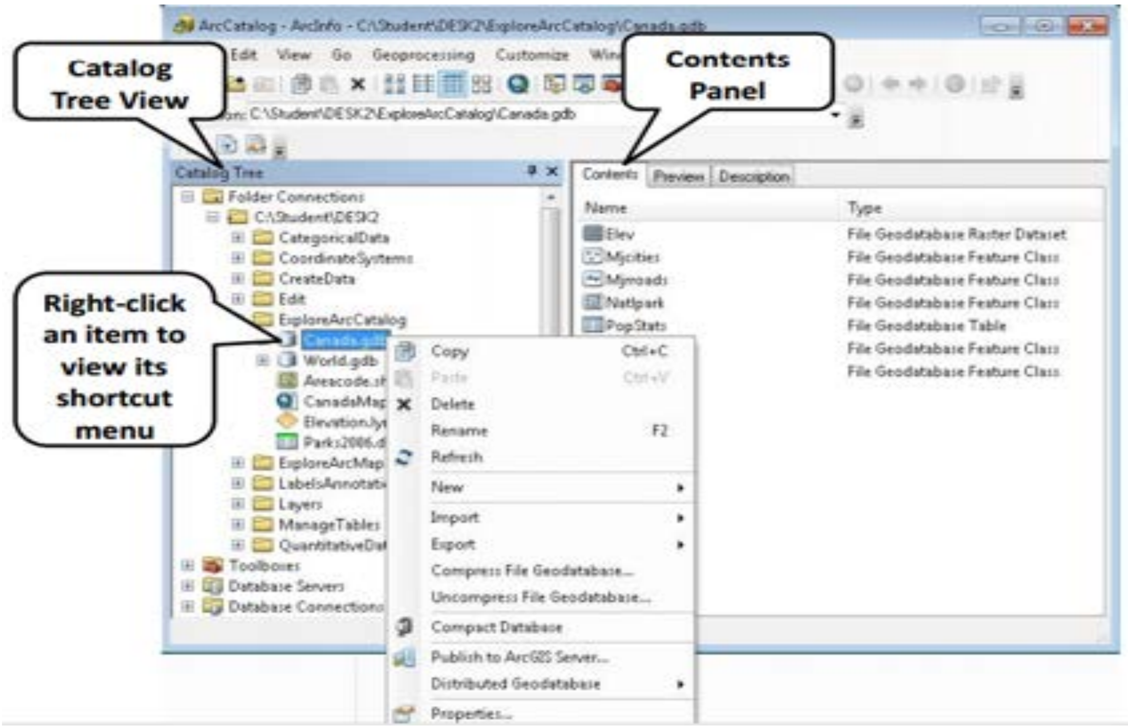
3.5 ARCGIS Desktop



3.6 Mapping application



3.7 Arc Catalog



3.8 Geo-processing shapefiles

This section introduces you on how to process a shapefile ready for analysis. This is a common task if you want to extract information from the spatial layer. The aim of processing is to make the data usable. Geoprocessing is essentially a GIS operation used to manipulate the spatial aspects of GIS data. In the broad sense the tools include: overlay, clipping, update, feature selection, union, and dissolve among others

3.8.1 Geo-processing tools

1. Convex Hulls - creates the smallest possible convex polygon enclosing a group of objects

Vector > Geoprocessing Tools > convex hull(s).

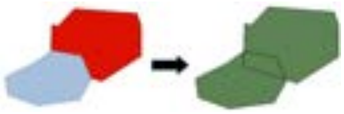
2. Buffers - creates an equal zone around specific features at a specified distance
   Vector > Geoprocessing Tools > Intersect.

3. Intersect - creates new layer based on the area of overlap of two layers

Vector > Geoprocessing Tools > Intersect

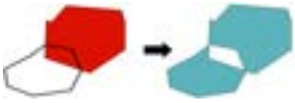
4. Union - melds two layers together into one while preserving features and attributes of both

Vector > Geoprocessing Tools > Union



5. Symmetrical Difference - creates new layer based on areas of two layers that do not overlap

Vector > Geoprocessing Tools > Symmetrical Difference

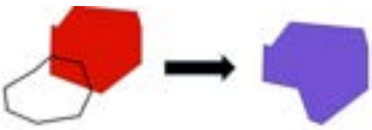


6. Clip - cuts a layer based on the boundaries of another layer

Vector > Geoprocessing Tools > Clip

7. Difference - subtracts areas of one layer based on the overlap of another layer

Vector > Geoprocessing Tools > Difference



8. Dissolve - merges features within a single layer based on common attributes in the attribute table

Vector > Geoprocessing Tools > Dissolve

9. Eliminate Sliver Polygons - merges left-over or misformed geometry with neighboring feature

4.0 GIS data sources

4.1 Introduction

The processes of data collection are also variously referred to as data capture, data automation, data conversion, data transfer, data translation, and digitizing.

Two main types of data capture are

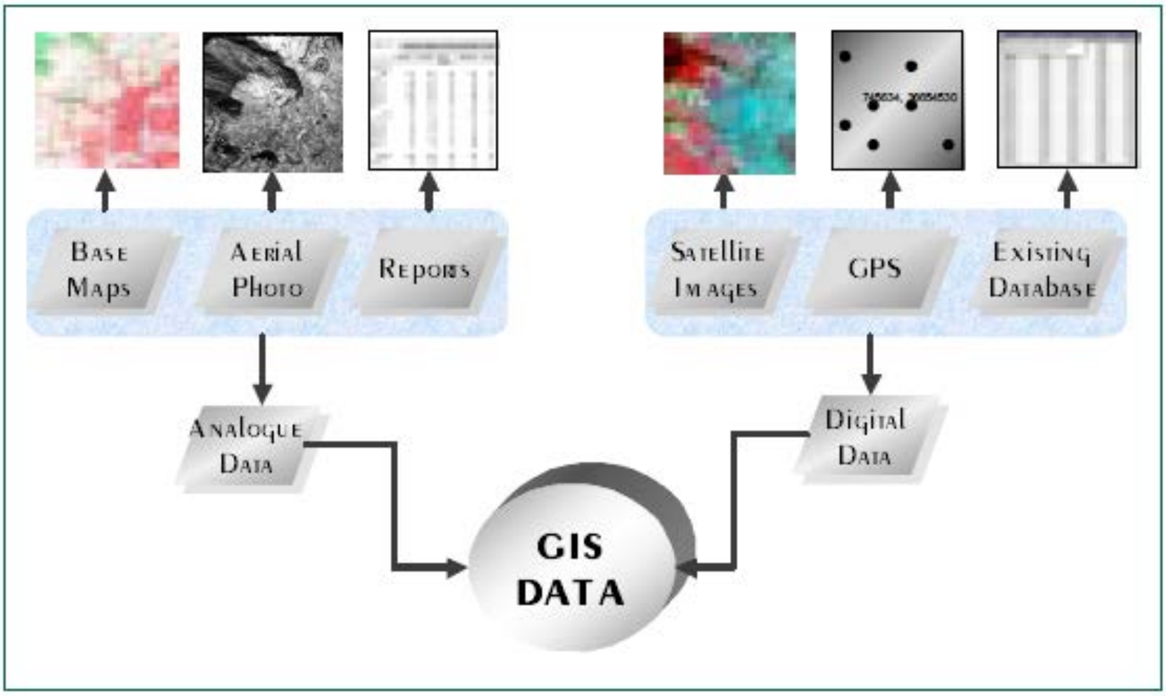
- Primary data sources are those collected in digital format specifically for use in a GIS project.
- Secondary sources are digital and analog datasets that were originally captured for another purpose and need to be converted into a suitable digital format for use in a GIS project.

4.2 GIS data collection workflow

a) Planning includes establishing user requirements, garnering resources, and developing a project plan.
b) Preparation involves obtaining data, redrafting poor-quality map sources, editing scanned map images, removing noise, setting up appropriate GIS hardware and software systems to accept data.
c) Digitizing and transfer are the stages where the majority of the effort will be expended
d) Editing and improvement covers many techniques designed to validate data, as well as correct errors and improve quality.
e) Evaluation is the process of identifying project successes and failures.

4.3 GIS data collection methods

	Raster	**Vector**
Primary	Digital remote sensing images	GPS measurements
	Digital aerial photographs	Survey measurements
Secondary	Scanned maps	Topographic surveys
	DEMs from maps	Toponymy data sets from atlases



4.4 *Source of GIS Data*

4.4.1 Introduction

Most projects begin with a search for baseline data. Some of this data exist either through online or offline domains. The online datasets are normally open sources and can be easily assessed, whereas the offline datasets are available through the mandated organizations such as NGOs, international development partners and government bodies. Indicated here below is a list spatial datasets and mandated institutions/organisations

No	General purpose	Type	Scope
	Online		
1	http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html	Land and ocean boundaries	World
2	http://asterweb.jpl.nasa.gov/gdem.asp	Elevation	World
3	http://www.worldclim.org/	Weather and climate	World
4	http://hydrosheds.cr.usgs.gov/	Hydrology	World
5	http://nelson.wisc.edu/sage/data-and-models/global-land-use/grid.php	Global land cover	World
	Regional Center for Mapping of Resources for Development	Spatial data	East and southern Africa
	Agriculture (online)		
	http://harvestchoice.org/	Agricultural related – yields, production, travel time to markets,	Africa

	http://gaez.fao.org/Main.html#	Agricultural related – consumption, suitability, yields, production e.t.c	World
	http://ratin.net/site/map	Storage facilities	EAC
	http://www.rtb.cgiar.org/RTBMaps/	Suitability, yields and production	Africa
	http://www.infrastructureafrica.org/documents/tools/list/arcgis-shape-files	Roads, boundaries, water bodies and power plants	Africa

5.0 Creating maps using digital geographical information

5.1 Introduction

This module exposes the participants on how to create maps using existing GIS datasets (raster and vector) collected from different sources to aid the spatial decision-making process.

5.2 Datasets

Making maps in ArcMap is very easy: Browse geospatial data in ArcMap and choose an appropriate presentation.

Steps	Challenges
Load geospatial data into Arcmap	Data formats and folder connections
Identify the features and attributes to present	Layer order, feature selection and projections
Define how to show the data	Transparency (raster and vector) data classification and layer file
Add map components	Geospatial data references
Export maps	Resolution and file formats

The working folder is named "**GIS folder"** and it contains the following spatial datasets

Datasets	Units
Districts	Meters
Lakes	Meters
Land use/cover	meters
Rivers	Meters
Protected areas	Meters
Elevation (30m)	Meters
Roads	Meters

5.3 Task

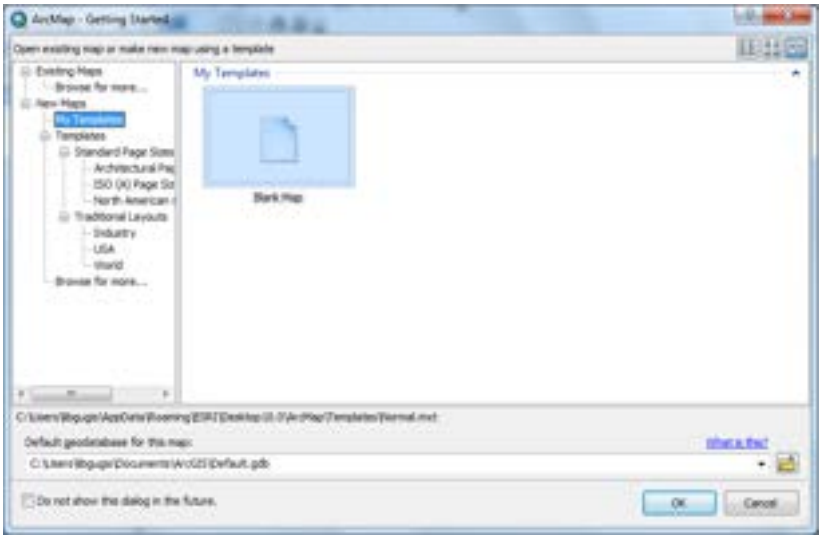
In this case, we want to create a **land use map for Mbale District**

5.4 Procedures

5.4.1 Load data

a) To launch Arcmap please click: Start -> All Programs -> ArcGIS -> ArcMap 10. By default, a start-up splash window will appear once ArcMap has loaded

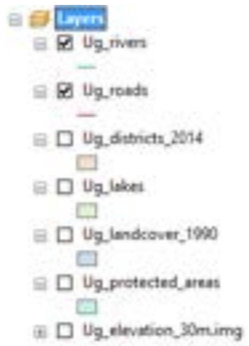
b) Click OK to proceed. You can ignore all other options.



There are two ways to add data: Click the ***Add Data***  button (Figure 2), which opens a window similar to Figure.

c) To browse to the file you want to play with, you can link to the folder containing all these files by clicking the **Connect to Folder**  button, then browse to add the folder that contains your files and click **OK**.

d) After that, you can locate the files listed below and add them in at one time by holding the **Ctrl or Shift button** when you are clicking mouse button to make selections. Please click the Add button just like any other file explorer dialogs in Windows to close the dialog.

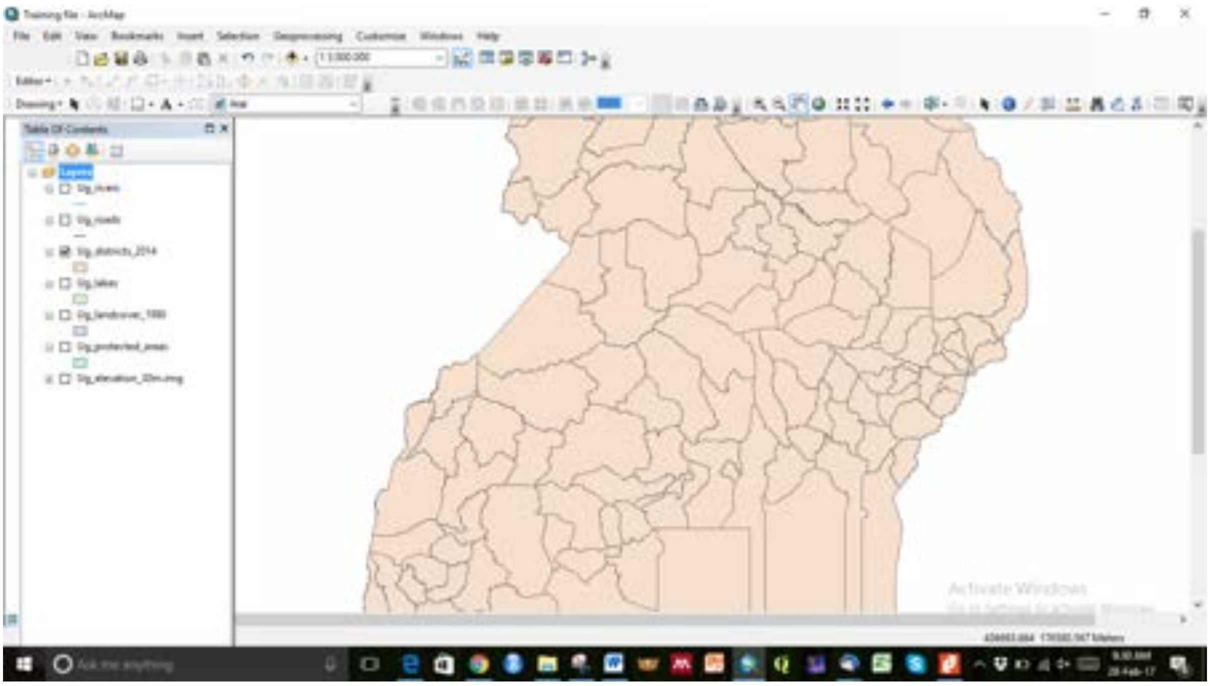


When data is loaded, all files will be listed in the left pane (table of contents). The geographic features (contents) are displayed in the right pane. And most controls can be found on the top pane (or by right-clicking on the object you are working at and checking the pop-up window).

5.4.2 Browse Geographic Features

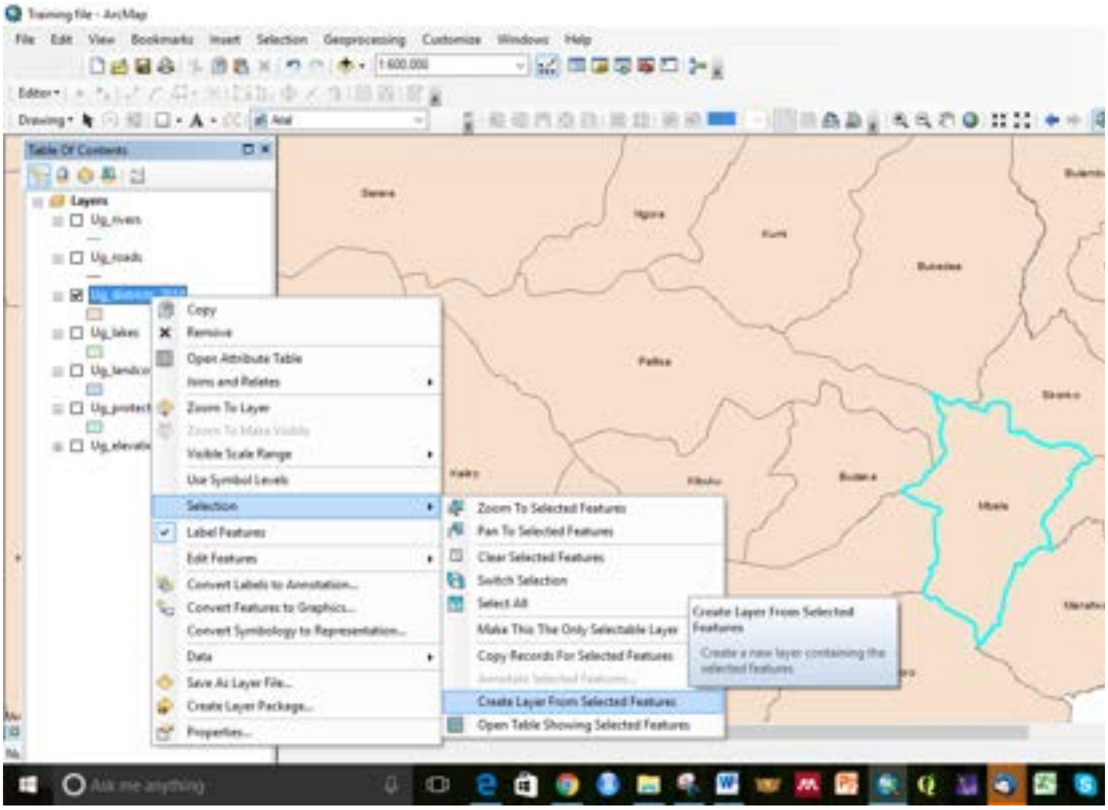
a) In ArcMap 10.2, ESRI starts to put most controls to browse data into one tool bar. If you cannot find this toolbar, please go to **Customize -> Toolbars and check** the Tools on.

b) Select **Mbale district** from the loaded **Ug_district layer**

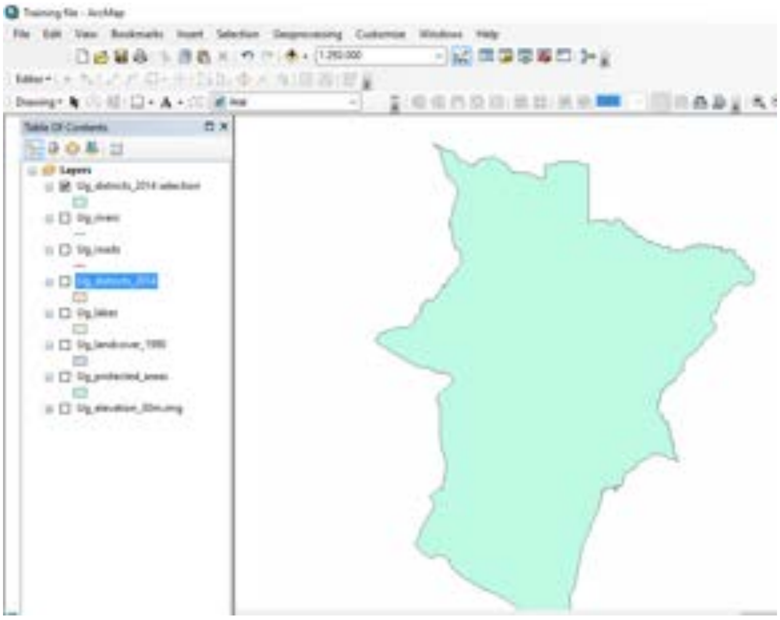


c) Click on the select features by rectangle and choose Mbale district

d) Extract Mbale from the broader Ugandan shapefile



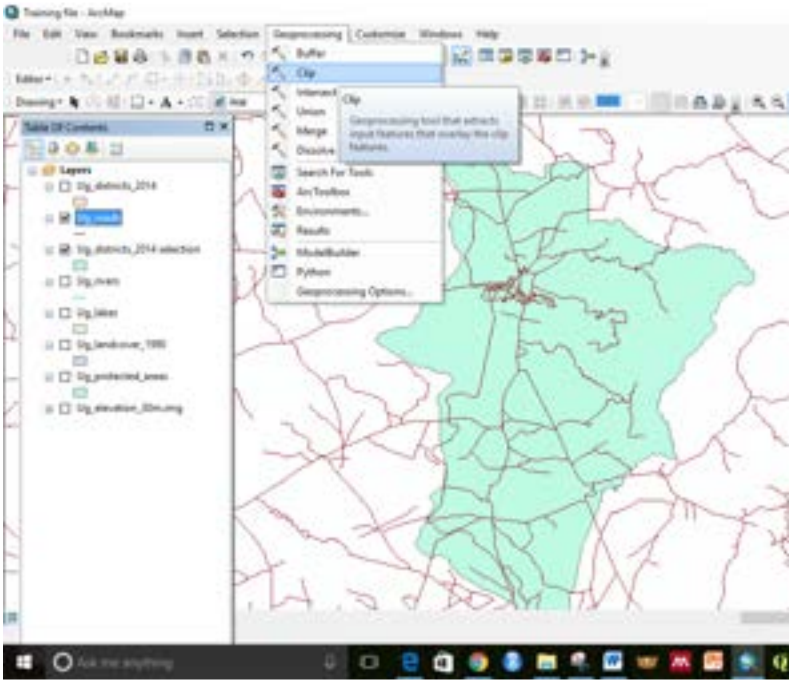
e) Extracted Mbale District



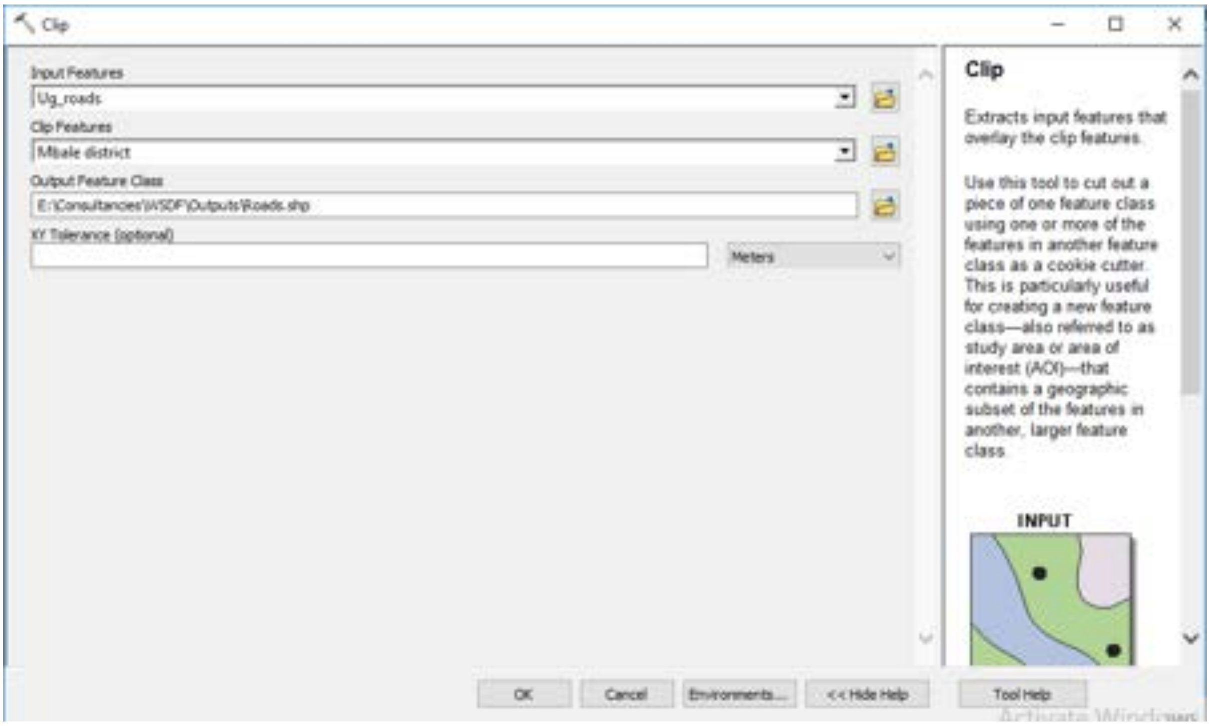
5.4.3 Geoprocessing

a) In this module we are going to extract features such as roads, rivers, protected areas etc that lie within Mbale District

b) Click on Geoprocessing from the Menu – **Clip** (Extracts input features that overlay the clip features)



c) In clipping



d) The output is as follows

e) Therefore repeat the same procedure for clipping (as in b-above) for the rest of the datasets (e.g. rivers, sub counties, protected areas etc)

Mbale district with clipped

a. rivers
b. sub counties
c. protected areas

f) The next step is to processes the clipped datasets from the table of contents

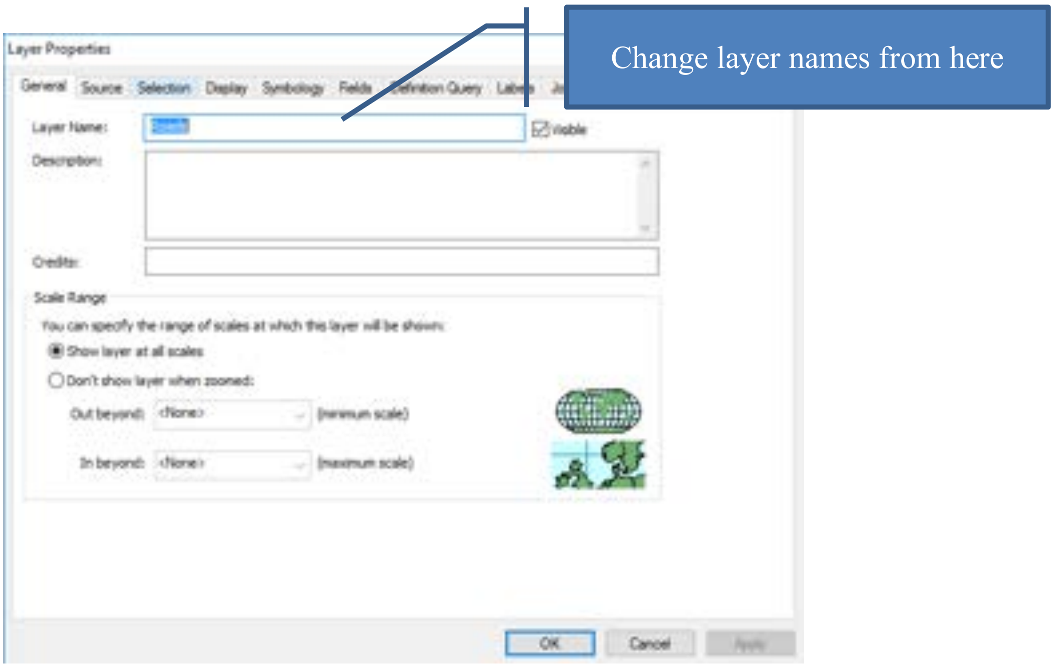
5.4.4 Defining the General and Symbology Properties for a Layer

In this section of the tutorial, you will learn how to organize your data layers' properties to start bringing some coherence to the map.

If you haven't turned off the labels already, turn them off now by right-clicking on the **roads data layer** for example and unchecking Label Features. This will speed things up while you work.

5.4.5 Assigning proper layer names

- First, you need to give the data layers better names than what they have (e.g., *roadclip* should say "Roads")
- Right click on the *road* layer and choose ***Properties*** (alternatively, you can double click On the data layer name).
- When you see the *Properties* dialog box, click on the *General* tab. In the *Layer Name*
- box, type in *Streets* instead of *road*. Press OK when finished.
- Give all the other layers more coherent names as best as you can (e.g. “Sub county boundary” instead of subcountyclip, “Rivers” instead of Rivers_clips, “Protected areas”
- instead of protected areas_clip). In the future, we will deduct points on assignments for
- having non-standard English "data-speak" names like "streetscl" appearing in your map

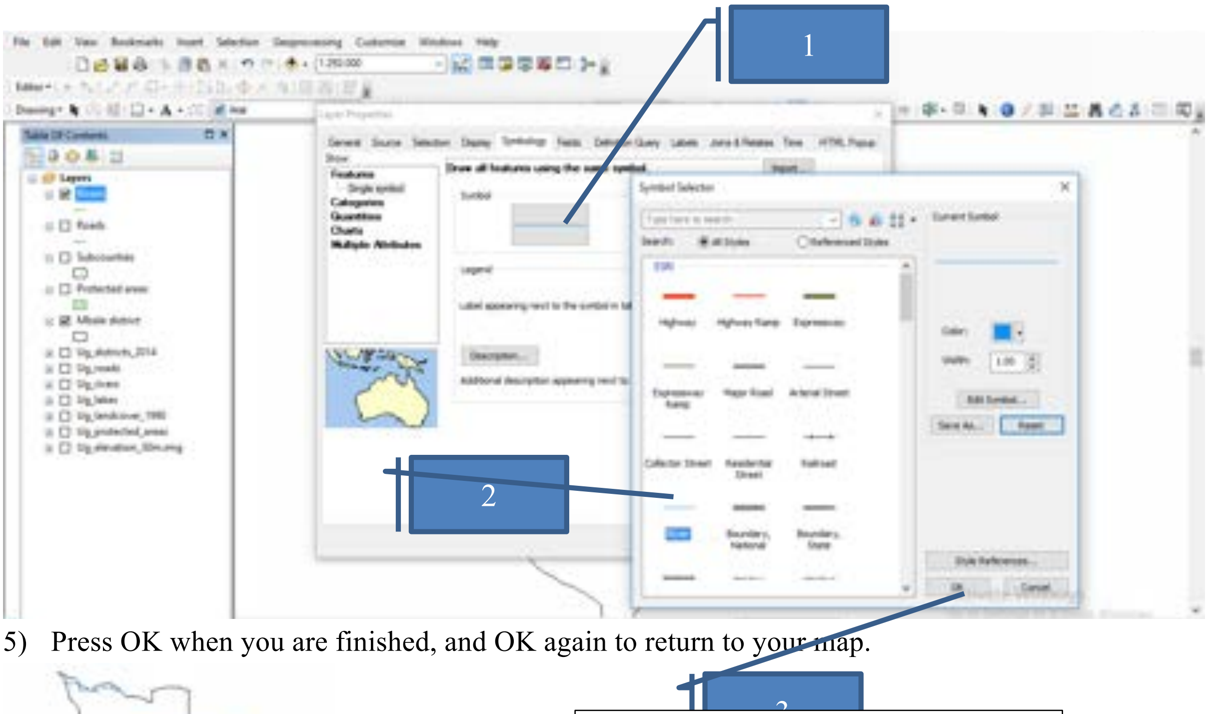


5.4.6 Assigning proper colors

Your map would be a lot better if the **rivers** were colored blue, the parks green, etc.

1) Right-click on the **rivers layer** to bring up the Properties dialog box again.
2) Click on the Symbology tab
3) To change the color of the layer, click on the colored box under Symbol - this should bring up the Symbol Selector box.

4) Click on the small colored box next to Fill Color, to see colors to choose from – choose a blue color for water



5) Press OK when you are finished, and OK again to return to your map.

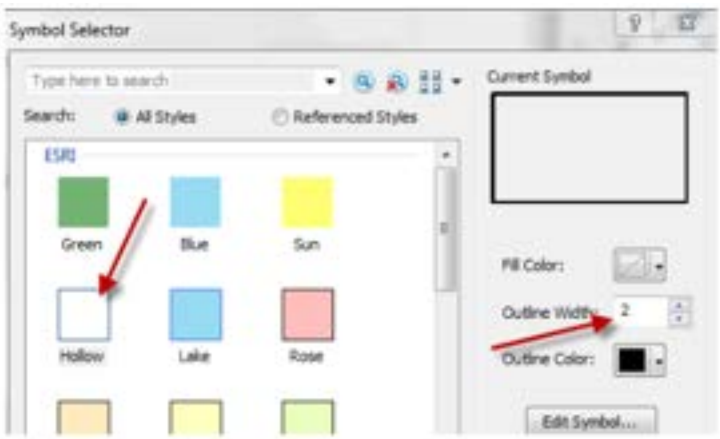
Note:

Assign appropriate colors to the remaining data layers

Note

6) The sub county layer still appears fairly **Light red (rose)** – that's because the symbology settings have applied a black outline around the gray fill. You (and your map's viewers) do not need to see these outlines.
7) Turn the outlines off by going back to the layer's properties and the Symbology tab. Once again click on the colored box under Symbol.
8) Then click on the small box just right of Outline Color, and choose No Color. Press OK and OK again to get back to your map. This is how you turn outlines off (you can also change their color or thickness).

Turn on the *neighborhoods* layer and go to its symbology properties. Use the "Hollow" scheme (no fill color, with an outline), and make the outline width thicker (e.g., 2) as shown below:

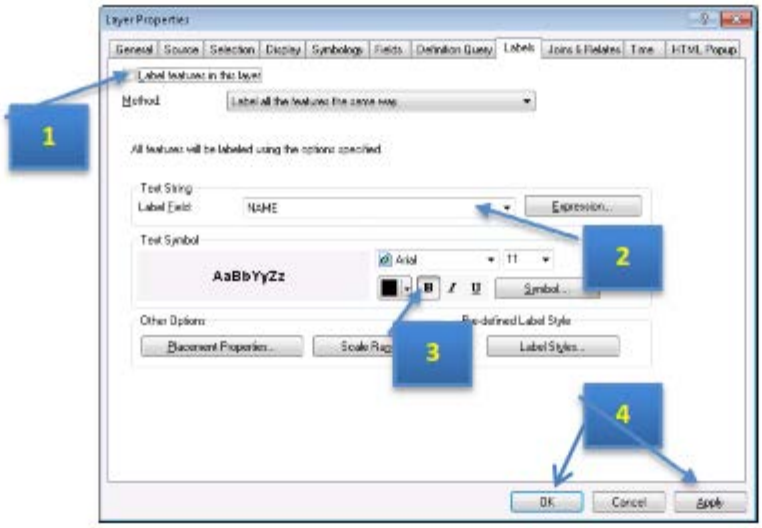


5.4.7 Labelling

The labels are an important feature of a map. By marking some property up on the map, for stance, the name of the marked location, labels can make your map more useful, informative, and visually appealing.

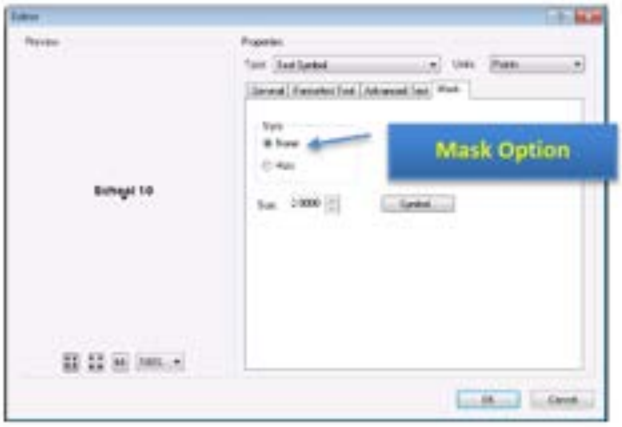
- To add labels to your map, please right-click on the layer that you want to add marks on (**sub counties**) and select Properties. Then follow the steps below
  - Select the **Labels** tab and check on (off by default) "Label features in this layer".

- Choose the attribute you want to display (**SNAME**) on the map in the dropbox of **Label Field**
- Change Font (**10 pt size**), so that it is clearly shown on the map.
- You can click on the **Apply** button to see the effect until it is satisfactory. Then click **OK** to save your setting and exit.



Labelled sub counties

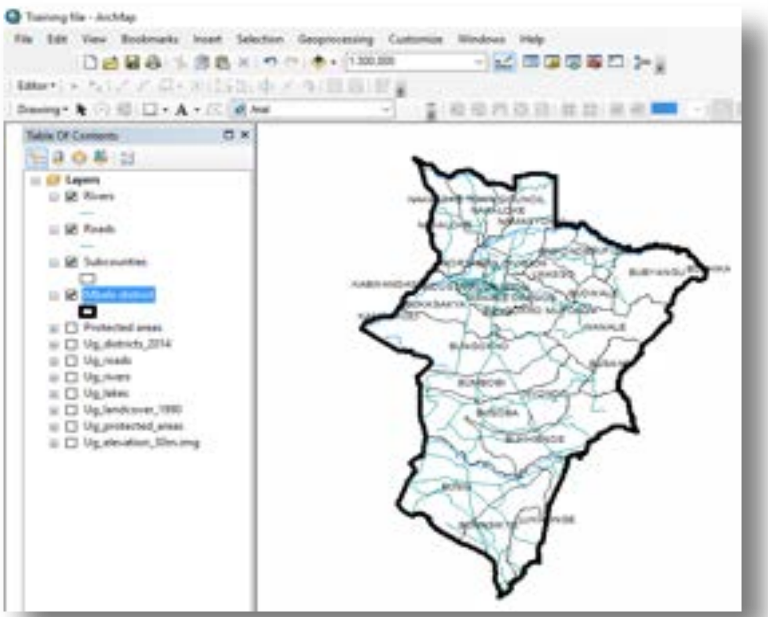
- To ensure a clear label, the option of mask can be used **Symbol**, which locates to the right of Font options as a **Symbol** button.
- Please click it and then click the **Edit Symbol** button, since label is a kind of symbol (text symbol) too.
- Navigate to the **Mask** tab shown in the figure below. Change the option of **Style** to **Halo**



Symbology Types and Their Normal Usage:

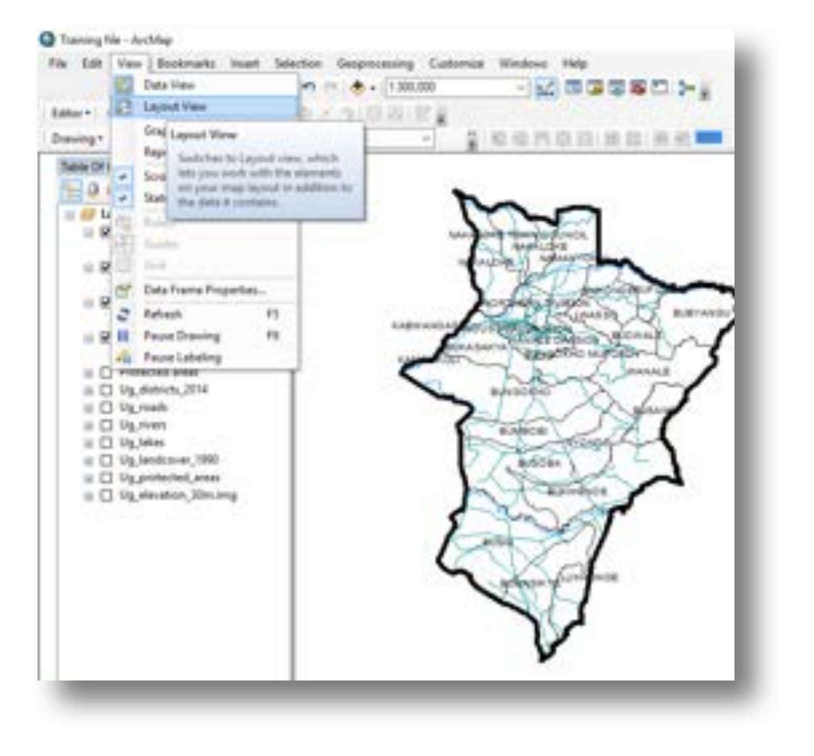
- *Features: Mainly used when you just want to mark geographic features on a map.*
- *Categories: Suit for the case when feature classification is needed.*
- *Quantities: Appropriate when numbers involve, i.e., population, income, depth, etc.*
- *Charts: Employed when not only quantity but also the relative importance is important as well. For instance, incomes from different types of consumers.*
- *Multiple Attributes: Utilized when multiple criteria are involved, which main not be quantitative. It can be regarded as a generalized case of Charts.*

Before we create our final map – make sure that layers are checked in the table of content and are as follows



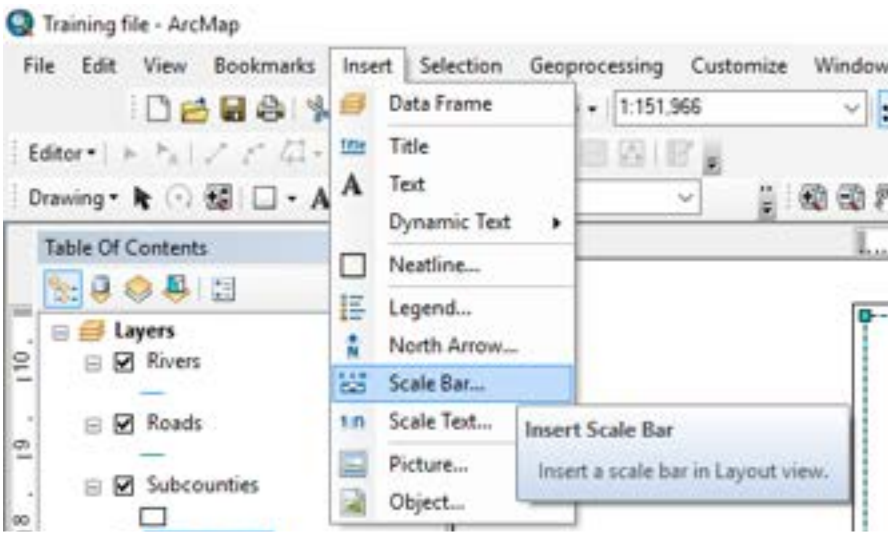
5.4.8 Map Components

Then you select **Layout View to** start adding map components, all components are gathered in the menu of Insert.

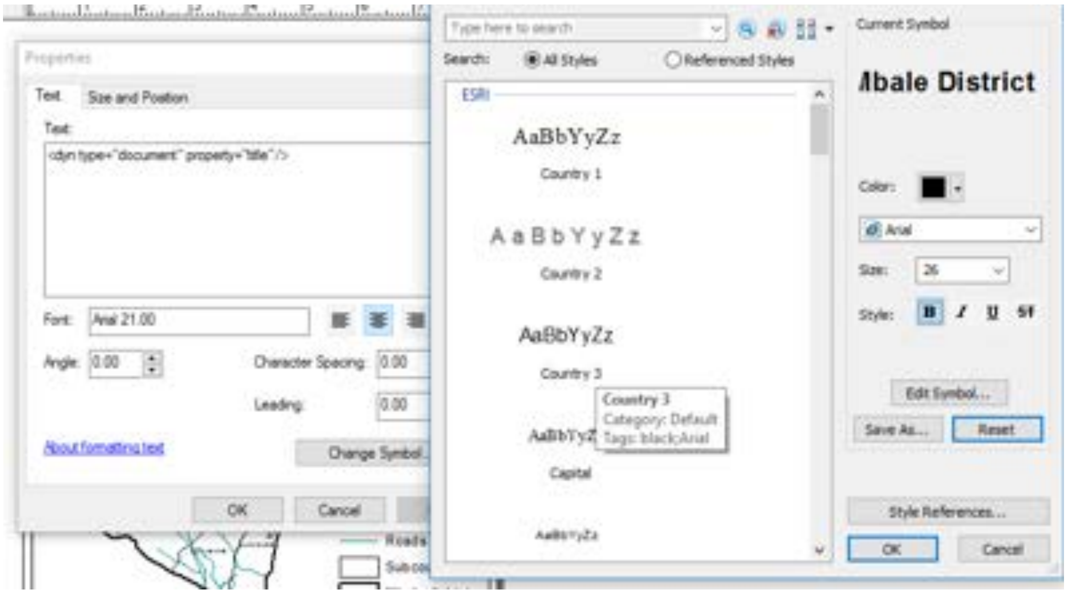


The key ones are:

- The title of the map (Purpose/Content);
- The scale of the map (Measurement);
- The North Arrow (Orientation);
- The Legend (how to interpret the map);
- (Optional) The reference (where you obtain the data)

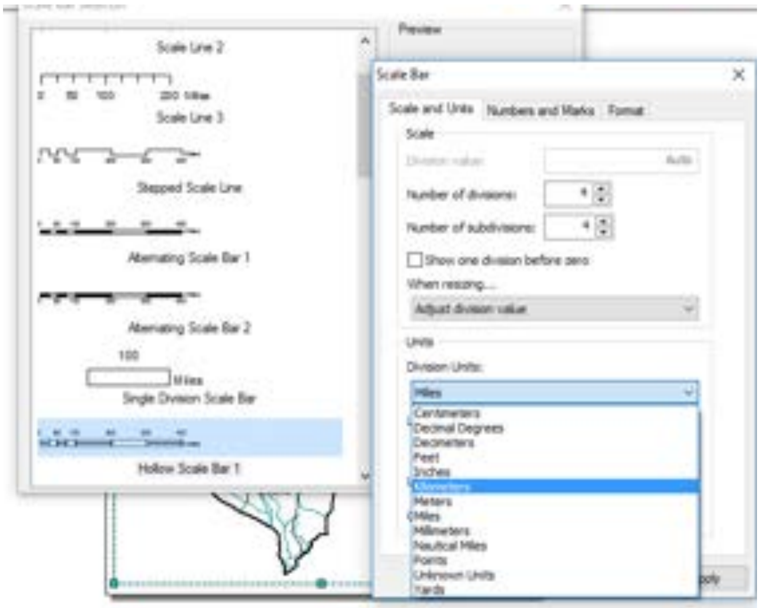


- Map titles are just a specific kind of text box with some pre-defined fonts. Hence, the usage of title and text are identical and intuitive: type in the content and customize the text properties.



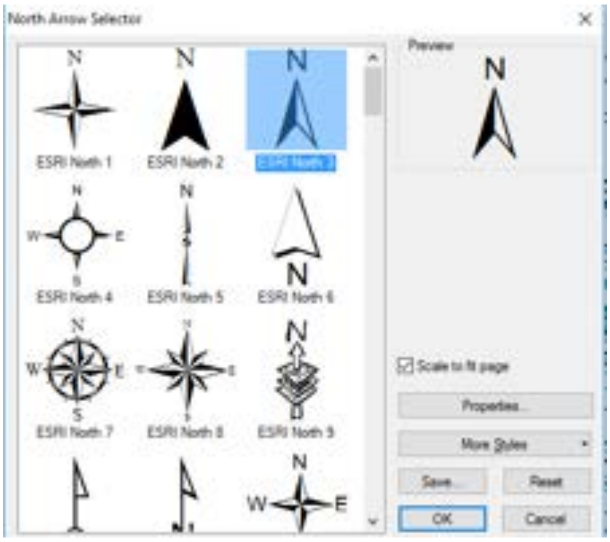
- To manipulate the title – double click – change system – change font to Arial – bold and click OK

- Add scale bar or scale text is also intuitive. The only thing that should be noted as the display unit, suchas meters, degrees, miles, etc. You can customize it by clicking the **Properties** button in the **Scale Bar (or Text) Selector**, which is the pop-up window when you choose **Insert** -> **Scale Bar** (or **Scale Text).** In the **Scale and Units** tab, you can choose an appropriate unit in the **Division Units** dropbox



- In addition, you can change the font style under the Format tab as well.

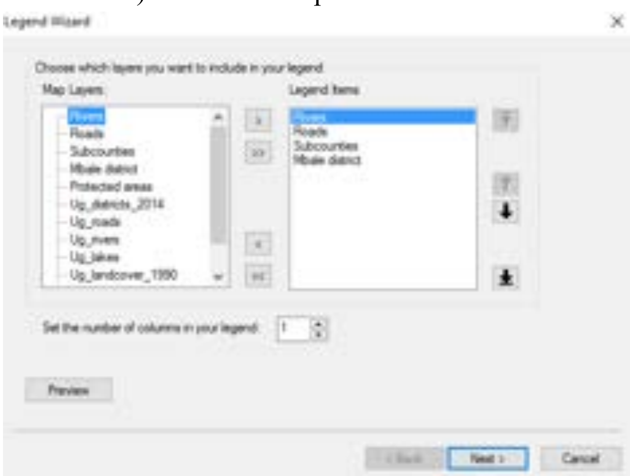
- Add North Arrow is the easiest task, which is very similar to add a scale bar. Just choose a pre-defined north arrow from the library shown in the left pane is ok. If your North Arrow is difficult to be distinguished from the background, you can add some background color, which has similar effect of "mask" for labels. This option normally locates in the **Frame** tab



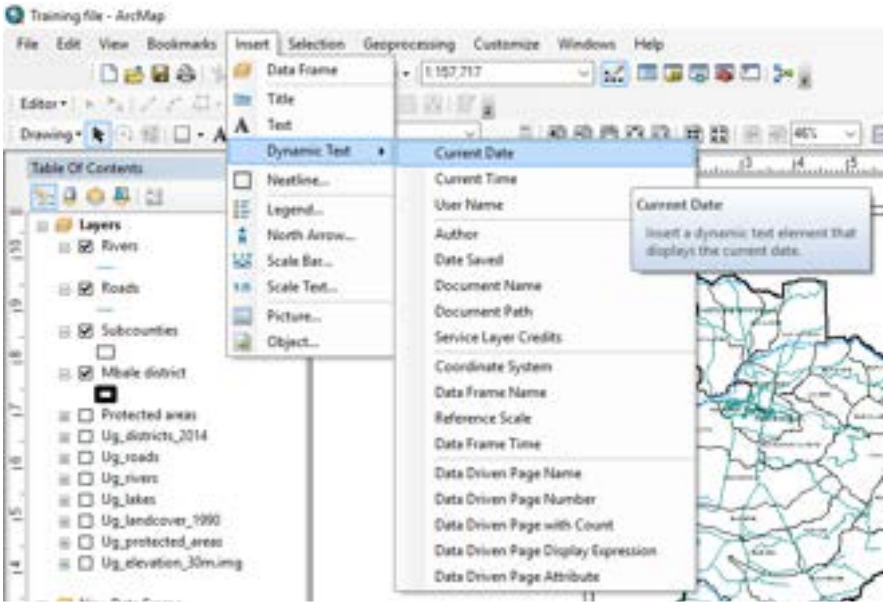
- Adding Legend is somewhat complex and deserves some explanation. When Insert -> Legend is selected, ArcMap will use a wizard guiding you through various options of making a legend.
- Note
    - At the first step, you will be asked about which layers need legend and the order of adding legend. The left pane Map Layers displays all layers (geospatial data) available for the map.
    - The right pane Legend Items shows the layers that will be added to the legend in order.

a) Add/Remove Layers: You can decide the layers to be added to the legend by clicking to add or to remove.

b) Change the Display Orders: The legend items will be added strictly in the order shown in the **Legend Items** pane. You can change the order by clicking a layer first (displayed in the blue bar) and move it up or move it down .



- Adding more information onto the map (e.g. date, projection parameters)

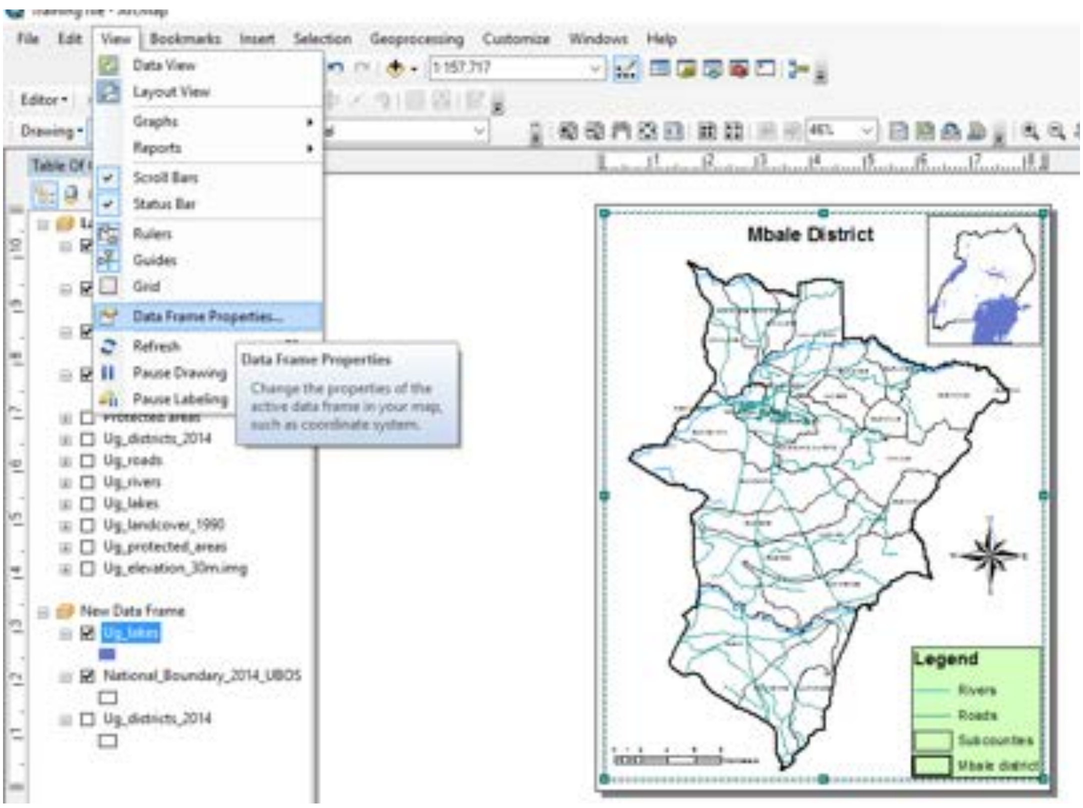


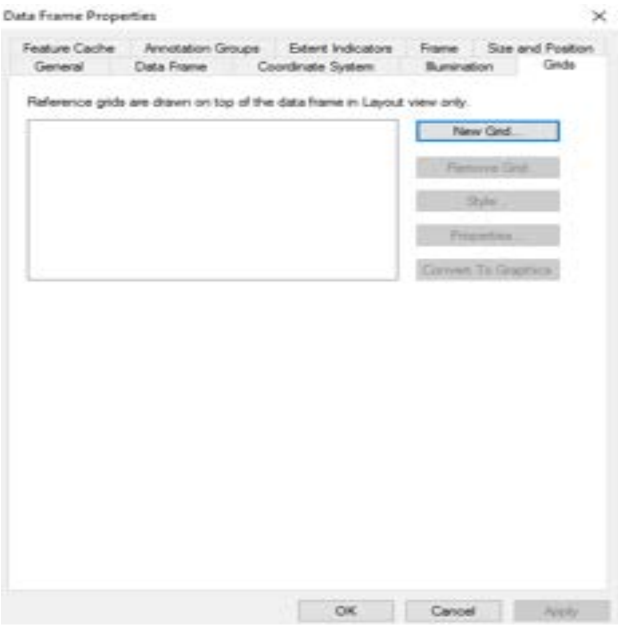
Some Components that are also frequently added:

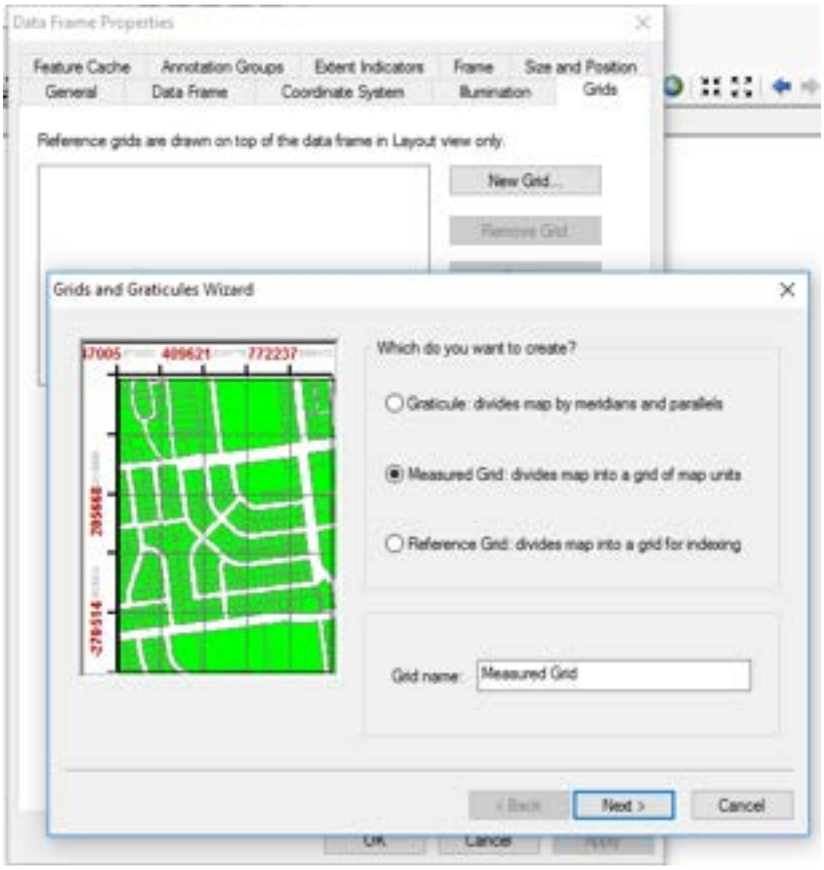
- *Author of the Map: Users may want to know who creates the map;*
- *Date Saved (Created/Modified): The more frequent a region changes, the more important it is for users to know when the map is created;*
- *Coordinate System: The globe is not flat, but a map is. Any kind of projection used to make the map distorts the reality in some way. Hence, it is critical for users to know how reliable their measurements on the map are, especially for pilots and navigators.*

- Insert grids into your map

Click on View – Data Frame properties – grids – new grid – measured grid – click next until OK


File
Edit
View
Bookmarks
Insert
Selection
Geoprocessing
Customize
Windows
Help
Data View
Layout View
Graphs
Reports
Scroll Bars
Status Bar
Rulers
Guides
Grid
Data Frame Properties...
Refresh
Pause Drawing
Pause Labeling
Data Frame Properties
Change the properties of the active data frame in your map, such as coordinate system.
Ug_districts_2014
Ug_roads
Ug_rivers
Ug_lakes
Ug_landcover_1990
Ug_protected_areas
Ug_elevation_30m.img
New Data Frame
Ug_lakes
National_Boundary_2014_UBOS
Ug_districts_2014
Mbale District
Legend
Rivers
Roads
Subcounties
Mbale district

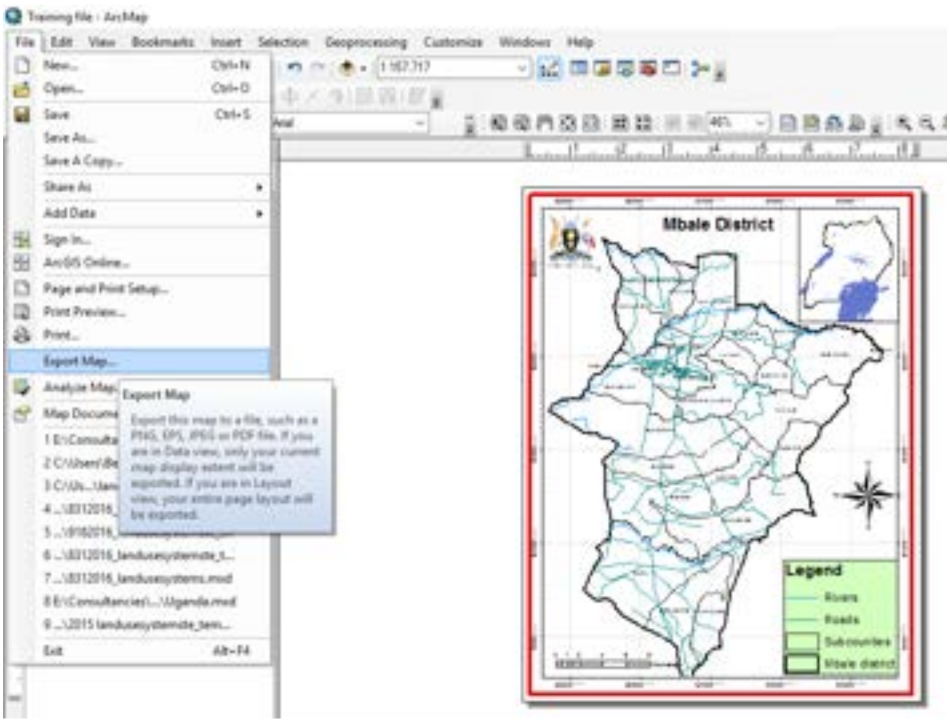

Data Frame Properties
Feature Cache
Annotation Groups
Extent Indicators
Frame
Size and Position
General
Data Frame
Coordinate System
Illumination
Grids
Reference grids are drawn on top of the data frame in Layout view only.
New Grid...
Remove Grid
Style...
Properties...
Convert To Graphics
OK
Cancel
Apply

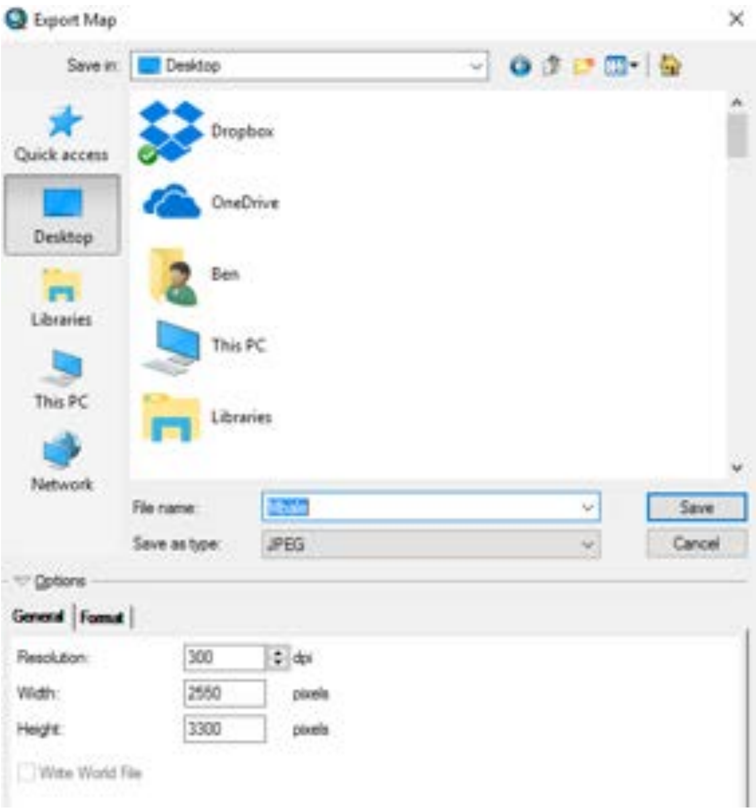


5.4.9 Export Maps

1) Format page settings (Decide if your work is to be printed A2, A4 etc paper size)

2) When you are satisfied with everything in the map and are ready to deliver, you can export your map by the menu of **File** -> **Export Map**, which will pop-up a dialog





Highlights

1) You can specify the directory and file name of the map in this dialog. But, most importantly, you need to choose an appropriate file format by click on the **Save as type** dropbox. The most frequent-used formats are JPEG and PDF. JPEG is a popular graphic file format, which is easy to be inserted into word as a graph, while PDF is best used for sharing. The printed copy of PDF will be identical regardless of your computer (and printer) environment.

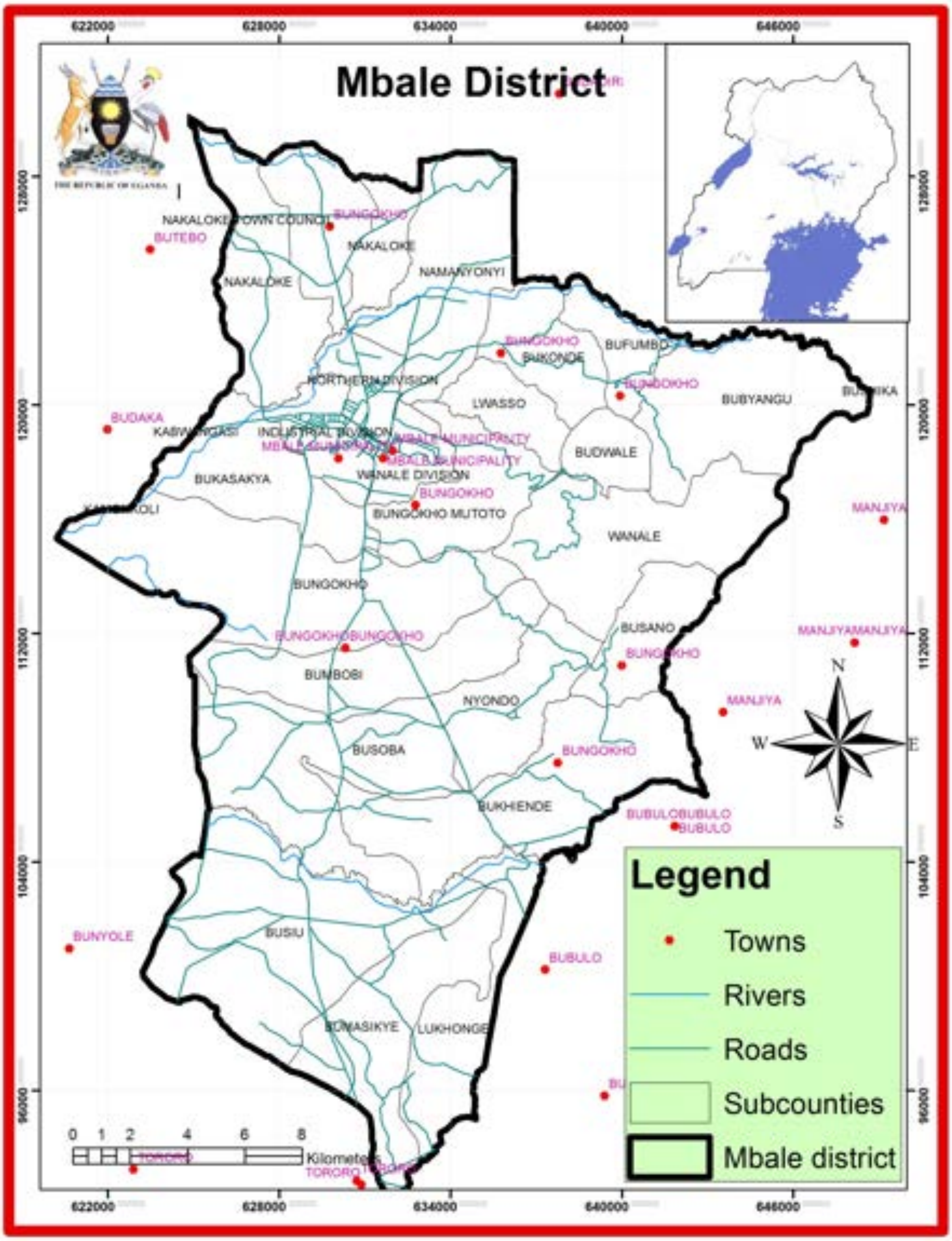
2) Please note that if the purpose of your map is to be shown on screen, **96 dpi** resolution is good enough. It is especially true when you want to publish your map online, given that lower resolution maps are much smaller, and therefore, easier to transfer via Internet. If you need hard copies of your map, please make sure that the resolution is set to **300 dpi** or **600 dpi**. Otherwise the output map might be obscure.

3) Other than export map to other file formats, you can directly print out hardcopies of your map by **File** -> **Print**. You can preview the result via **File** -> **Print Preview** to ensure satisfactory result. And, of course, you can customize page and printer setup via **File** -> **Page and Print Setup**, such as page orientation, page size, printer configuration (color or grey), and so on. All these operations are intuitive and very similar to other applications, such as Microsoft Word.

Brief Explanation of Graphic File Formats:

- *EMF file: Enhanced Metafile, specified for Windows, which can be regarded as an alternative of TIFF file. EMF is an not recommended option;*
- *EPS file: Enhanced PostScript file, specified by Adobe for printer drivers. It is popular in open-source editors, for instance, LaTeX and TeX. But it seems to be a buggy option. Try to avoid it;*
- *AI file: Adobe Illustrator file. A major vector graphic file format. A good choice if you work with Adobe products, such as Illustrator, Flash, and MacroMedia ones;*
- *SVG file: Scalable Vector Graphics, an open-source vector graphic standard. It is becoming more and more popular and can be accepted by many vendors;*
- *BMP file: BitMap file, which is a mature loss-less uncompressed raster format. The quality is great. But its file size tends to be huge. It can be used if you need both high-quality output and compatibility ;*
- *PNG file: Portable Network Graphics, which is an open-source standard designed to replace BMP and GIF. It is a true-color loss-less raster file format. PNG file is slightly larger than JPEG (compressed with quality loss). And some old browsers and operating systems do not support PNG files;*
- *TIFF file: Tagged Image File Format. A major raster graphic file format provided by Adobe (AI for vector). Best to be used for raster file editing on Adobe Products, such as Photoshop;*
- *GIF file: Graphics Interchange Format. An uncompressed raster file format with 256-color limitation. Hence, if your map contains only a few colors (vector-based data), GIF is a good candidate.*

Final map


Mbale District
NAKALOKE TOWN COUNCIL
BUTEBO
NAKALOKE
NAMANYONYI
BUFUMBO
BUKONDE
NORTHERN DIVISION
LWASSO
BUBYANGU
BUDAKA
INDUSTRIAL DIVISION
MBALE MUNICIPALITY
BUDWALE
WANALE DIVISION
BUKASAKYA
BUNGOKHO MUTOTO
WANALE
BUNGOKHO
BUSANO
BUMBOBI
NYONDO
MANJIYA
BUSOBA
BUKHIENDE
BUBULO
BUNYOLE
BUSIU
BUMASIKYE
LUKHONGE
TORORO
Kilometers
Legend
Towns
Rivers
Roads
Subcounties
Mbale district

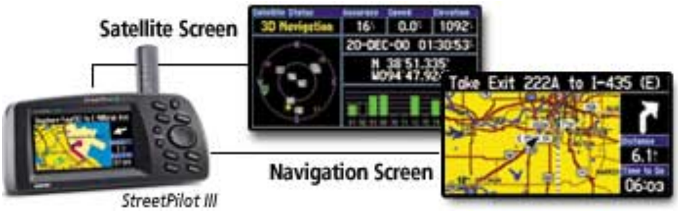
6.0 Mapping of environmental features using GPS units

6.1 Introduction to Global Positioning Systems

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day.

6.2 How it works

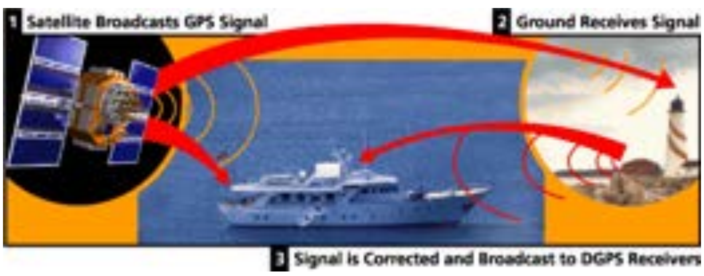
GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use trilateration to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.



A GPS receiver must be locked on to the signal of at least 3 satellites to calculate a 2-D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3-D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

6.3 How accurate is GPS?

Today's GPS receivers are extremely accurate, thanks to their parallel multi-channel design. Our 12 parallel channel receivers are quick to lock onto satellites when first turned on, and they maintain strong locks, even in dense foliage or urban settings with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. Garmin GPS receivers are accurate to within 15 meters, on average.



Newer Garmin GPS receivers with WAAS (Wide Area Augmentation System) capability can improve accuracy to less than 3 meters on average. No additional equipment or fees are required to take advantage of WAAS. Users can also get better accuracy with Differential GPS (DGPS), which corrects GPS signals to within an average of 3 to 5 meters. The U.S. Coast Guard operates the most common DGPS correction service. This system consists of a network of towers that receive GPS signals and transmit a corrected signal by beacon transmitters. In order to get the corrected signal, users must have a differential beacon receiver and beacon antenna in addition to their GPS.

6.4 The GPS satellite system

The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. They are constantly moving, making two complete orbits in less than 24 hours. These satellites are travelling at speeds of roughly 7,000 miles an hour.

GPS satellites are powered by solar energy. They have backup batteries onboard to keep them running in the event of a solar eclipse, when there's no solar power. Small rocket boosters on each satellite keep them flying in the correct path.

Here are some other interesting facts about the GPS satellites (also called NAVSTAR, the official U.S. Department of Defense name for GPS):

a) The first GPS satellite was launched in 1978.
b) A full constellation of 24 satellites was achieved in 1994.
c) Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.
d) A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.
e) Transmitter power is only 50 Watts or less.

6.5 What's the signal?

GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band. The signals travel by line of sight, meaning they will pass through clouds, glass and plastic but will not go through most solid objects such as buildings and mountains.

A GPS signal contains 3 different bits of information - a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is

transmitting information. You can view this number on your Garmin GPS unit's satellite page, as it identifies which satellites it's receiving.
Ephemeris data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position.

The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.

6.6 Some of the GPS applications in the agricultural sector

The application of GPS in agriculture is not limited to; location of beneficiaries, farm size determination, mapping infrastructure, monitoring weeds, pests and disease spread, and crop damage due to drought and hailstorms.

A field map can be created using GPS to record the coordinates of field borders, fence lines, and point locations such as wells, stores, buildings, and landscape features. The resulting field map might be the first layer a producer would develop for an on-farm GIS (Geographic Information System). Additional layers showing crop damage from hail or drought, and riparian areas or wetlands could be mapped using GPS.

6.7 Sources of GPS signal errors

Factors that can degrade the GPS signal and thus affect accuracy include the following:

- Ionosphere and troposphere delays - The satellite signal slows as it passes through the atmosphere. The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.
- Signal multipath - This occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.
- Receiver clock errors - A receiver's built-in clock is not as accurate as the atomic clocks on-board the GPS satellites. Therefore, it may have very slight timing errors.
- Orbital errors - Also known as ephemeris errors, these are inaccuracies of the satellite's reported location.

- Number of satellites visible - The more satellites a GPS receiver can "see," the better the accuracy. Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.
- Satellite geometry/shading - This refers to the relative position of the satellites at any given time. Ideal satellite geometry exists when the satellites are located at wide angles relative to each other. Poor geometry results when the satellites are located in a line or in a tight grouping.
- Intentional degradation of the satellite signal - Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. Department of Defense. SA was intended to prevent military adversaries from using the highly accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

6.8 Setting up GPS

GPS receivers are simple electronic devices and as such the way their set up will affect what data is collected. Before going into the field all staff must know how to use the GPS receiver, what to check for before collecting data, and simple maintenance of the devices. Every GPS receiver will be slightly different, so it is not possible to give exact details in this document. The manual that came with the GPS receiver should be used to find the exact methods to carry out the tasks listed below.

GPS receivers work by receiving signals from satellites that orbit the Earth. When you use the receiver for the first time, it has to find the satellites and update all its information on satellite locations. Most GPS receivers call this “Searching the sky”. This process can take up to 30 minutes, during which the GPS should be left somewhere with a clear view of the sky. Once the process is complete the position will be shown on the screen. This process must be repeated if the receiver is not used for 4 months or if it is moved large distances, i.e. between countries or within very large countries. If you move less than 200km from the previous location then the update will not be required.

6.9 Recording GPS coordinates

Waypoint coordinates may be recorded in different ways: Write on paper record in the device and download later, Type into a database, Enter into a storage device. The simplest is to have two columns on a paper form to enter the coordinates. The X coordinate and Y coordinate can simply be written down into the correct columns. It is important to ensure they are written down correctly. Having written down the coordinates it should be double checked to reduce errors.

This method works best if other information is being collected at the same time, e.g. information about a case or structure. If only the coordinates are being collected then it can be stored in the GPS receiver as a waypoint. Most GPS receivers will store up to 250 waypoints at a time. Having got the location the waypoint is created or marked. This stores the coordinates to be downloaded directly into a computer at a later date. If storing coordinates this way, you still have to keep a written record of what each waypoint represents. Care needs to be taken to ensure these waypoints are downloaded. Check frequently to avoid the memory filling up.

By storing the location as waypoints in the GPS device, Google Earth can map the waypoints directly (in Google Earth select Tools / GPS select Garmin – waypoint and click Import).

6.10 Maintenance

a) GPs receivers should be regularly checked and maintained. There are two main parts to this:
b) Check batteries. GPS receivers batteries usually only last for between 14 – 16 hours. The simplest way to do this is to turn the receiver on and there is no "Low battery" warning. It is vital that especially when going to remote locations that there are spare batteries.
c) Clean up memory. Receivers store information and this can be confusing. GPS receivers should be regularly cleaned up with all waypoints and tracks removed so that all the memory is available.

6.11 Defining protocols for field use

The information that should be defined as part of the field protocols includes:

a) Coordinate system and Map Datum

The default coordinate system and map datum should be latitude and longitude, and WGS 84. Only on rare occasions should anything else be used

b) Acceptable accuracy for waypoints

Standard GPS receivers are only guaranteed accurate to 20m however in locations with only 1 storey buildings the accuracy is usually better than 10m. The accuracy required should be defined and waypoints only collected when the accuracy is below that threshold.

c) Position to stand to find location

   a. So a protocol defining the default locations should be tested before starting field work. For village centroids or area centroids, somewhere on the main road / path through the village may be a suitable location.
   b. For a house it may be suitable to stand 1 – 2m in front of the main entrance to the house

d) Checking / maintenance routine

There should be a protocol for verifying the coordinates collected and for maintenance of the GPS receivers

6.12 Field Area calculation

a) Switch on your GPS units and wait shortly for an improved accuracy
b) Go to the main menu and select Area calculation

You can calculate Area and Display in:

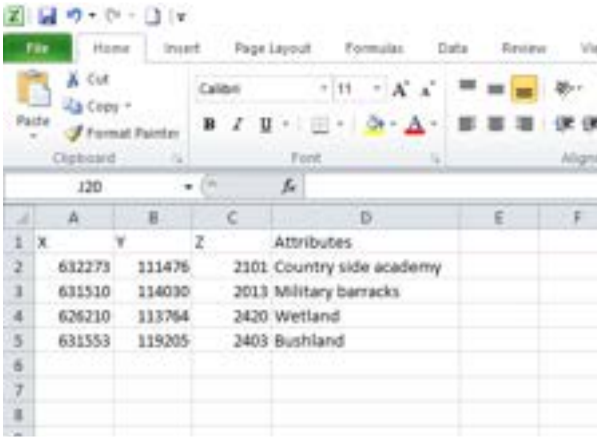
a) Acres
b) Square Miles
c) Square Feet
d) Hectares
e) Square Kilometers
f) Square Meters

c) Press START and you move around the field until you reach the original departure point and then stop the calculator
d) Record the field computations in your Notebook
e) Enter the recorded computations into an excel sheet as an attribute "area"

6.13 Procedures of adding the collected coordinates into Arcmap

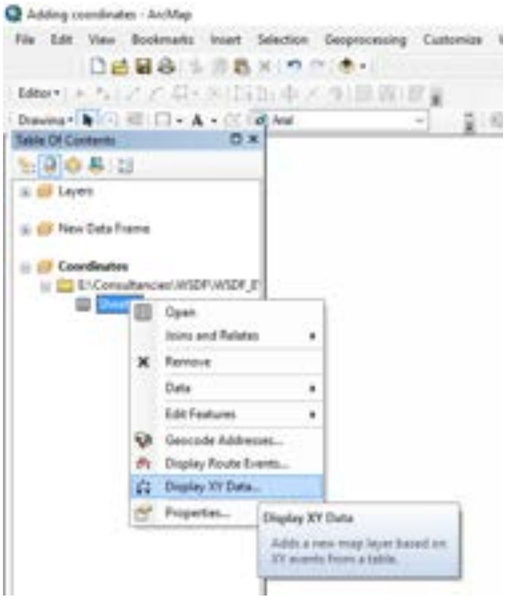
6.13.1 How capture coordinates

a. Open Ms Excel and enter the captured coordinates from the field for spatial display and analysis
b. Save the excel file in your working folder and close excel



c. Launch ArcMap and load the excel file to add the coordinates
d. Navigate to your Excel spreadsheet and double-click the sheet

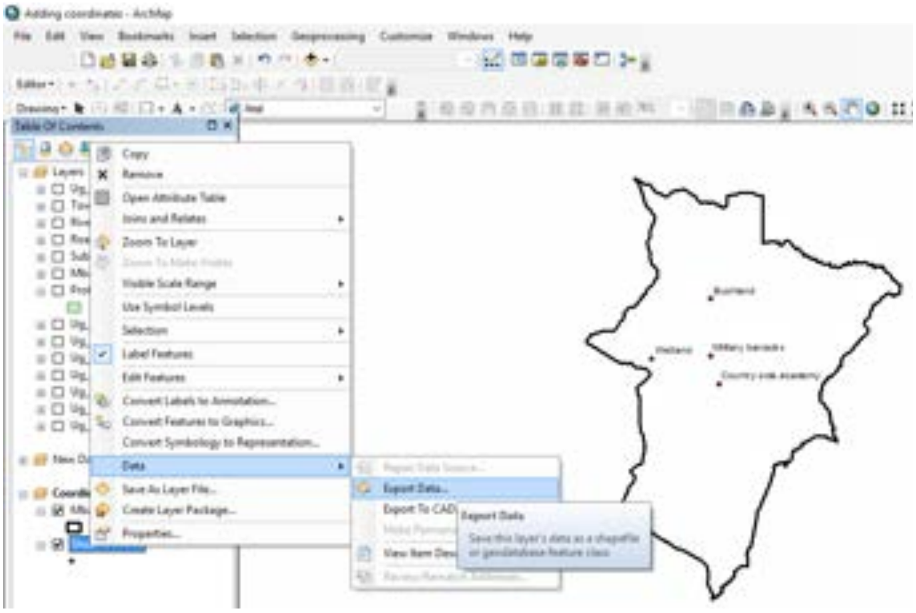
e. Select "sheet 1"
f. The Excel table will be added to ArcGIS and appear in the table of contents.
g. Right click the added excel table from the table of contents – **Display XY data**



h. Define X and Y fields and then click OK
i. An event later will be created with your points.

j. Label the add XY points and also add the Mbale district boundary data using the previous exercise of creating a map using existing layers

k. Lastly, save the displayed points as a feature class, this is because:
   a. This XY data will not be saved in memory once ArcGIS is closed. To save the points data, you need to create a feature class or shapefile.
   b. So right-click the event layer and export data (data > export data). Click "use the same coordinate system as the data layer".
   c. Save the file and you have just created a spatial file from an Excel spreadsheet.

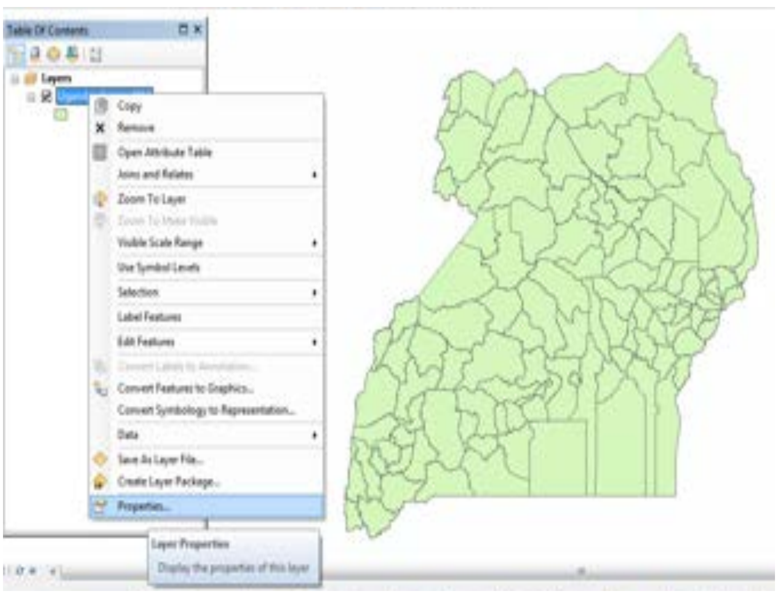


1. Save the shapefile in your working folder as (Mbale_GPS_coordinates)

6.14 *Symbolizing layers*

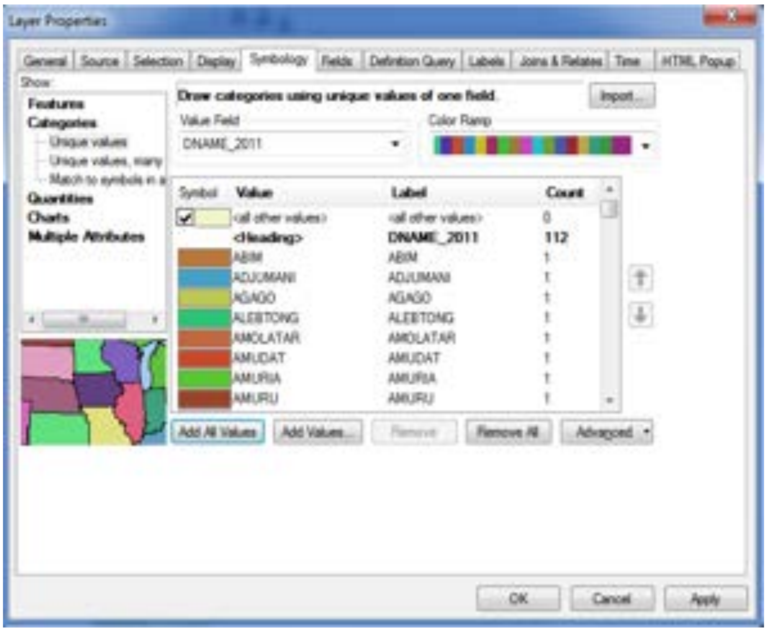
6.14.1 Manipulation of layer properties

1. Double click -> shapefile from table of contents or Right click -> the shapefile ->properties->symbology



6.14.2 Layer Catergories

2. Click symbology -> categories ->unique values
3. Value field -> DNAME2011 -> click on add all values -> OK



6.15 Lab Exercise: Data Capture, Analysis and Dissemination with a focus on GPS and Coordinate Systems

PART A: Aerial Photography

Section 1. Understanding aerial imagery in ArcMap

We will be discovering the properties of an aerial photograph. The aerial photo we will use comes from the Virginia Base Map Photography (VBMP) program.

1. Open ArcMap to a new map, and add the aerial photograph **D0_S03_9621_10.sid** to your map.
2. First, learn about the aerial photograph. From the layer properties, record the following:
   1. Columns and Rows:______________________________
   2. Number of bands:______________________________
   3. Cellsize (X, Y):__________________________
   4. Pixel depth:____________________________________

> ***Note about images****: Images can require substantial disk space. The space required to store an image is a function of the number of rows and columns, the number of bands, and the pixel depth, or number of bits of data stored for each image pixel.*

3. Estimate the number of megabytes needed to store this image: multiply the number of rows times the number of columns times the number of bands times the number of bytes (not bits!) of pixel depth.
   1. Bytes to store image:______________________
   2. Megabytes (divide by 1,048,576 bytes in a megabyte; record to two decimals):___ _____________

3. Check this answer against the "uncompressed size" recorded in the layer properties. Also, you can get an idea of the importance of image compression by looking at the space that this file uses in your folder (in My Computer, look at the files in the folder, using the "details" view to see file sizes. Remember that 1 MB is 1,024 KB).

4. Now record information about the coordinate system used for this image:
   1. Linear unit:____
   2. Spatial reference (coord. Sys.):______________________________
   3. Datum:____

> ***Note****: If you zoom into an individual pixel and use the measure tool to measure it, does it confirm the pixel cellsize recorded above? Pay attention to units.*

Section 2. Examining the impact of coordinate datums

Now we will see what happens when map data is displayed in different coordinate systems in ArcMap.

5. Find a location in your image that you can zoom to repeatedly and find the same point to within one pixel (e.g., a sidewalk corner, a painted patch on a road, a lamppost, etc.). Now zoom in to where you can clearly see the individual pixel (i.e., a scale of around 1:20 to 1:40). Move your cursor to either a center or corner of the pixel and record the coordinate displayed in the lower right of the ArcMap window. These coordinates should be in the same coordinate system as the image (recorded as the spatial reference above).
   1. X-Coordinate:______________________________
   2. Y-Coordinate:______________________________
6. Now, change the coordinate system of the Data Frame to be UTM NAD **27** (predefined, projected coordinate systems, UTM, NAD 27, Zone 17N). Record the coordinates:
   1. X-Coordinate:______________________________
   2. Y-Coordinate: ____________________________
7. Now, change the coordinate system of the Data Frame to be UTM NAD **83** (predefined, projected coordinate systems, UTM, NAD 83, Zone 17N). Record the coordinates:
   1. X-Coordinate:______________________________
   2. Y-Coordinate: ____________________________
8. Calculate the difference between these:
   1. Difference in X ('easting'; 7a - 6a):__________________________
   2. Difference in Y ('northing'; 7b - 6b):________________________
   3. Distance (square root of ([8a * 8a] + [8b * 8b])):______________
   4. This distance (in meters) represents the shift between the datum NAD 27 and the datum NAD 83.

PART B: COLLECTING, ANALYISING AND MAPPING FIELD DATA

Section 3. Collecting and storing GPS Data.

In this section, you will work with other trainees to collect coordinates at corners of an assigned area on campus.

9. You will be issued one GPS unit per two- or three-person team, along with instructions for using the unit and an assigned area in which to collect data.
10. Be sure you understand how to identify and change the coordinate system with which your GPS unit will display coordinates. <u>You should set your unit to display coordinates in UTM, WGS84, meters</u>.
    1. Visit the area and collect data per your instructions. Your primary task is to collect positions at corners of the area you are assigned.
11. At each location (waypoint, landmark), store the point on your GPS unit, but also fill in the appropriate information on the attached data sheet.
12. Next, open Microsoft Excel and enter your data into a spreadsheet.
    1. Make sure you use the column headings specified on your worksheet (when you save this in a different format, column headings with spaces or special characters create problems).
    2. You do not need to enter the comment column but you may if you wish.
13. When you are done, save your worksheet file as an Excel workbook (use the last name of one of the team members).

Section 4. Importing GPS data into ArcMap.

Next, we will load the data file containing GPS coordinates into a format for use by ArcMap. We must "define" a coordinate system for our data files so that ArcMap can display our maps appropriately.

14. Open ArMap and add the Uganda Administrative Boundaries layer provided. Follow the ArcMap Help instructions for "Adding XY Data" to add the points from your Excel file into ArcMap. You will have to instruct ArcMap what coordinate system was used for your GPS points.
15. An "Events" layer will be added to your map, consisting of points. This is not a shapefile, but you will convert it to one:
    1. Right-click on the layer name and select "Data" then "Export Data…"
    2. In the Export Data dialog, pay attention to the choices offered and make sure you understand them. *Is the coordinate system for the data frame different than the coordinate system for your Events layer?*
    3. Add the exported shapefile to a map.
    4. To avoid later confusion, remove the "Events" layer.
16. Examine your map to see how well the GPS points overlay in the appropriate locations on the Uganda Administrative Boundaries layer.

Section 5. Calculating Area manually.

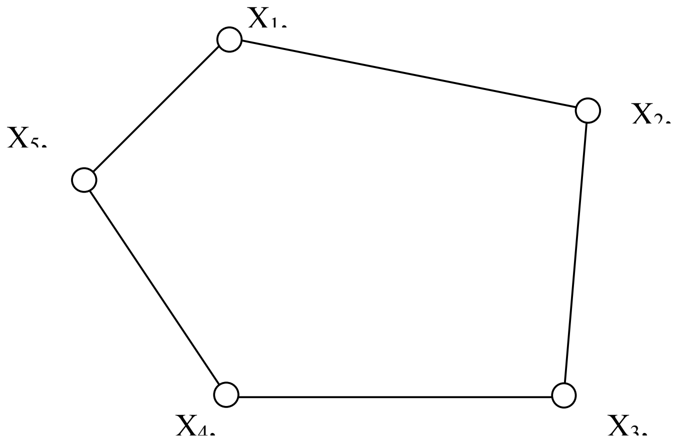
Next, we will calculate the area bounded by the GPS points you collected. We will do this in two ways: manually and within ArcMap. You can perform the manual approach either using an Excel spreadsheet or a hand calculator. The algorithm will be described here, and it will be up to you to implement this with calculator or spreadsheet.

Area Calculation Algorithm:

Consider a series of **n** coordinate pairs, (X_1, Y_1) to (X_n, Y_n); these pairs are in clockwise sequence around a polygon:

The area of the polygon is calculated as the absolute value of:

$$\frac{\sum_{i=1}^{n} [(X_i Y_{i+1})-(X_{i+1} Y_i)]}{2}$$



Where $X_{n+1} = X_1$
and $Y_{n+1} = Y_1$

So for the example polygon shown, n=5 and the area is calculated as:

$$A = [(X_1Y_2 - X_2Y_1) + (X_2Y_3 - X_3Y_2) + (X_3Y_4 - X_4Y_3) + (X_4Y_5 - X_5Y_4) + (X_5Y_1 - X_1Y_5)] / 2$$

Area (A) will be expressed in square distance units of the coordinates. If coordinates are in meters, Area will be in square meters.

17. What is your polygon area (square meters)?________________________

18. What is the polygon area in acres?________________________________

Section 6. Creating a polygon from GPS points.

We have a point shapefile of the GPS points you collected. But points don't have area; polygons do! We must create a polygon shapefile from these points. There are several ways to do this, but you might as well learn how to create polygons through "on-screen digitizing", or "heads-up digitizing", where the map you are digitizing is displayed on the screen in front of you.

19. First, we must create an empty polygon shapefile that we will subsequently edit to add a polygon:
    1. Open ArcCatalog.
    2. Select the folder where you want this shapefile to be created.
    3. From the ArcCatalog "File" menu, select "New" and then "Shapefile…"
    4. Give your new shapefile a name and specify that it is to be a polygon feature type.
    5. Click the "Edit" button in the Spatial Reference area to *Select* the UTM, WGS84, meters coordinate system as you did before when adding XY data.
    6. Click OK. ArcCatalog will create a new, empty file ready for your polygon.

20. Go back to ArcMap and add this shapefile to your map. It will be empty, but the symbol that displays in the table of contents should indicate that this shapefile will contain polygons, not lines or points. If it doesn't, then you did not do step 19 correctly!
21. In ArcMap, zoom in to your GPS points shapefile; you may leave the aerial photo displayed in the background.
22. We need to add the Editor toolbar to your ArcMap interface:
    1. From the "Tools" menu, select "Customize…"
    2. Check the box for the "Editor" toolbar.
    3. Click "Close".
    4. You now have the Editor toolbar in your interface. It contains the Editor pull-down menu, some icons, and places to specify your editing "target" and "tasks".
23. From the Editor pull-down menu, select "Start Editing" to edit the shapefile you added above.
24. Set the Editor "Target" to be this new, empty polygon shapefile.
25. From the Editor pull-down menu, select "Snapping". ("Snapping" allows you to "snap" your digitized points exactly to points in another layer. In this case, we will want to snap exactly to the GPS coordinates in your *point* file).
    1. Check the box to indicate that you want to snap to "Vertex" in the point layer.
    2. Close the Snapping Environment window.
26. Now, in the Task menu on the Editor toolbar, set the Task to be "Create New Feature".
27. We are now ready to digitize the polygon:
    1. Click on the pencil icon to the left of the Task menu.
    2. Move the cursor into the map; your cursor should be a crosshairs with a circle. As you move it near one of your GPS points, you should see it jump slightly, or "snap" to the point. (By the way, from the Editor pulldown menu, you can select Options and click on the "General" tab to specify a snapping tolerance; this is the distance away from a point that you must be to avoid snapping to that point).
    3. Move your cursor onto one of your GPS point and click. This starts the polygon at that point.
    4. Move your cursor to the next GPS point and click to digitize that point.
    5. Continue until you come to the last point (before you return to the starting point); at this one, you will double-click to end the polygon at this last point. The polygon will automatically close back to the first point.
    6. Your polygon should be created. If it did, from the Editor menu select "Stop Editing" and save your edits.
28. You now have a polygon file; you can change the map symbology, set transparency, etc.

Section 7. Computing Polygon Area in ArcMap.

Now we have a polygon of the area you walked around with the GPS unit. However, ArcMap has not automatically calculated polygon area. We must force it to do that now!

29. First, we need to add a field in the attribute table of your polygon shapefile to store the polygon area:
    1. Open the attribute table of the shapefile that you created in the previous section.
    2. Click the Options button on the table, and select "Add Field…"
    3. Set the field name to be "Area"
    4. Set the field type to be "Double"
    5. Set the precision to be 12 (this will be how many digits the field will hold).
    6. Set the scale to be 4 (this will be how many digits to the right of the decimal).
    7. Click OK.
30. Next, we need to make ArcMap compute the polygon area and store it in this field:
    1. Right-click on the Area column heading in the attribute table.
    2. Select "Calculate Geometry".
    3. Set the property to be calculated to "Area".

4. Specify that you will use the coordinate system of the data source.
5. Set the Units to be square meters; click OK.
6. When you have followed these instructions, you should see a value for area in the attribute table.

31. What is the polygon area according to ArcMap (in sq. m.)?__________________

> ***Key Point****: Now you have proved that you can calculate a polygon area just as well as a powerful GIS can. Obviously, manual calculation of polygon area can get very tedious if you have lots of GPS points, which would be the case if you followed a winding road or stream as part of your area boundary. But for simple shapes, you can do pretty well with a spreadsheet or calculator.*
>
> *Also, you have learned to digitize a polygon on-screen, snapping to features in other layers. If you have roads or streams layers, you can "snap" to them to make sure your digitized line follows them exactly. There are lots of additional tools to digitize (such as appending adjacent polygons without slivers or overlaps).*

Section 8. Generating a map of the Polygon in ArcMap

Task: Using the geographical knowledge and skills, generate a map of the polygon you have created in ArcMap for dissemination.

FOR 4114
GPS Data Collection Sheet

PointID	XCoord	YCoord	Elev	Comment

PointID: Enter an identifier for your point, such as "Pt001"; you may wish to use the identifier that the GPS receiver automatically assigned the point.
XCoord: X-Coordinate (Longitude) in UTM meters (Zone 17, NAD 83)
YCoord: Y-Coordinate (Latitude) in UTM meters (Zone 17, NAD 83)
Elev: Elevation in meters
Comment: Optional text comment about your point location

7.0 Georeferencing

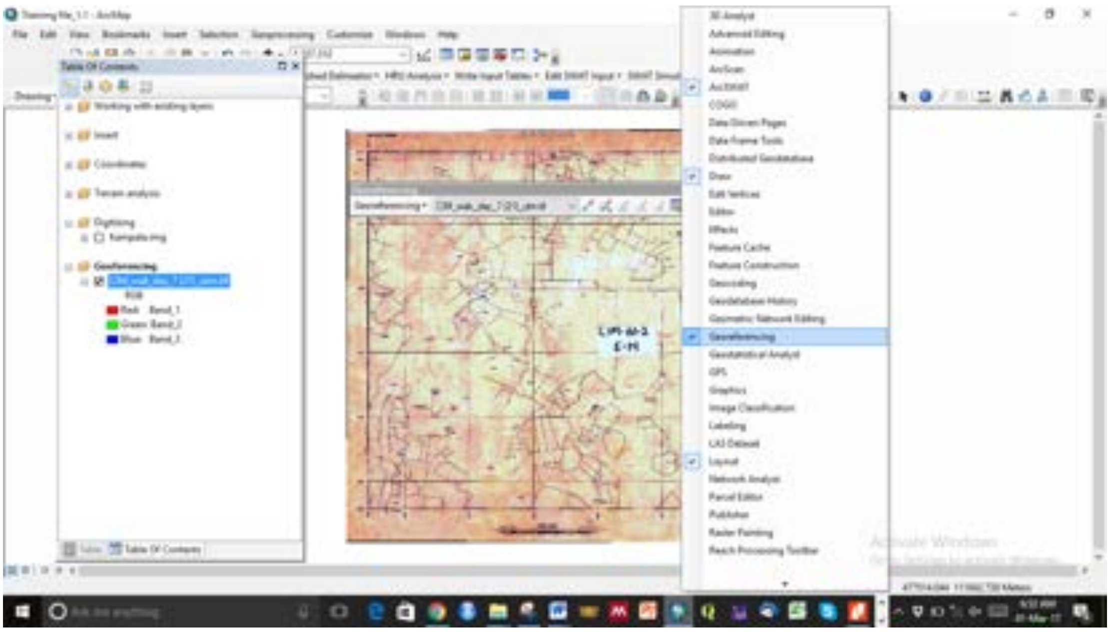
7.1 Introduction

Most often digital geographic data are acquired by scanning aerial photographs or paper maps. Once the data are input they need to be assigned their proper map coordinates so that they will occupy a real world space.

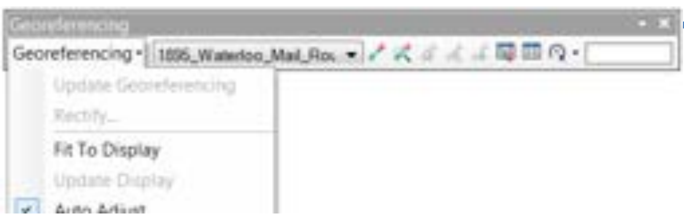
Georeferencing defines the location of a dataset using known map coordinates and assigns it a coordinate system. This allows for the dataset to be viewed, queried, and analyzed with other geographic data. Typically in a GIS environment such as ArcMap, raster datasets (such as images) are georeferenced using a control layer or control points. This layer contains known coordinates and is used as a point of reference for the georeferencing process.

7.2 Procedures

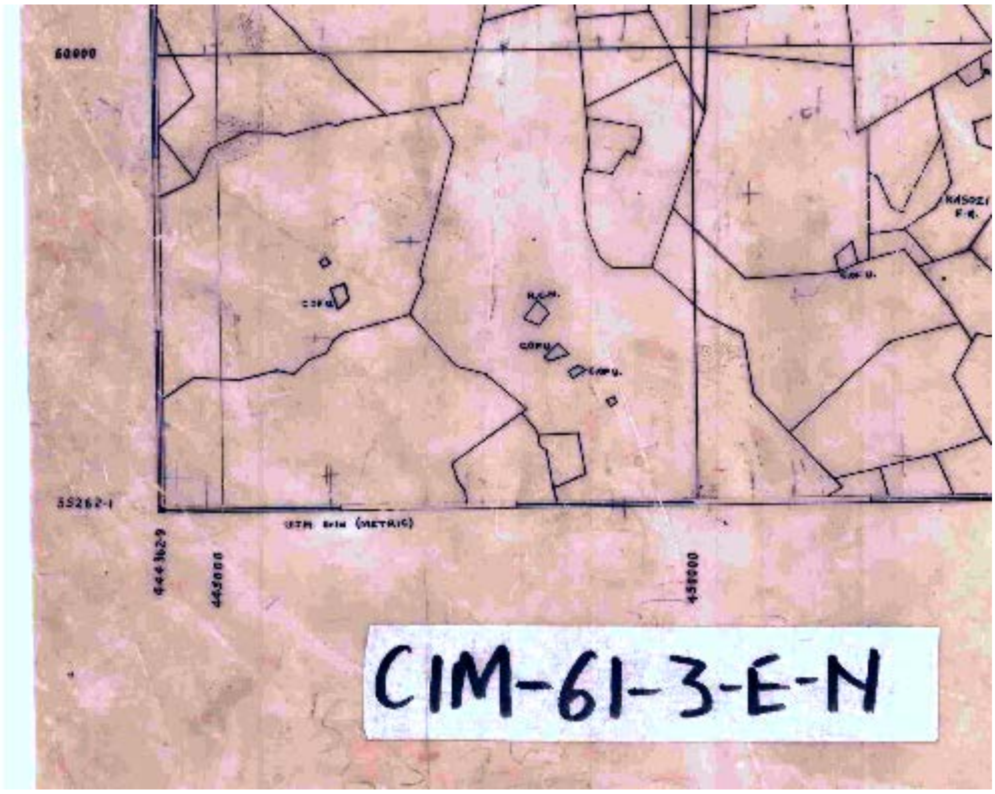
1. Click on **File** ☾<u>Add Data</u> and select the **'CIM_wak_day_7 (32).TIF'** from your working folder.
2. *Note: The control layer is the layer with the known coordinates*
3. Click on **File** ☾<u>Add Data</u> and select the dataset to be georeferenced
4. Turn on the **Georeferencing** toolbar by clicking on **View** ☾**Toolbars** ☾<u>Georeferencing</u>



5. Make sure that the **Layer** list box is set to the image that is to be georeferenced.
6. From the toolbar click **Georeferencing** ☾<u>Auto</u> <u>Adjust</u>. This will update the image with the addition of each control point



7. Zoom to the full extent of the coordinates systems
8. Most likely the image will not be visible by default. This can be corrected by clicking **Georeferencing** ☾Fit To Display



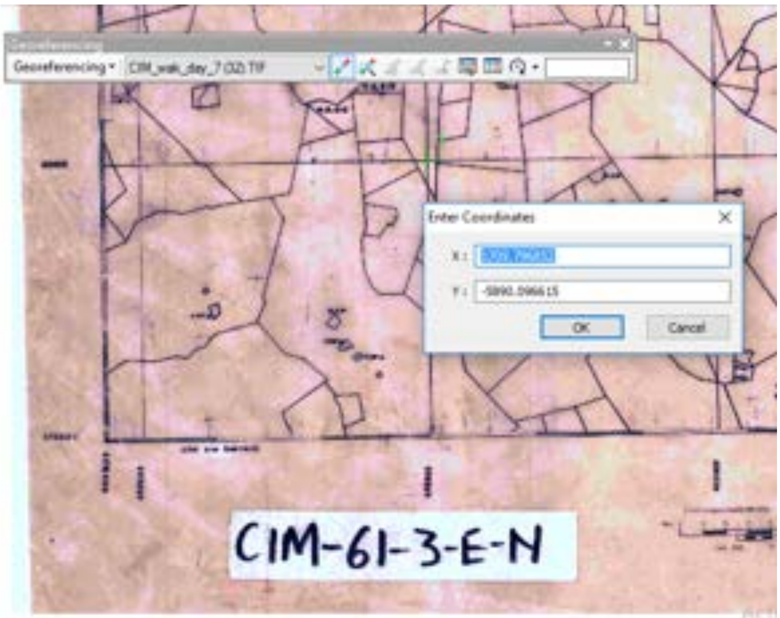
9. *Note: When georeferencing a map to a specific control layer it is good practice to project the control layer using the same projection as the paper map in order to minimize any distortion*

7.3 Geoferencing the data

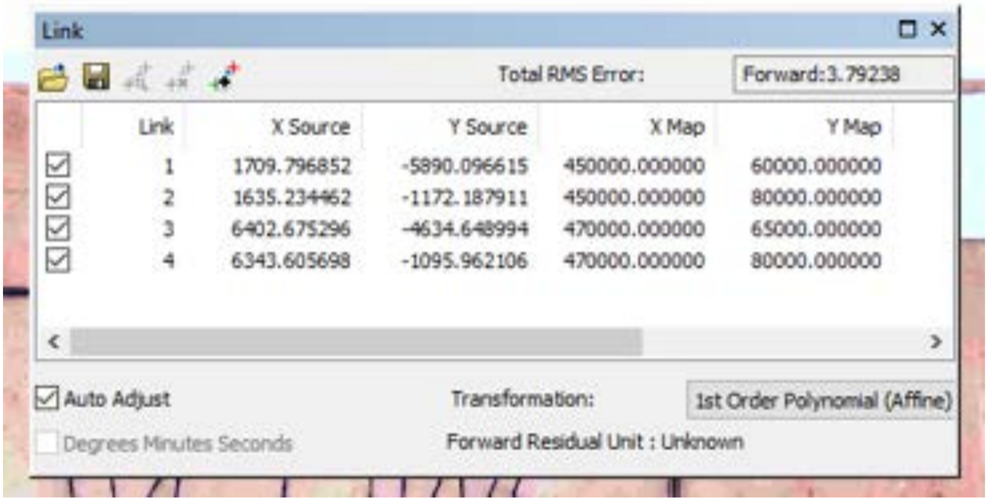
1. Begin by clicking the Add Control Points button 

2. Select a point on the image and add a control point. When georeferencing images, it is often helpful to use the corner coordinates
3. *Tip: Use the magnification window to avoid having to zoom in and out at different extents. Click on **Window** ☾Magnifier*

4. Continue adding the control points until the desired level of accuracy has been achieved.



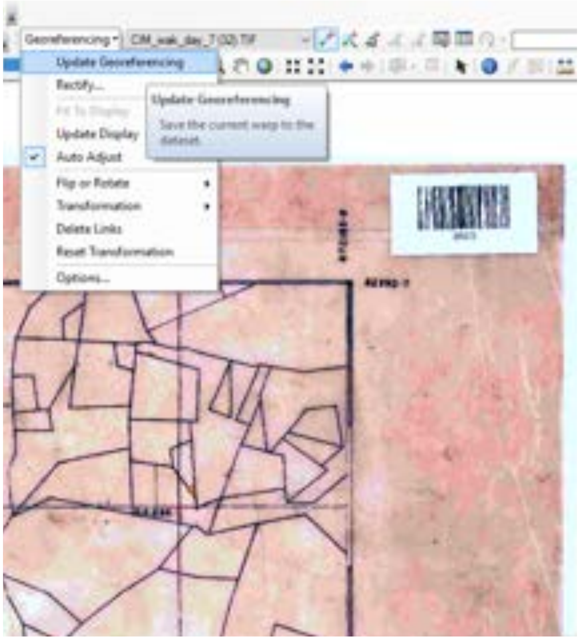
5. The image will update automatically if **Auto Adjust** is enabled
6. At any time the attributes of each control point can be viewed by clicking on the View Link Table button . This dialogue shows the map coordinates of the source (**X Source** and **Y Source**) and destination points (**X Map** and **Y Map**).
7. By double clicking on the **X Map** and **Y Map**, the destination coordinates can be altered if they are incorrect. Also, any control point can be deleted via the **Link Table** dialogue



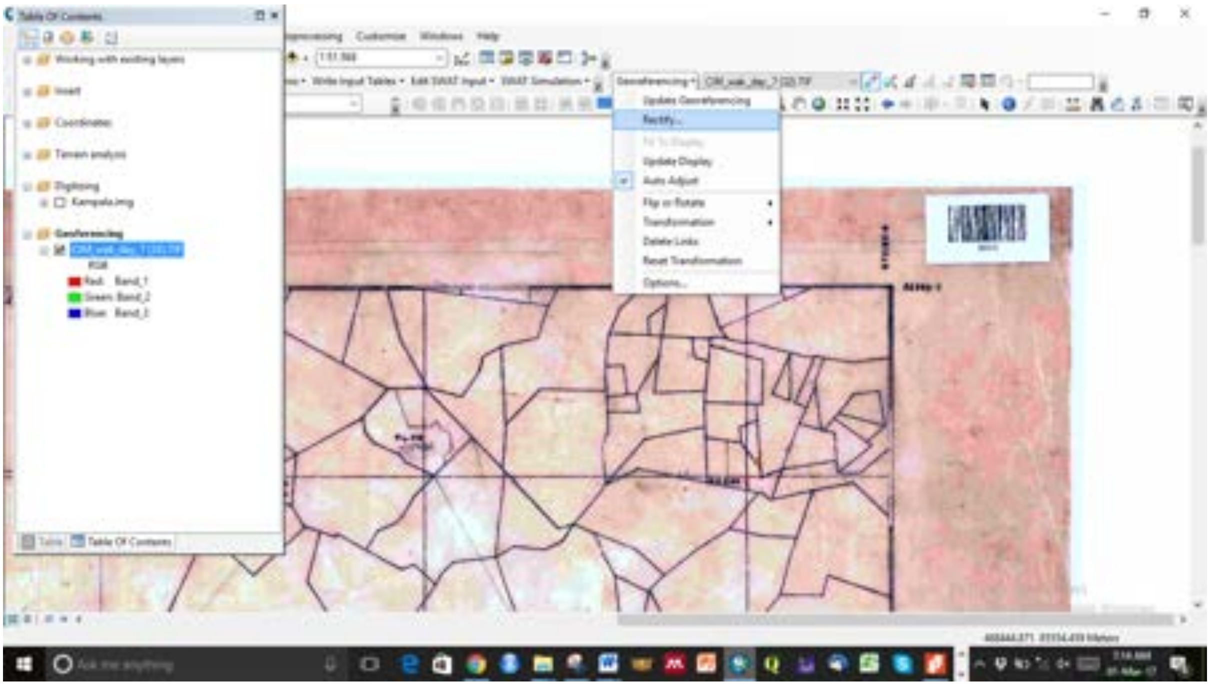
Link	X Source	Y Source	X Map	Y Map
1	1709.796852	-5890.096615	450000.000000	60000.000000
2	1635.234462	-1172.187911	450000.000000	80000.000000
3	6402.675296	-4634.648994	470000.000000	65000.000000
4	6343.605698	-1095.962106	470000.000000	80000.000000

8. Once four control points have been added an RMS error can be calculated for each point. The RMS error measures the accuracy of the control points and can be used to find inaccurate entries. Frequently, major projects will require that the RMS error does not exceed half the pixel size, however, other projects will just try to minimize the amount of error. Acceptable error levels depend on the accuracy required for the project and the data being georeferenced

9. Once all the control points have been added the image must be updated and, if needed, rectified.
10. From the toolbar click **Georeferencing** → <u>Update Georeferencing</u> to store the control points. If this image is going to be used in ArcMap again there is no immediate need to rectify the image. Once the image is added to ArcMap it will be transformed on the fly using the coordinates obtained from the control points.
11. A permanent transformation can be applied by **Rectifying** the image



12. To Rectify the image, click on **Georeferencing** → <u>Rectify</u> and specify the **Output** path and filename. Leave all other values as default



13. The image will be transformed and a new raster will be created in a TIFF file format

8.0 Digizitilisation

8.1 Introduction

Digitizing in GIS is the process of converting geographic data either from a hardcopy, digital or a scanned image into vector data by tracing the features. During the digitizing process, features from the traced map or image are captured as coordinates in point, line, or polygon forma

8.1.1 Heads up digitizing

Heads-Up digitizing is a technique that is useful for capturing or updating data from digital imagery on screen. High-resolution digital imagery now allows GIS users to edit and delineate features directly on the screen using desktop GIS software.

The following considerations should be carefully planned out in advance.

1) The user must document procedures when using this technique.
2) Scale used for data capture should be established & documented. Recommended scales for digitizing should be between 1:1200 to 1:4000 over DOQQ. Below 1:1200 the imagery becomes extremely blurred. Above 1:4000 accuracy could be compromised.
3) Digitizing tolerances should be established and documented.

4) Users should maintain clear definitions or classifications of features that are being interpreted and delineated.
5) Ground truth (field verification) remains an important step in establishing the quality of heads-up digitizing, particularly for land cover delineation.
6) Make sure appropriate entries concerning

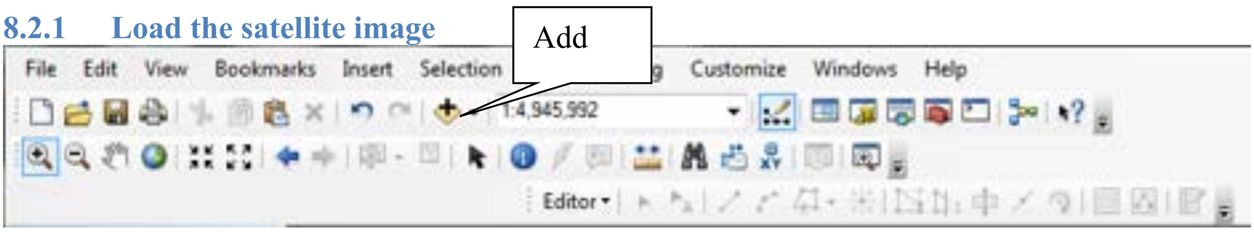
8.1.2 Tablet Digitizing

Tablet digitizing is a common method of getting data into a GIS. The procedure involves tracing lines or locating points with a computer mouse on a digitizer. The manuscript's lines should be clear and complete with no gaps or shortfalls. Operators should not interpret and digitize at the same time. The digitizer should concentrate solely on capturing the exact nature of the features.

All maps shall be edge matched prior to digitization to eliminate cartographic errors and reduce digital problems. Digital accuracy shall be evaluated by proof plotting the digital data to the base at the same scale as the manuscript and overlaying the data to the original map. The line work should be digitized in such a way as to create a digital copy that is within +/- one line width of the original. Edits can be flagged and corrected such that the standard is met. Coverage TICS should be identified and RMS errors documented in the metadata.

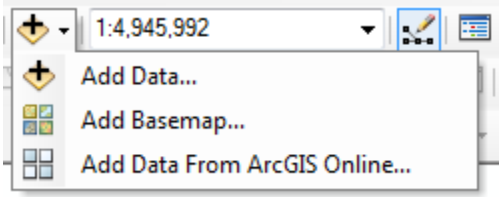
8.2 Short description 'How to digitize'

8.2.1 Load the satellite image



Main menu

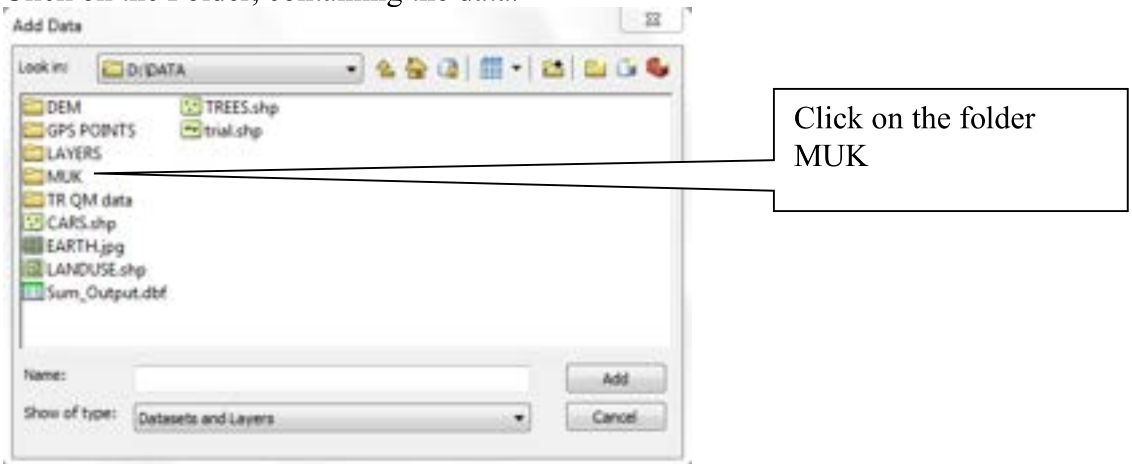
Click in the **Main Menu** on **Add Data**

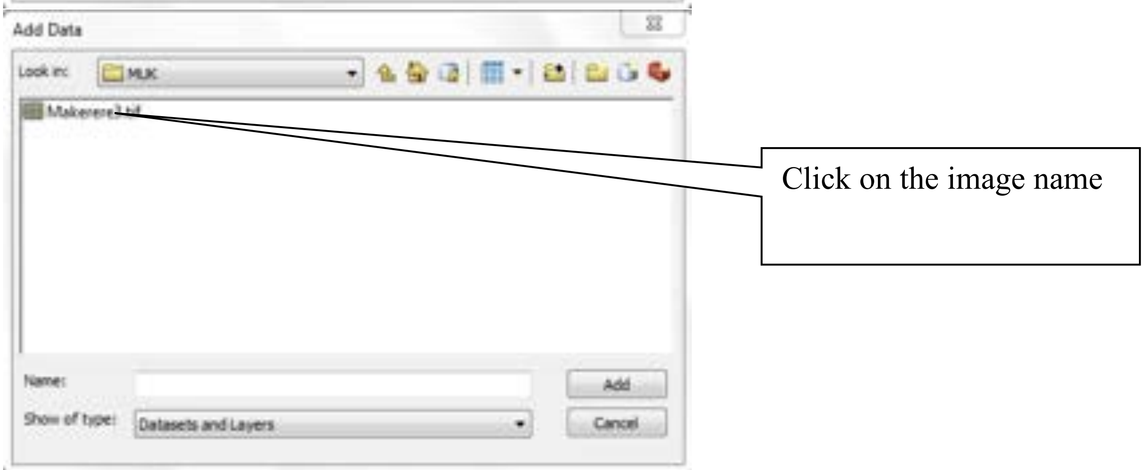


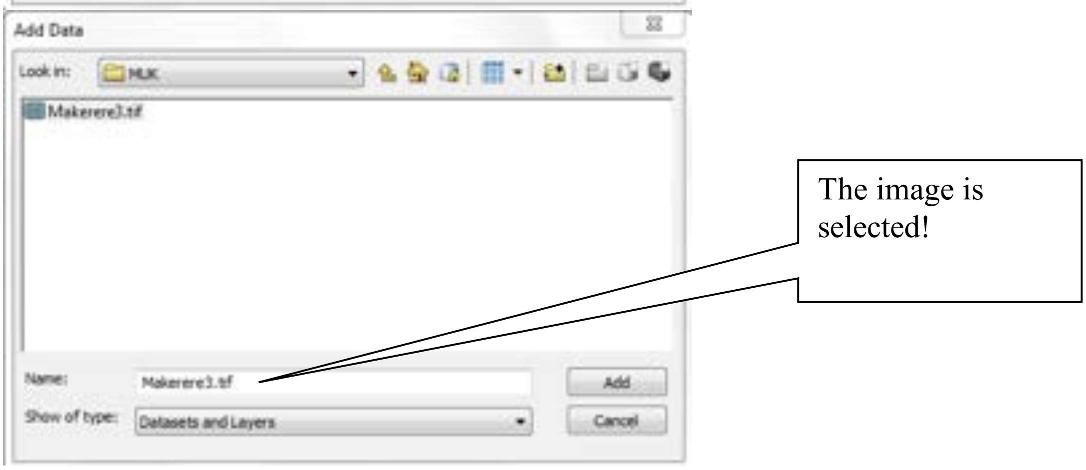
Click on **Add Data**

Linked Folders

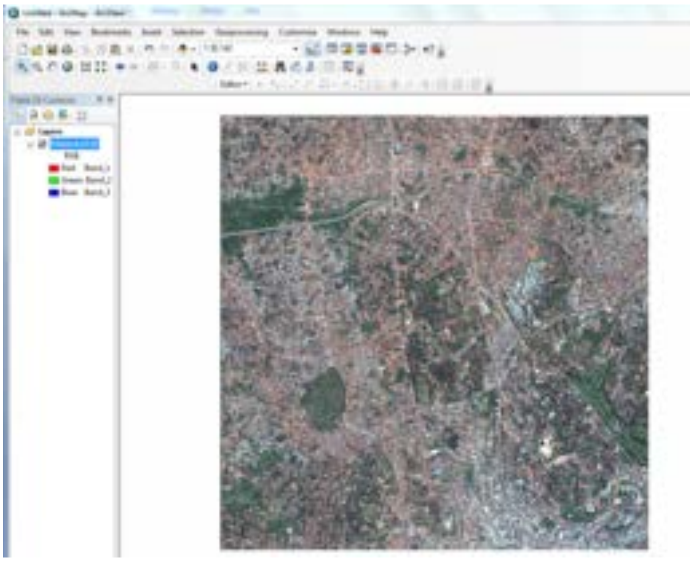
Click on the Folder, containing the data.







Click on **Add**

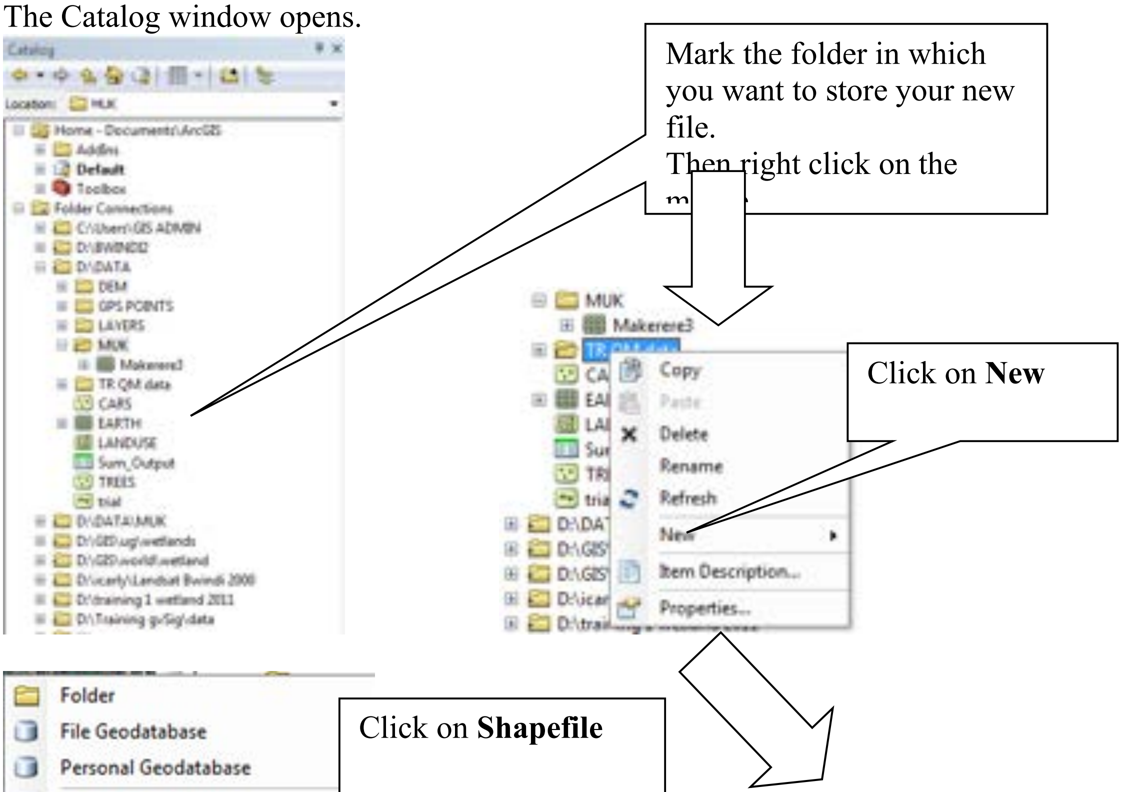


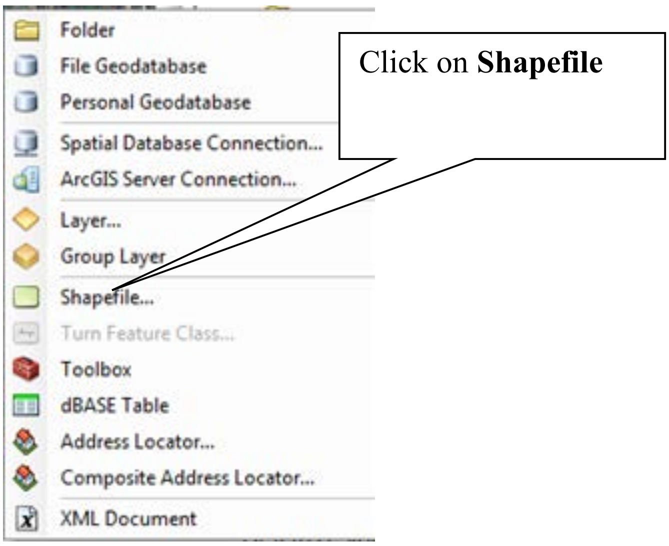
Display of the selected image

Zoom in to enlarge the area of the Makerere University

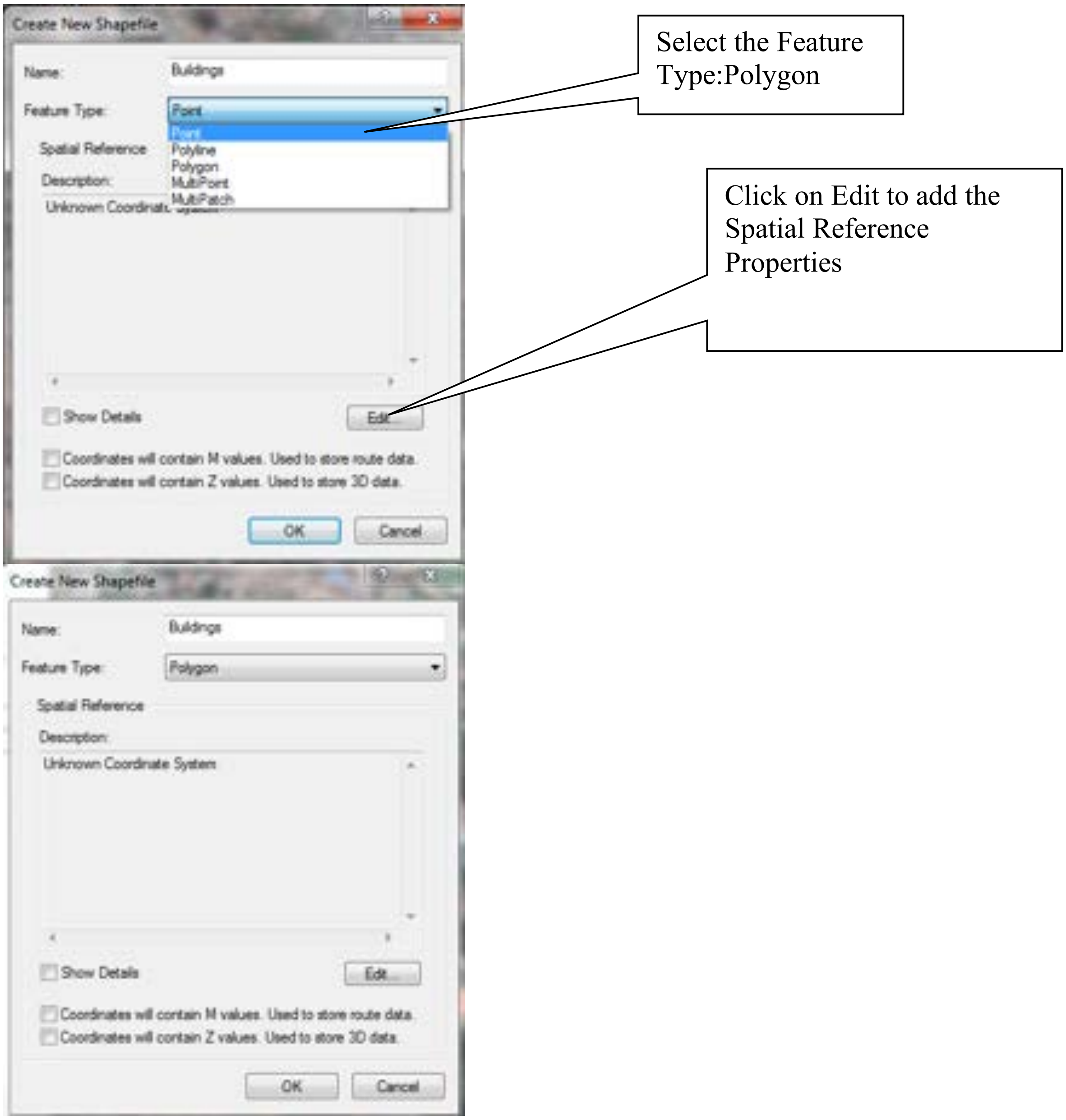
8.2.2 Create a new shape file

The Catalog window opens.



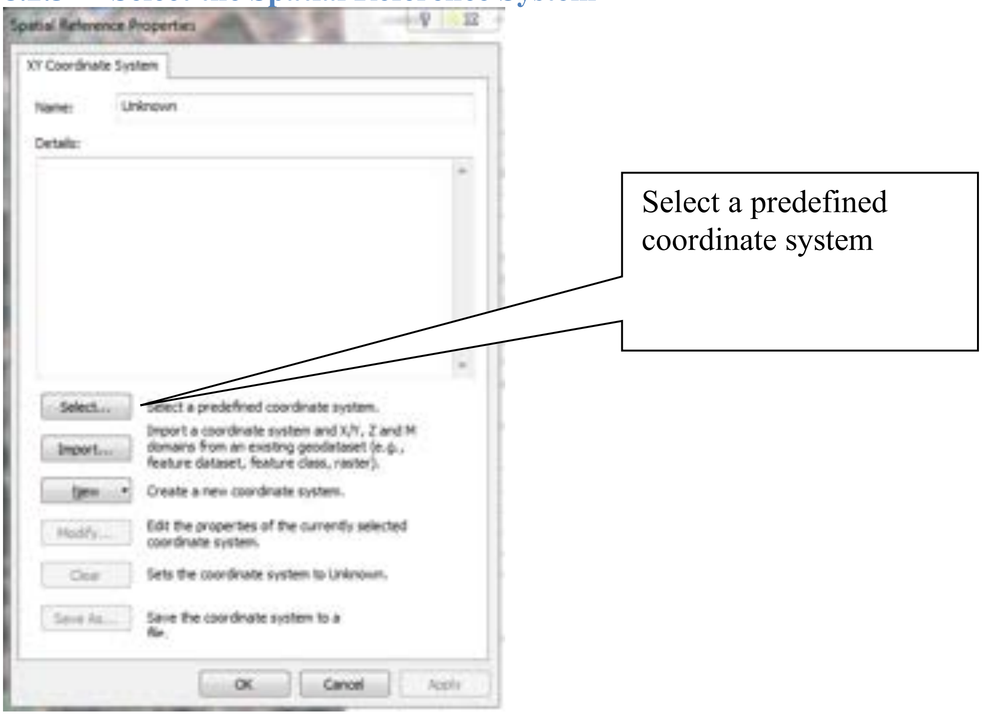


The window Create New Shapefile will open.

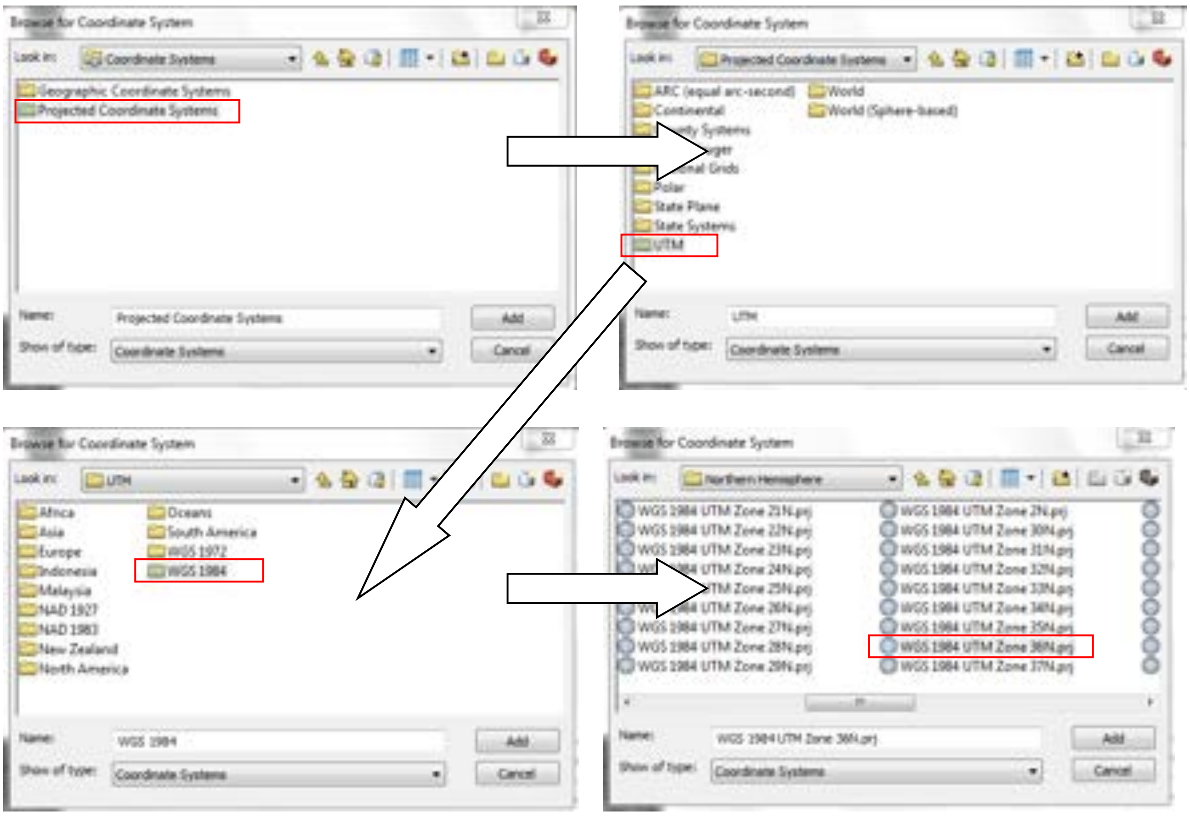


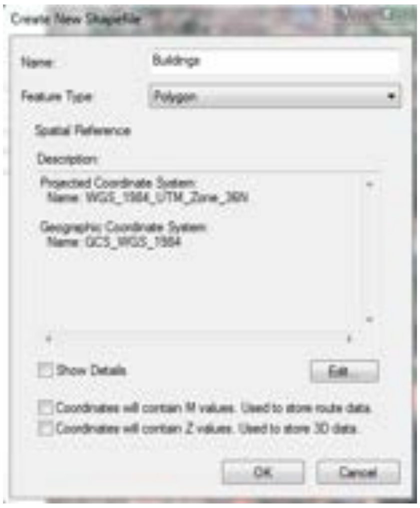
Window Create New Shapefile

8.2.3 Select the Spatial Reference System



The following sequence of windows will bring you to the used coordinate system:
WGS84 UTM Zone 36N.prj



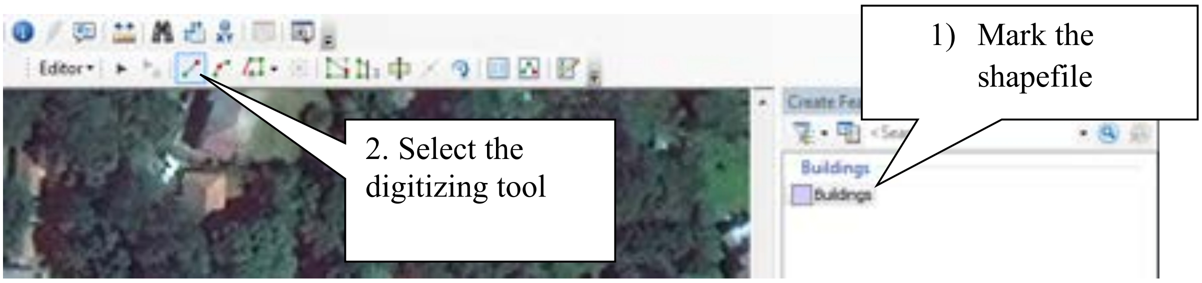


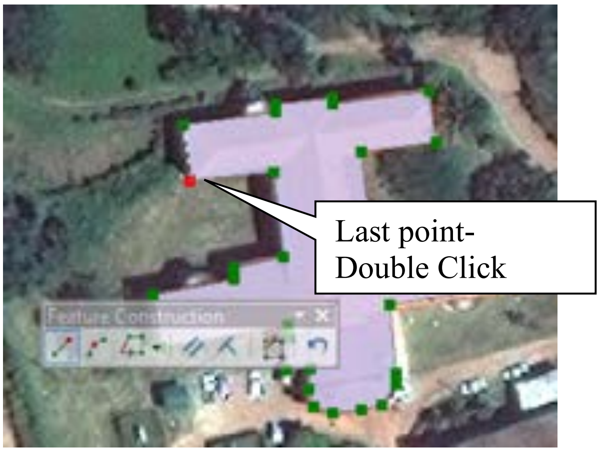
New created vector is added to the Table Of Contents

8.2.4 Start digitalization

Start editing

When you click on Start Editing the window Create Feature will open.

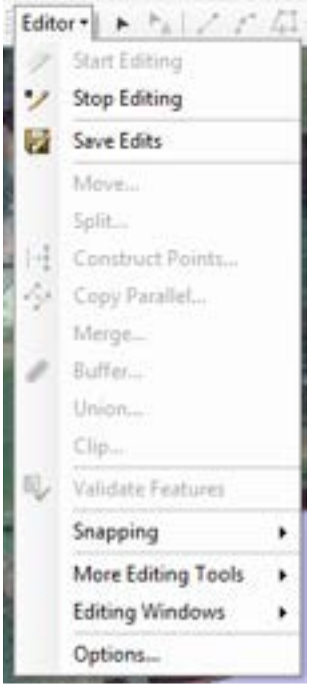




Double click at the end to finish digitalization.

Figure 1: Result

8.2.5 Save and Stop Editing



You can save your digitalization during Editing.
After finishing you save and click on Stop Editing. The window **Create Feature** will be closed.

9.0 Terrain analysis for hydrological and hydraulic modelling

9.1 Introduction

9.1.1 What is a terrain?

A multi-resolution layer providing access to elevation values for use in analysis with functions for slope, aspect, and hillshade.

9.1.2 Description

This dynamic image service provides numeric values representing ground surface heights, based on a digital terrain model (DTM). The ground heights are based on multiple sources. Heights are orthometric (sea level = 0), and water bodies that are above sea level have approximated nominal water heights.

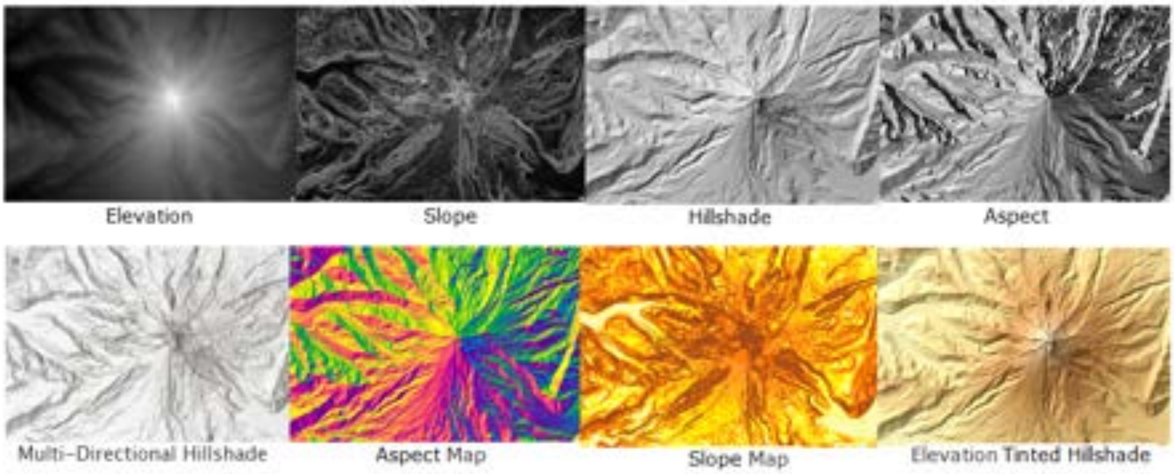
9.1.3 What can you do with this layer?

1. Use for Visualization: This layer is generally not optimal for direct visualization. By default, 32 bit floating point values are returned, resulting in higher bandwidth requirements. Therefore, usage should be limited to applications requiring elevation data values. Alternatively, client applications can select from numerous additional functions, applied on the server, that return rendered data. For visualizations such as multi-directional hillshade, hillshade, elevation tinted hillshade, and slope, consider using the appropriate server-side function defined on this service.
2. Use for Analysis: Yes. This layer provides data as floating point elevation values suitable for use in analysis.

This layer has server functions defined for the following elevation derivatives:

1. Slope Degrees
2. Slope Percentage
3. Aspect
4. Ellipsoidal height
5. Hillshade
6. Multi-Directional Hillshade
7. Pre-symbolized Elevation Tinted Hillshade
8. Pre-symbolized Slope Degrees

9. Pre-symbolized Aspect



9.1.4 Data Sources

The data for this layer comes from the multiple sources listed below, with original source data in its native coordinate system.

Source Data	Source Native Pixel Size	Approximate Pixel Size (m)	Primary Sources
England 2m	2 meters	2	Environment Agency
Wales 2m	2 meters	2	Natural Resources Wales
Netherlands 3m	3 meters	3	Rijkswaterstaat
Austria 10m	10 meters	10	Geoland
Denmark 3m	3.2 meters	3	Geodatastyrelsen
Denmark 10m	10 meters	10	Geodatastyrelsen
Finland 3m	3 meters	3	NLS
Finland 10m	10 meters	10	NLS
Spain 5m	5 meters	5	IGN
Spain 10m	10 meters	10	IGN
Norway 10m	10 meters	10	NMA
OS Terrain 50	50 meters	50	Ordnance Survey
FEMA LiDAR DTM	3 meters	3	FEMA
NED 1/9 arc second	0.000030864197530866 degrees	3	USGS
NED 1/3 arc second	0.00009259259259259 degrees	10	USGS
NED 1 arc second	0.000277777777777779 degrees	31	USGS
NED 2 arc second	0.000555555555555556 degrees	62	USGS
SRTM 1 arc second	0.000277777777777779 degrees	31	NASA
SRTM 1 arc second DEM-S	0.000277777777777779 degrees	31	Geoscience Australia
SRTM v4.1	0.000833333333333333 degrees	93	CGIAR-CSI
EarthEnv-DEM90	0.000833333333333333 degrees	93	N Robinson,NCEAS

9.1.5 Accuracy

The accuracy of these services will vary as a function of location and data source.

9.2 Introduction to Shuttle Radar Topography Mission Elevation data

9.2.1 Description

The SRTM data (30m) shall be used for this exercise.

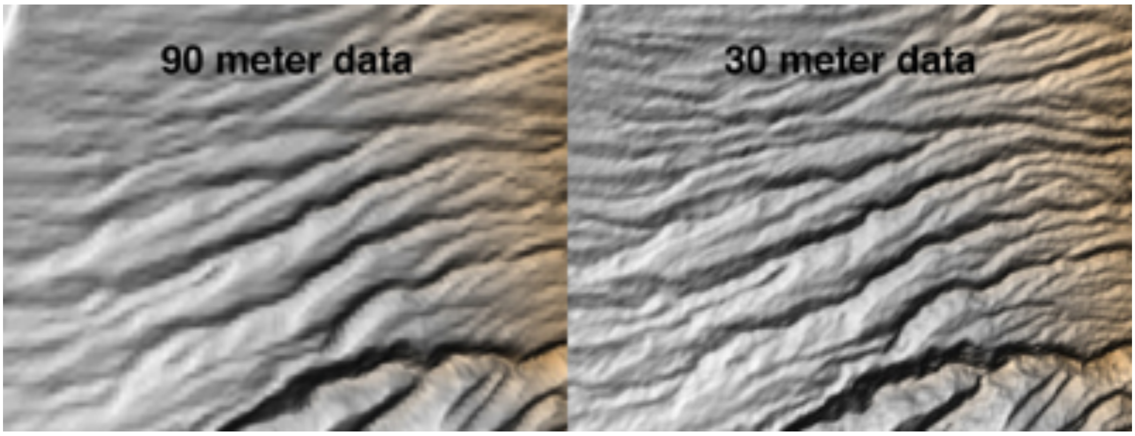
The Digital Elevation Data (DEM) contains one elevation value (as measured above Mean Sea Level) in each pixel, or cell, of data.

9.2.2 Release of data

On September 23, 2014, the White House announced that the highest-resolution topographic data generated from NASA's Shuttle Radar Topography Mission (SRTM) in 2000 was to be released globally by late 2015. The announcement was made at the United Nations Heads of State Climate Summit in New York. Since then the schedule was accelerated, and all global SRTM data have been released.

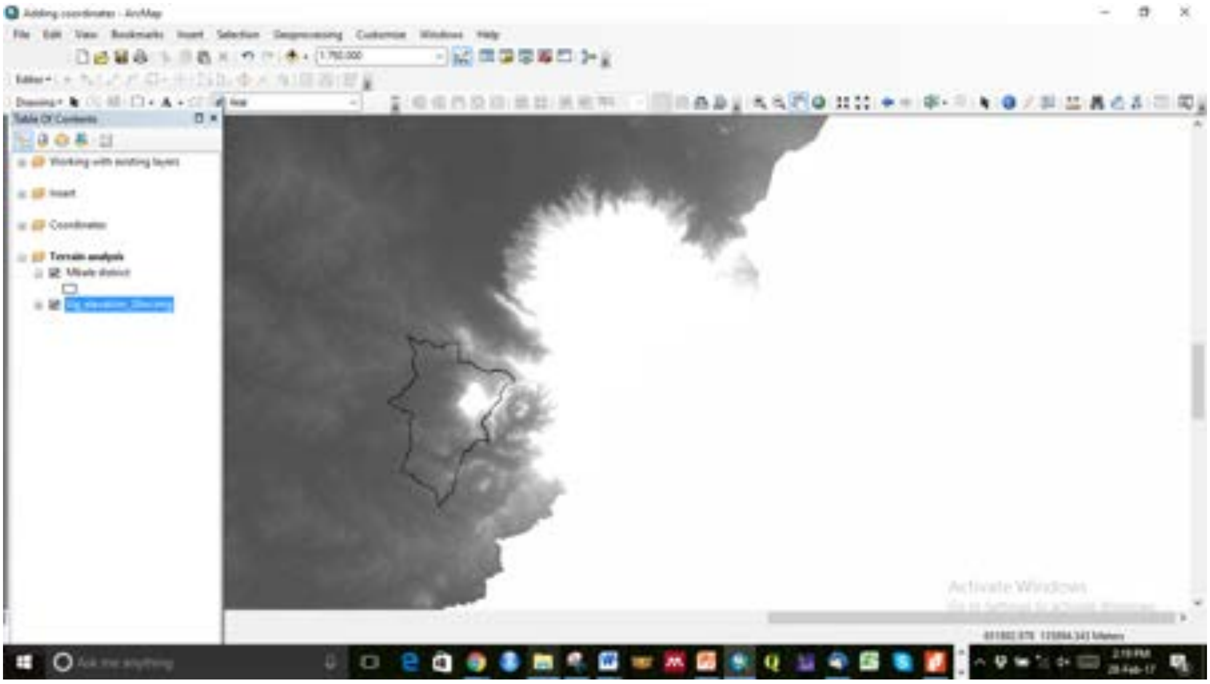
> NASA has released a void-filled version of the Shuttle Radar Topography Mission digital elevation model, known as "SRTM Plus" or SRTM NASA Version 3. SRTM Plus uses SRTM Version 2 where the radar interferometric method was successful (not void). Most voids are filled with elevation data from the ASTER GDEM2 (Global Digital Elevation Model Version 2). ASTER is a sensor on NASA's Terra satellite that uses stereoscopic imaging to measure elevations via optical parallax where not obscured by clouds. Additional void filling of small areas used the GMTED2010 elevation model compiled by the US Geological Survey. SRTM Plus was produced under NASA's "Making Earth System Data Records for Use in Research Environments" (MEaSUREs) Program.

The image at left has data samples spaced every 90 meters (295 feet); the image at right has samples spaced every 30 meters (98 feet).

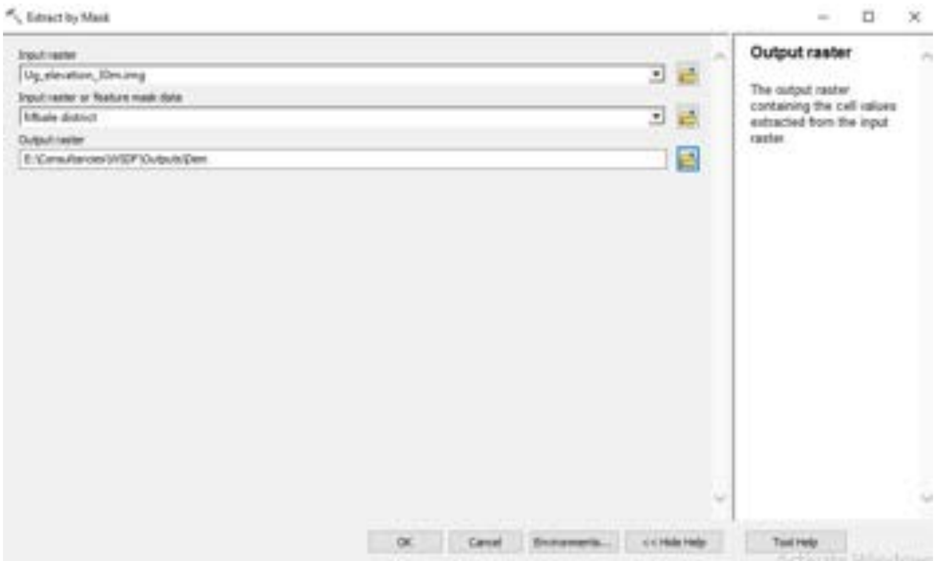


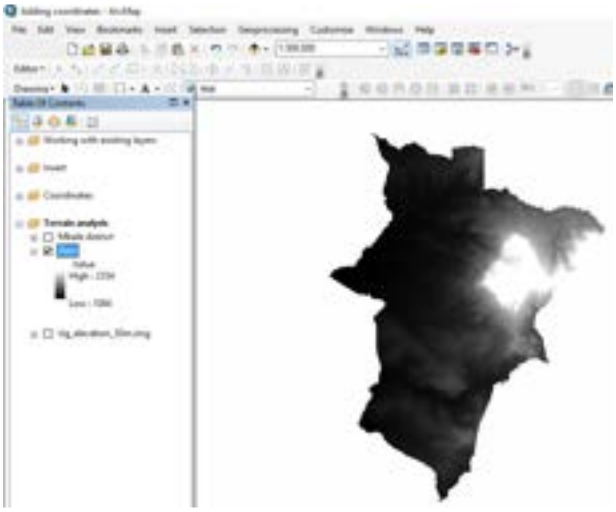
9.3 Procedures

1. Launch ArcMap software and load the following datasets
   a. Digital Elevation Model (from the 'terrain analysis' folder)
   b. Mbale District administrative boundary



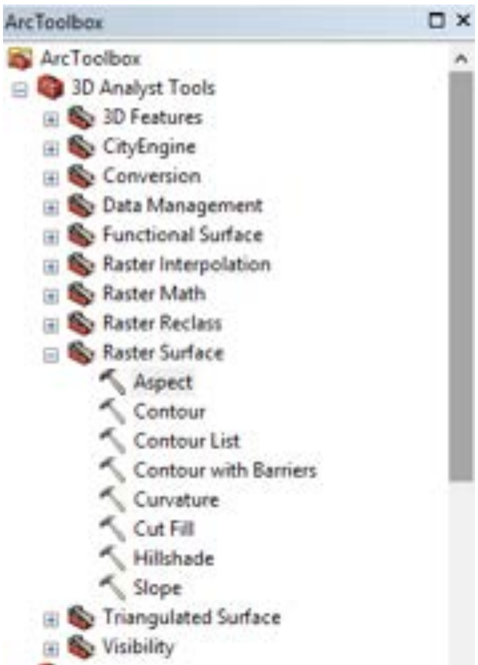
2. Extract the Mbale boundary from the broader elevation data for easier manipulation and rendering
   a. Load the arcTOOL box
   b. Spatial analyst tools - Extraction – Extract by Mask
   c. Input raster – Ug_elevation; while
   d. Feature mask data – Mbale district and click OK



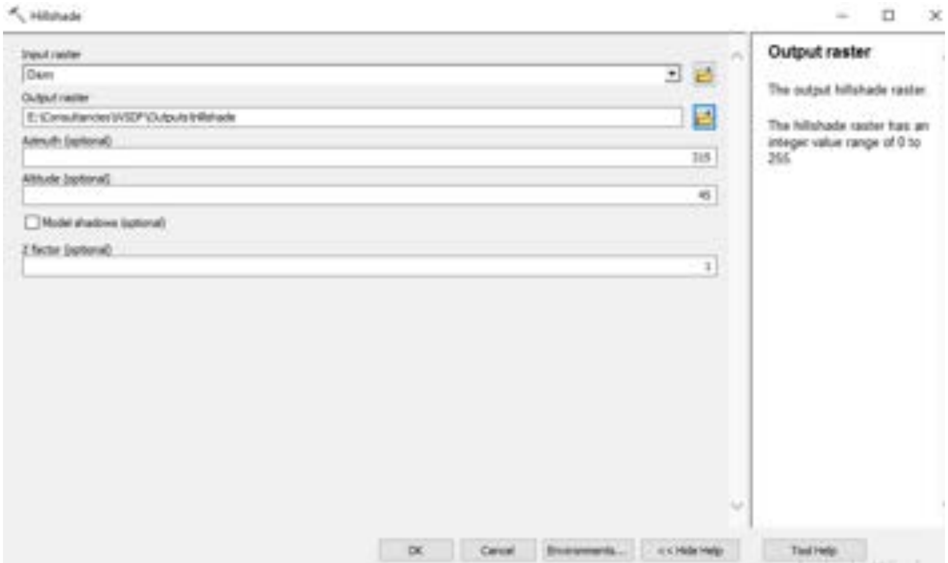


3. To extract elevation derivatives such as slope, hillshade follow the steps outline below
   a. Arctoobox – 3D analyst tools – Raster surface – aspect, contours, hillshade, slope
   b. Hillshade

   The hillshade tool creates a shaded relief layer from a surface raster by considering the illumination source angle and shadows. The resulting hillshade raster creates a pseudo 3D display of topography



   c. For this exercise, I will create the hillshade and you will be required to proceed with the subsequent layers (slope, aspect, contours etc)



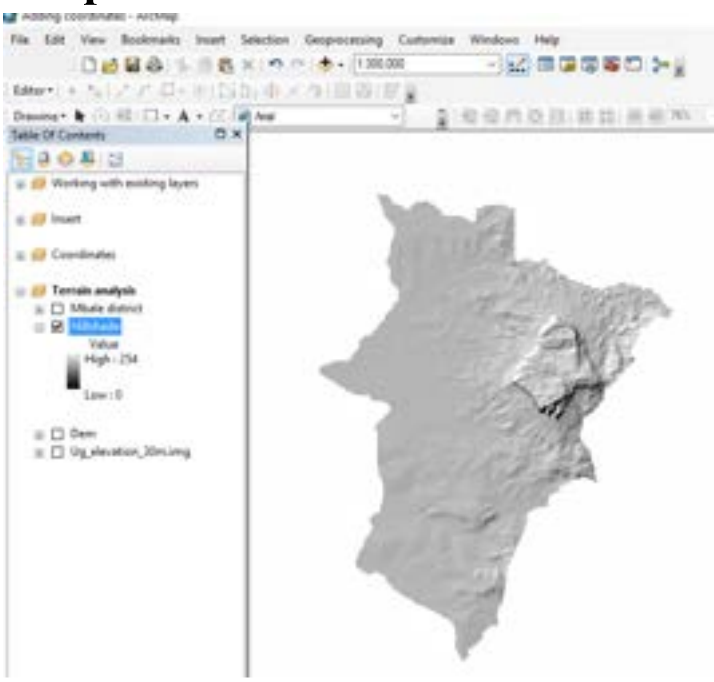
d. Accept defaults for Azimuth and Altitude

e. Note: You can try checking on Model Shadows, it can be helpful in visualization, but in some cases it may make little difference.

f. Z factor (optional): For DEMs with vertical (Z) units in meters, enter 1, or else leave as default 6. Click OK to run.

g. The output raster is added to your map as a new layer

Output = Hillshade for Mbale District



4. Proceed with the creation of slope, aspect, contour datasets

9.4 Home work

Undertake 3D Analysis/Visualization using ArcScene using the Mbale DEM

Pseudo-3D visualization is achieved in GIS by rendering surfaces in a perspective view, animating these displays, and draping other geographic features or images.

9.5 Watershed modelling using ArcSWAT and HECRAS

Bibliography

Bolstad, P. (2016). GIS fundamentals: A first text on geographic information systems. Eider (PressMinnesota).

Garbrecht, J., Ogden, F. L., DeBarry, P. A., & Maidment, D. R. (2001). GIS and distributed watershed models. I: Data coverages and sources. *Journal of Hydrologic Engineering*, *6*(6), 506-514.

Konadu, D. D., & Fosu, C. (2009). Digital elevation models and GIS for watershed modelling and flood prediction–a case study of Accra Ghana. In *Appropriate technologies for environmental protection in the developing world* (pp. 325-332). Springer, Dordrecht.

Lloyd, C. (2010). *Spatial data analysis: an introduction for GIS users*. Oxford university press.

Ridwansyah, I., Pawitan, H., Sinukaban, N., & Hidayat, Y. (2014). Watershed Modeling with ArcSWAT and SUFI2 In Cisadane Catchment Area: Calibration and Validation of River Flow Prediction. *International Journal of Science and Engineering*, *6*(2), 92-101.

Strager, M. P., Fletcher, J. J., Strager, J. M., Yuill, C. B., Eli, R. N., Petty, J. T., & Lamont, S. J. (2010). Watershed analysis with GIS: The watershed characterization and modeling system software application. *Computers & Geosciences*, *36*(7), 970-976.