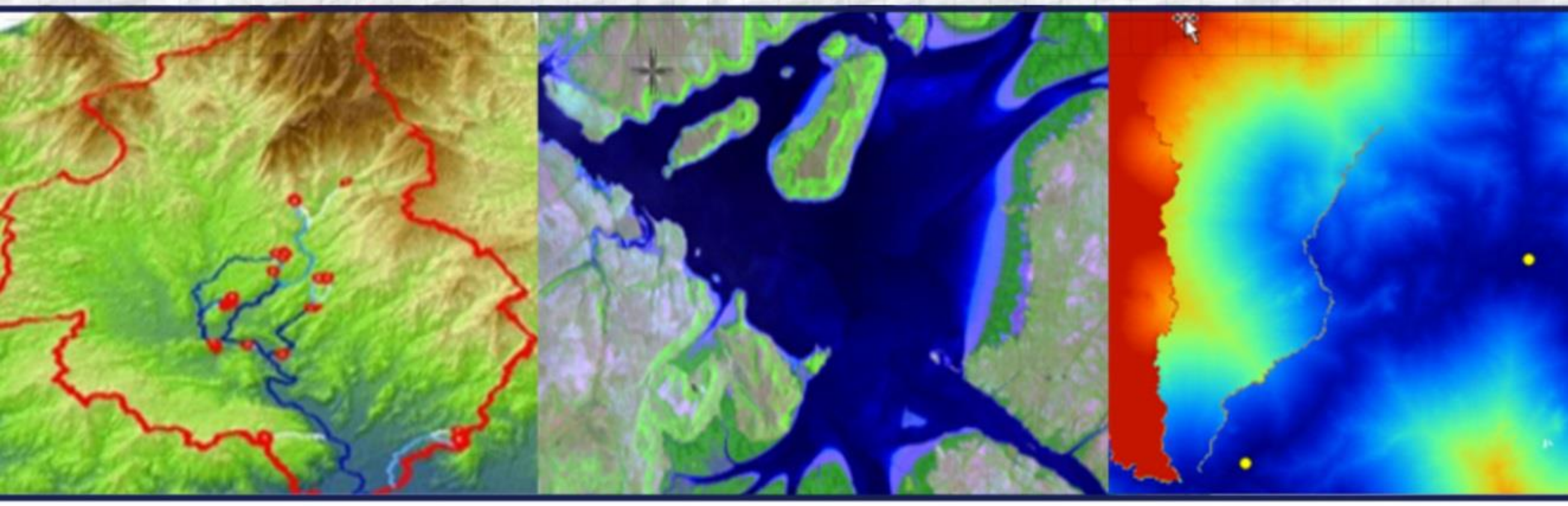
Satellite Image Analysis and Terrain Modelling

A practical manual for natural resource management, disaster risk and development planning using free geospatial data and software.

SAGA GIS 4+



Australian Aid

CHARLES DARWIN UNIVERSITY

Pemerintah Provinsi NTT, Badan Lingkungan Hidup Daerah

Satellite Image Analysis and Terrain Modelling

A practical manual for natural resource management, disaster risk and development planning using free geospatial data and software.

Version 2
SAGA GIS 4

June 2017

Pemerintah Provinsi NTT, Badan Lingkungan Hidup Daerah

Website: sagatutorials.wordpress.com

This manual has been developed as a collaboration between three universities in Eastern Indonesia and Australia; Charles Darwin University (Darwin), UNDANA University (Kupang – West Timor) and Haluoleo University (Kendari – South East Sulawesi) with support from the Australian Government's (DFAT) Partnerships for Development project: Artisanal and small-scale mining for development in Eastern Indonesia.

First Printing: June 2017

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Facebook Group - Remote Sensing & GIS with SAGA
https://www.facebook.com/groups/208599582556485/

Website (Bahasa Indonesia): https://sagagisindonesia.wordpress.com/

Website (English): http://sagatutorials.wordpress.com/

Forward

Throughout the ages, humans have sought ways to understand and depict our environment. As in many areas of human endeavour, new technologies give us much more powerful ways of interrogating the natural world, of interpreting what we find, and presenting that information. Importantly, in the digital era such technologies are becoming ever more affordable and ubiquitous, potentially accessible to many more people in many more countries.

However the vast majority of environmental management decisions are not made by scientists, but by local people — local government, NGO's and universities working with farmers and householders seeking to feed their families and to earn a livelihood. Our challenge is to find ways of combining scientific understanding with fine-grained local knowledge and experience to develop better and more sustainable ways of managing natural resources and improving human livelihoods.

The use of satellite and digital elevation data for mapping, monitoring and modelling has become an important tool assisting effective and timely natural resource management. But we need local knowledge to help us to interpret mapped landscapes and observed changes so that these data become more useful for management and policy. This training manual is a great example of a tool that will assist in bringing together local knowledge and experience, with very sophisticated remote sensing and landscape modelling technologies. The application of satellite data, once an expensive and specialist skill, has become cheap and accessible due to falling hardware costs and the availability of high-quality free satellite data and software.

This manual was produced as part of ongoing collaboration between Charles Darwin University (Darwin, Australia), Nusa Cendana University (Kupang, West Timor), Halu Oleao University (Kendari, South East Sulawesi) with funding support from the Australian government (DFAT) through their government partnerships for the development program. This training output provides a platform for long-term and sustained capacity building throughout the region.

Professor Simon Maddocks
Vice-Chancellor

Charles Darwin University

1. Introduction

Geospatial applications for land resource mapping, monitoring and modelling provide key data underpinning natural resource management planning (NRM). The current generation of free and open source (FOS) geospatial software and free data has removed the need for licencing and data purchase, which has been a significant barrier to broader involvement in land resource mapping, monitoring and modelling for local governments. The increasing availability of free satellite imagery, elevation data and raster-based spatial analysis software is providing new opportunities for local stakeholders to combine the quantitative analysis of 'hard' data with qualitative local knowledge. (Fisher et al, 2017)

Whilst open source geospatial software is free, it is in no way inferior to commercial GIS applications. On the contrary, free and open source (FOS) software is commonly considered to be more secure, reliable, and adaptable to their commercial counterparts (Fisher et al, 2017). This is particularly true with geospatial software where a suite of robust and highly functional applications are available that often outperform commercial options. SAGA GIS, the focus of this manual, is constantly updated by developers and the user community, keeping it relevant with cutting edge geospatial research. Currently, SAGA offers more than 700 geo-scientific modules responding to scientific questions and needs (Conrad et al, 2015). In addition, the flexibility and responsiveness allow FOS geospatial software to quickly and seamlessly incorporate tailor-made functionality to facilitate specific processes or to address particular NRM issues.

Whilst there are a number of sophisticated free open source raster analysis packages available, including GRASS, White Box and ILWIS, SAGA GIS was chosen as the focus of training as it:

1) provides the easiest one-step process for Landsat data visualisation.
2) has a simple, one-step, process for sophisticated hydrological and terrain modelling
3) is a compact package that does not require installation and is thus easy to share
4) has an easy to comprehend interface similar to other GIS packages
5) works seamlessly with all standard GIS data formats; and
6) has an active development team responsive to user suggestions for processing tools and bug fixes

However, one general criticism of open source software, which is also valid for SAGA, is a lack of clear and comprehensive training material. This manual aims to help fill this gap and provide a training resource to support the decentralised application of sophisticated geospatial analyses using satellite and elevation data to improve natural resource governance.

This manual has been developed in tandem with the following English and Indonesian language websites that provide further tutorials and links to all the datasets used in the examples shown:

- **sagatutorials.wordpress.com**
- **sagagisindonesia.wordpress.com**

These sites also include a number of screen-shot videos that show you step-by-step how to follow many of the procedures presented. We also encourage people working with SAGA to share their work at our user Facebook page: www.facebook.com/groups/208599582556485/

This training manual has been developed with support from the Australian government via funding provided through their *Artisanal and Small-scale Mining for Development* project being implemented by Charles Darwin University. This project has been run and the material for this manual developed in collaboration between three universities in Eastern Indonesia and Australia 1) Charles Darwin University (Darwin), 2) UNDANA University (Kupang) and 3) Haluoleo University (Kendari – South East Sulawesi).

References

Fisher, R., Hobgen, S. et al. (2017, in press). Free satellite imagery and digital elevation model analyses enabling natural resource management in the developing world: case studies from Eastern Indonesia *Singapore Journal of Tropical Geography*.

Conrad, O. et al., (2015). System for Automated Geoscientific Analyses (SAGA) v. 2.1.4. *Geoscientific Model Development*, 8, pp.1991–2007.

1.1 What will you learn

The aim of this manual is to provide a basic overview of functions within SAGA GIS that enable applications in two key areas important for evidence-based natural resource management. They are (1) satellite-based mapping and monitoring, and (2) terrain analysis and hydrological modelling. The manual is divided up into the following sections:

Quick start: This section is designed to enable you to jump into SAGA so you can become familiar with its layout and functionality. You will learn here how to import satellite imagery, elevation and other forms of GIS data. You will also visualise landscapes in 3D and 'fly' through satellite imagery.

GIS Concepts: This section describes fundamental concepts and terminology used when referring to map data. For example, what is GIS, what is spatial data, what types of spatial data there are. You will also learn about how data is displayed in a GIS, how satellites collect earth images and elevation data, and how you can access them free on-line

Terrain Analysis: This section will introduce basic concepts in terrain analysis and how to prepare elevation data for hydrological analysis. SAGA enables the creation of multiple terrain layers which can be used for a broad range of ecological modelling, disaster risk, catchment function and agricultural applications. You will be surprised how easy it is and how much useful landscape information you can produce using SAGA and one data layer – Elevation.

Working with Landsat/Sentinel 2 Data: The Landsat satellite provides an incredibly powerful archive of earth imagery for the whole globe going back many decades. Landsat is the primary tool for scientists, governments and NGO's monitoring the earth's natural resources because it provides regular high-quality imagery that's easy to access, and it's free! Sentinel 2 is a new satellite launched by the European space agency, similar to Landsat, but providing higher resolution imagery. Using these data you will learn how to quickly and easily import and map land cover and land cover change using sophisticated remote sensing techniques.

Applications: This section will present a number of example applications building on what you have learned in the preceding sections. The section will cover these three broad application areas:

1. Fire mapping
2. Forest cover change
3. Off-site mine impacts with sediment flow path tracing.

Advanced concepts: This section will explore some more advanced ideas in satellite image analysis and also present some additional techniques for getting the most out of SAGA. This section also explores the use of SAGA for Travel time analysis**.** Modelling travel time to services has become a common public tool for planning infrastructure for improving service provision. The aim of the tools described in this section is to provide simple, open source, adaptable, interactive travel time modelling tools to allow greater access to, and participation in, service access analysis.

Using the manual

It is suggested that you start at the *Quick Start* section to get an idea of the layout and functionality of SAGA. Whilst working with satellite data in this section it may be useful to flip through sections 3 and 4 which provide background on spatial data and satellite imagery.

At the start of each section where a practical exercise is used there will be a description of the data used, which can be downloaded from the accompanying website or DVD. Links will also be provided where there are associated web-based video tutorials. This manual only covers a small fraction of the potential uses and functions of SAGA and is only meant to be an introduction to promote your own exploration. In some cases there will be additional tutorial material on the website not included in the manual.

Data access: All the data used in the tutorial examples shown in this manual are available for download here: sagatutorials.wordpress.com/downloads/

Web support:

- **Additional online training material: sagatutorials.wordpress.com**
- **SAGA GIS website and user forums: www.saga-gis.org**

Youtube video channel providing a range of SAGA GIS screen shot tutorials related to this manual.

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1.2 What is SAGA?

SAGA stands for **S**ystem for **A**utomated **G**eoscientific **A**nalyses. SAGA GIS has been developed by a small group of developers primarily based in Germany. Most past and current SAGA developments come from the team of J. Böhner and O. Conrad, both of whom now work at the Institute of Geography, Section for Physical Geography, Klima campus and University of Hamburg, Germany. This team has accompanied the SAGA development from its very early beginnings.

The idea for the development of SAGA evolved in the late 1990s during work on several research projects at the Dept. for Physical Geography, Göttingen. A research focus was the analysis of raster data, particularly of Digital Elevation Models (DEM), which have been used, to predict soil properties, terrain controlled process dynamics, as well as climate parametres. This required the development and implementation of many new methods for spatial analysis and modelling.

SAGA has now evolved into a mature robust geospatial analysis package used by scientists and natural resource managers around the world.

Which version of SAGA?

One of the main advantages of open-source software is that they are regularly updated. This results in bugs being found and fixed quickly and new ideas and processing options being incorporated regularly. This makes the software generally more robust and up-to-date than commercial packages. However, with every new release and update there are changes, some minor and some quite significant, making keeping up with the latest version difficult at times. In SAGA's case, there is a new release every three to six months depending on how much work the developers have done. This means that training material developed five years ago could be up to ten SAGA versions out-of-date. So there is always a balance between keeping up with the latest release and using what you know. For this training manual, we are using the latest release at the time of writing which was **SAGA 4.0.** Of course, we know that things will change over time but the fundamental processes and ideas will stay the same.

SAGA support

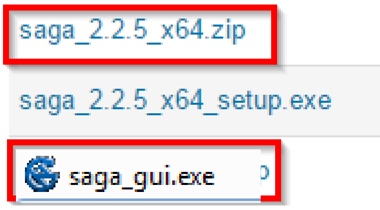
Remember that SAGA is created by users to be supported users, so it is up to us to proactively support communication between SAGA users and developers. We need to work together to develop SAGA and the SAGA user community and importantly, where possible, contribute to the development of training material.
The SAGA developers are a very small team of volunteers but they are amazingly responsive to user questions and suggestions. We recommend joining the SAGA GIS user forum where you can post suggestions and questions (https://sourceforge.net/p/saga-gis/discussion/).

Some other sources of SAGA training references include:

- http://marinedataliteracy.org/margis.htm
- https://rohanfisher.wordpress.com/saga-gis-tutorials/
- https://iradafmandaya.wordpress.com/
- https://sourceforge.net/p/saga-gis/wiki/Tutorials/

1.3 SAGA Download and Installation.

if you do not have the DVD accompanying this training manual you will first need to download SAGA from: **https://sourceforge.net/projects/saga-gis/files/**.



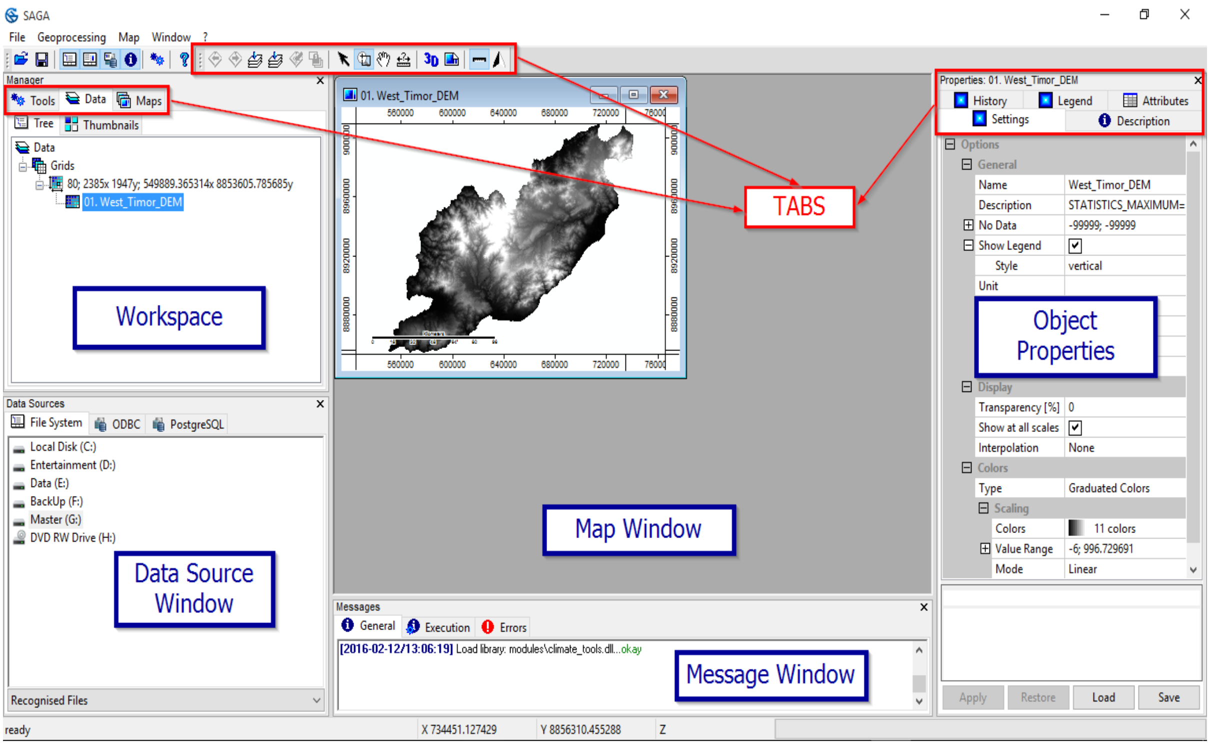
It is recommended you download the latest version in a zipped format appropriate for your computer (ie 32 bit or 64 bit). It is then simple a matter of on unzipping this file and finding the SAGA GIS executable file. You can double-click on this file to run it straight from this file. It can also be good to right click on this file and 'send to desktop', so you have a short-cut there you can easily access anytime.

2. Quick Start

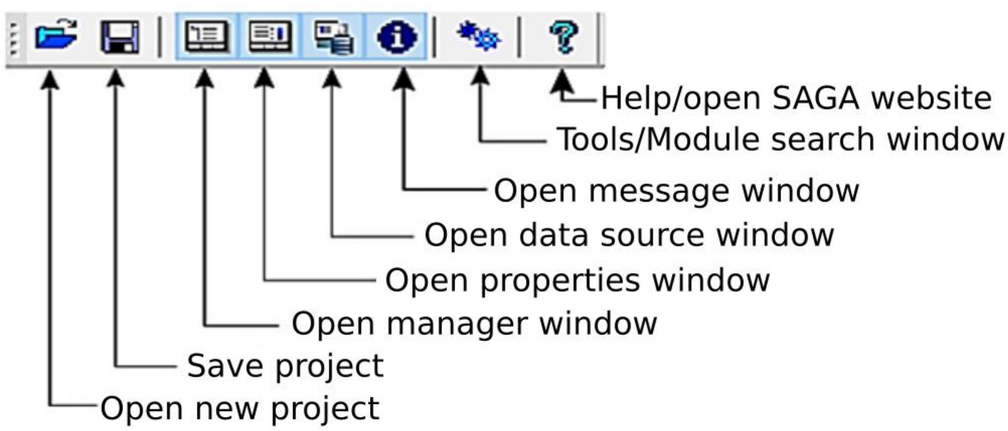
2.1 SAGA Layout

When you open SAGA you will see a layout consisting of the following windows:

- **Workspace**: is the window where you can, by click through the tabs at the bottom of the window, view processing **modules**, the data you have loaded, and the display maps you have created from your data.
- **Work area**: is where image maps and other associated data (Attribute Tables, Histograms, Plots) are displayed.
- **Object Properties**: this window displays and allows you to alter information about your loaded data and map displays.
- **Message Window**: provides information about processes being run by SAGA



Each of the windows can be opened and closed in with the top menu bar icons:



Workspace Tabs

Tools Tab

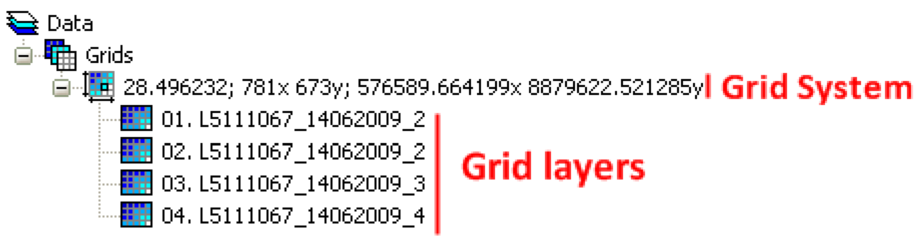
Tools are the SAGA processing functions. SAGA comes with a comprehensive and growing set of free tools (over 700 in version 2.3). Not all modules are highly sophisticated analysis or modelling tools; many modules perform simple data operations, whilst other modules are state-of-the-art in their field of analysis. They include:

- Data Import & Export
- Cartographic Projections & Georeferencing
- Numerous Raster & Vector Data Tools
- Image Processing
- Terrain Analysis
- Geostatistics

Tools can also be easily accessed through the top 'Geoprocessing' drop down menu where they are grouped into logical processing groups and are thus generally easier to access.

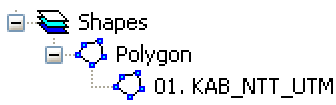
Data Tab

The data tab displays any raster (Grid), vector or tables data you have loaded. All raster data is displayed as **grid layers** within a **grid system**. A **grid system** groups **grid layers** that have the same grid cell size, have the same number of rows and columns and cover the same geographic area. Generally, spatial analysis operations are performed on grids with the same grid system



A wide variety of raster data can be imported into SAGA, however when raster data is saved from SAGA it is saved in a SAGA format (.sgrd). It is possible to change the name of loaded grid systems or grid layers in the object properties window.

When vector data is opened into SAGA it will create a new layer defined as either point, line or polygon data.

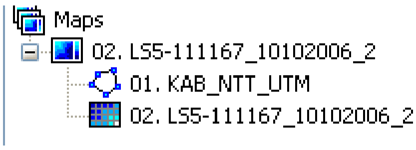


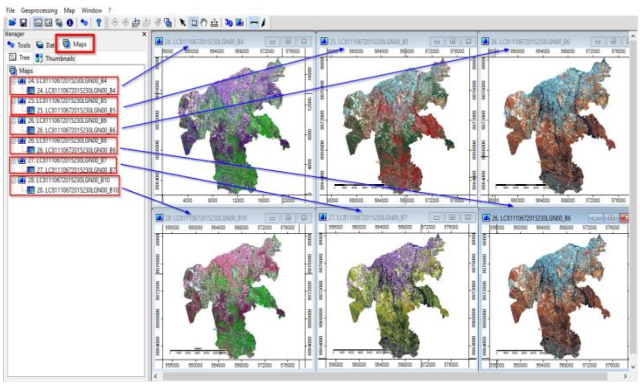
To display loaded data either right-click on a data layer and select ‘show’, or simply double click on that layer; this data is now opened into a window. To view the data layers displayed in a map window click the **Map Tab**.

Map Tab

Multiple data layers from different grid systems can be displayed in a single map layer:

Map layers can be ‘turned off’ by right clicking a map layer and deselecting ‘show layer’ or by simply selecting the layer and pressing ‘enter’. The order in which map layers are displayed can also be changed by right clicking and selecting ‘move up’ or ‘move down’.





Object Properties Tabs

Settings Tab

There are a variety of data layer dependent factors that can be viewed and edited as ‘parametres’ in the ‘Settings’ area. The ‘Settings’ tab area provides users with the opportunity to make adjustments to how a data layer appears in the data and map view windows.

Description Tab

This tab shows information (size, geographic projection) about the selected layer. This data cannot be edited.

Legend Tab

Displays the legend or shows what colours are being used to display which data values from the selected layer.

History Tab

This window displays the processing history for the selected layer.

Attributes Tab

This tab is used with the ‘Action’ ( )tool for displaying the attribute information for a selected grid cell on a grid data layer or the attributes associated with a selected vector feature on a shapes data layer.

Work Area Tools

These tools facilitate interaction with a displayed map as described in the following table.

	**Cursor/Action tool – for selecting points or areas**
	**Zoom – zoom in or out of a map display**
	**Pan Tool – move around a displayed map**
	**Measuring tool**
	**Zoom to layer tools**

2.2 Import and view digital elevation data

One advantage of SAGA software is the ease in working with digital elevation model (DEM) data. In this section, we will explore some basic elevation data visualisation techniques using DEM data for West Timor (Indonesia). This DEM has been produced from data derived from the Shuttle Radar Topographic Mission (**See section 4.4**). The DEM provided has been clipped to west Timor (Indonesia).

This section uses elevation data from west Timor: West_Timor_(SRTM_80m)

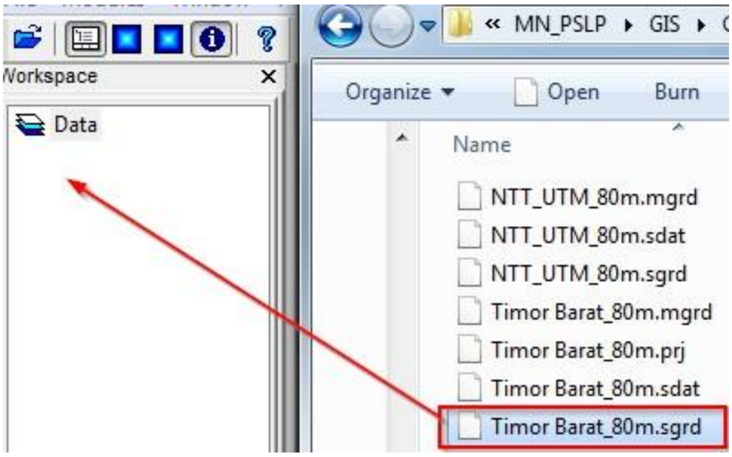
Access tutorial videos here: sagatutorials.wordpress.com/import-and-view-digital-elevation-data/

Loading DEM Data

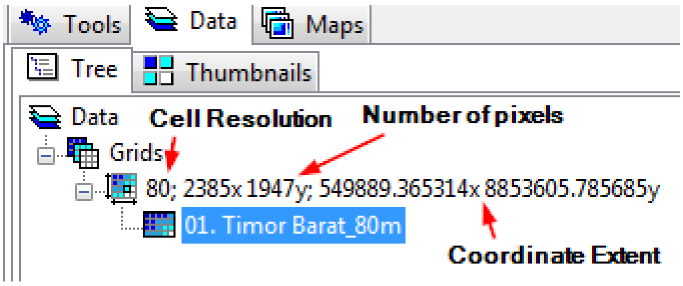
We will start by loading the DEM data.

The easiest way to bring data into SAGA GIS is to simply drag and drop data files from explorer.

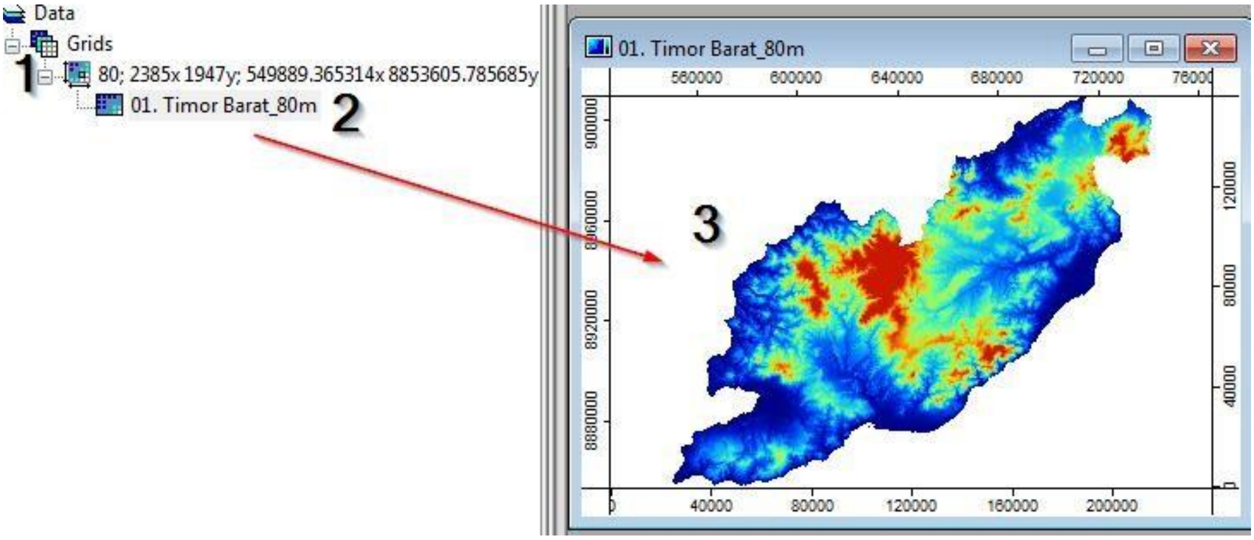
Start by dragging the Timor elevation data into SAGA.



In the data Tab window you will see the imported data. It is displayed under a **Grids** heading which describes the cell size (80m), the number of pixels (2385x1947) at the bottom left coordinate value (549889, 8853605). Below this the imported **Grid** name is then shown.



To display the elevation data double-click the grid (2) and it will appear in the (3) display window.

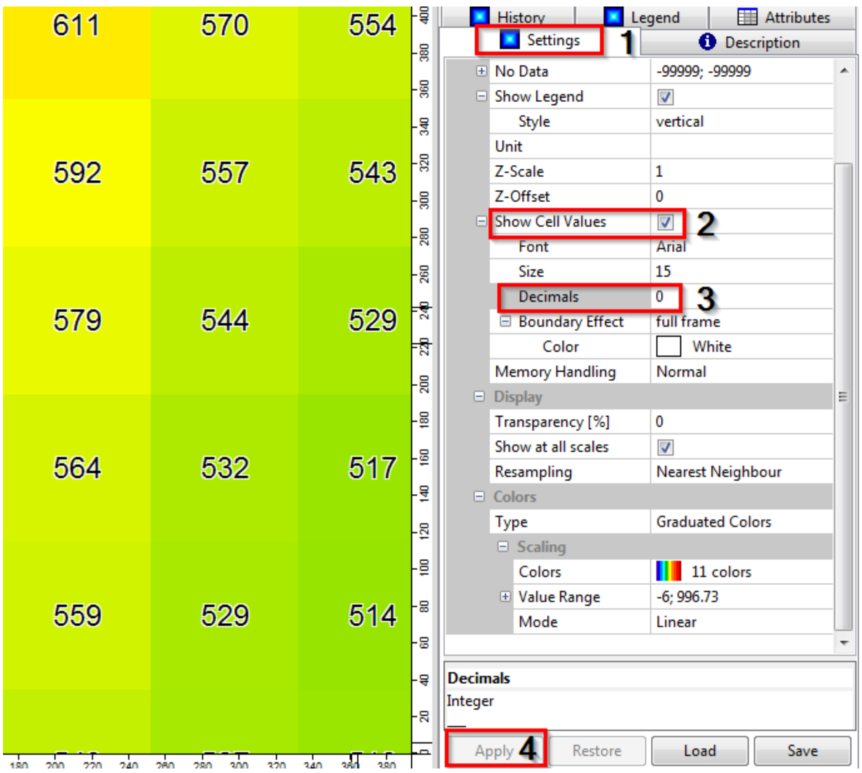


If you scroll over this grid you will see the easting (x), northing (y) and elevation (z) values displayed in the bottom right-hand corner.

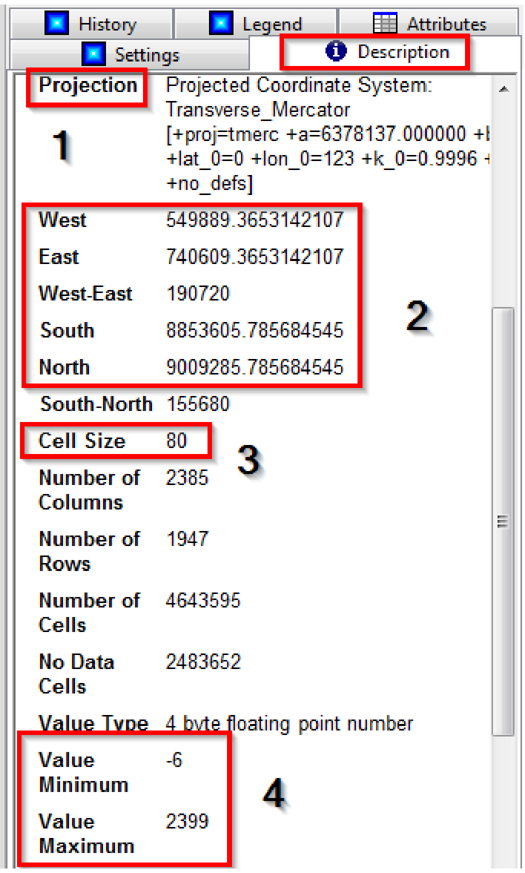
We can view the digital value of each cell by selecting:

1. **Object Properties Settings Tab**
2. check mark in the 'Show Cell Values'
3. Change Decimals value of 2 to 0 (optional)
4. Click 'Apply'.

After that, in the view (zoom) several times until you see the grids (pixels) and a digital value of each pixel that. In the example of West Timor DEM, the value indicates elevation in metres.



To see more details about loaded data, click on the **Description** tab in the **Object Properties** window.



Displayed are:

1. The coordinate system
2. The coordinate extents
3. The Cell size
4. The maximum and minimum data values in the grid.

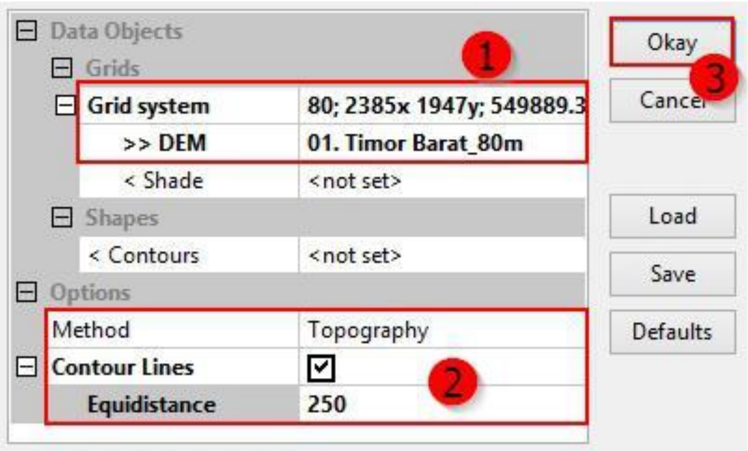
2.3 3D Visualisation

SAGA has a number of tools for creating 3D landscape visualisation using DEM data sets.

The terrain map view tool creates a hill shading layer and drapes it over the DEM data coloured with an elevation colour scheme.

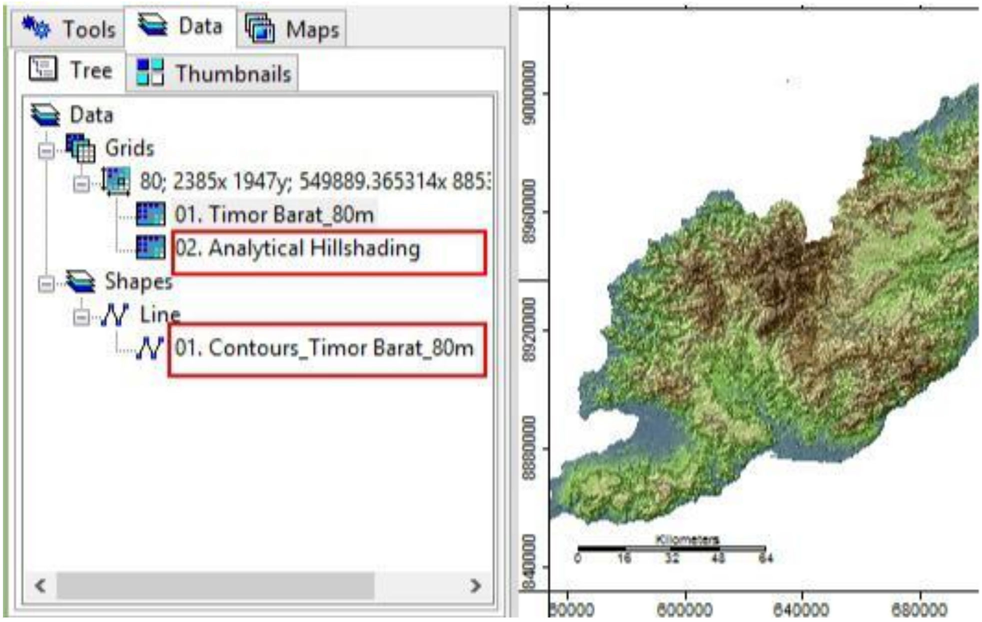
Use: **Geoprocessing > Visualization > Grid >Terrain Map View**

1) Select the DEM grid system and the DEM grid.
2) Make the contour lines 250m
3) Click OK.



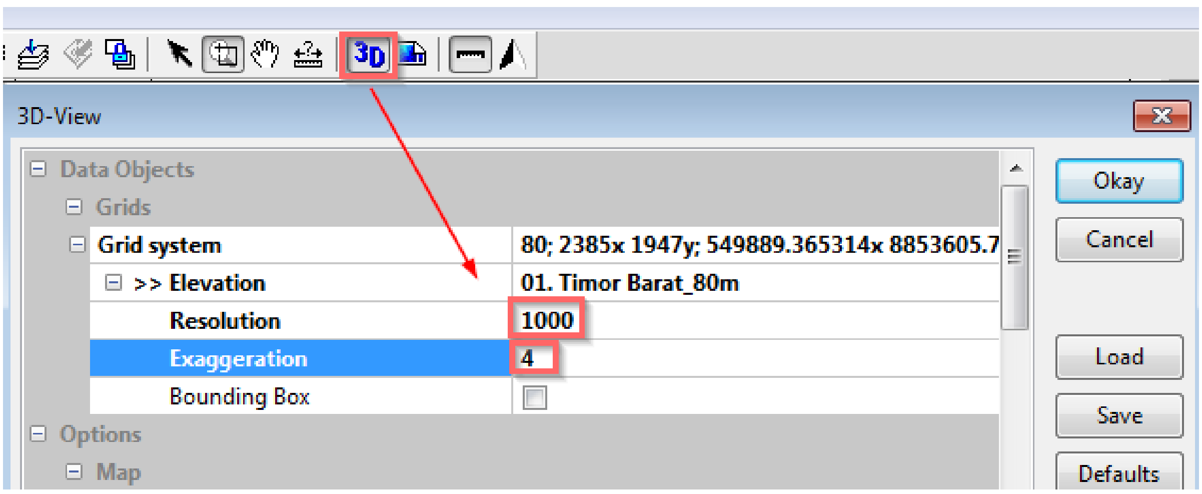
You will see three new data layers appear in the data tab and the terrain view appears in the display window and the map tab.

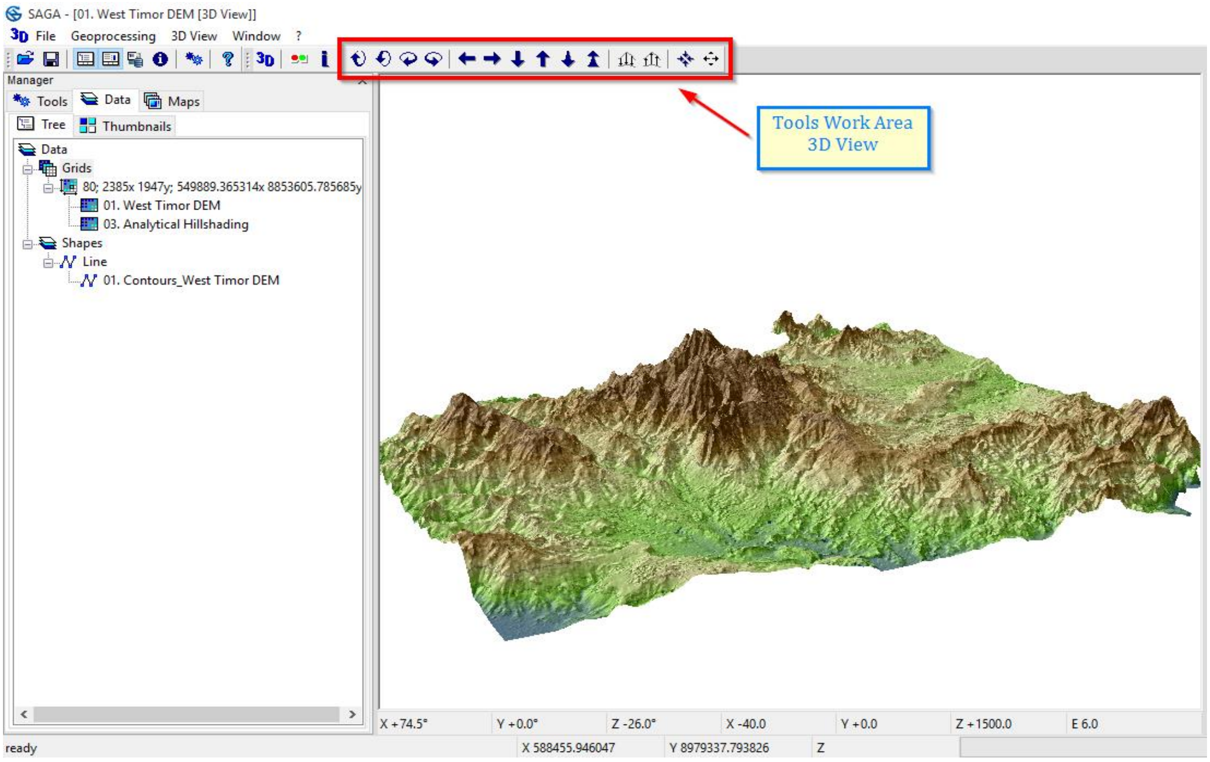
Explore how the map layers are they arranged in the map tab. Look in the settings tab to determine which layer has a transparency setting?



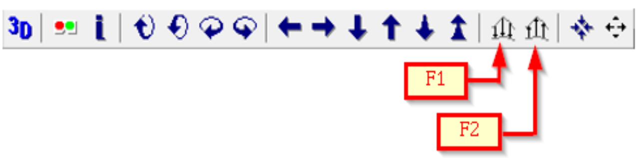
We can view any elevation data in 3D as long as it is not in a latitude/longitude projection (**see section 7.1**). 3D landscape visualisation can be very useful to assist understanding the terrain context of any spatial data you are exploring at.

For 3D display have the data you want to visualise in 3D displayed in your map window then click the 3D button on the top menu bar. Set your elevation data, the display resolution, and exaggeration. Setting a display resolution of 1000 will produce a good quality view without using too much computing resources. The exaggeration setting increases the vertical axis, giving this a value of 4 should produce a good view.





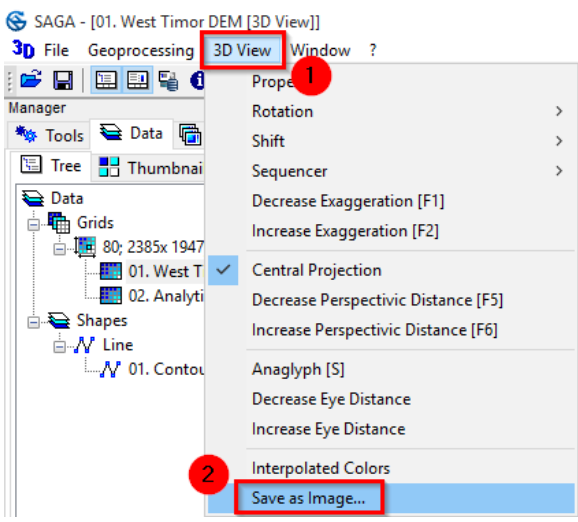
You can change the DEM display exaggeration with the keyboard keys F1 and F2, or on the top menu bar as shown to the right.



Save the 3-D image.

Use: 3D View> Save as Image

Then specify where these files are stored and specify the desired image format (in this example the image is stored in the Portable Network Graphics format *.PNG).



2.4 Import and View Landsat data.

The import function in SAGA-GIS makes working with Landsat data a simple one-step process. There is no other tool, free or commercial, providing an easier way to import and visualise Landsat data.

The SAGA tool combines three separate functions into one easy dialogue box.

- **Reprojecting:** Landsat data is by default in a UTM North coordinate system, which is problematic for southern hemisphere scenes and people who need their data in a geographic (Lat/Long) projection. The Landsat import tool allows you to select the scene's UTM hemisphere or geographic coordinate system
- **RGB composite display:** The import tool allows you to choose a red, green, blue band combination to display directly on import.
- **Contrast enhancing:** On import the band combination of choice will automatically appear in the map display window with a histogram stretch applied to produce a scene that is immediately useable. In addition to this, SAGA provides a way to enhance the image display on-the-fly based on the currently displayed map window, allowing the rapid stretching of image data to show the most detail in your area of interest.

The SAGA-based Landsat import and display method has some advantages over some web-based image viewing services, including:

- **Data integration.** The use of a desktop GIS platform allows the simple incorporation of other spatial data a user may have. For example, *.GPX* and *.shp* files can be simply dragged and dropped into the SAGA display.
- **Band combinations:** The freedom to choose band combinations is important for users to find the best way to view the landscape feature of interest. For example for fire monitoring and mapping burnt areas the use of a thermal band in a display is very helpful. Thus choosing a 4,5,10 band combination for import produces an instant burnt area visualisation.
- **Internet access limitation:** For many people internet connections are slow and unstable. Being able to download once then access, share and explore full resolution imagery is important.
- **Multiple image dates:** Many Landsat users are interested in using the extensive archive to explore land cover change. With the SAGA import option, it is a very simple task to import and display multiple image dates into a single map layer.
- **Building analysis skills:** Having full resolution multiband Landsat imagery in a desktop image processing package facilitates the ongoing learning about remote sensing and GIS analysis. From understanding basic concepts to building capacity in more sophisticated image analysis such as classification, elevation data integration, and modelling.

2.5 Displaying Landsat data in SAGA.

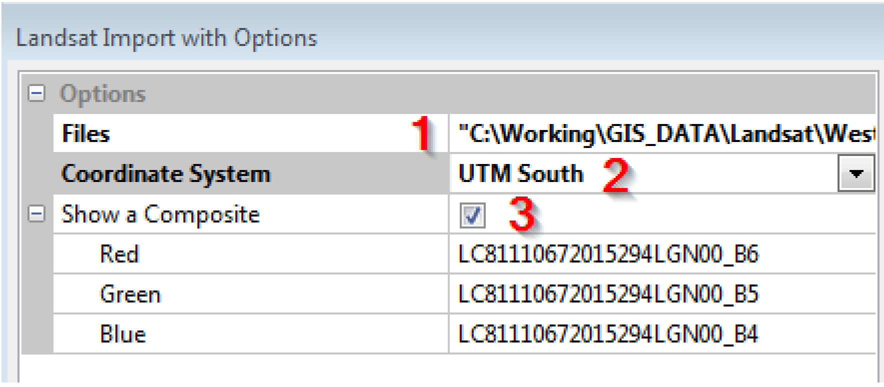
This section uses Landsat data from west Timor: West_Timor_Landsat (200mb)

To automatically import and display Landsat imagery we need to use the **Landsat import with options** tool.

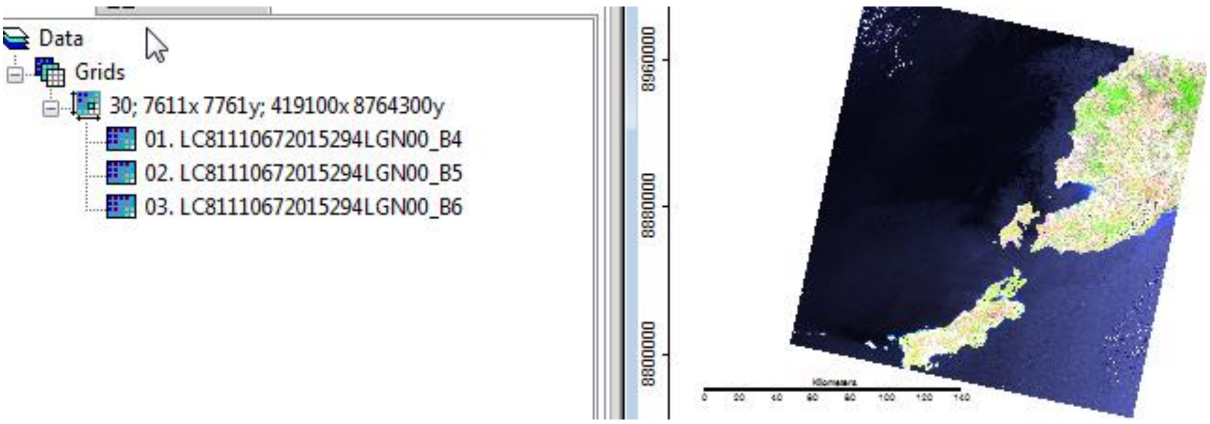
Use: **Geoprocessing>Imagery>Landsat>Landsat Import with Options.**

Tip: Once you have accessed a geoprocessing tool once it will then appear at the bottom of the geoprocessing dropdown menu for quick access.

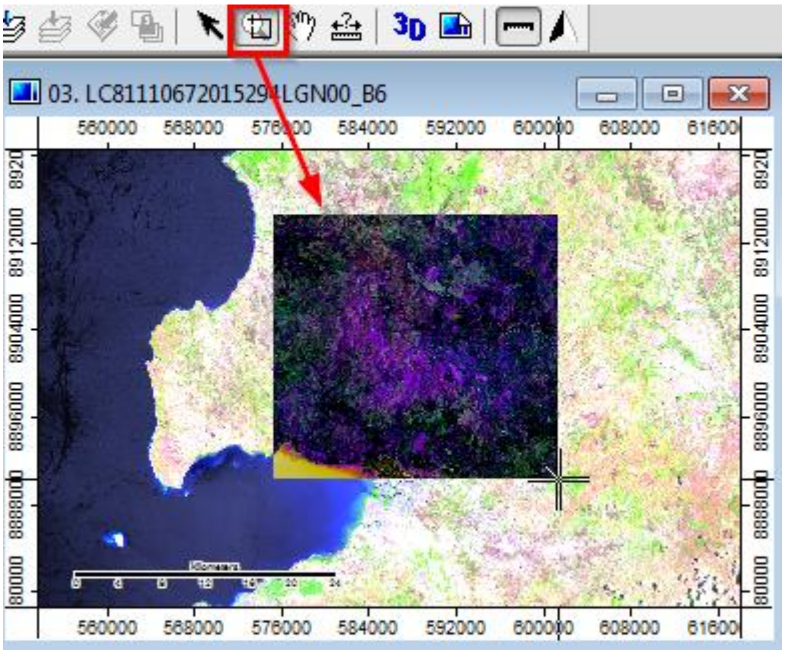
1. Navigate to the location of the Landsat GeoTiff files. Select the bands you want to display
2. Choose the output coordinate system you would like the imagery displayed in.
3. If you have chosen more than 2 image bands you can choose to display it as an RGB composite image. In the example below, we have chosen bands 4 (Red), 5 (Near Infrared 1), 6 (Near Infrared 2)



The image automatically opens as a red, green, blue display in a UTM coordinate system



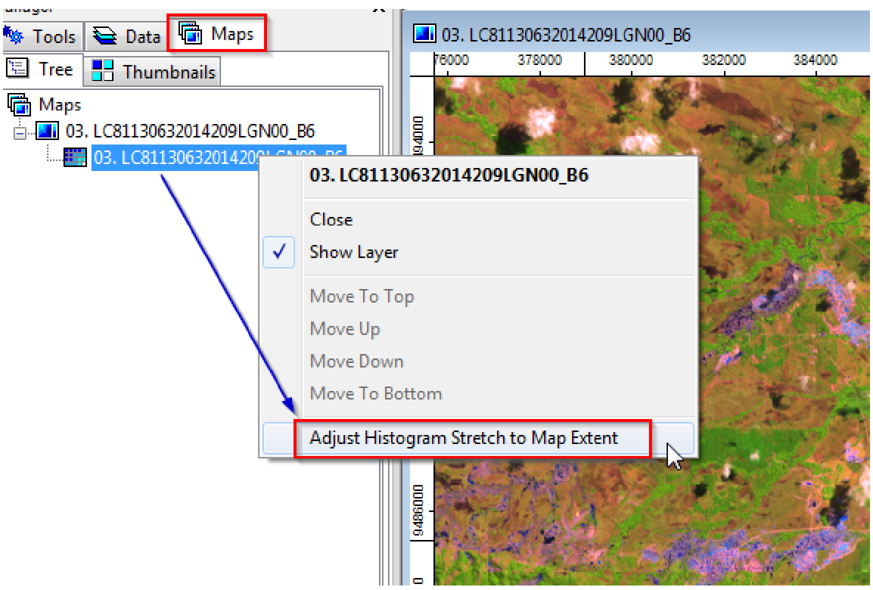
Now try and zoom to an area of interest using the zoom tool.

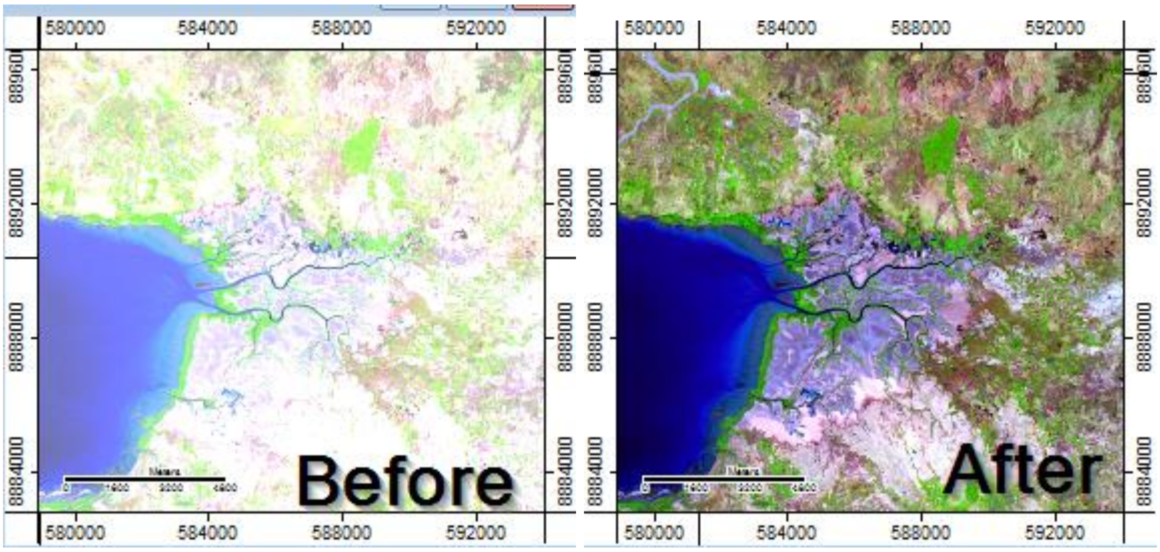


Adjusting display contrast

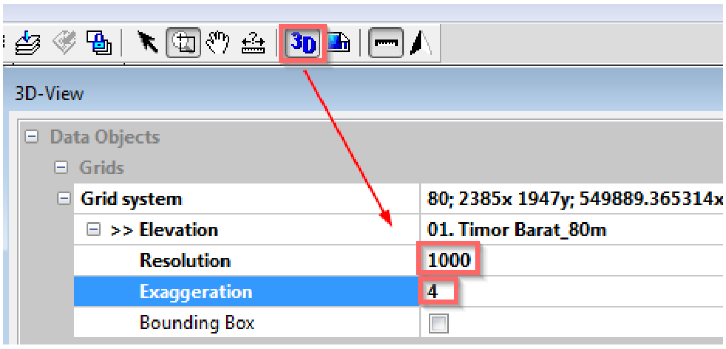
You can improve the display using a technique similar to a 'contrast enhancement', by clicking on the displayed band and selecting: ***Adjust Histogram Stretch to Map Extent.*** in the **map tab** right

This essentially adjusts the contrast to the colour range in the displayed window.



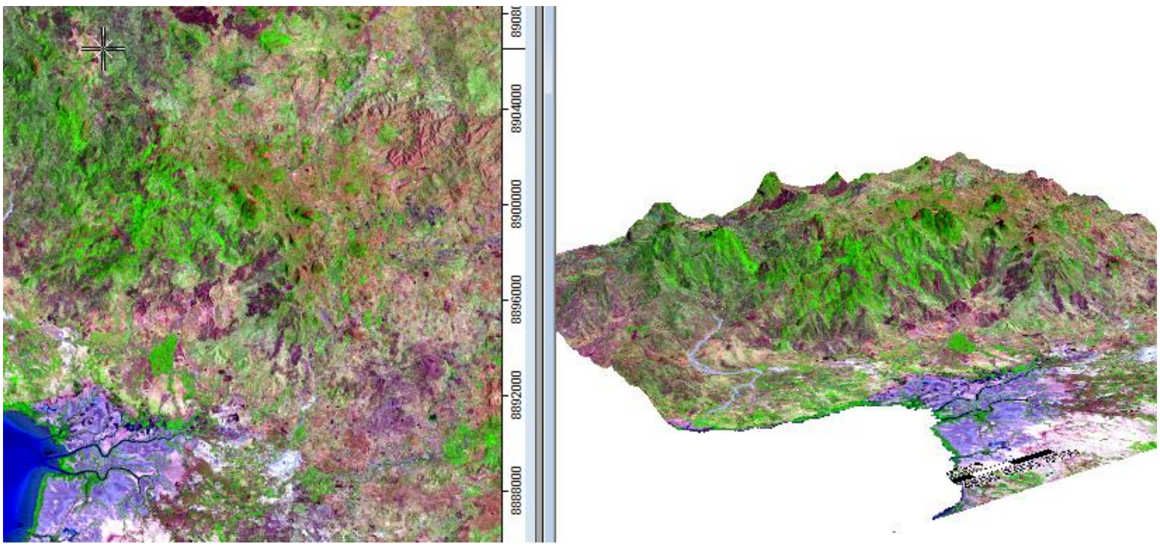


Landsat 3D visualisation



If you have the digital elevation data loaded for the same region and in the same coordinate system as your displayed Landsat image you can use this to view the Landsat in 3D.

Use exactly the same steps as you used previously to display the DEM in 3D but this time make sure you have your Landsat image display window selected.

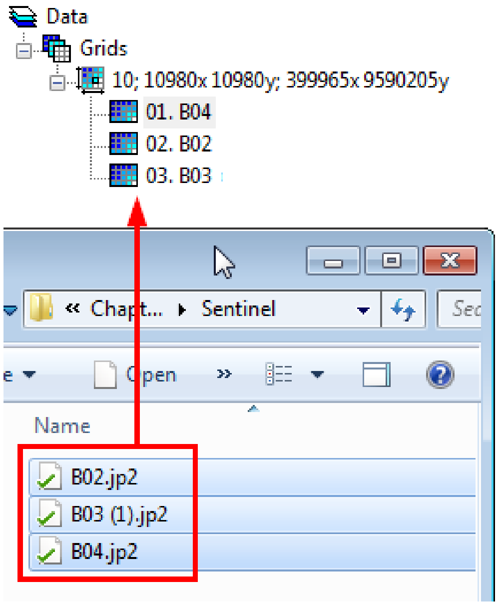


2.5 Import and viewing Sentinel Data

This section uses Sentinel-2 data from west Timor: West_Timor_Sentinel-2 (220mb)

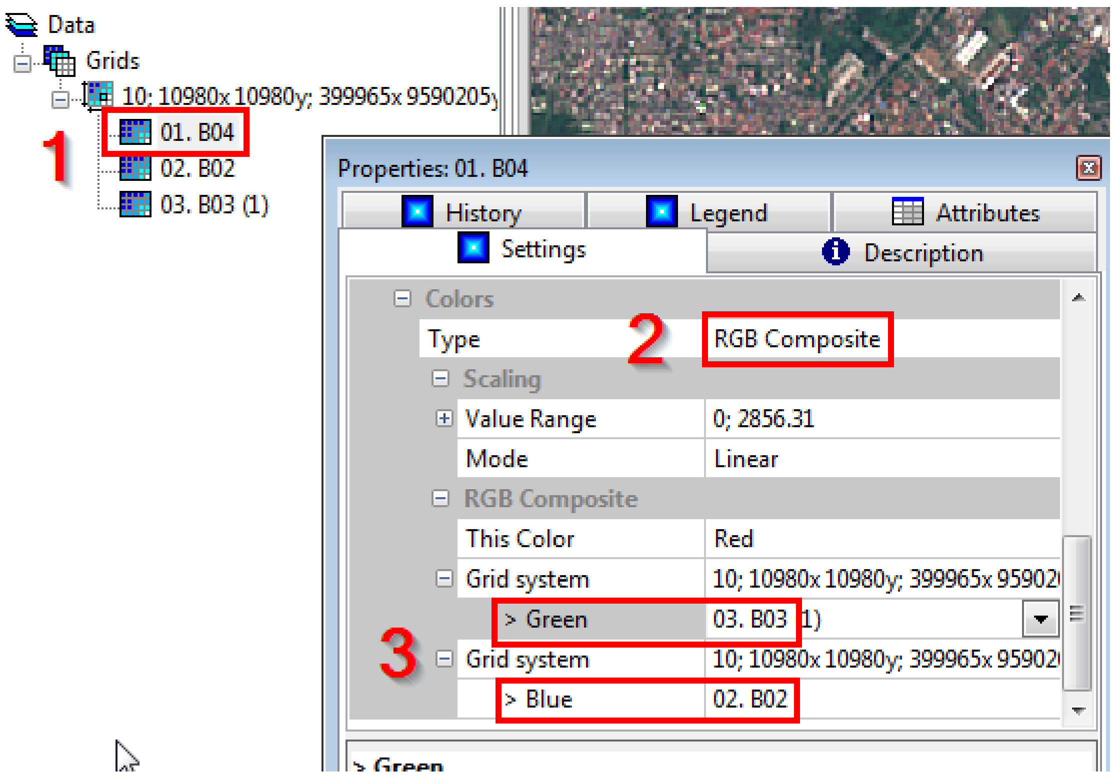
Access tutorial videos here: sagatutorials.wordpress.com/viewing-sentinel-2-imagery/

To view sentinel data you can simply drag and drop the files straight into SAGA. (Refer to **section 3.9** for downloading Sentinel data.)



To view the data as a colour image you need to display the Red band (band 4) as an RGB composite image by:

1. Selecting band 4
2. In the settings tab changing the display type to an RGB composite image
3. Then setting the Blue to the band 2 (B02) and Green to Band 3 (B03).



Exercise

Try displaying the Sentinel imagery together for the same area with Landsat imagery and viewing the difference in pixel size or spatial resolution. The example below illustrates this difference with the Sentinel 2 imagery (left) and Landsat 8 imagery (right) for Kupang airport in west Timor.

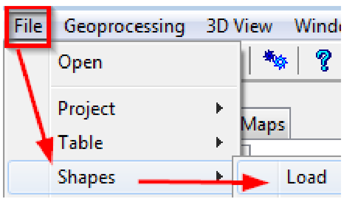
Sentinel 2 Imagery (10m) **Landsat 8 Imagery (30m)**

The concept of spatial resolution in discussed further in **Section 4.1 of this manual.**

2.6 Adding vector data

This section uses a polygon shape file of the boundary for the main city in West Timor (Kupang): West_Timor_Vector

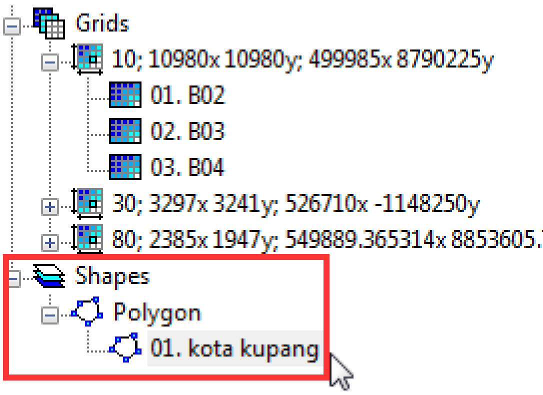
Adding vector data in SAGA can be done by simply dragging and dropping the *.shp* (shapefile) vector file into SAGA. For example, to add the vector polygon for the boundaries of Kupang city, find the Kota_Kupang.shp file and drag it into SAGA.



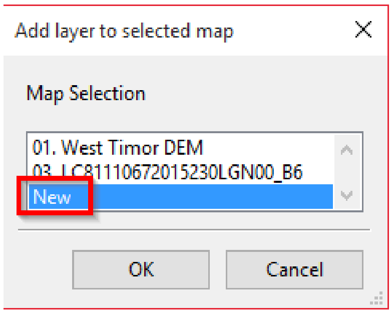
Alternatively from the top menu:

Use: Geoprocessing>File>Shapes >Load

It should be noted that SAGA will divide raster and vector under different data type titles. Raster data appears at the SAGA workspace as *Grids*, and vector data appear as *Shapes* in either line (line), area (polygon), or points (point) format.

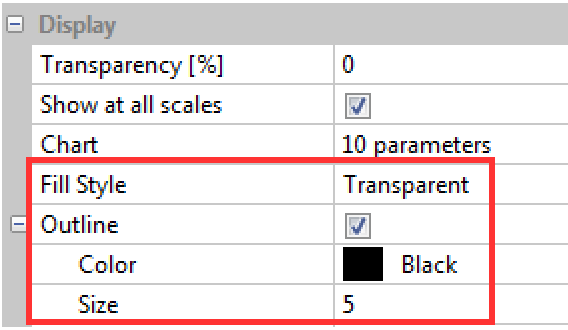


To open the shapefiles in a new map double click on one and select new.

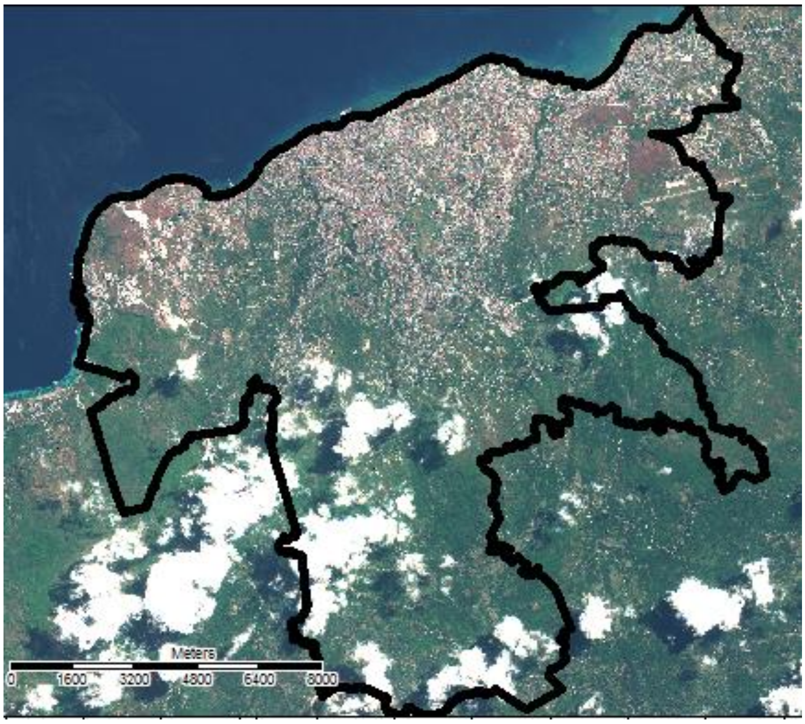


We could also display the vector layers over the top of one of our existing maps ie, the West Timor DEM, Sentinel-2 or Landsat imagery.

To display the vector layer over an image select the polygon file in the **Data Tab** then change the display attributes in the **Settings Tab**; change the fill style to Transparent, the outline colour to black and the line size to 5.



This will make it easy to see the boundary over, for example, the Sentinel image as shown here:



Both the Sentinel data and the city boundary vector file are in the same coordinate projection so they display accurately together.

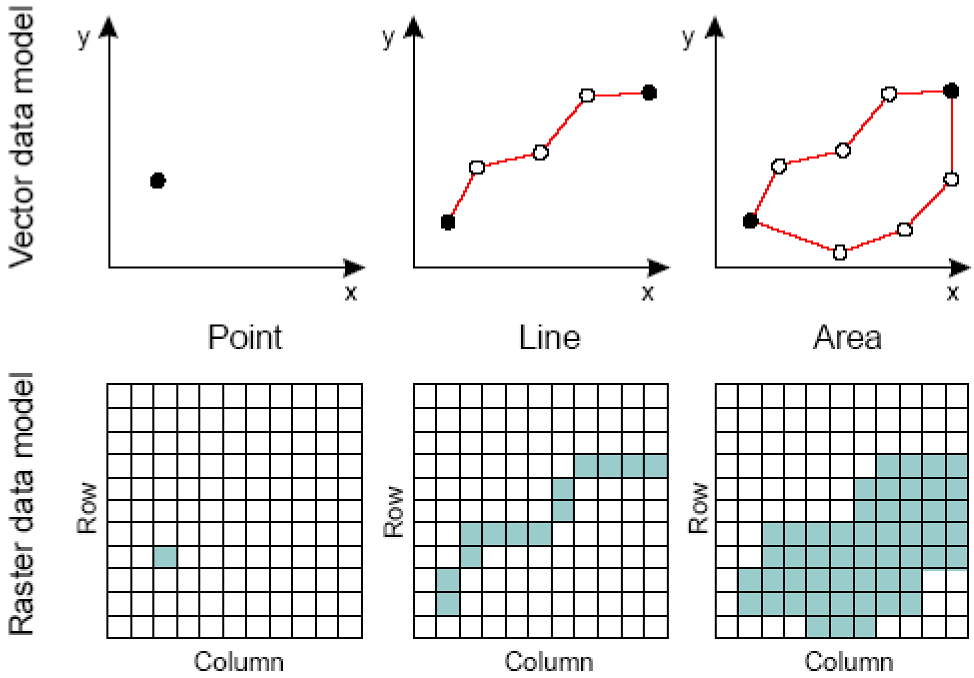
Coordinate projections are discussed further in **section 3.4** of this manual.

3. Introduction to spatial data concepts

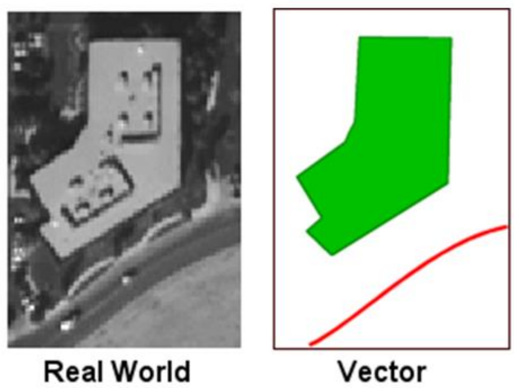
The field of mapping and GIS has its own language. This next section explains some key concepts and words you might come across when working with map data, especially in a fire management context.

3.1 Data Types

Map data identifies features and positions on the Earth. Within the field of mapping/GIS there are two data types used to represent these features; **vector** and **raster** data. The main difference between these two data types is that vector data is presented as a point, line or area, whereas raster data is represented as a grid of pixels as shown below.



3.2 Vector Data



Vector data maps features on the ground as points (distinct locations), lines and areas (also known as *polygons*). Polygons are line boundaries around the perimetre of a feature.

The example to the right is a photo of a feature in the real world, and how it might be displayed as 'vector' map data, or lines and polygons.

Common types of vector data include:

- GPX (GPS Exchange format) is a file type associated with GPS', used for collecting data in the field. This format allows GPS data (waypoints, routes and tracks) to be opened by different GPS devices and software, allowing for easy sharing of data without the need for file format conversion. We will go over GPS and field data collection later in the course.

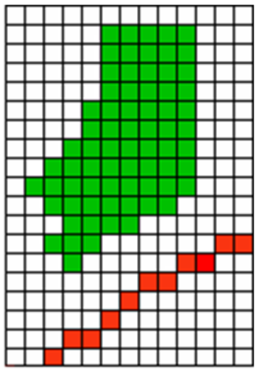
- KML (Keyhole Markup Language) is the file type used to display geographic/locational data in web-based mapping applications such as Google Earth.

- SHP (shapefile) is one of the most common vector file types and can be opened in many GIS programs.

3.3 Raster Data

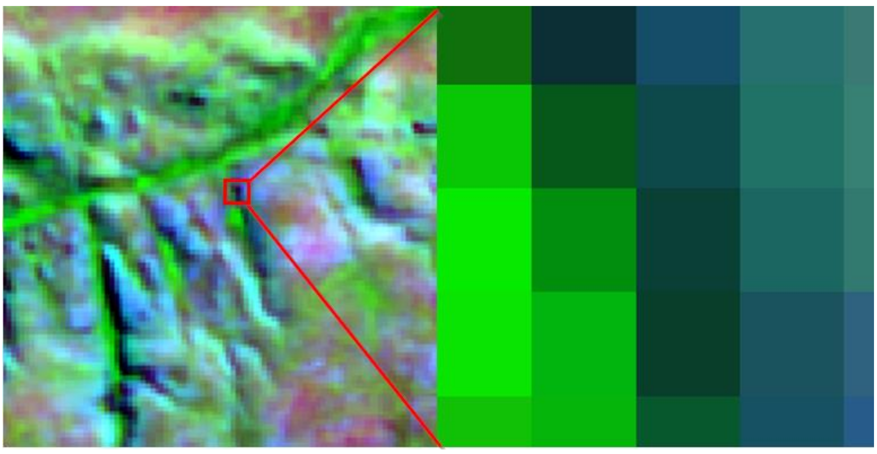
Raster data represents the earth's surface as a grid of cells (also called pixels). Each pixel is the same size, and each one represents a location. Each pixel has a number value that represents some characteristic of that region. The satellite imagery from which fires are mapped is one example of raster data. With satellite imagery, each pixel has a number value representing the amount of reflected sunlight captured by the satellite sensor.

Real World



Raster

The image to the right shows a region of the Arnhem Land escarpment. When we zoom in we can see the actual pixels making up that image. This is very similar to the way a digital camera or a phone stores photos.



It is common to display vector and raster data together. For example, you may have a GPS point you gathered in the field (Vector) and displayed over satellite imagery (Raster) on Google Earth. Each data type can support our planning work in different ways.

3.4 Coordinate systems

A coordinate system is a system of recording a location on the earth's surface – every location can be identified by a unique set of numbers. The two most commonly used coordinate systems you will come across are the Geographic Coordinate System that uses latitude and longitude to mark points on the earth, and the Universal Transverse Mercator (UTM) system that uses Eastings and Northings.

The Geographic Coordinate System draws parallel straight lines running east-west from the top to the bottom of the earth called lines of latitude (LAT). These lines are measured in the number degrees they are from the equator. Lines around the earth (radiating out from the north and south poles) are called lines of longitude (LON). These lines are measured in the number of degrees they are from an imaginary line called the prime meridian. The image below shows this system.

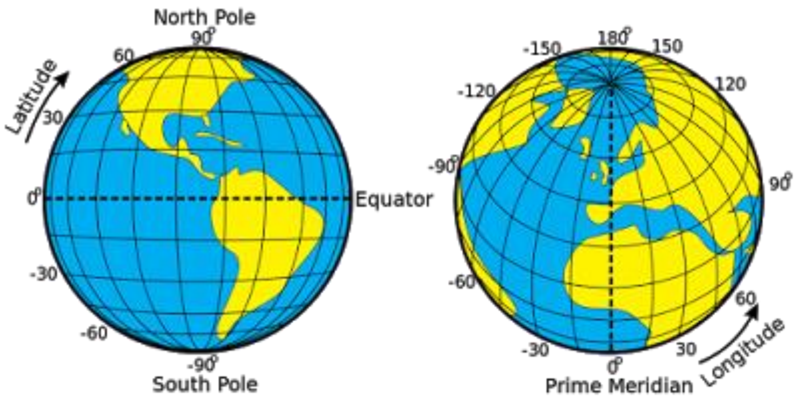
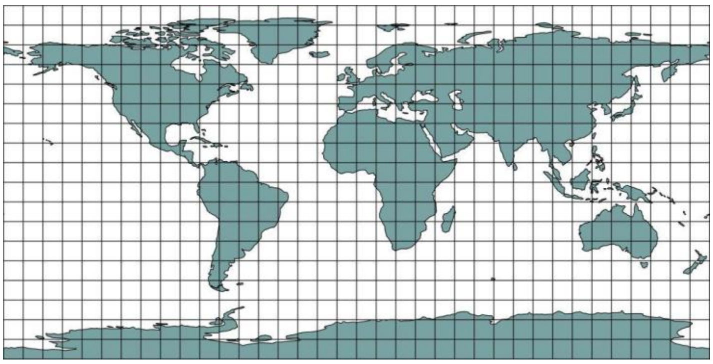


Image reproduced from Wikipedia http://en.wikipedia.org/wiki/File:Latitude_and_Longitude_of_the_Earth.svg)



The UTM system divides the world into grid zones, and position is indicated by an easting and northing position within one of these grid cells

Each of these systems has advantages and disadvantages.

The UTM coordinate system relies on the metre unit of measure, which incorporates the simplicity of the decimal system and its easy-to-comprehend units.

On the other hand, the LAT/LON coordinate system relies on the degree, minute, and second unit of measure, incorporating the angular system and its cumbersome units of 60. However, the UTM system is cumbersome when working across grid zones. In northern Australia, which covers a large area and crosses many grid zones, we generally work in a geographic (latitude and longitude) system. However, when working across small landscapes, it can be useful to work in a UTM system. The most important thing is to understand how your system works.

4. Introduction to satellite imagery

Pictures (raster images) of the earth's surface captured from satellites orbiting the earth are a vital tool for natural resource management.

http://www.nasa.gov/sites/default/files/thumbnails/image/australia.a2015194.0435.250m.jpg

The image above, from the MODIS satellite, shows smoke coming from many fires in the Top End of Australia in July 2015.

These **Earth Resource satellites** are specifically designed to measure aspects of the earth's surface using onboard 'sensors' (cameras). These satellites orbit/circle the Earth in a known and consistent way so they pass over the same spot on the earth's surface at regular intervals.

There are many Earth resource satellites, each with different sensor and orbit characteristics. It is important when using information derived from these satellites to understand the type of information each provides and how it can be used.

4.1 Key terms in satellite data.

Key to understanding satellite data are their **spatial** and **temporal** characteristics.

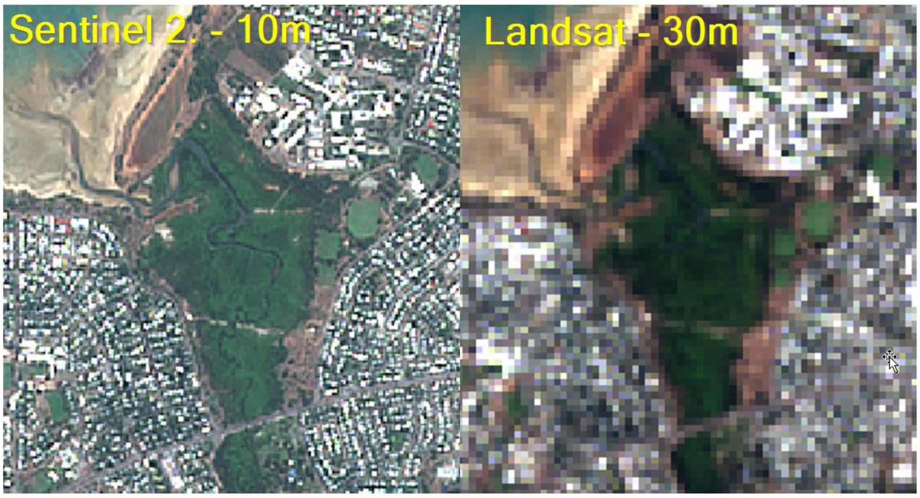
- **Spatial** *(space)* in the context of satellite data refers to the size of the image. This is described in terms of resolution and extent.
    - **Spatial resolution** refers to the on-ground size of a pixel in a satellite image.
    - **Spatial extent** refers to the on-ground width of a satellite image overpass.

- **Temporal** *(time)* refers to how long a satellite has been capturing imagery (extent) and how frequently it captures imagery (resolution). The temporal frequency is also referred to as the revisit frequency.

Spatial Resolution

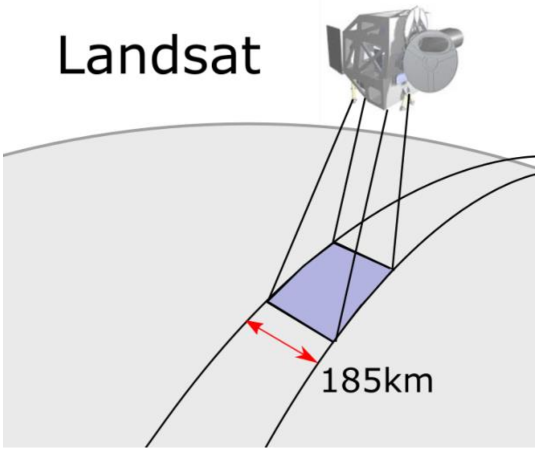
The graphic to the right shows the on-ground resolution or pixel size of two earth resource satellites: (1) Sentinel 2, with each pixel measuring 10 x 10 metres, and (2) Landsat, with a 28 x 28 metre resolution.

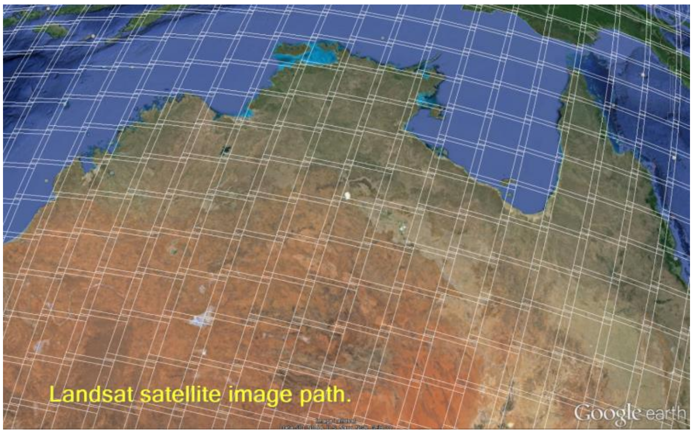
The on-ground resolution has significant implications for a satellite's ability to accurately map on-ground fire activity.



Spatial Extent

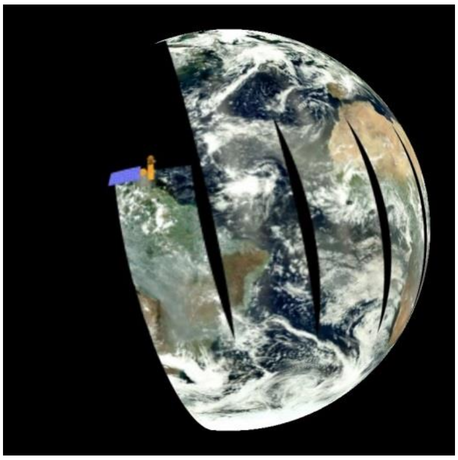
Every Landsat orbit (overpass) captures imagery along an 185km-wide path. This means that to capture satellite pictures for all of north Australia, many orbits and hundreds of images would be required.





Temporal Resolution (Revisit frequency)

The other key factor is revisit frequency or the amount of time between when a satellite captures an image of the same spot on the earth's surface.

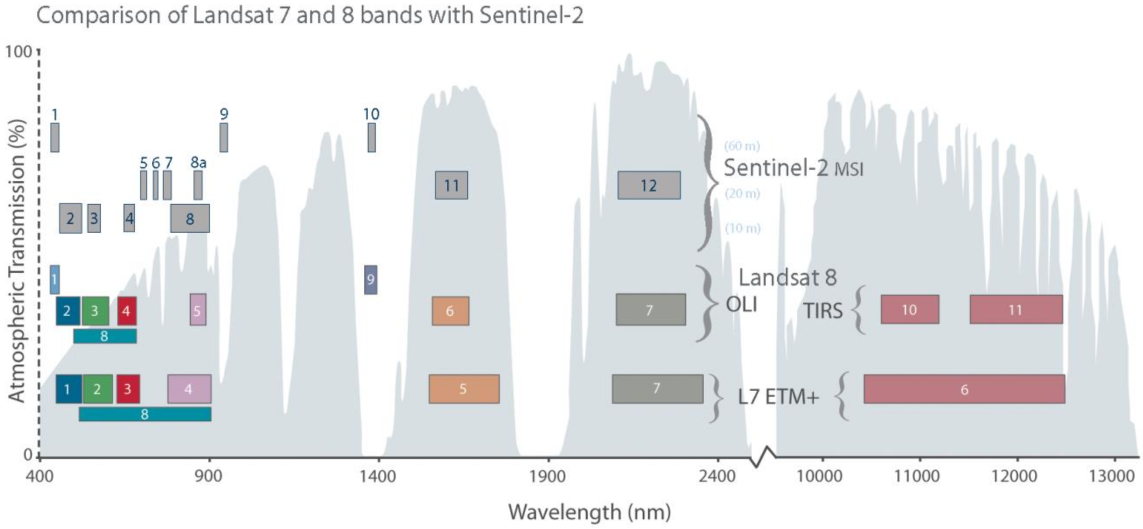


Spectral Resolution

This describes the number of wavelengths of light sensed by the satellite sensor. The graphic below shows the wavelengths and Landsat and Sentinel 2 satellites and Band numbers used to store data captured for each wavelength.

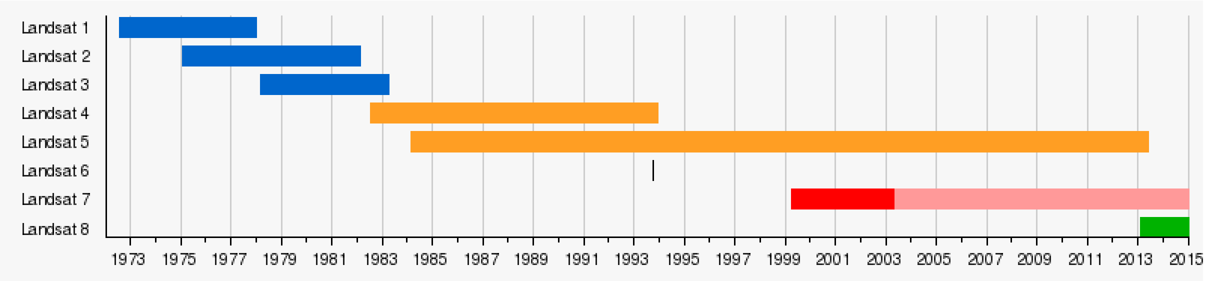
The figure below shows the difference between Landsat 7 and Landsat 8 bands – ie for Landsat 7 Blue, Green and Red are bands 1,2,3 respectively whilst in Landsat 8 they are bands 2,3,4. The infrared bands are 4,5,7 for Landsat 7, and 5,6,7 for Landsat 8. For all the satellites band 8 is a high-resolution band covering a broad spectrum of light.

Once downloaded each spectral band appears as a separate file and can be displayed individually or as a (red, green, blue) image composite. Each band has a different range of applications.



4.2 What is Landsat?

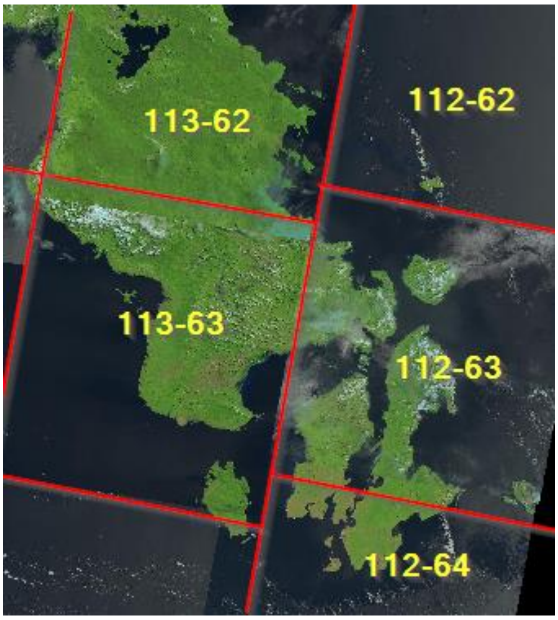
The Landsat series of satellites is the longest running program capturing earth resource imagery. Beginning in 1972 the Landsat satellites have collected millions of images for the entire globe, making it the most comprehensive collection of earth resource data available. The most recent in the series is Landsat 8 launched in February 2013. Landsat 8 produces high-quality earth imagery for everywhere on the planet every 16 days and is provided as a free service through the United Sate Geological Survey (USGS).

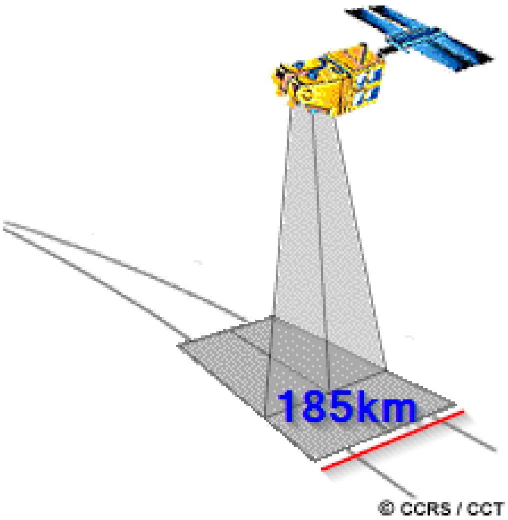


Landsat 8 imagery has a pixel resolution of 28.5 metres and one additional band with a 15m resolution. Each satellite overpass images 185 km of the earth. These image paths are subdivided into scenes to allow for easier management and distribution

Landsat 8	Resolution	Extent
Spatial	28.5m/15m	175km
Temporal	16 days	2 years
Spectral		11 bands

Each image scene is given a path and row number as shown for South East Sulawesi in the figure below.

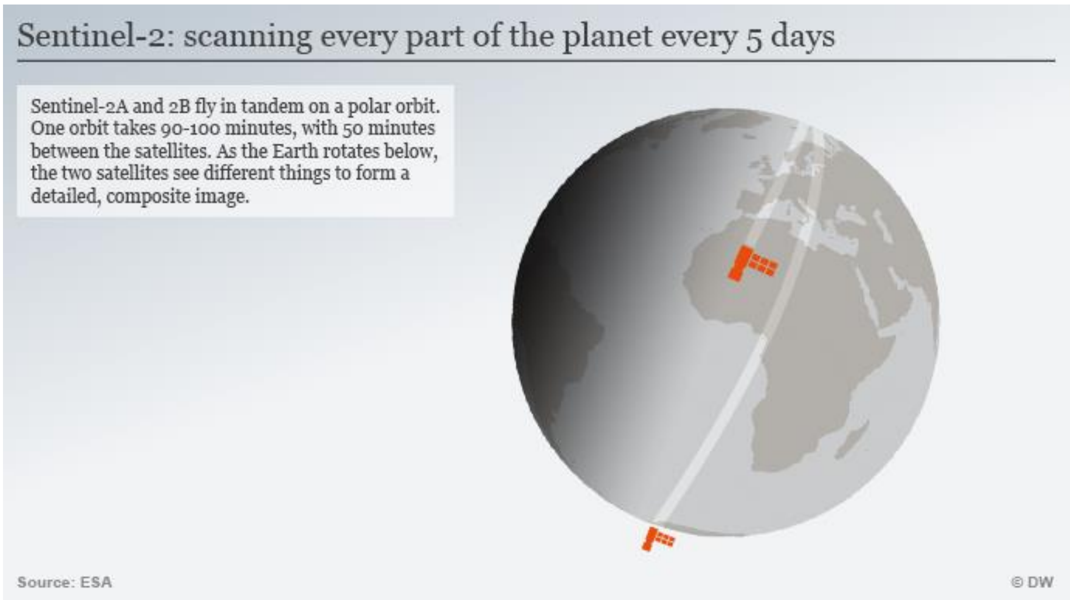




The primary difference between Landsat 7 and Landsat 8 imagery is the number of spectral bands collected. All recent Landsat imagery contains a combination of visible wavelength bands, ie red, green, blue, some infra-red wavelengths and some thermal bands.

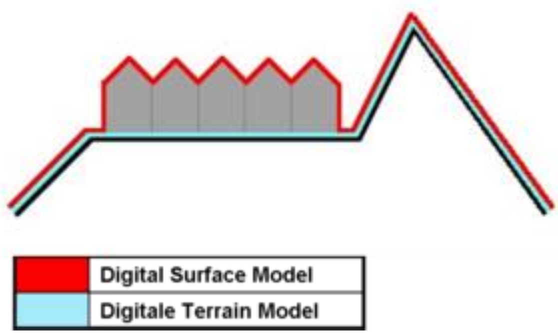
4.3 What is Sentinel 2?

Sentinel 2 is a sensor on two earth resource satellites (Sentinel 2a and Sentinel 2b). 2a was launched in June 2015 and 2b in March 2017. Both of the satellites are part of a fleet set up by the European space agency Copernicus Earth Monitoring program, which is the world's largest environmental monitoring project. As described above, Sentinel 2 imagery has a higher spatial resolution (10-20m) and, with two sensors in the sky, a much higher temporal resolution (5 days). Sentinel 2 replicates most (but not all) Landsat image bands (wavelengths) making it easy to compare Landsat and Sentinel 2 imagery.



4.4 What is digital elevation data?

Digital elevation data are 3D models of the earth's surface, usually stored as a pixel grid (Raster) format where each cell has the average elevation value of its coverage area. There are two forms of digital elevation models (DEM):

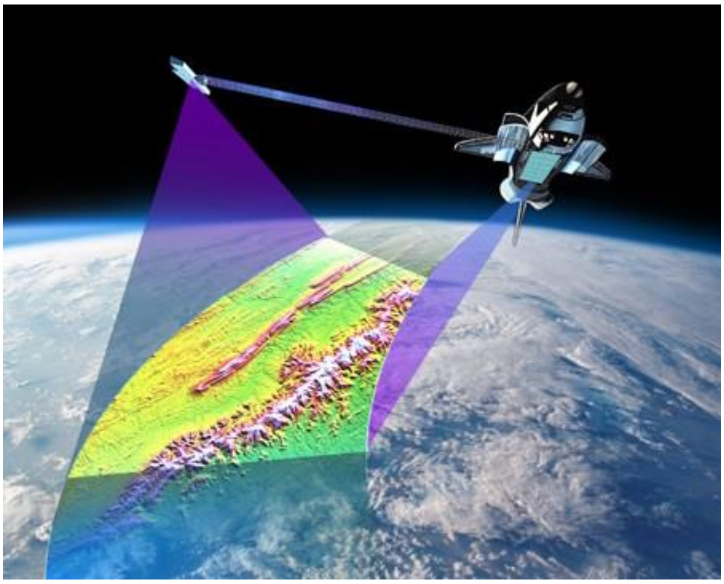


1. Digital surface models where each pixel value is the average height of all surface features including buildings

and vegetation canopy. Digital surface models are commonly produced from satellite or photo image pairs.

2. Digital terrain models where the value of each pixel represents the elevation of the ground surface. These data are commonly produced by RADAR imaging systems.

The primary source of free global elevation data is from the Shuttle Radar Topographic Mission (SRTM). These data were produced in 2003 from a dual radar system mounted on the space shuttle, at a 90-metre resolution for the whole globe. More recently these data have been further processed using other reference data to produce a 30-metre product.



This illustration shows the Space Shuttle Endeavour orbiting some 233 kilometres above Earth. With C-band and X-band outboard antennae at work, one located in the Shuttle bay and the other located on the end of a 60-metre deployable mast, the SRTM radar was able to penetrate clouds as well as provide its own illumination, independent of daylight, obtaining 3-dimentional topographic images of the world's surface up to the Arctic and Antarctic Circles. The mission completed 222 hours of around the clock radar mapping. (https://mix.msfc.nasa.gov/abstracts.php?p=2850)

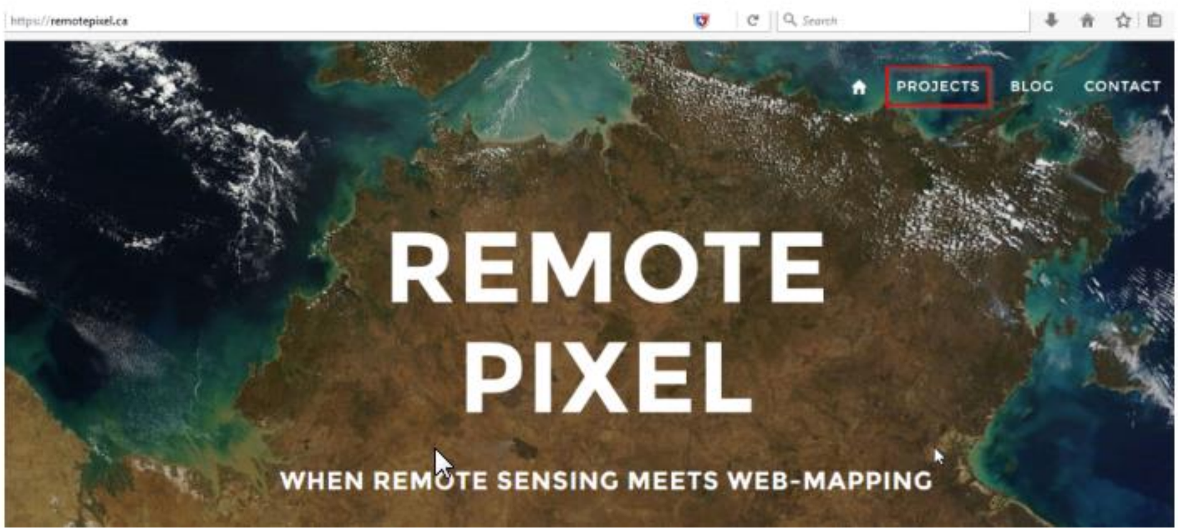
5. Accessing free spatial data

This section covers multiple ways of accessing satellite data free via the internet. The following web portals are described:

- Recent Landsat 8 and Sentinel imagery via Remote Pixel (https://remotepixel.ca)
- Historic Landsat imagery via USGS GloVis Next (http://glovis.usgs.gov/next/)
- SRTM elevation data via SRTM tile tool (http://dwtkns.com/srtm/).

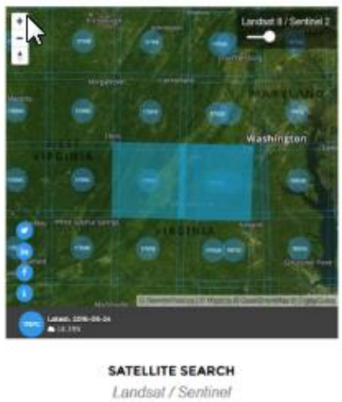
5.1 Downloading Landsat and Sentinel 2 imagery

Remote Pixel is a third party web service that provides a number of excellent interface tools for downloading satellite imagery. When opening *Remote Pixel* (https://remotepixel.ca) go to the “PROJECTS” page at the top right as shown below:



This will take you to a page of tiles linking to a range of image download projects. For accessing Landsat 8 and Sentinel data click on the SATELLITE SEARCH (Landsat/Sentinel) tile.

https://remotepixel.ca/projects/satellitesearch.html

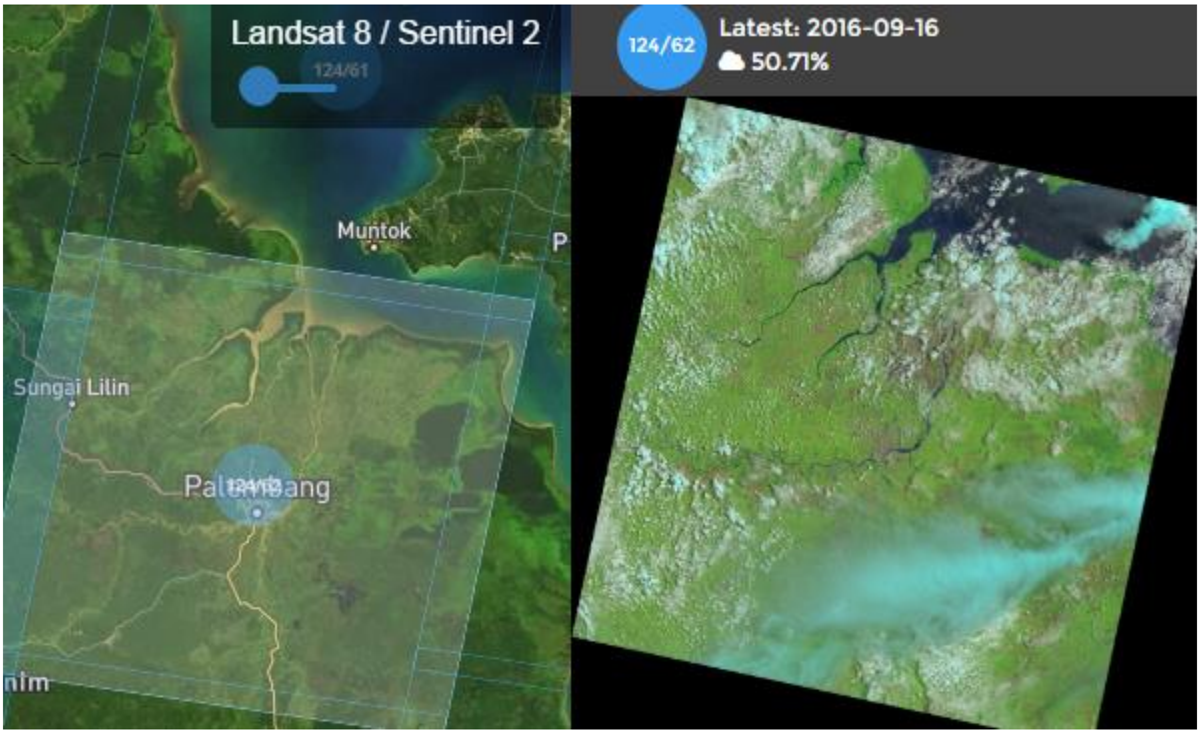


This will open a map view where you can select either Landsat 8 or Sentinel data view.

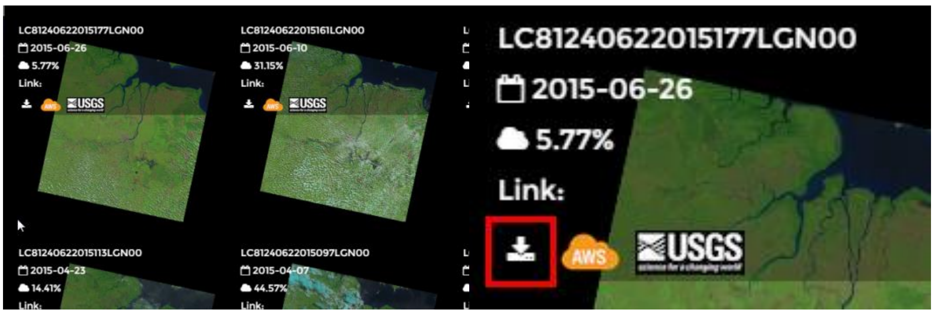
With the Landsat 8 view you will see the individual scenes and their path-row numbers

With Sentinel data you will see sentinel ‘tiles’; These are subsets of whole Sentinel scenes.

When you click on a scene it shows, (to the right), the most recent image.



Clicking on this image then opens a window showing all the available Landsat scenes.

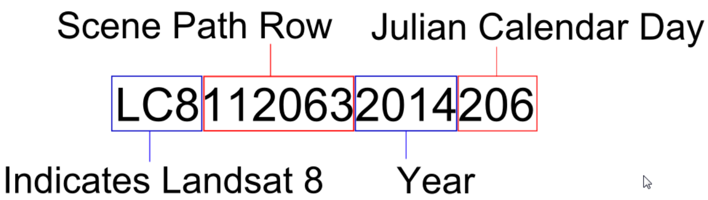


If you click on the download icon on one of the available scenes from this window a band list will appear.

Clicking on a band then starts the download.

Direct Download L8 band (Right Click on link)
B1 - Coastal aerosol
B2 - Blue
B3 - Green
B4 - Red
B5 - Near Infrared
B6 - Shortwave Infrared 1
B7 - Shortwave Infrared 2
B8 - Panchromatic (15m)
B9 - Cirrus
B10 - Thermal Infrared 1
B11 - Thermal Infrared 2

When you download a Landsat image each band will be labelled with the following description code:



This is followed by an underscore and the band number (ie, _B8). Each band is in a GeoTiff format and a UTM North projection. To bring Landsat data into SAGA in a southern hemisphere UTM projection use the Landsat Import tool as described in **section 2.4.**

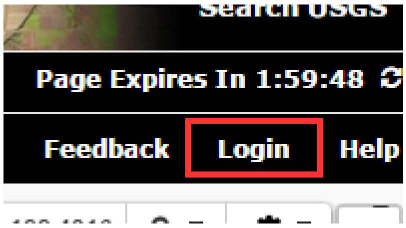
Similarly, for Sentinel data clicking on a tile shows the latest available images. Clicking on the latest image then opens up a new window with all available imagery. For Sentinel 2 data this is only goes back to the start of 2016.

Direct Download S2 band (Right Click on link)
B1 - Coastal (60m)
B2 - Blue (10m)
B3 - Green (10m)
B4 - Red (10m)
B5 - Vegetation Classif 1 (20m)
B6 - Vegetation Classif 2 (20m)
B7 - Vegetation Classif 3 (20m)
B8 - Near Infrared (10m)
B9 - Water vapour (60m)
B10 - Cirrus (60m)
B11 - Thermal Infrared 1 (20m)
B12 - Thermal Infrared 2 (20m)

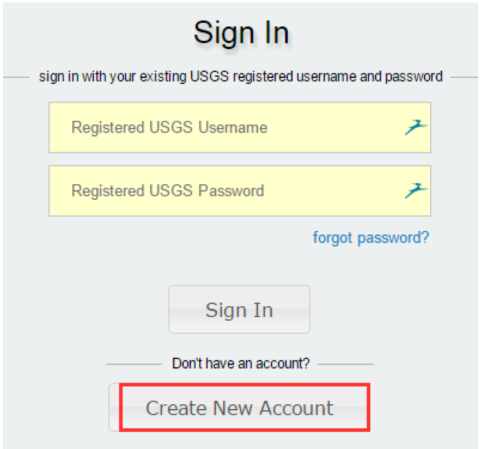
Sentinel data are in a jp2 format (JPEG 2000) and are by default in a UTM projection. Sentinel 2 data can be dragged straight into SAGA, no import is required.

5.2 Historic Landsat Data downloads – 1972-Present

To download older Landsat data currently the easiest way is US government through their **Glovis Next** portal. **(**http://glovis.usgs.gov/next/**)**



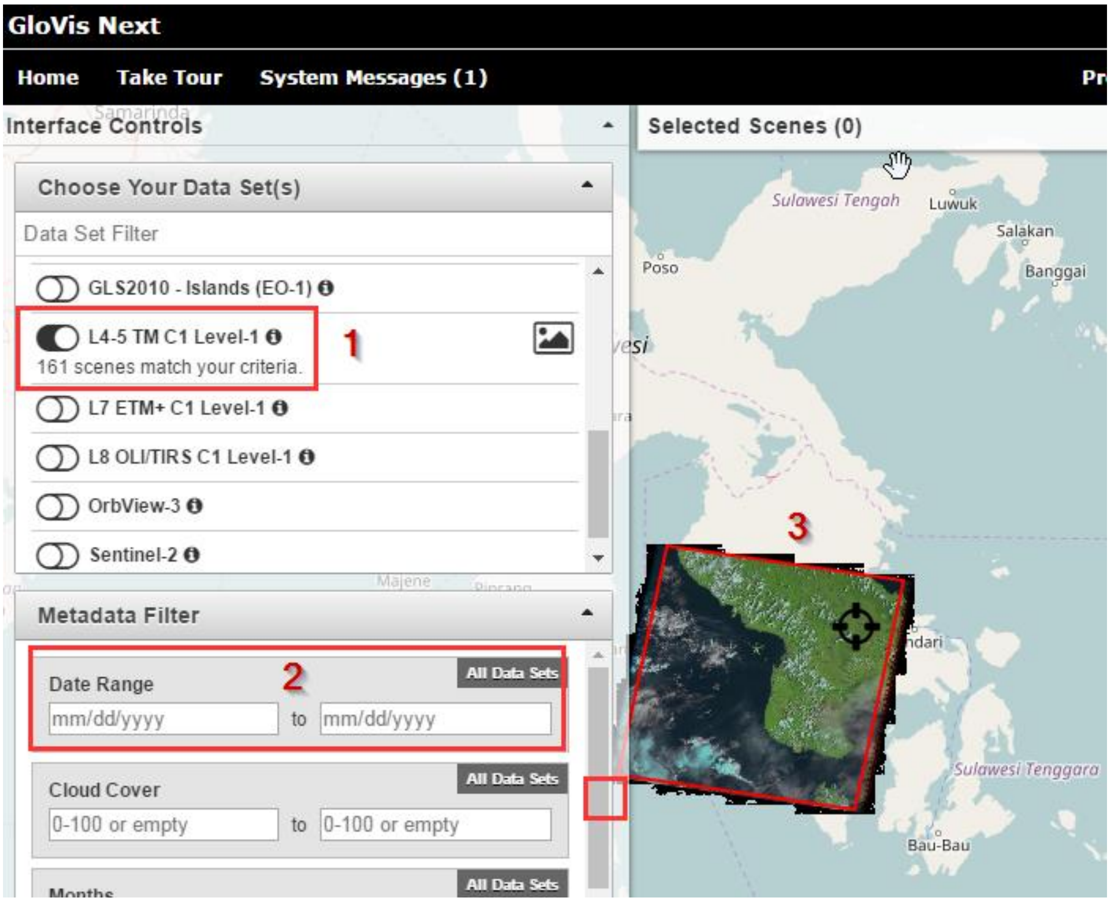
To use Glovis Next you will first need a USGS account. To go to the Login page by clicking the login button on the top right of the Glovis Page:



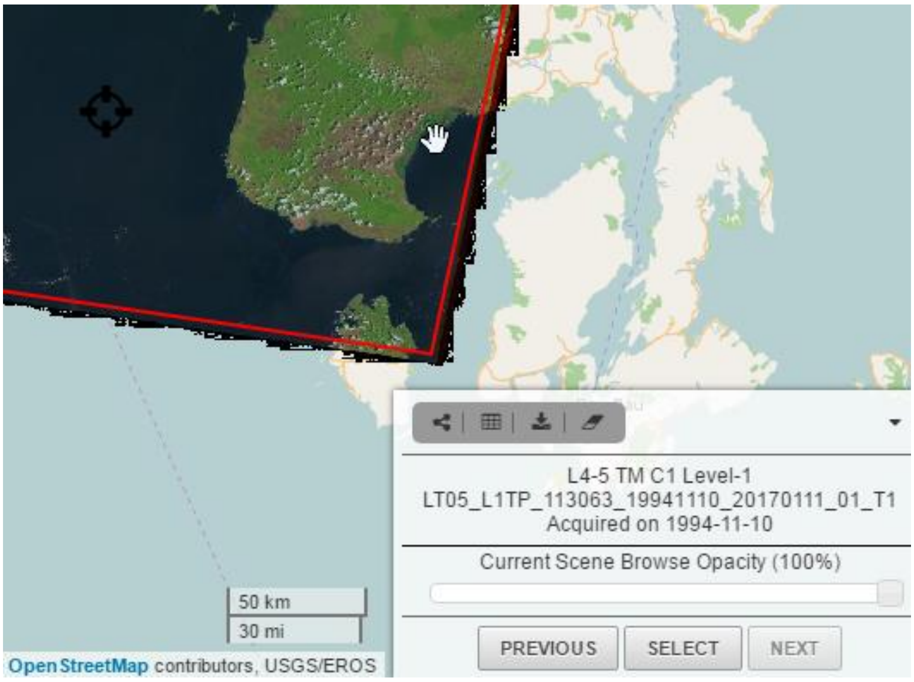
There you will need to enter your login details or if you have not already registered create a new account.

Using the Glovis interface you will need to:

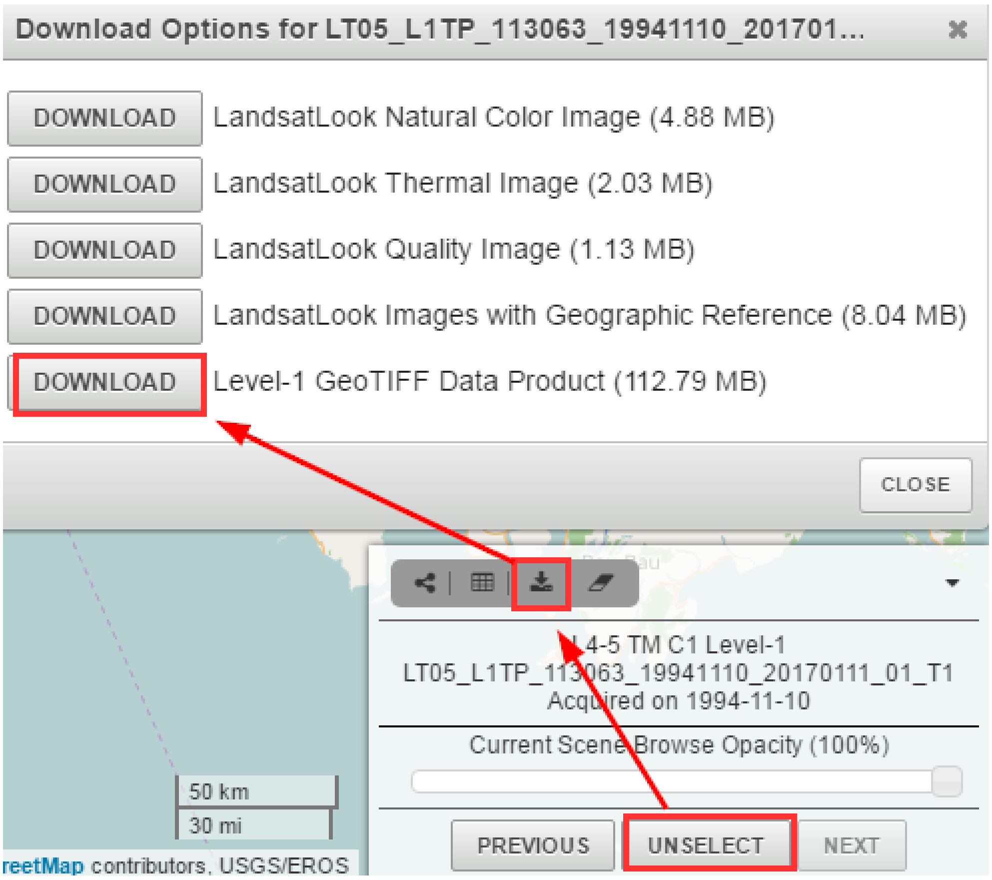
1. Choose the data sets you wish to access. For older historic data choose Landsat 4-5 TM. Refer to **section 4.2.**
2. The Date range of imagery you are after.
3. Centre your map on the scene of interest.



After clicking apply the most recent image in your chosen date range will appear in an information box in the bottom right that will display the name and date of the image. Using the **previous** and **next** buttons allows you to move onto the next image date available. The **Select** button allows you choose an image for further information or download



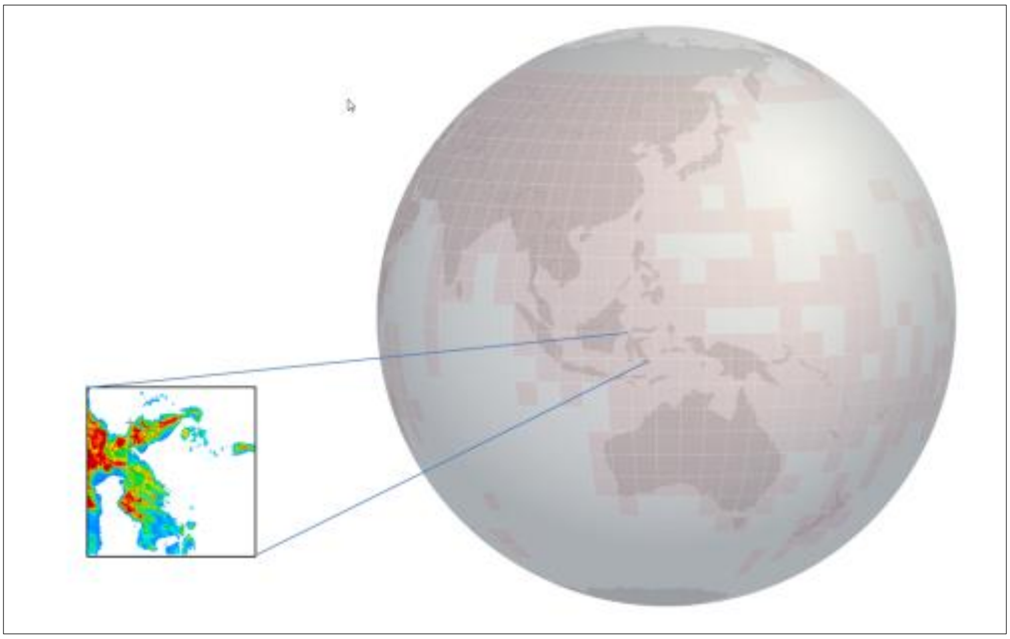
By clicking **Select,** the download icon produces a pop-up window showing the image to download. Select the Level-1 GeoTiff data Product to get all image bands for that scene.



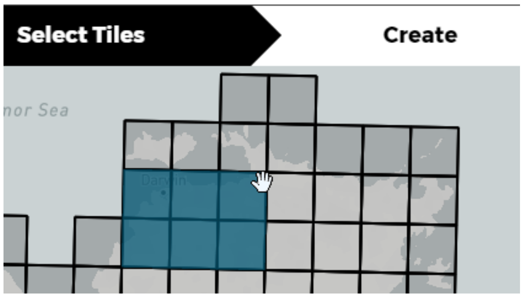
This will automatically start the download of the scene in a zipped (Tar,gz) format. Once downloaded, right click on the file to unzip it. You will need to unzip twice, first to the Tar format, then to the scene band folder.

5.3 Downloading elevation (SRTM) data

The easiest way to access and download SRTM data is via the STRM file grabber website (**http://dwtkns.com/srtm/**). From the interactive globe simply choose the tile that covers your area of interest and download the Geo-tiff.



Higher resolution (30 Metre) SRTM data also can be downloaded from the *USGS Earth Explorer* website or from the Remote Pixel **SRTM 1ARC**



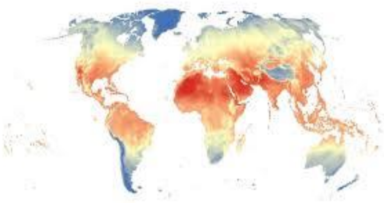
Tile Mosaic project:
https://remotepixel.ca/projects/srtm1arc-gl.htm.

This project allows you to select a number of 30m resolution SRTM tiles that will then be automatically mosaicked together and emailed to you.

Note: Before SRTM elevation data can be used for terrain and hydrological modelling in SAGA it first needs to be projected into an equal area (metres) coordinate system. This process is described in detail in section 7.1**.**

5.4 Other Global Spatial Datasets

Global climate data



WorldClim (http://www.worldclim.org/) is a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometre. The data can be used for mapping and spatial analysis.

Infrastructure

OpenStreetMap (https://www.openstreetmap.org) is an initiative to create and provide free geographic data, such as street maps, to anyone. The OpenStreetMap Foundation is an international not-for-profit organisation supporting, but not controlling, the OpenStreetMap Project. It is dedicated to encouraging the growth, development and distribution of free geospatial data and to providing geospatial data for anyone to use and share.

6. Visualising satellite data

This section covers the following techniques for visualising satellite data:

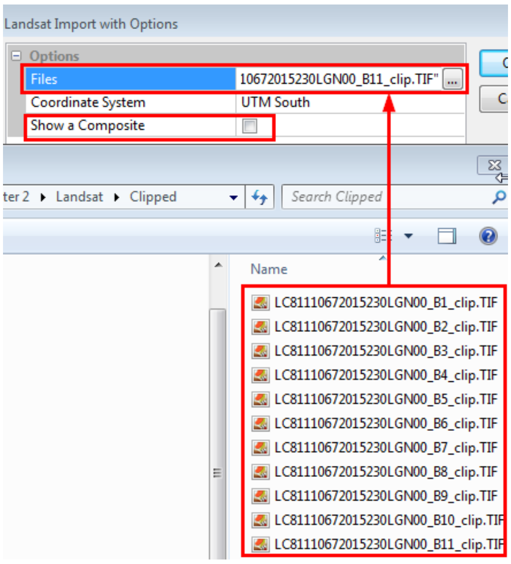
- Working with multiple satellite image band combinations.
- Creating higher resolution Landsat image visualisations
- Creating vegetation indices.
- Displaying multi-date imagery to view land cover change

This section we uses Landsat data for West Timor: West Timor - Landsat Data **(204mb)**

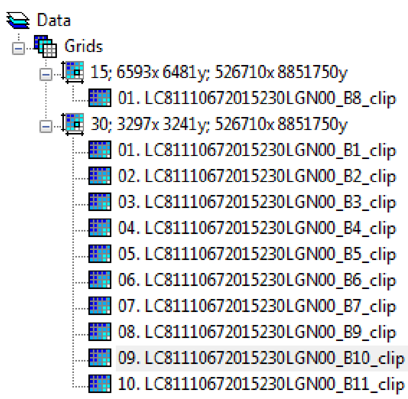
6.1 Changing band combination display

Satellite imagery is captured in multiple wavelengths of reflected light otherwise known as image 'Bands' **(see section 4.1)**. We can combine three image bands into one picture by displaying each band as either Red, Green, or Blue to produce what is commonly known as an RGB composite display. In this example, we will load all the image bands for the west Timor scene and create some RGB composite displays.

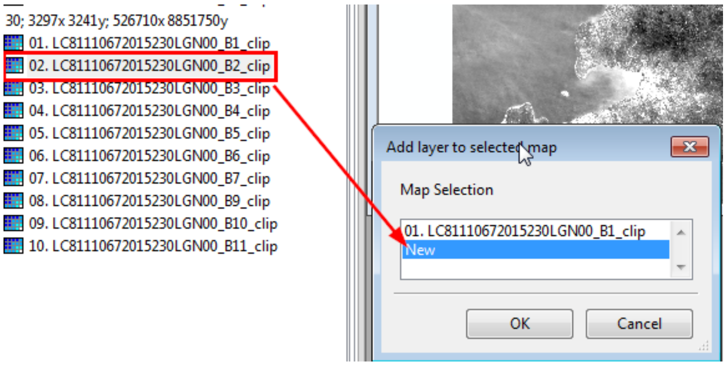
Using the *Landsat import* tool, import all the bands but deselect "Show a Composite". In this exercise, we will make the composite image manually.

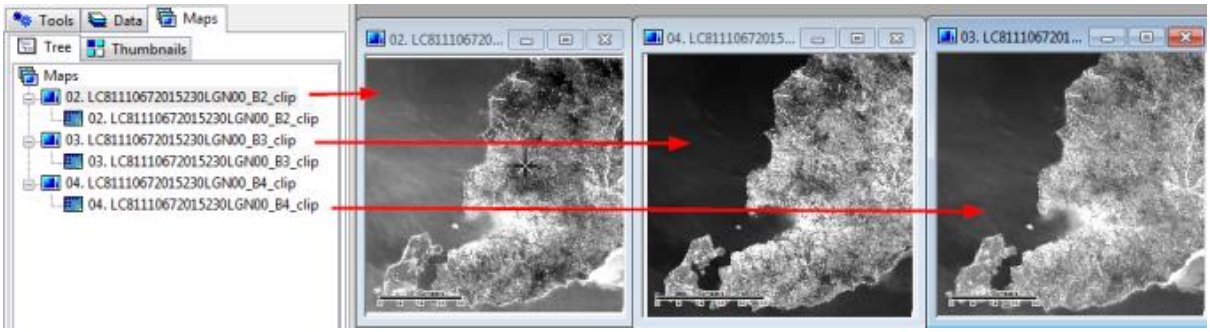


The loaded data will appear as two new grid systems. One for the 30-metre bands and one for the 15-metre resolution band 8.



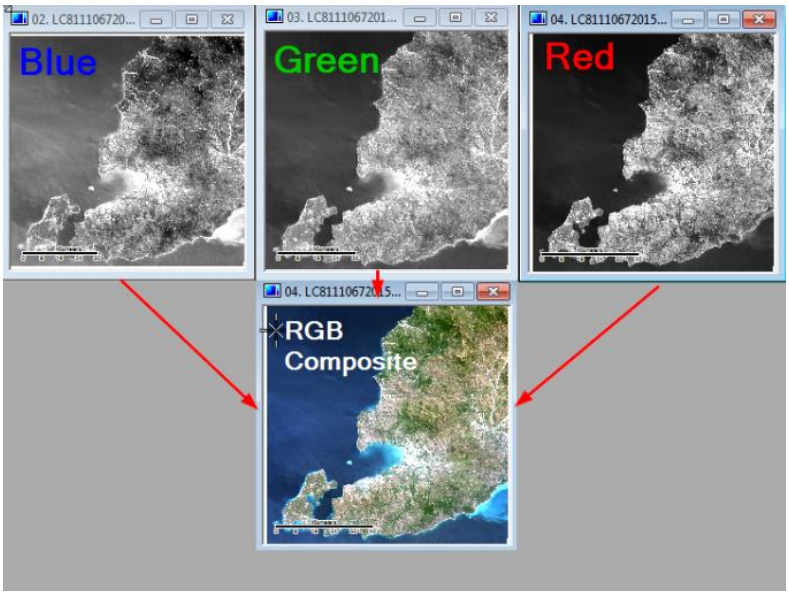
Now display each band separately in a new map layer, as shown below.



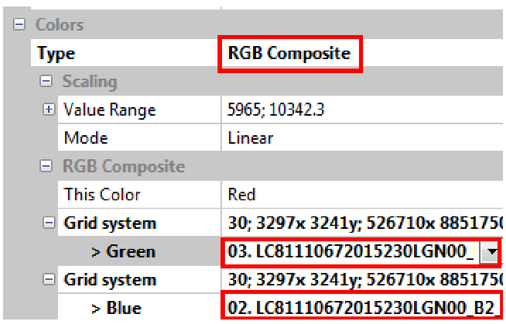


Have a look at the difference in the way each image band appears. What you can see is the difference between the wavelengths of reflected light stored in each band.

We will now combine these to produce a 'natural colour' RGB composite image.



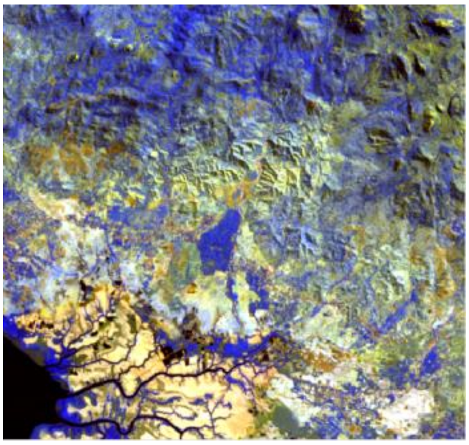
To do this select and display the band you want to be our red colour. For a 'natural colour' use Band 4 as 'Red'. In the settings tab change the colour type to *RGB composite* and set 'Blue' to Band 2 and 'Green' to Band 3 then click 'apply'.



This will result in the display to the right, which is similar to what you would see from space.

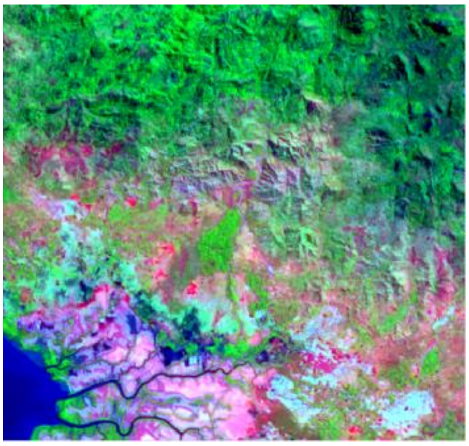
Try displaying Band 6 as Red (ie the one to set to display as RGB composite), Band 5 to Green and Band 4 to Blue. This band (right) combination highlights growing vegetation.

This third image on the right displays the RGB band combination 7 6 5.



This last combination uses Band 10 as Red, Band 5 as Green and Band 4 as Blue. Land that has recently been burnt or cleared is often warmer than surrounding areas. So in this image combination areas that may have been burnt appear as a bright red.

However, it is important to note that field investigation is required to properly determine what is happening on the ground.

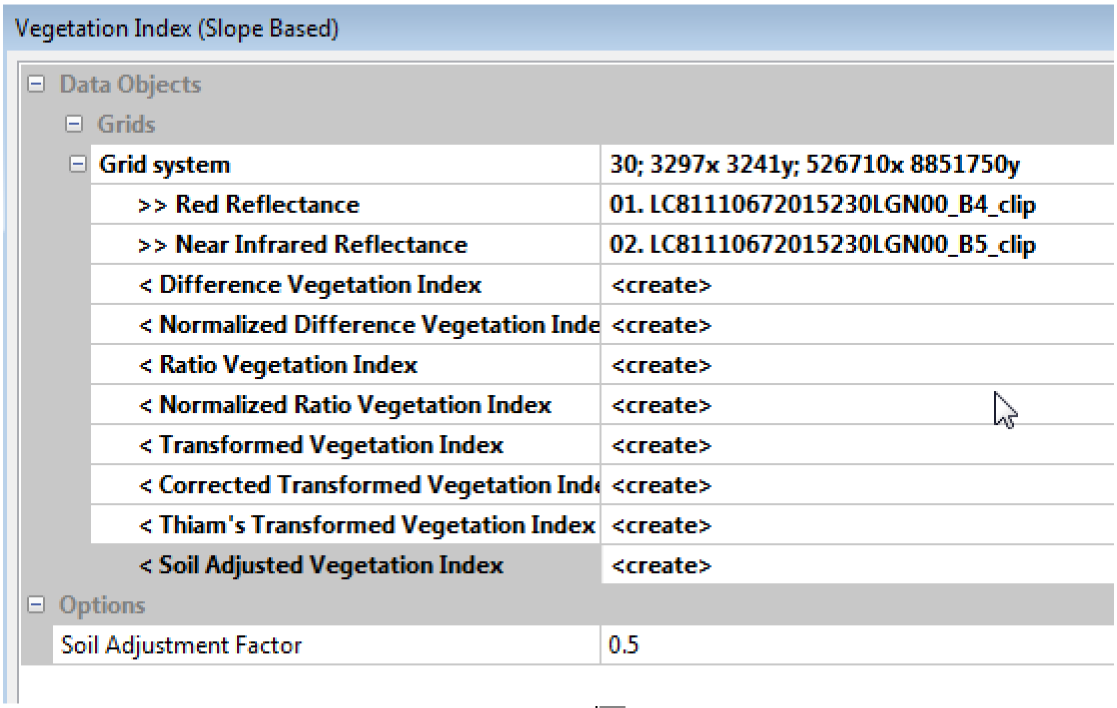


6.2 Vegetation Indices

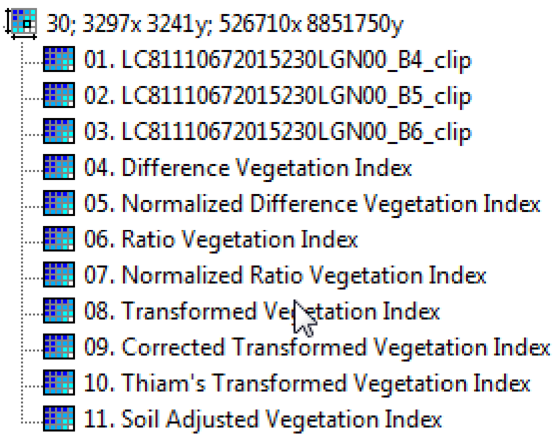
A variety of algorithms have been developed by researchers in an attempt to extract the most information from the satellite image spectral bands. Many of these are vegetation indices used for monitoring and mapping vegetation vigour. SAGA allows the automated calculation of a number of these.

Use: Geoprocessing>Imagery>vegetation Indices

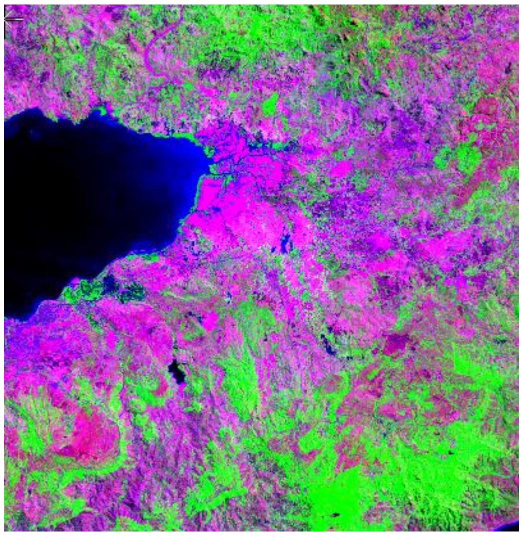
The example shown below is using the Vegetation Index (Slope Based). Simply enter the Red and Near Infrared bands (4 and 5 for Landsat 8) and select <create> for the index you would like to calculate.



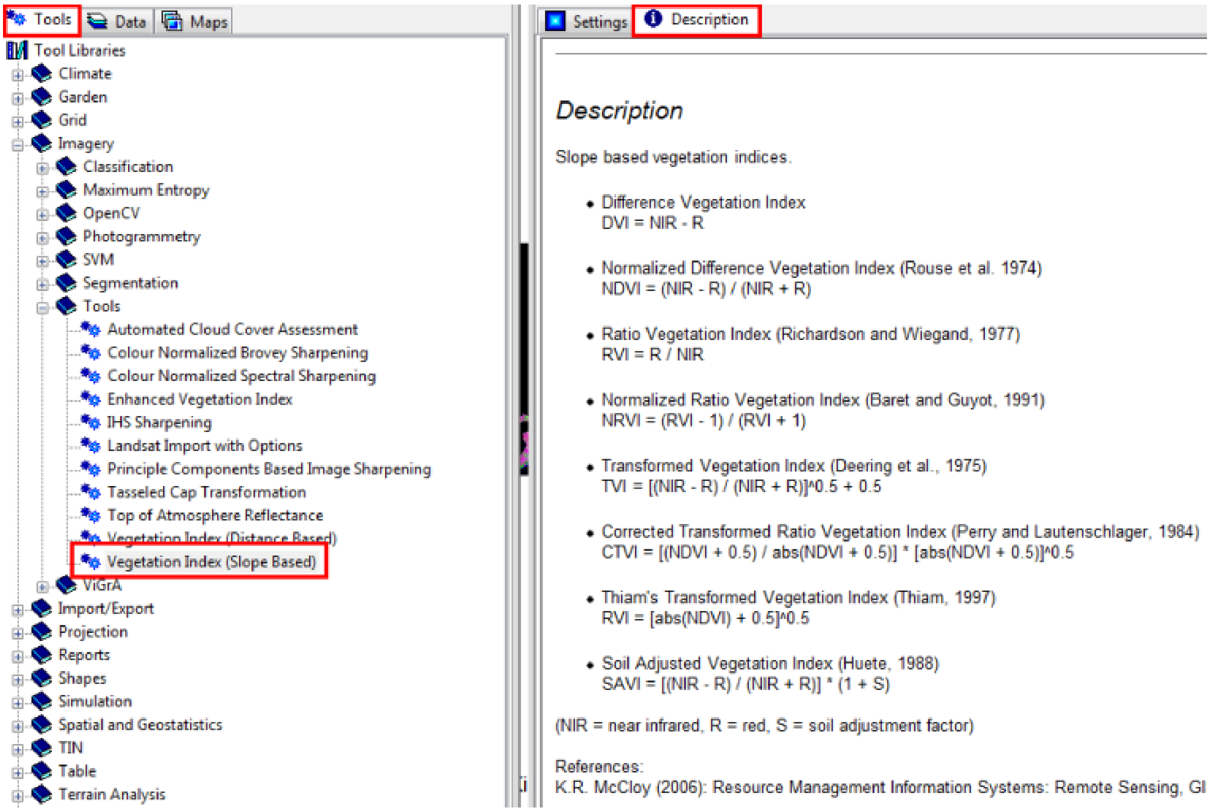
You will see all the new band combinations/indices in the data tab:



Displaying one of the vegetation indices as green as an RGB composite display really highlights the distribution of actively growing (high photosynthetic activity) vegetation as shown in the image below.



To find out the meaning of all the different vegetation indices and how they might be interpreted you can view further information if you select the vegetation index module in the Tools tab and select the description tab. As shown below it provides a description of the algorithms used to calculate each indices and references to more information.

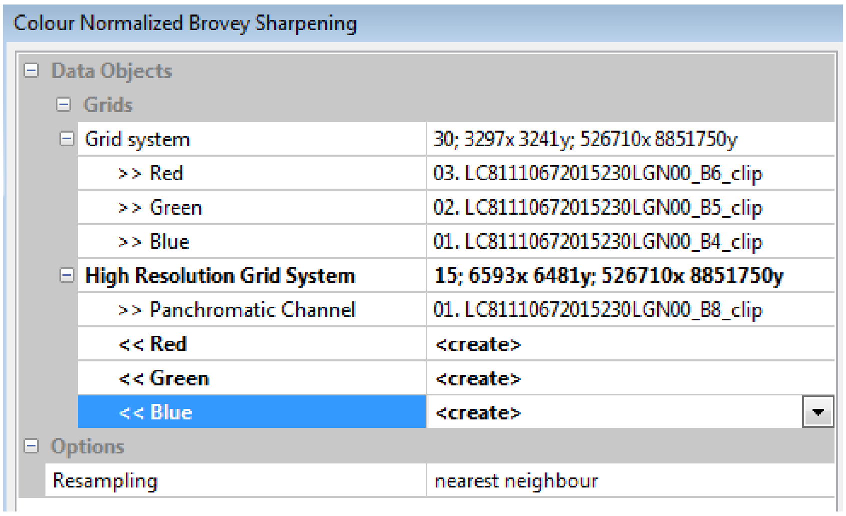


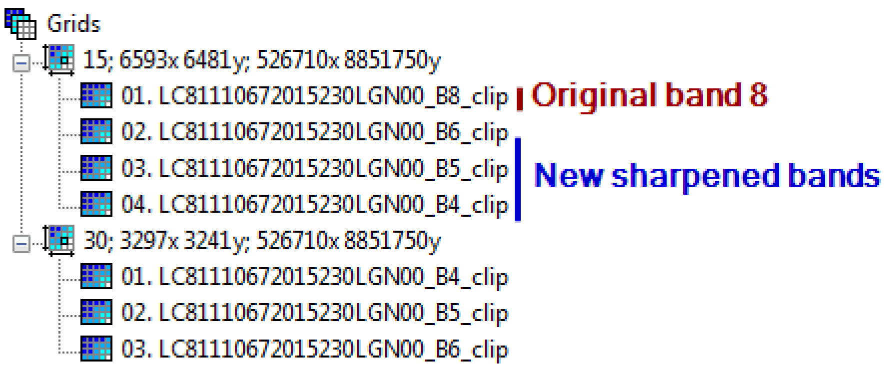
6.3 Producing a higher resolution Landsat display using band 8

There are several tools within SAGA for combining the 15 metre Landsat 8 Band 8 with the multi-spectral 30-metre bands. Using the west Timor satellite imagery try one of the image sharpening options. For example:

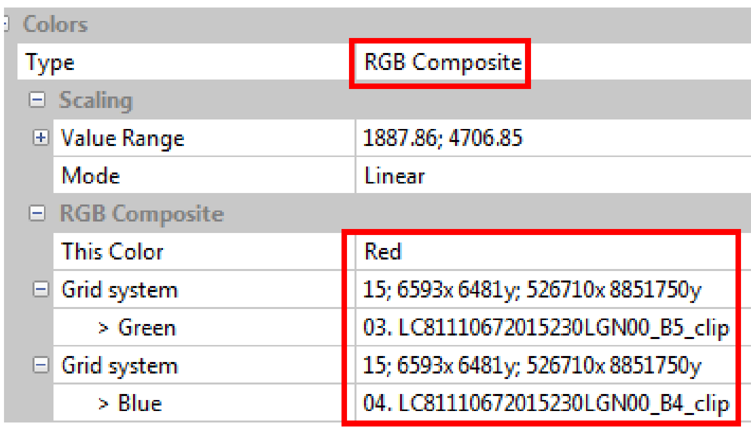
Use: Geoprocessing>Image sharpening>Colour Normalised Brovey Sharpening

Enter the 30-metre bands you wish to sharpen and the band 8 grid for the high-resolution band.

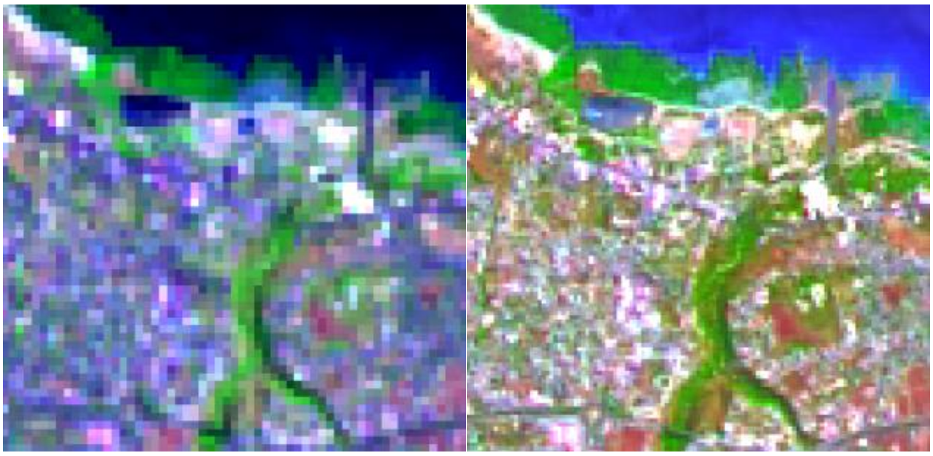




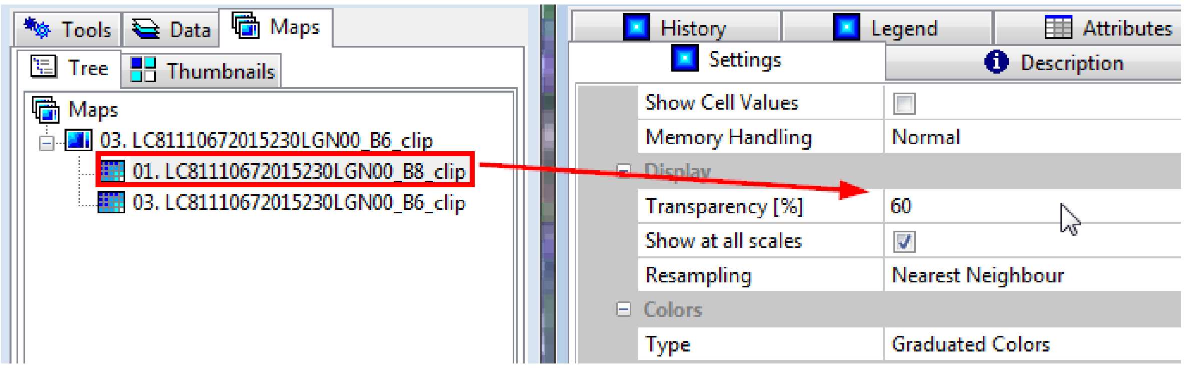
Now display the new band 6 grid (15m) as a band composite image in the settings tab.



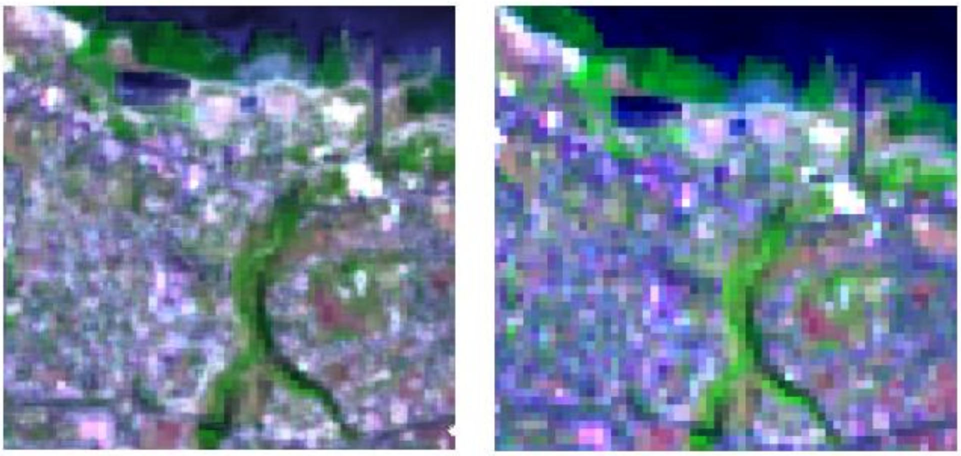
Display the original 30m band (left image) with the 15m band composite (right image) to compare the resolution difference.



Alternatively a simpler way to combine the two resolutions is to display the band 8 image with a transparency setting over the top of an RGB composite display of the 30m bands.



The result is shown in the left image below. More detail in the image is evident compared to the original image (right), however, some spectral (colour) clarity is lost.



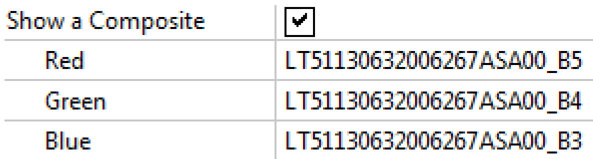
6.4 Multi-temporal image display

It is possible to display multiple images from different dates (year) to view changes in land cover over time. We will do this to examine changes in land cover due to mining.

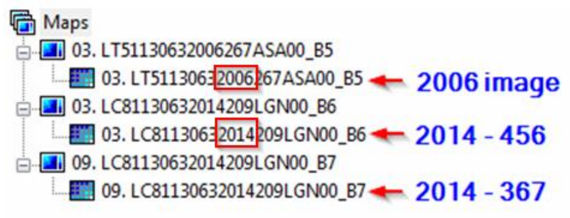
For this section, we will use imagery of a small-scale gold mining area in South East Sulawesi (Indonesia). This site in the 'Bombana' district experienced a gold rush in 2008. Using Landsat 5 and Landsat 8 imagery we will look at the land cover change caused by the mining activity. Later in **section 10.2** we will use the same imagery to conduct a classification for the same area in South East Sulawesi.

For this section use: Landsat data from Sulawesi from 1996 and 2015. (219mb)

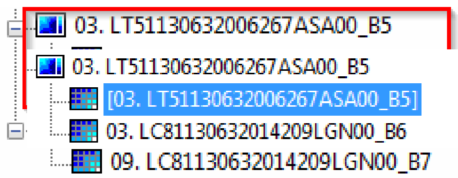
Let's now display a Landsat 5 image from 2006 (\Landsat\113-63\2006). The Landsat 5 bands **3,4,5** (Red, NIR, SWIR1) are equivalent to the Landsat 8 bands we used earlier (4,5,6). Load the 2006 image with the Landsat 5 bands as shown here.



You will now see in the maps tab that we have 3 images displayed: 2 with differing band combinations for 2014 and our new 2006 image. Each image is displayed in a different map layer.

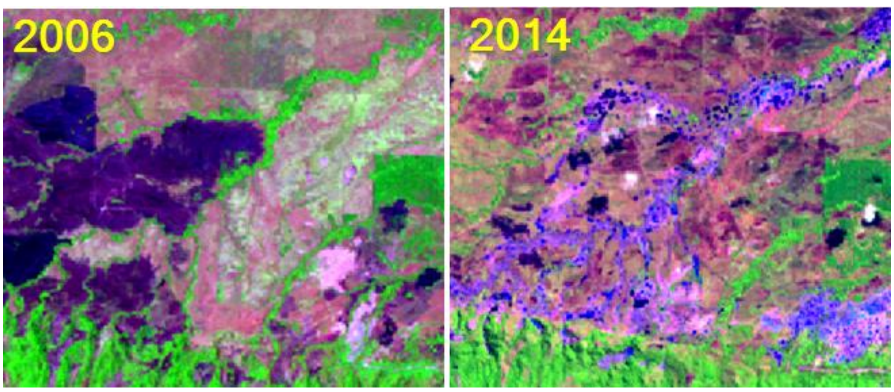


To view the imagery from 2006 and 2014 together drag the 2014 (4,5,6) image into the 2006 map layer as shown here:



Now by selecting the top-most scene and pressing enter we can tab between the image dates and easily view changes in land cover.

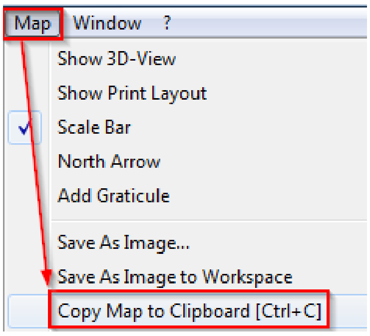
For example the images to the right clearly display the difference between the 2006 and 2014 images in the Bombana mining region.



It is important to understand and be able to identify the difference between land cover change events that are seasonal and temporary, and those that are longer term. In the September 2006 scene above, (late dry season), large areas of burnt grassland can be seen as black scorched areas across the westen half of the image whilst in the 2014 image back burnt areas are no longer obvious, whilst blue/purple areas of mining activity can be clearly seen.

Exercise

In the 2014 scene (early dry season), mined areas appear blue, water filled. Look around the scene; what other long and short term changes can you see? What changes are temporary and what are likely to e long-term?



To identify some land cover change:

Use: Map>Copy Map to clipboard

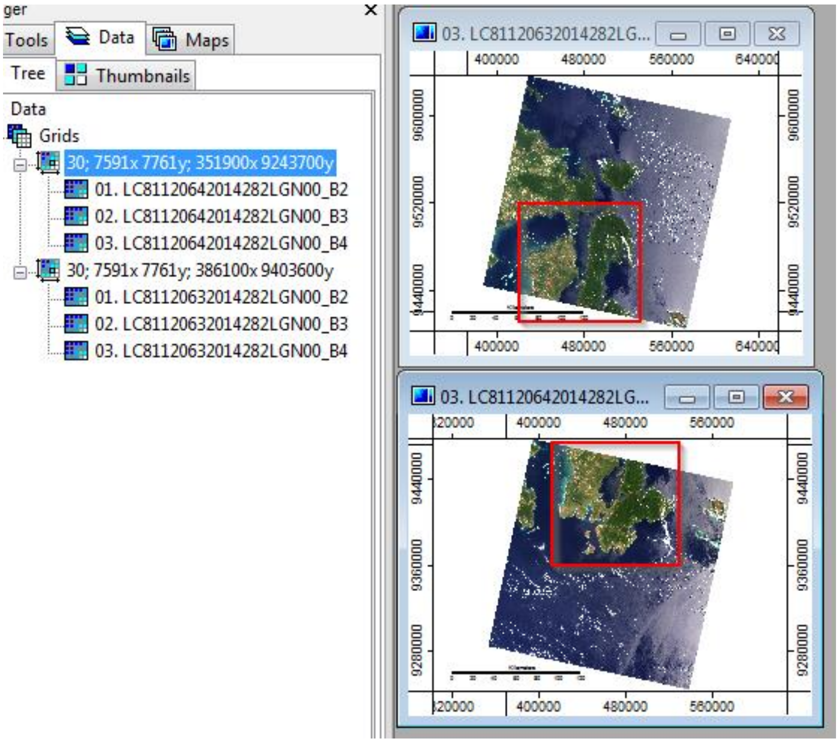
tool to copy the images into PowerPoint. Annotate and explain what you think has caused the land cover change.

6.5 Mosaicking Satellite imagery

Image mosaicking allows you to combine multiple image scenes or tiles. This is very useful if your area of interest sits between two images along a Landsat path or multiple SRTM Elevation data tiles.

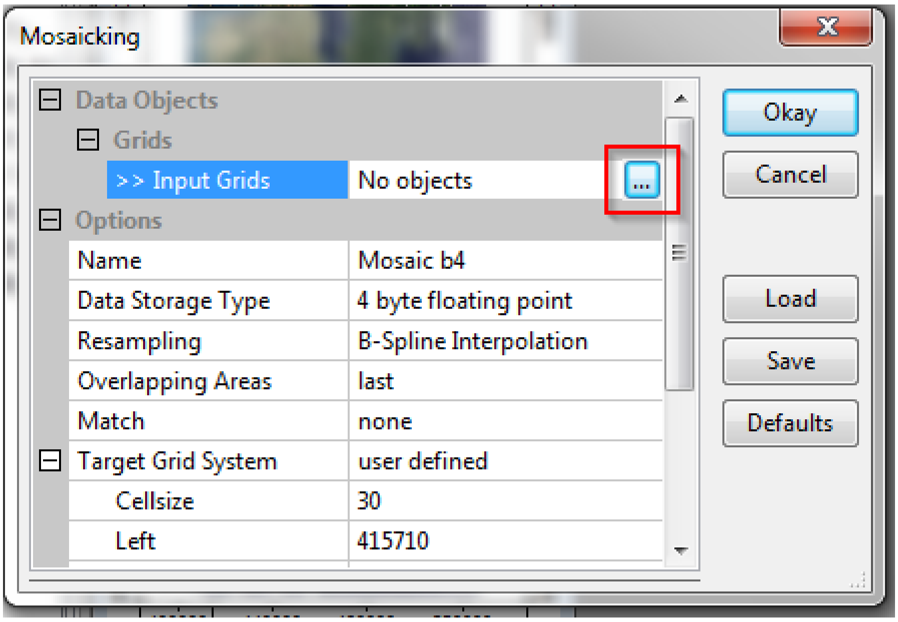
Following is a step-by-step process for mosaicking Landsat scenes.

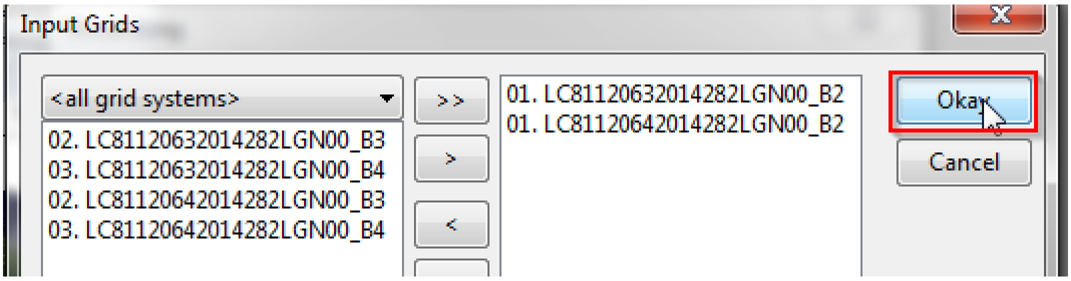
This first example here shows the mosaicking of two consecutive Landsat scenes from the same path (112/063, 112/064) as shown below.



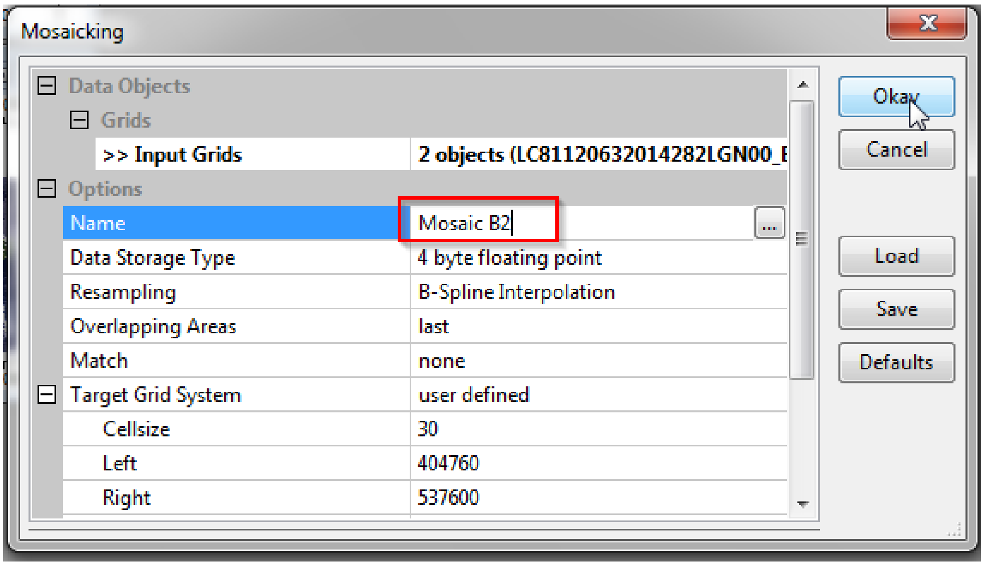
Open the mosaicking tool:

Use: Geoprocessing>Grid >Grid system>Mosaicking

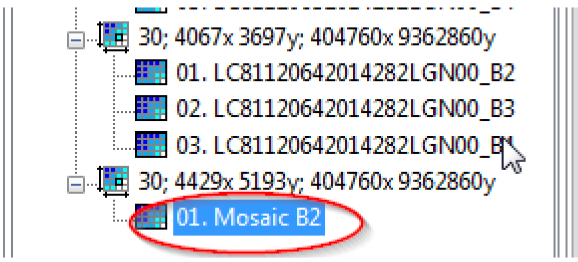




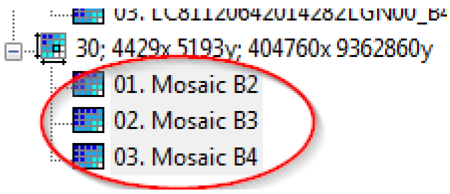
Input two grids of the same image bands from the two scenes. In the example shown here the two band 2 grids have been loaded. Name the output Grid with its band ID.



This will result in a new Grid System with the new mosaicked grid.



Do this for each band from the two Landsat scenes.



Displaying the final mosaicked image as a RGB composite will give you the image shown below.

7. Processing tools

This section describes a number of standard raster image processing tools. These include:

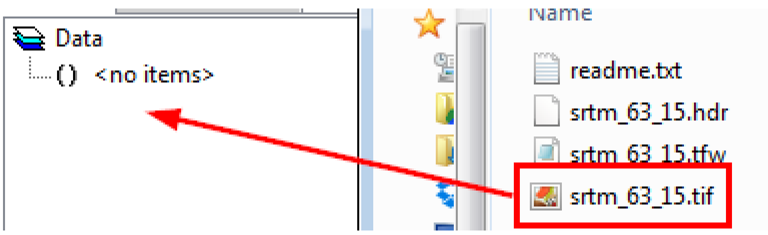
- Coordinate transformation; a way of reprojecting raster and vector files between coordinate systems.
- Clipping raster data with polygons
- Reclassification
- Data import and export; important for getting data into and out of formats for different software.

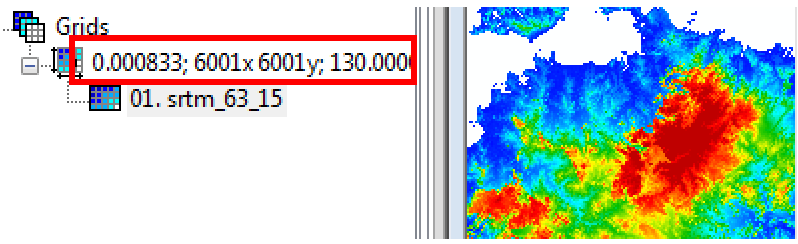
For the Coordinate transformation, clipping and reclassification processes we will use data from the Top-End of northern Australia to produce a grid with slope classes for a national park.

The data provided for this section is: SRTM data in with an accompanying (Kakadu) national park boundary file.

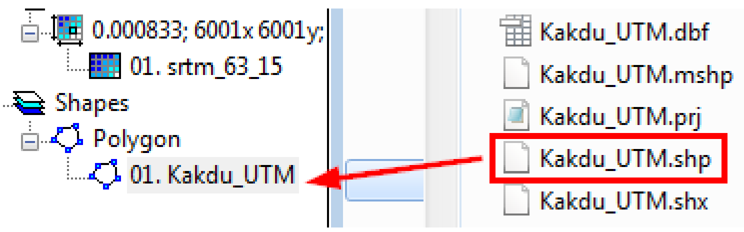
7.1 Coordinate transform

Drag and drop the SRTM data into SAGA. The resulting data is in a geographic coordinate system (Lat/Long).



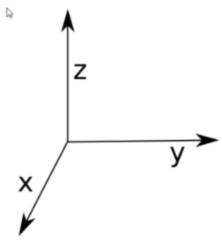


You can load shape file (vector) data into SAGA by simply drag and dropping the *.shp* file.



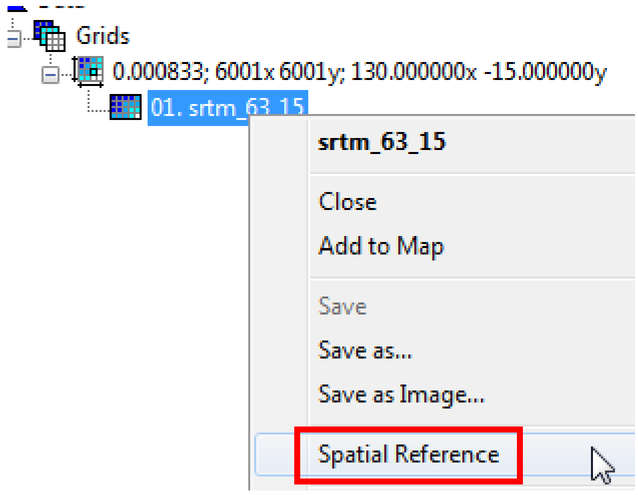
The example here uses a polygon shape file for Kakadu National Park boundary. This file is in a UTM (Universal Transverse Mercator) projection.

To be able to conduct 3D visualisation and terrain modelling elevation data sets need to be in an equal area or metres grid projection. This is so the xy-axis values (metres between cells) is the same as scale as the z-axis (metres above sea level value of each cell).

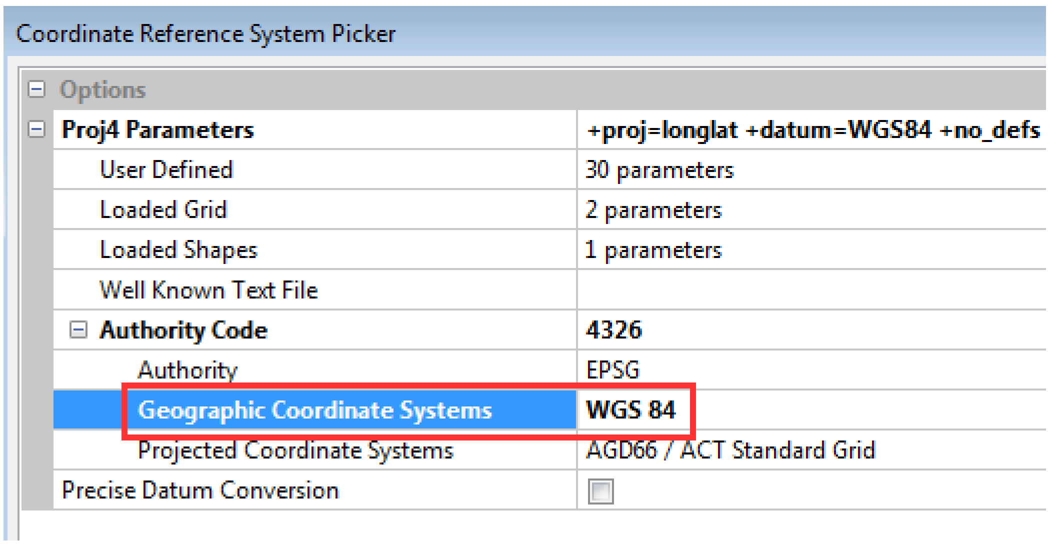


Reprojecting the SRTM data to a UTM projection will also allow us to combine it with the UTM national park polygon file. To reproject first set the projection of the current data set.

Right click on the SRTM grid layer and select spatial reference:



Set the spatial reference to the WGS 84 geographic coordinate system as shown below:

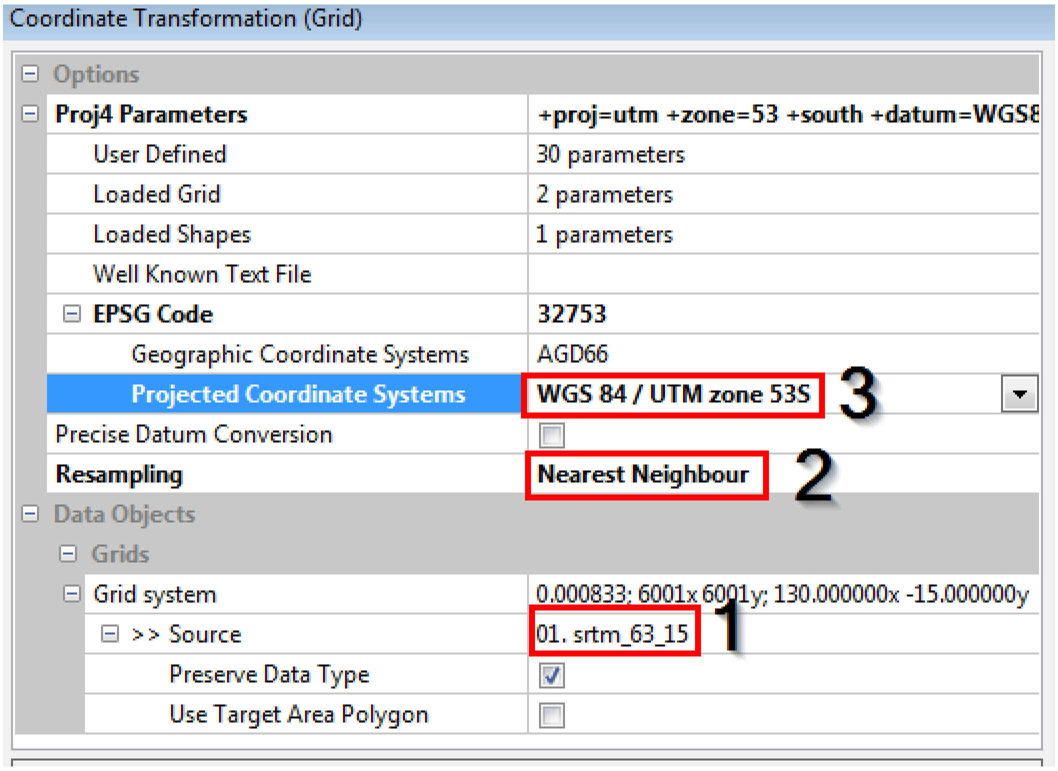


We can now reproject the elevation data into our UTM zone (53).

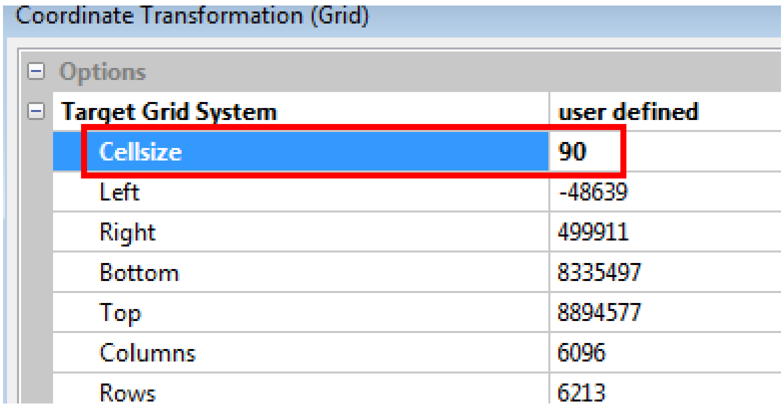
Use: **Geoprocessing > Projection > Coordinate transformation Grid**

In the module dialogue window:

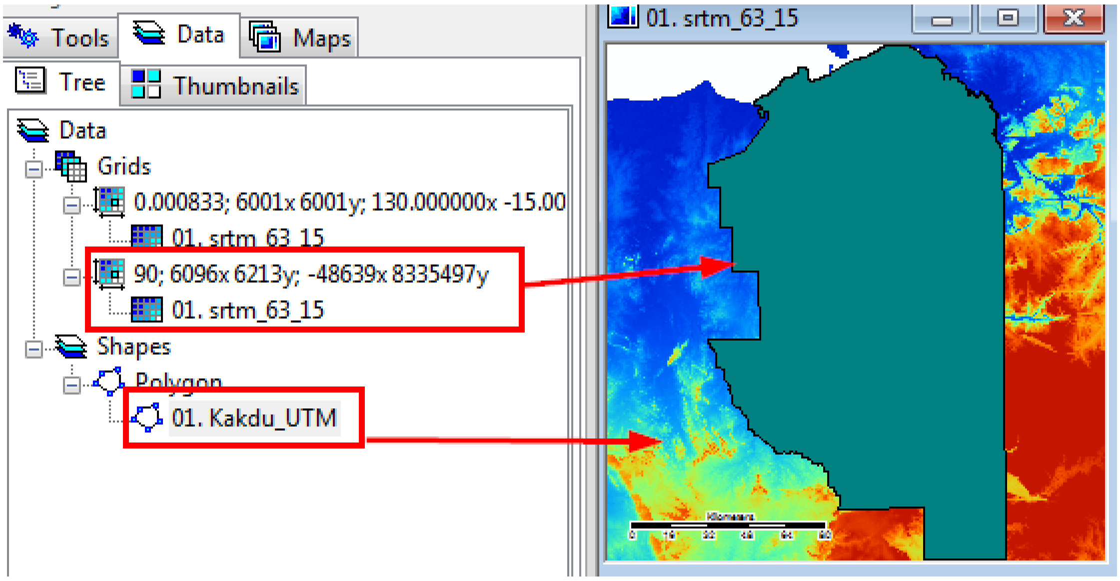
1. Enter the SRTM grid to be projected
2. Set the resampling to "Nearest Neighbour"
3. Set the Projected Coordinate system to UTM Zone 53.



A new dialogue box will appear where you can set the output cell size. For standard SRTM data this should be 90 metres.



You should now be able to display the Kakadu boundary vector data over the top of the new reprojected elevation file.



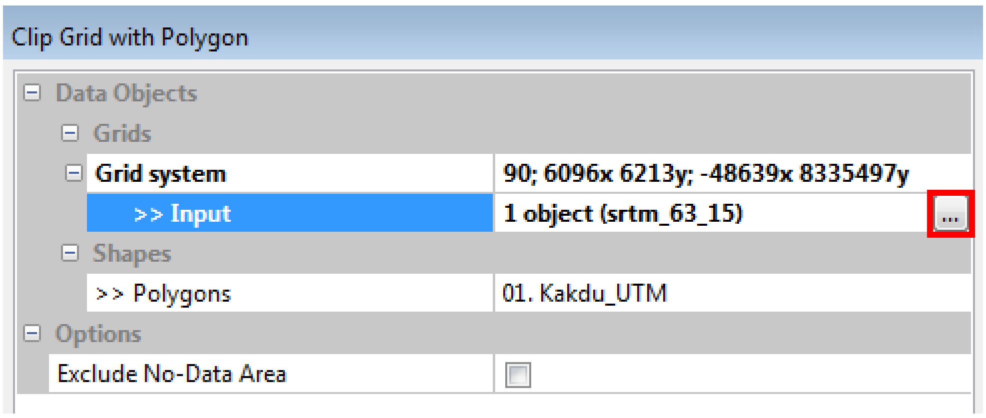
To view the grid data under a polygon file set the fill style to '*Transparent*' in the display settings tab.

7.2 Clipping grids with polygons

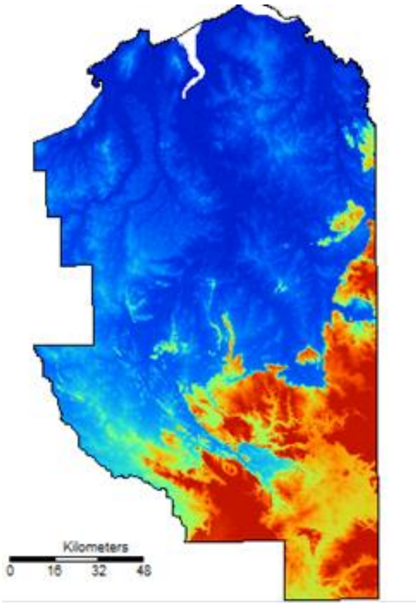
Now we can clip the elevation raster grid with the Polygon data using the *Clip Grid with Polygons* module:

Use: Geoprocessing>Shape>Grid>Spatial Extent>Clip Grid with Polygons

In the dialogue box choose the reprojected SRTM data and the Kakadu polygon.



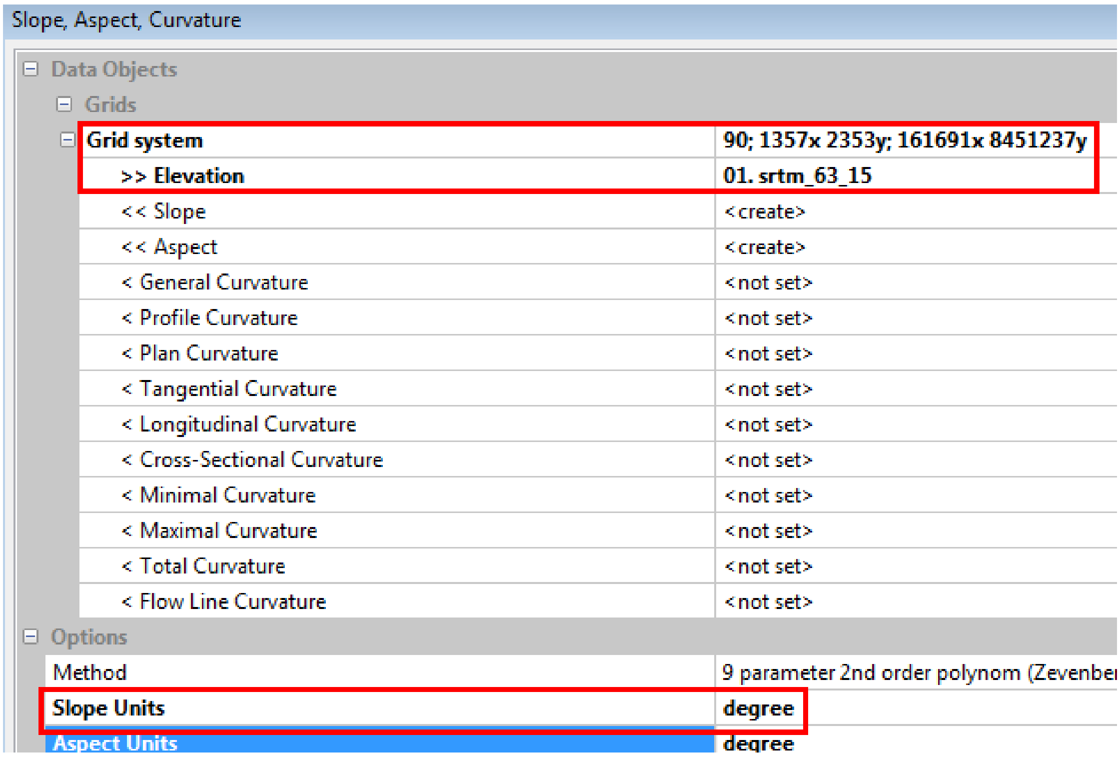
The resulting clipped grid as shown here:



7.3 Reclassification

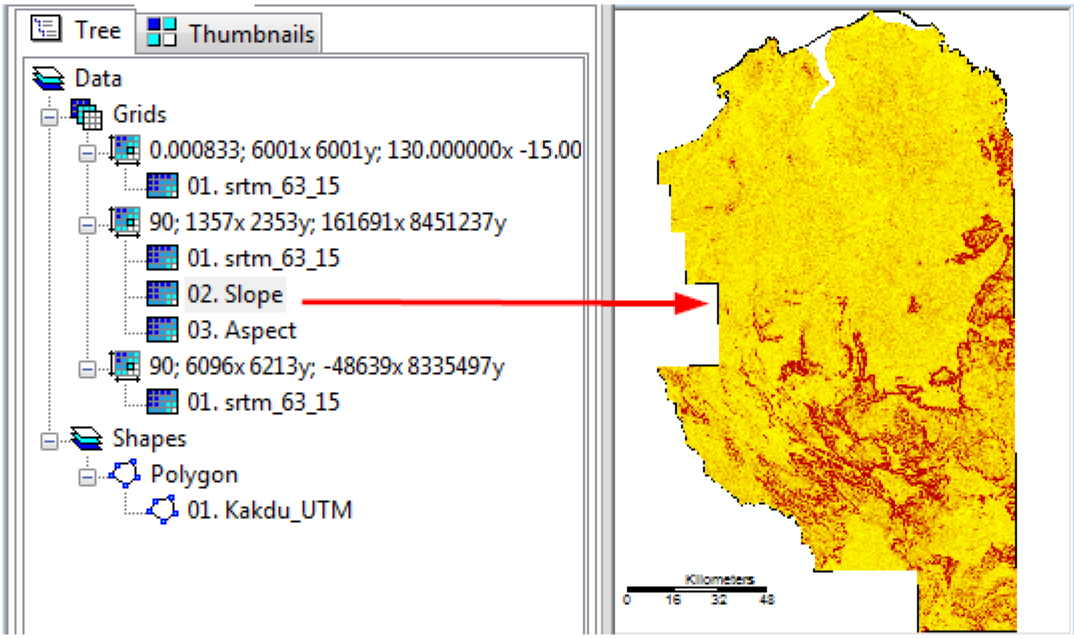
We will now use this elevation dataset to create a slope classification file from Flat to very steep. First, we need to create our slope grid:

Use: Geoprocessing>Terrain Analysis > Morphometry > Slope, Aspect Curvature

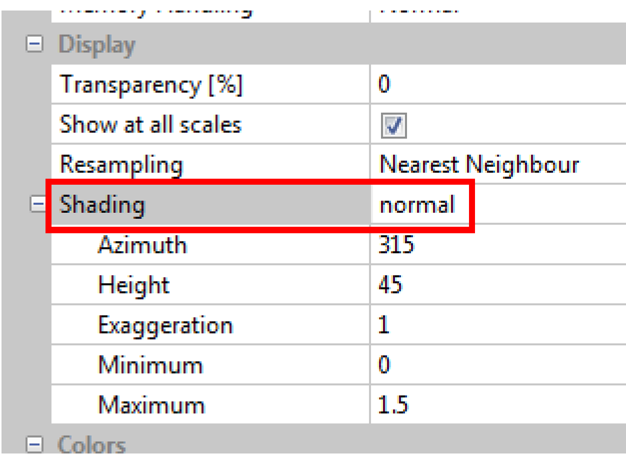


In the dialogue box set the elevation to your clipped elevation data set and the slope units to degrees.

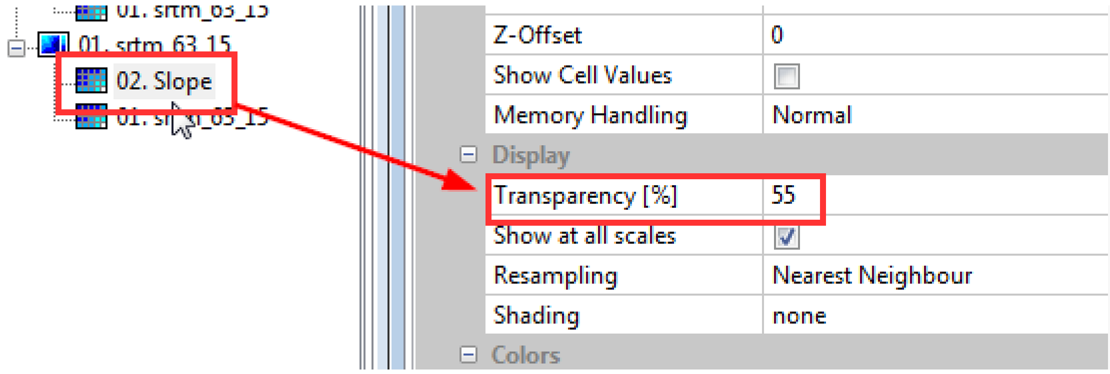
You will get a result as shown below.

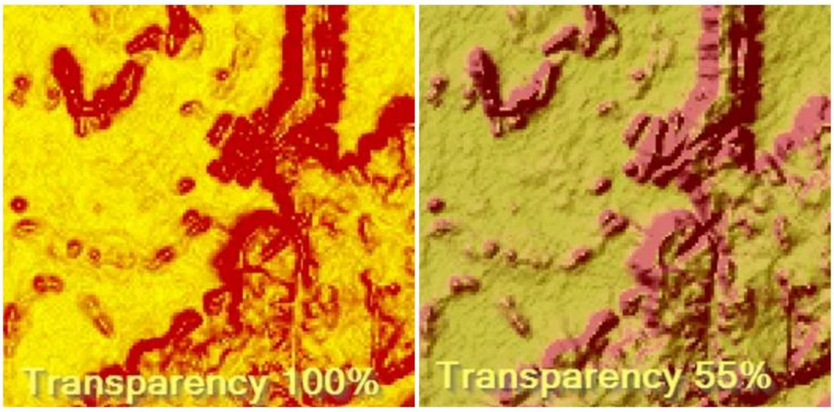


It can be informative to view the resulting terrain metric with hill shading in the background to give a better idea of the values being represented. The easiest way to do this is, with the clipped SRTM elevation data selected, in the settings Tab set the Display Shading setting to normal.



Display the slope grid over the SRTM grid (with shading set) and set the transparency to 55:



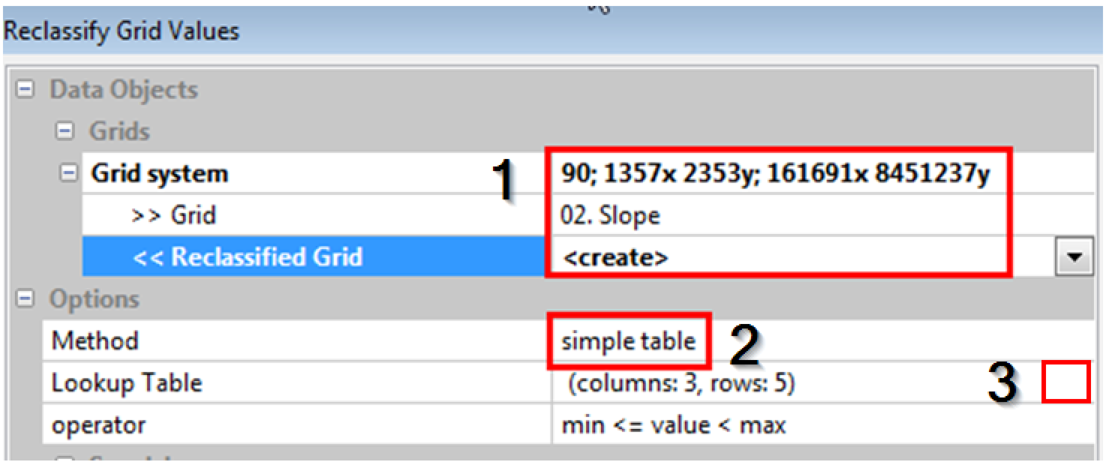


Now reclassify the slope data into slope zones (Classes) using the **Reclassify Grid Values** tool.

Use: Geoprocessing> Grid>Values> Reclassify Grid Values

In the dialogue box:

1. Load the slope grid
2. For the classification method choose “simple Table”
3. Open the table

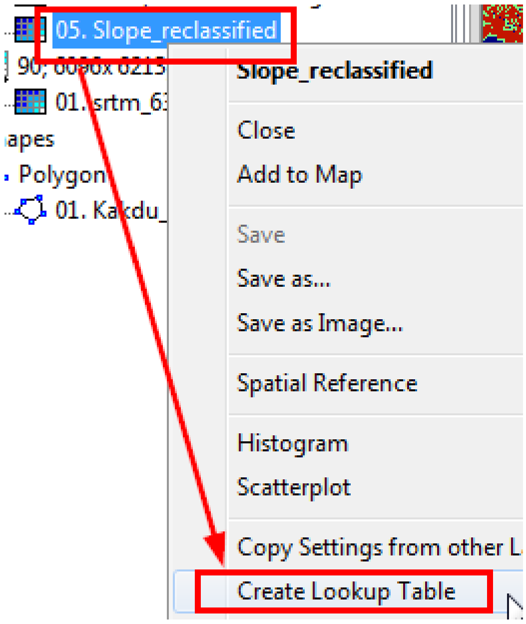


The lookup table set the slope minimum and maximum and the new slope class.

Lookup Table

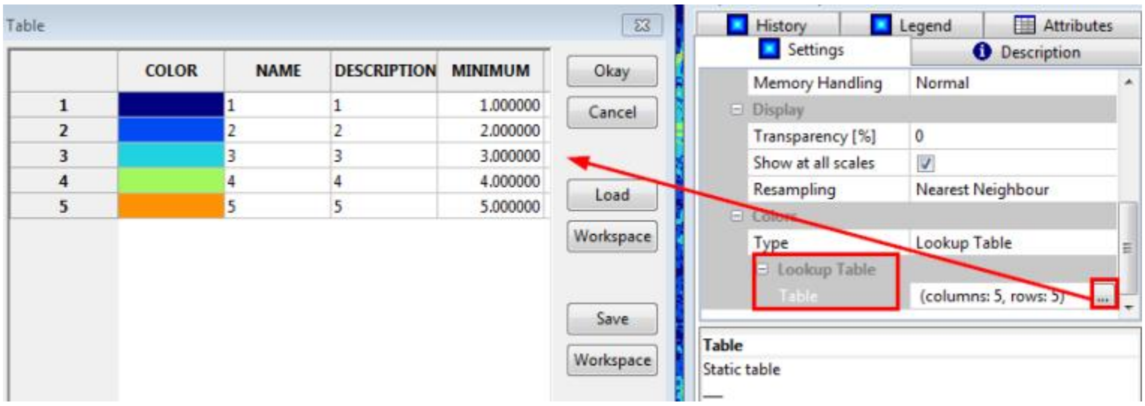
	minimum	maximum	new
1	0.000000	2.000000	1.000000
2	2.000000	5.000000	2.000000
3	5.000000	15.000000	3.000000
4	15.000000	45.000000	4.000000
5	45.000000	90.000000	5.000000

With the new ‘Slope reclassified’ grid right-click and select ‘*Create lookup Table’*

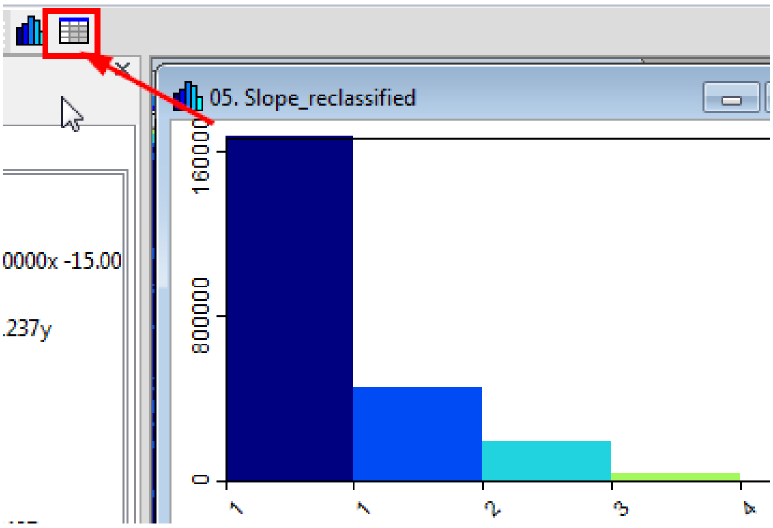


Select *unique values* as the **‘Classification Type’.**

You can see and edit the resulting look-up table and colours in the Settings tab.



Now right click and select ‘Histogram’. This will open a graph showing the number of cells in each class. Clicking the table button opens a table of the grid values.



This table shows the area in square metres of each slope class. Right clicking on the table in the data table allows you to export it to a format readable be excel.

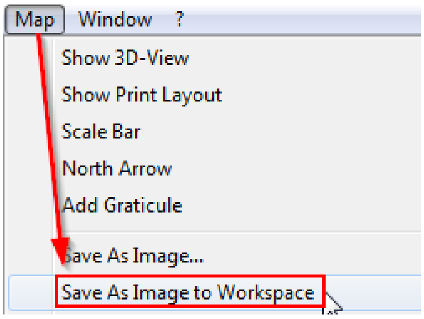
02. Histogram: Slope_reclassified

	CLASS	AREA
1	1	13525760700.000000
2	2	3678299100.000000
3	3	1572007500.000000
4	4	325790100.000000
5	5	1239300.000000

7.5 Exporting an image map

It is often useful to be able to export a map you have created in SAGA for further work in another GIS package or as an image for a report or presentation.

To export a displayed map for printing or field work:

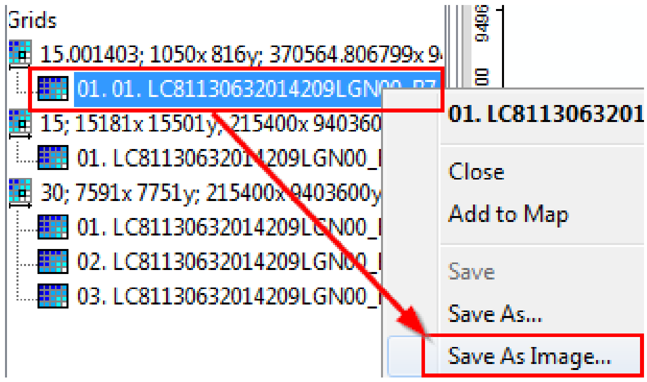


Use: Geoprocessing>Map>Save as image to workspace

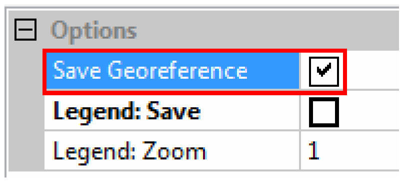
Select a cell size equivalent to the imagery you have displayed (ie Landsat band 8 15m all other bands 30m).

Go to the data tab and you will notice a new grid system and grid layer will have been produced containing the saved image.

Right click on this to save the image to a **tiff** file format.



In the options select **Save Georeference**. This will enable you to open the file in other GIS software in the correct coordinate projection and overlay other data. For example, you may wish to include other spatial data layers and make a map in ARC-Map or Open-Jump



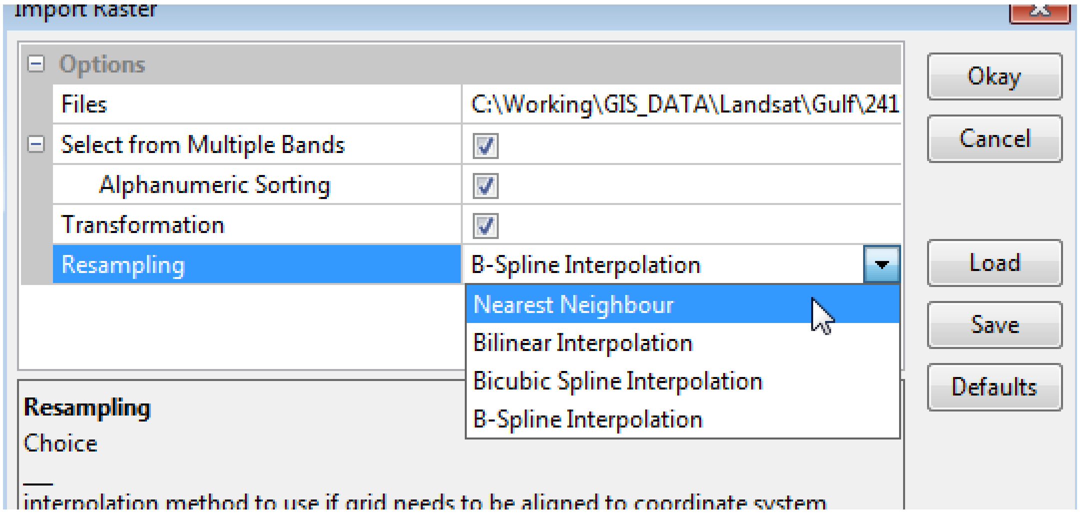
7.6 Importing Data

This section describes how to import Raster (Grid), Vector and field data.

Raster Data

Most raster data formats can be dragged and dropped straight into SAGA GIS; inbuilt import functionality automatically converts data into a SAGA format. However, you may find that dragging and dropping raster data will use a default averaging (B-Spline) resampling method. This will change (average) the values of the imported pixels. To make sure you keep the same values for imported data you will need to change the resampling import method to **Nearest Neighbour** using the import tool as shown below.

Use: Geoprocessing>File>Grid>Import>Import Raster



Vector Data

Shape Files

Shape files can be loaded by either dragging and dropping the .shp file into SAGA or opening the file through the data tab or through the top menu

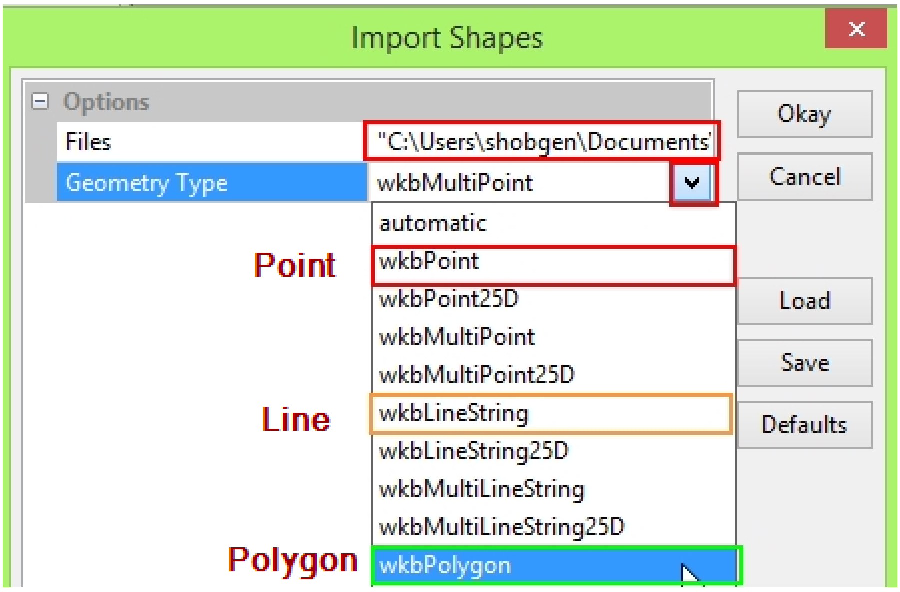
Use: Geoprocessing>File>Shapes>Load

Google Earth KML

If you have made a point, line or polygon in Google Earth using the drawing tools you can import them into SAGA after first saving as a KML file. Then:

Use: Geoprocessing> File> Shapes> Import Shapes

You then need to define the type of KML file you are importing (point, line or polygon) as shown below. This will import the vector layer into the SAGA data tab.



7.7 Field data

The most common way to collect geospatial data in the field for display and analysis in a GIS is using a GPS. It is, however, becoming more common to use smartphone apps connected to the phone's inbuilt GPS functionality to assist data collection. This section describes how you can import field data collected using either a GPS or a smartphone application (Avenza Maps).

GPS Data import.

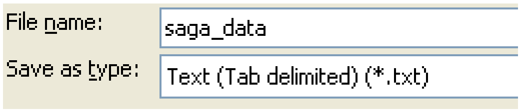
Data collected on a GPS is commonly stored in a GPX format. To import GPX field data simply drag and drop it into SAGA, which will automatically convert the GPX into your collected points and lines.

Another common and effective way to collect data with field information is using a pen and paper and manually recording a point location from a GPS and a set of standard attributes for that location. This data can then be entered into an excel table and imported into SAGA.

For example the excel table below was produced from hardcopy field notes from a survey in Indonesia.

point	easting	northing	vegetasi	% tutupan	warna tanah
1	593833	8885774	B	80	h
2	585459	8885076	H	40	c
3	588600	8893989	TK	0	w
4	597132	8887804	TK	0	w

To get this data into SAGA first save from excel as a *.csv* or *.txt* (tab delimited format) file.

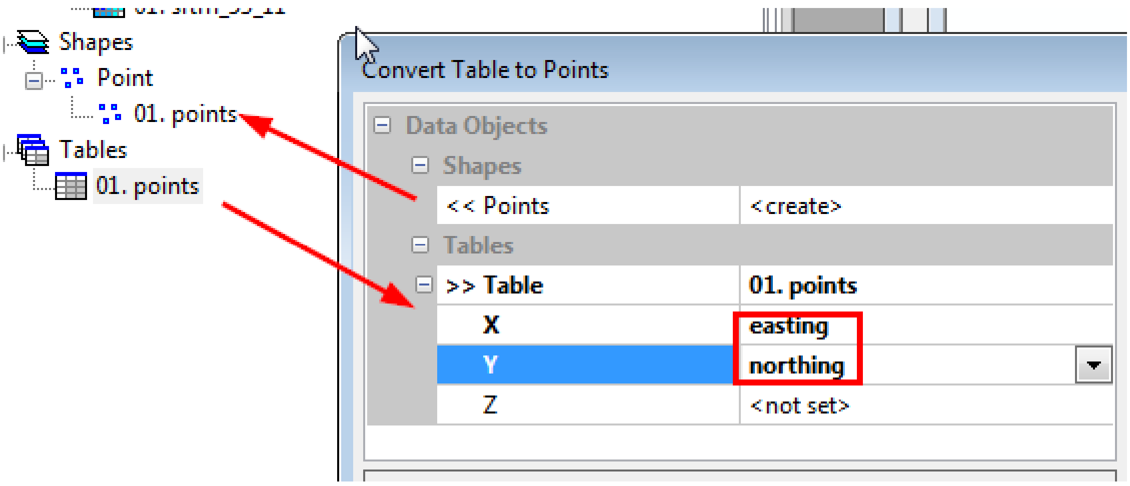


Then drag and drop this file into SAGA. It will appear as a new table layer in the data tab.

To import this as attributed point data use:

Use: Shapes>Conversion>Convert table to points

Choose the new table layer as the table to be converted and X as your Easting (or Latitude) and Y axis as you Northing (or Longitude) values.



This will then add a new point data layer with associated field attributes.

Export map image to field data collection app.

In this section, we will look at how to transfer image maps produced in SAGA-GIS to the smartphone [Avenza Map](#) application for collecting point field data.

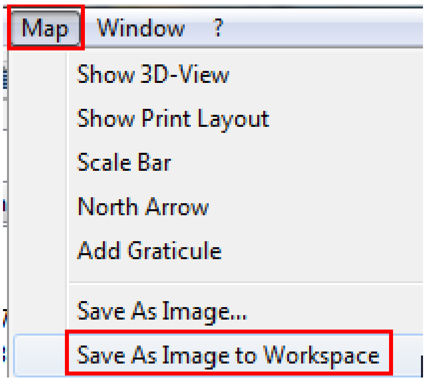
Using Avenza it is possible to navigate in the field with reference to an image map you have created in SAGA. This can be very useful if you need to collect field data for a satellite image land cover classification and/or if there is a feature on a satellite image that you need to 'ground truth'. Avenza also allows you to collect location data and attribute each point with field information and link them to site photos.

The process involves the following seven steps:

1. Import satellite imagery into SAGA in a geographic (lat/long) format
2. Zoom to your field area of interest
3. Save image to workspace
4. Save as SAGA grid
5. Save as image
6. Zip the resulting '.tiff', '.twf' and '.prj' files
7. Import .zip file into Avenza

1. Import the Landsat imagery using Geographic Coordinates as the coordinate system, and nearest neighbour as the interpolation method.

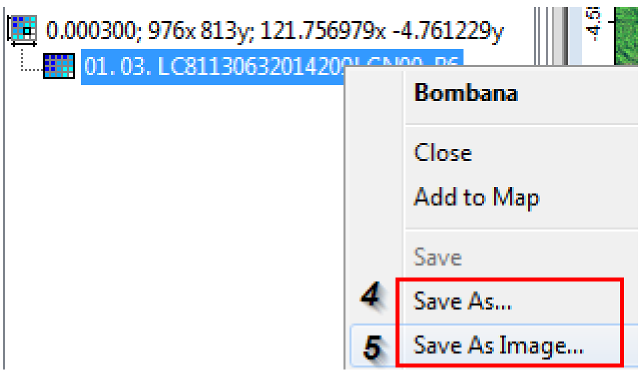
2. Zoom to your areas of interest



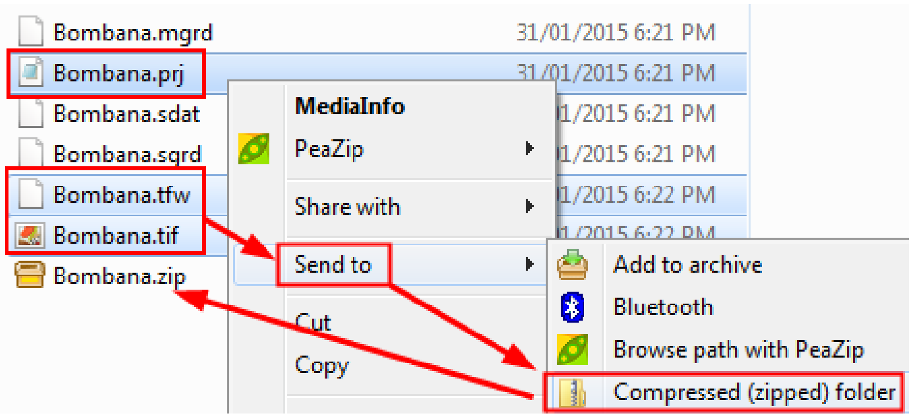
3. **Use: Map>Save As image to workspace,** Set the cell size to 0.003 (~30m for Landsat imagery). This will save your area of interest as a new layer in the data tab.

4. Right click on the new image layer in the data tab and save as SAGA Grid (.sgrd). Make sure you give it a new name describing the area of interest.

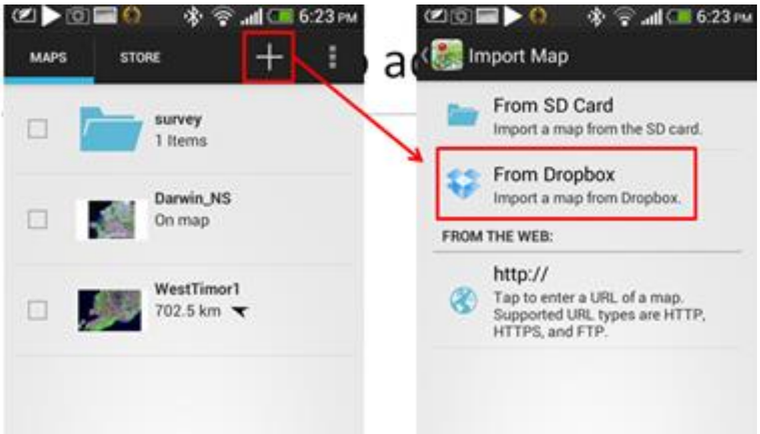
5. Right click on the new image layer in the data tab and Save As Image and save it as a GeoTiff. Make sure you give it the same name as you gave the SAGA Grid and save the Georeference.



6. Go to the folder where you saved the SAGA Grid and image files and select the.tiff, .twf, .prj files, right click and zip them.



7. You can now import this zipped file into PDF-MAPS via – email, dropbox or your device's SD card.



Try downloading Avenza maps for your phones and some Landsat imagery for where you live and test it in the field.

Note that to use Sentinel-2 data for with Avenza maps it first needs to be reprojected into a geographic (lat.long) coordinate system from its native UTM format.

8. Satellite Image classification

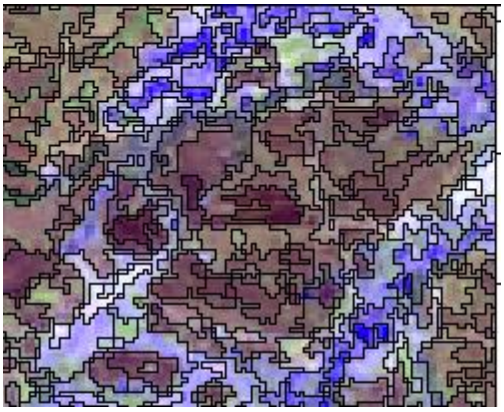
Image classification is the process of grouping image pixels into similar classes. These classes are usually based on a land cover marine environment type. Classification techniques can however also be used be monitor environmental changes such as mapping burnt areas. There are two main forms of classification commonly practised (1) pixel-based classification and (2) object-based classification.

Pixel based classification looks at the spectral response or digital numbers for each pixel and uses one of a number of mathematical methods assigns them into a class. There are two methods by which pixel classes can be assigned; **unsupervised and supervised classification.**

Classes can be assigned automatically based on a grouping algorithm choosing how a pixel should be assigned. Generally, the only user inputs into this process are to choose the image bands to be used in the assignment process and the number of eventual output classes. This method is commonly referred to **as unsupervised classification**. These classes are usually assigned a Land cover class by reference to ground data and the satellite image post-classification. In SAGA unsupervised classification is referred to as **cluster analysis.**

In contrast **supervised classification** requires a user to define 'training sites' of known land cover type. Pixels are then grouped into classes based on the spectral data from the training site pixels. Pixel based classifications are fast and efficient; they can, however, result in errors that are hard to adjust or edit. Unsupervised pixel classification is used in the 'monitoring land cover change' tutorial in this manual.

Object-based classification, rather than looking at individual pixels, groups pixels into regions (segments) of similar spectral properties. These segments are usually in the form of polygons attributed with statistical information about the mean spectral characteristics of the region. These objects can then be classified using unsupervised or supervised techniques as with pixel-based classifications. Object-based classification allows more flexible editing of classified areas and allows more sophisticated methods incorporating of segment shape and context.



This section has three classification examples:

1. An OBIA based rapid classification of a large mine in Lombok.
2. A pixel based unsupervised classification of land cover in Kupang Bay (West Timor).
3. An OBIA based supervised classification of land cover of the same area.

8.1 Object-based classification of Sentinel 2 imagery.

Rapid mapping of a mine area extent

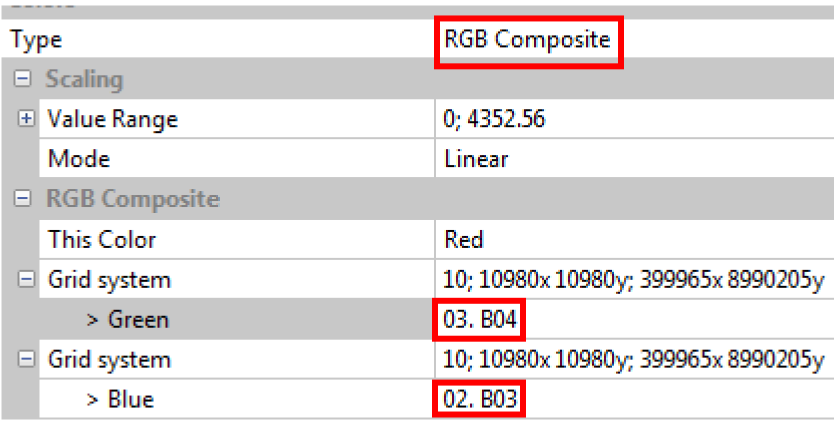
Demonstrated in this exercise is a rapid way of producing an accurate classification and area map of a single feature. In this case it is a large mine site on Lombok Island in Indonesia. There are five main steps required:
Step 1: Display Sentinel 2 imagery downloaded from remote pixel (remotepixel.ca)
Step 2: Clip to your area of interest
Step 3: Run the image segmentation
Step 4: Delete non-mine site polygons.
Step 5: calculate area.

For this section we will be using data: Sentinel 2 imagery Lombok (73mb).

Access video tutorial for this section here: https://sagatutorials.wordpress.com/segmentation-and-sentinel-2-imagery/

Display and clip

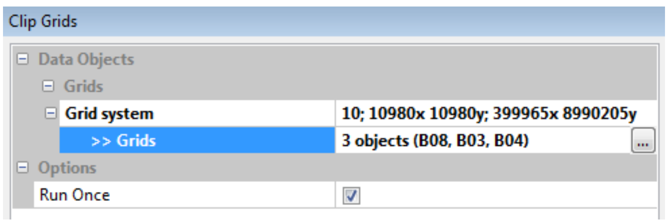
Open the downloaded Sentinel image bands into SAGA by simply dragging and dropping them into SAGA. They will automatically open in a UTM coordinate Grid System. We will only need bands 2,4,8 for this classification. Once they are open in the data tab display them as an RGB composite



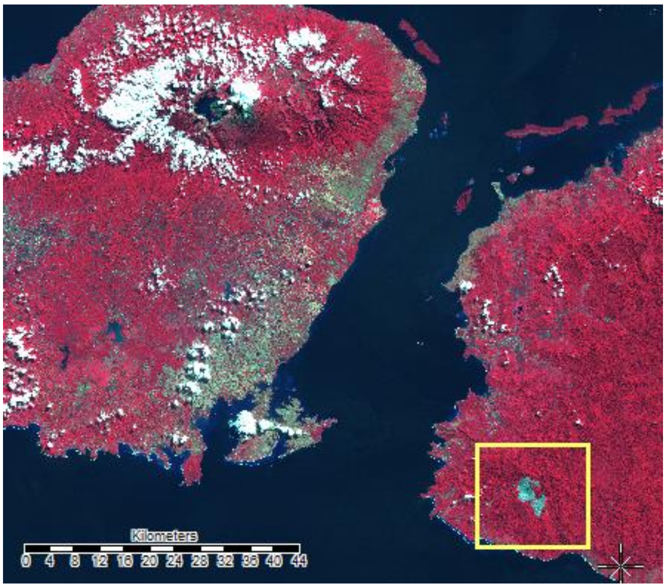
We now need to crop the image to our area of interest (ie the mine site).

Use: Geoprocessing>Grids>Grid System > Clip Grids interactive

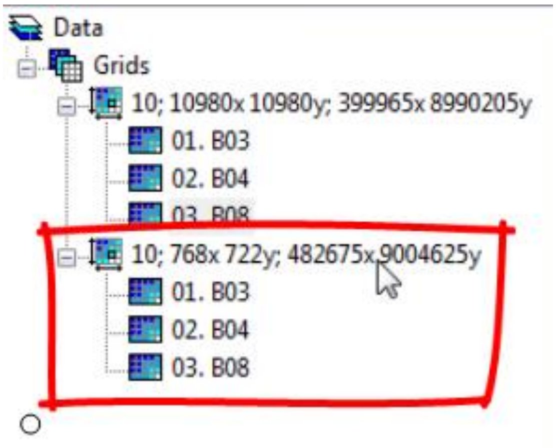
Select the 3 sentinel bands as our input grids.



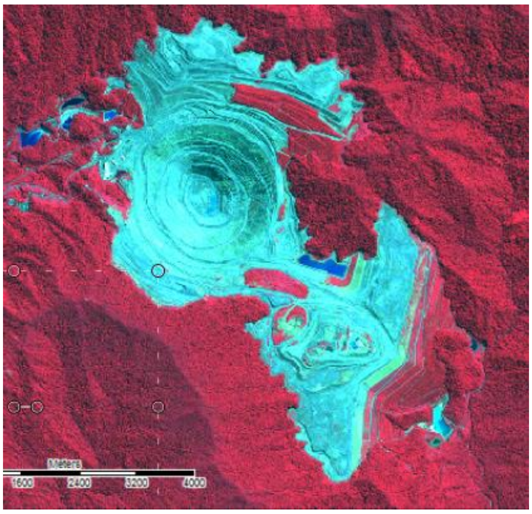
Using the pointer tool draw a box around the mine area.
Click OK to select the default properties on the pop-up clip window:



You will see a new grid system with a smaller extent has appeared. You can now delete the old grid system containing the whole image.



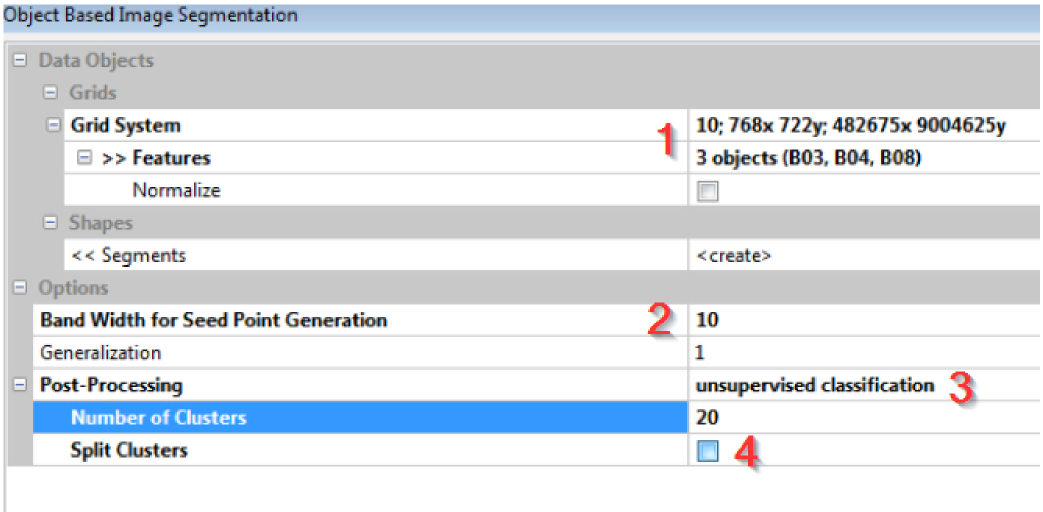
You will now need to display the image as an RGB composite again. First display band 8 then change the display settings in the settings TAB.



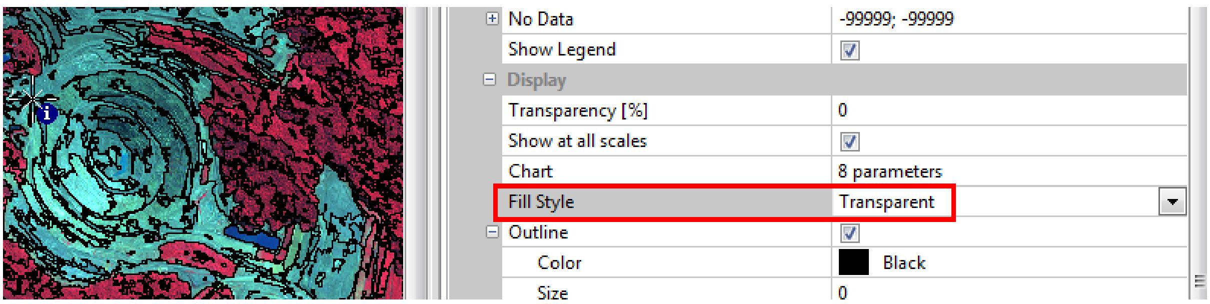
Now we can run the Segmentation process:

Use: **Imagery>Segmentation>Object Based Image segmentation**

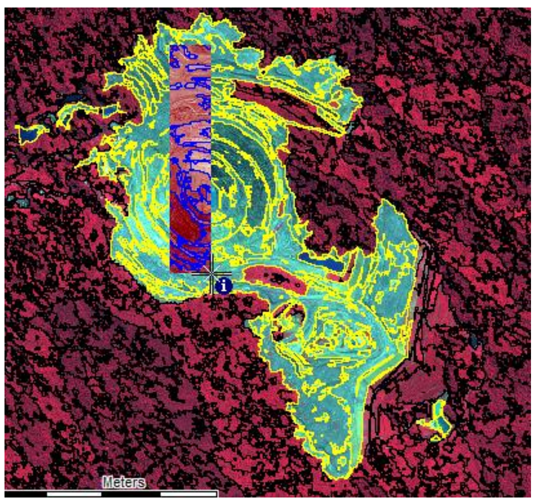
1. Select the 3 Sentinel image bands
2. Make the image band
3. Choose ‘Unsupervised Classification’ for your post processing
4. Deselect split clusters.



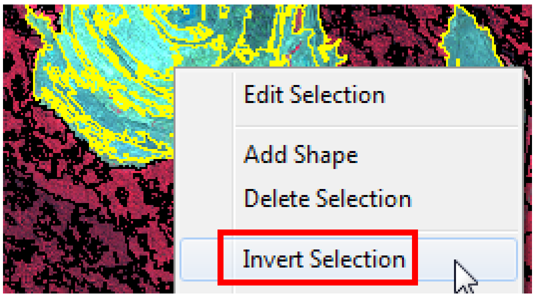
Display the resulting polygon segmentation layer over the image and set the fill style to ‘**Transparent’** in the settings tab:



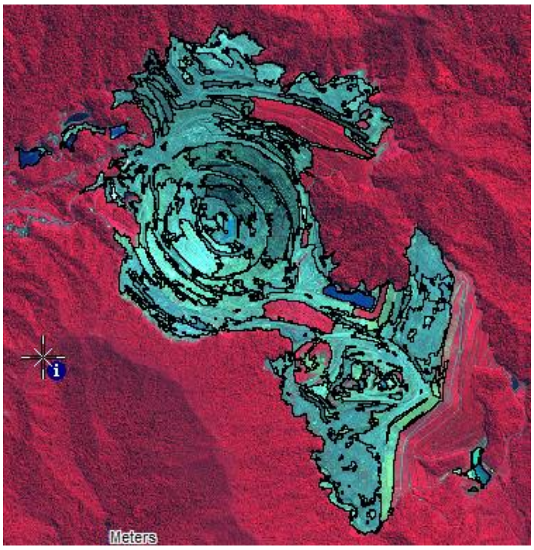
Now using the pointer tool drag a box across polygons within the mine area. This will automatically select all polygons of the same class which should result in all the mine areas being selected.



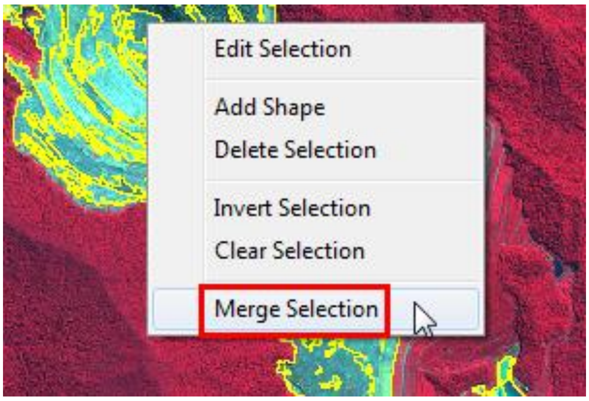
Now right click and select **Invert selection.** This will result in all the non-mine area polygons being selected. Delete these to leave only the mine polygons by either right click and 'clear Selection' or pressing delete on the key board.



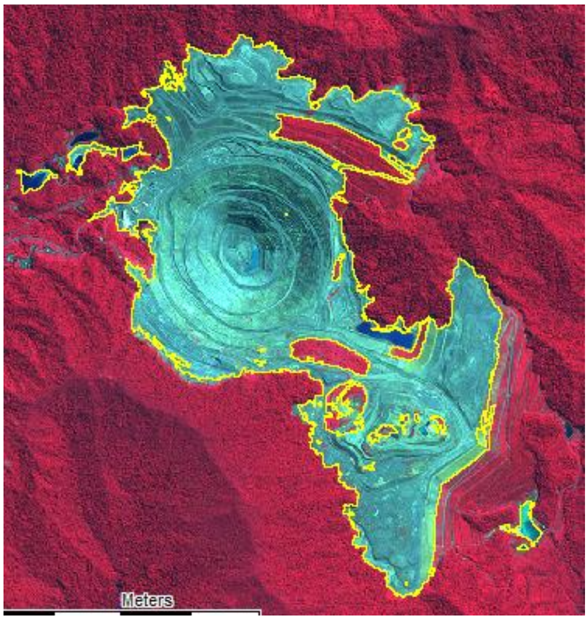
This should result in just the mine area polygons remaining as shown to the left.



Now we will '**merge'** the remaining polygons to produce one mine area polygon. Select all remaining polygons, right click and select '**Merge'**.



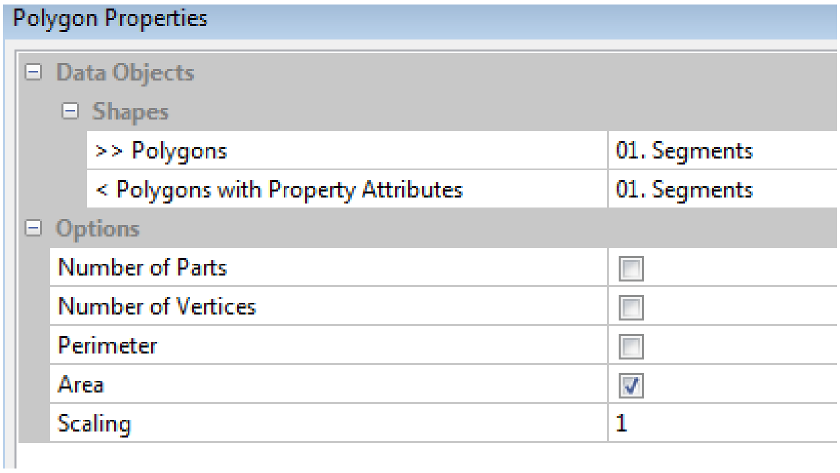
This should result in just one mine area polygons remaining as shown here:



We can now calculate the area of this polygon:

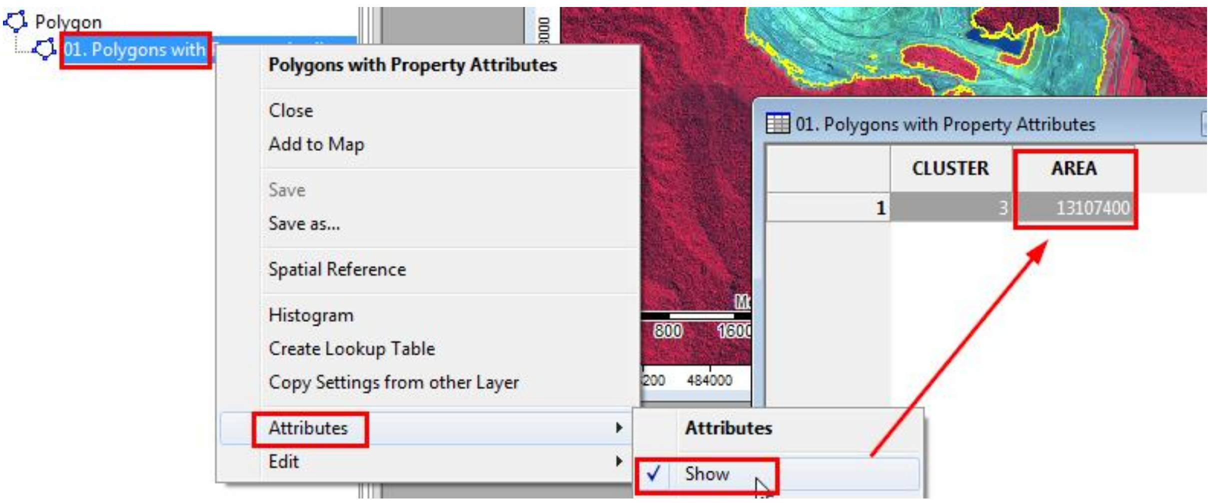
Use: Geoprocessing>Shapes>Polygons>Polygon Properties

Select segments as our input and output polygon. This will produce a new attribute in the polygon table of the area in square metres. To calculate area directly in hectares, change the scaling factor to 0.0001. In the example below, we will first create the m^2 area then use a table calculator to create Ha.



Once you have run the property attributes tool open the attribute table by right clicking on the attribute layer and selecting: **Attributes>>Show**

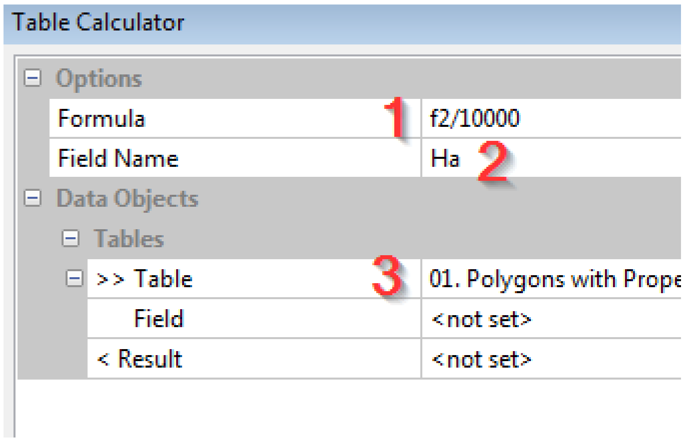
The table will appear showing the area in m^2.



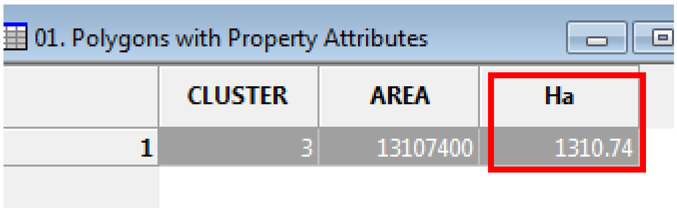
To add another field in the table displayed as hectares:

Use: Geoprocessing>table>calculus>table calculator

1. Set the formula to f2/10000. This divides the second attribute field by 10000.
2. Set the field name to Ha.
3. Set the input table to your input segmentation polygon.



The new area in hectares attribute will then appear:



8.2 Unsupervised Classification

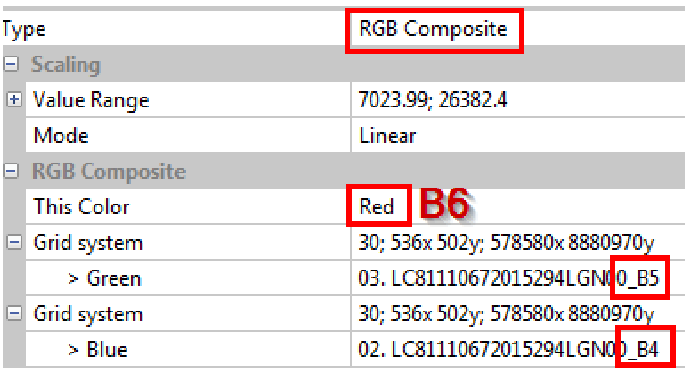
This exercise shows a simple unsupervised classification technique for grouping areas of similar spectral response. For this exercise we will classify a coastal area in west Timor containing ocean, mud flats, grassland and forest.

The data for this section can be downloaded already clipped to our area of interest here: Kupang Bay Landsat 8 Clipped (2.2mb).

There are four main steps:

1. Load and display the imagery
2. Conduct our unsupervised classification
3. Reclassify our unsupervised classes to land cover classes
4. View the area statistics.

Load the image bands and display the image as an RGB composite with Band 6 and Red Band 5 as Green and Band 4 as blue.



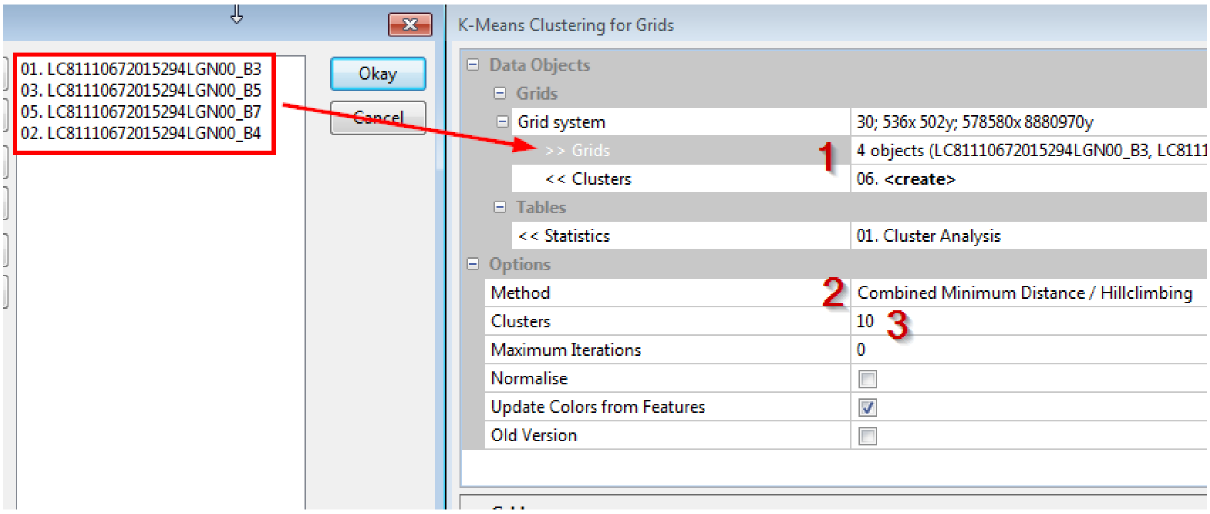
Type	RGB Composite
Scaling	
Value Range	7023.99; 26382.4
Mode	Linear
RGB Composite	
This Color	Red B6
Grid system	30; 536x 502y; 578580x 8880970y
> Green	03. LC81110672015294LGN00_B5
Grid system	30; 536x 502y; 578580x 8880970y
> Blue	02. LC81110672015294LGN00_B4

You should get a display like this:

To conduct the supervised classification:

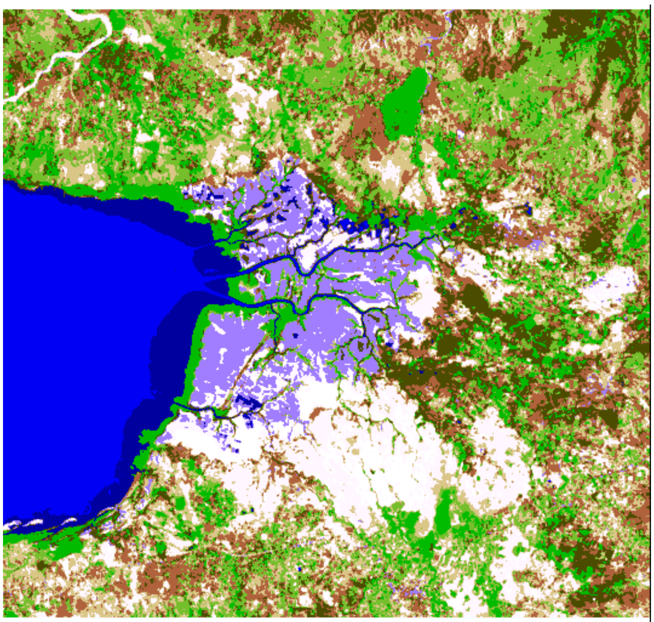
Use: Imagery>Classification>Unsupervised>K-Means Clustering for grids

1. Select bands 3,4,5,7 as your input bands
2. Choose a classification method
3. Set the number of clusters (Classes) to 10.



If you have **'update colours from features'** checked the output classes will be similar to your first three input image colours. Make sure band five is the second input grid in your list as this will assure that you get vegetation as green on your output classes.

The outputs will look something like the image to the right:



Try changing the bands and number of classes you use for your classification. You will notice different bands produce different classification results.

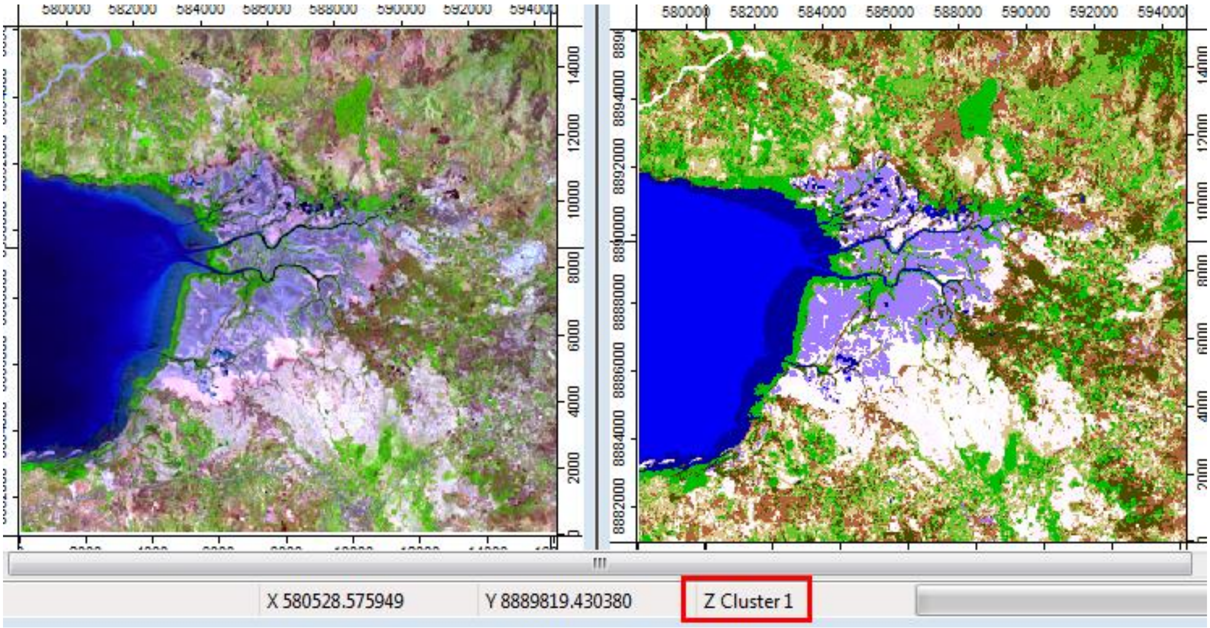
The next step is to reclassify these arbitrary classes into land cover classes. To do this you need to have good knowledge and field data for the area you are trying to classify so you can define what output classes are appropriate and what feature on the image represents these classes.

For this exercise we want to reclassify the ten classes to the following six land cover types:

1. Ocean
2. Mudflat
3. Open Land
4. Grass
5. Open Forest/Scrub
6. Closed Forest

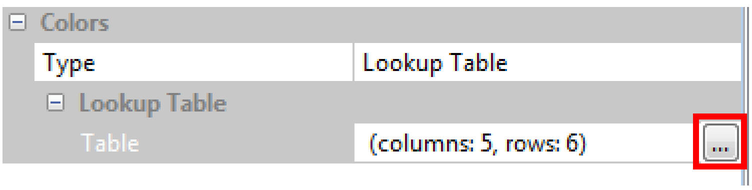
To determine which features represent which land cover type you display the RGB composite image next to the cluster image. Using the pointer tool, move it over the classified image display the cluster value displayed at the bottom of the screen.

In the image below the RGB composite display is on the left and the classified image on the right. the cluster value for an area the pointer is over is shown at the bottom.

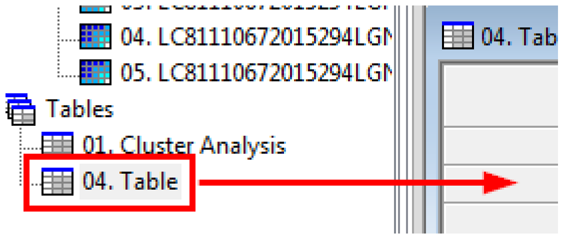


By examining the image and comparing it to the clusters you should be able to determine the main land cover type of each cluster. Once you have done this open the classification (Cluster) image lookup table and edit the description of each class to fit what you have found.

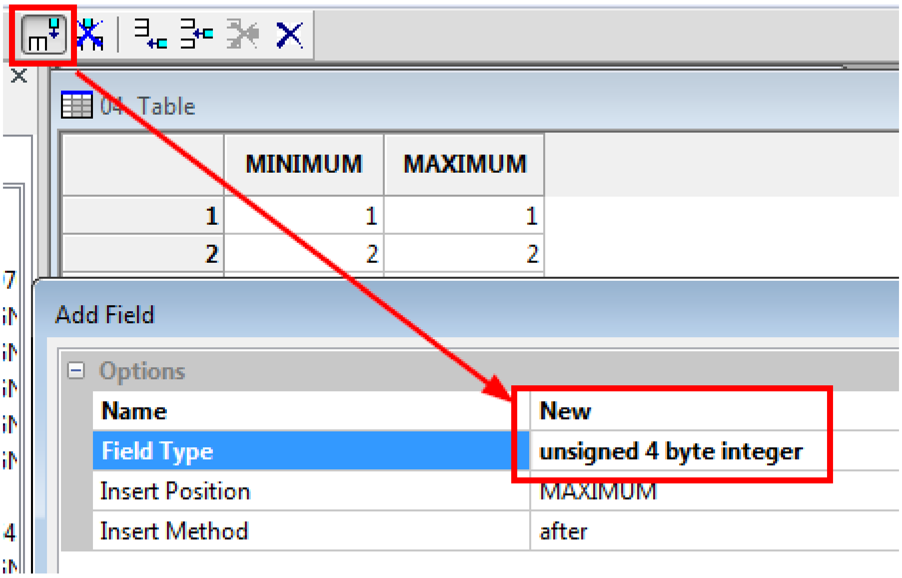
We will use this table to make a reclassification look-up table.



Save the table to which you have added the Land Cover description to the SAGA data tab by pressing the Workspace button. You will see a new table appear as shown here:



Open the table and press the '*add field*' button on the top menu bar as shown here. We want to add a new field that will contain our land cover class value.

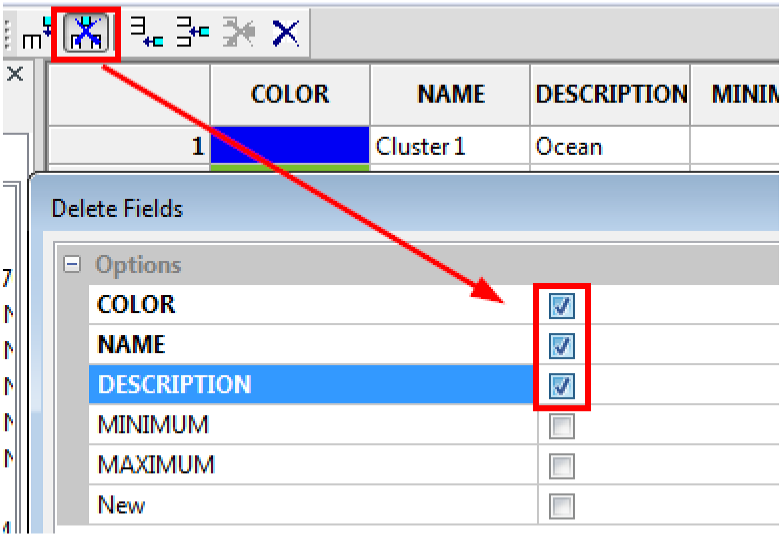


Name the field **'New'** and make it an integer (number) value.

Assign the '**new** ' field the land cover class value for each cluster value as shown below:

COLOR	NAME	DESCRIPTION	MINIMUM	MAXIMUM	New
	Cluster 1	Ocean	1	1	1
	Cluster 2	Open Forest	2	2	2
	Cluster 3	Grass	3	3	3
	Cluster 4	Bare Ground	4	4	4
	Cluster 5	Ocean	5	5	1
	Cluster 6	Bare Ground	6	6	4
	Cluster 7	Mud Flat	7	7	5
	Cluster 8	Grass	8	8	3
	Cluster 9	Forest	9	9	6
	Cluster 10	Grass	10	10	3

Once you have done this delete the Color, Name and Description fields using the delete field button.



This should result in a table as shown here that will be used as our reclassification table

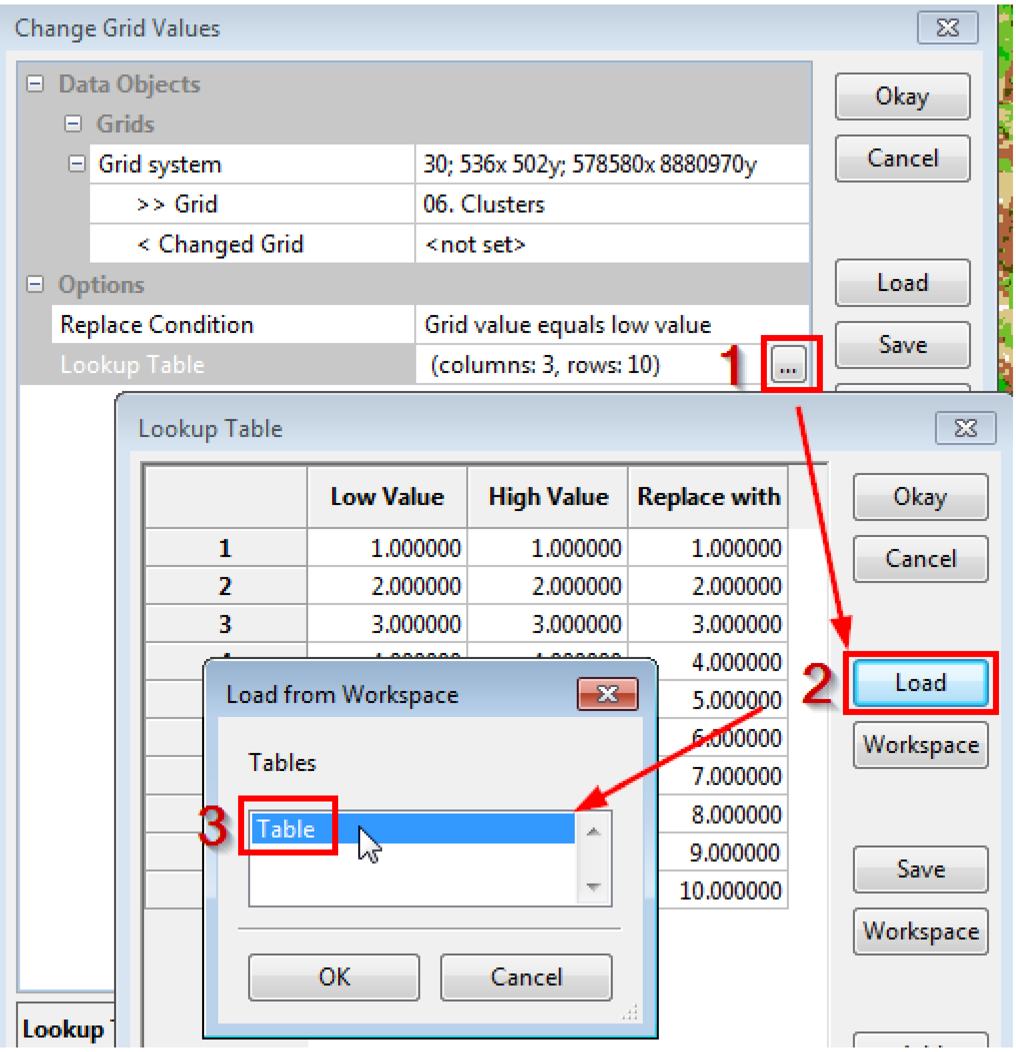
MINIMUM	MAXIMUM	New
1	1	1
2	2	2
3	3	3
4	4	4
5	5	1
6	6	4
7	7	5
8	8	3
9	9	6
10	10	3

To reclassify the cluster grid:

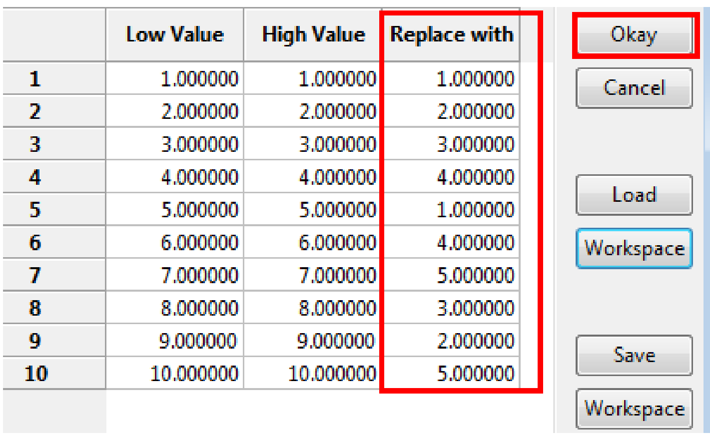
Use: **Geoprocessing>Grid>Values>Change Grid Values**

Select the cluster grid to reclassify then:

1. Open the reclassification look up table
2. Press the load button
3. Select the table you have just modified from the workspace

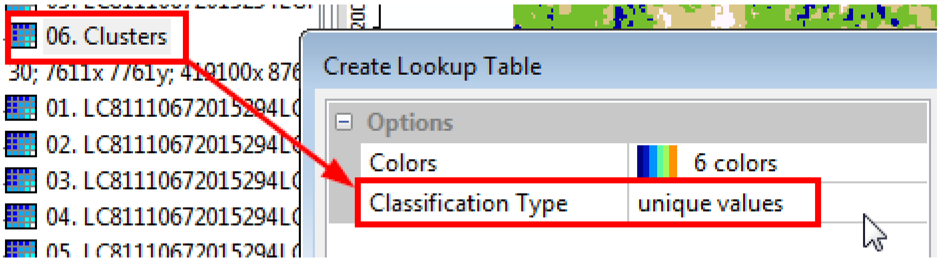


This will load your table; click '*Okay*' to run the reclassification.



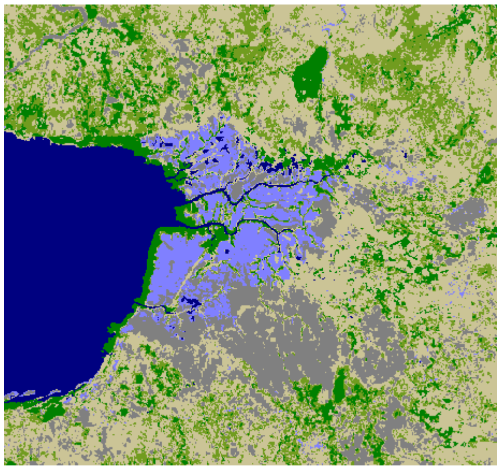
	Low Value	High Value	Replace with
1	1.000000	1.000000	1.000000
2	2.000000	2.000000	2.000000
3	3.000000	3.000000	3.000000
4	4.000000	4.000000	4.000000
5	5.000000	5.000000	1.000000
6	6.000000	6.000000	4.000000
7	7.000000	7.000000	5.000000
8	8.000000	8.000000	3.000000
9	9.000000	9.000000	2.000000
10	10.000000	10.000000	5.000000

Right click on the resulting change grid to create a lookup table with unique values. This will allow us to colour and name each class.

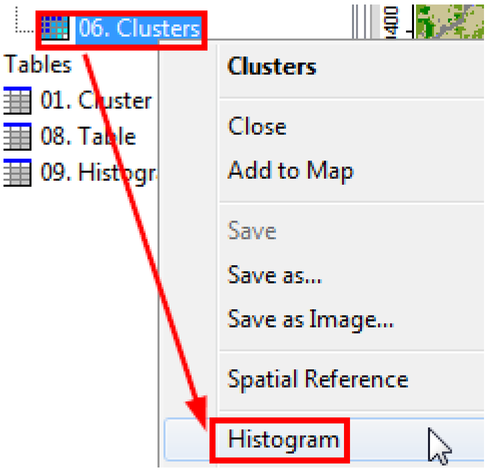


Change the colour and name of the reclassified grid to match the land cover classes:

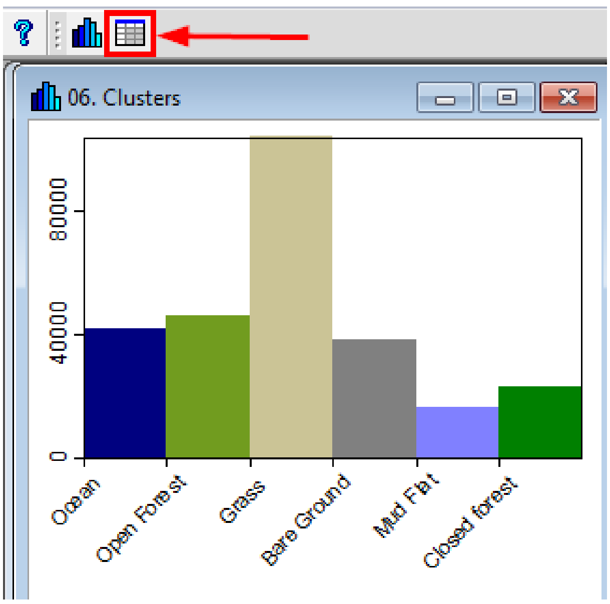
COLOR	NAME	DESCRIPTION	MINIMUM	MAXIMUM
(dark blue)	Ocean	Laut	1.000000	1.000000
(olive green)	Open Forest	Semak	2.000000	2.000000
(beige)	Grass	Rumput	3.000000	3.000000
(grey)	Bare Ground	Tanah K	4.000000	4.000000
(light blue)	Mud Flat	Rawah	5.000000	5.000000
(green)	Closed forest	Hutan	6.000000	6.000000



It is now also possible to view the area values of each class: Right click on the reclassified grid and Select Histogram:



The histogram window shows the number of cells for each class.



Clicking the table button in the top menu bar above the histogram opens a table showing the area in m^2 class.

CLASS	AREA	COUNT	CUMUL	NAME
1	37823400	42026	42026	Ocean
2	41405400	46006	88032	Open Forest
3	93137400	103486	191518	Grass
4	34278300	38087	229605	Bare Ground
5	14679000	16310	245915	Mud Flat
6	20841300	23157	269072	Closed forest

8.3 Supervised OBIA

This exercise shows a simple Segmentation classification technique for grouping areas of similar spectral characteristics. As with the previous unsupervised classification classify a coastal area in west Timor containing ocean, mud flats, grassland and forest.

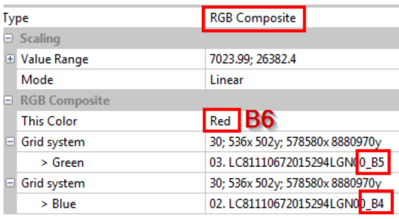
> **For this section Landsat data has been clipped to our area of interest here:** Kupang Bay Landsat 8 Clipped (2.2mb).

Access a supervised OBIA video tutorial:
sagatutorials.wordpress.com/supervised-segmentation-classification/

There are six main steps:

1. Load and display the imagery
2. Conduct our segmentation
3. Select 'training sites' telling the computer what Land cover type (class) various segments (polygons) are in.
4. Run the supervised classification
5. Edit the classification
6. Create and view area statistics

Load the image bands and display the image as an RGB composite with Band 6 and Red Band 5 as Green and Band 4 as blue.

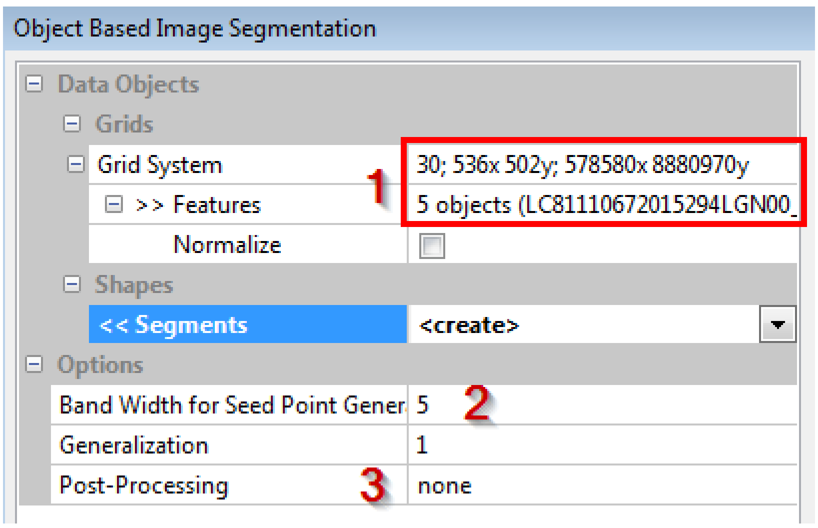


Run the image segmentation:

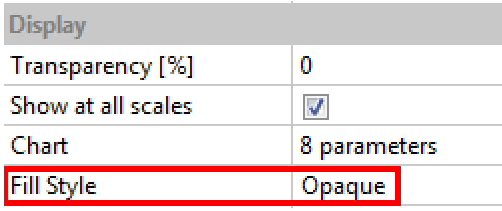
Use: Geoprocessing>Imagery>classification>Obia

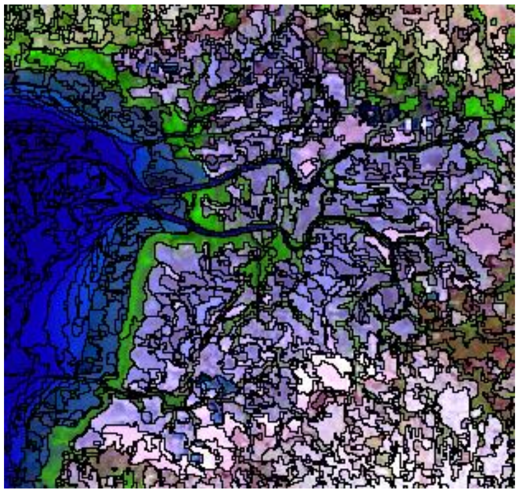
Then:

1. select bands 3,4,5,6
2. Adjust the Band Width for seed generation to 5 (this will slightly increase the size of polygons produced).
3. Set post processing to none.

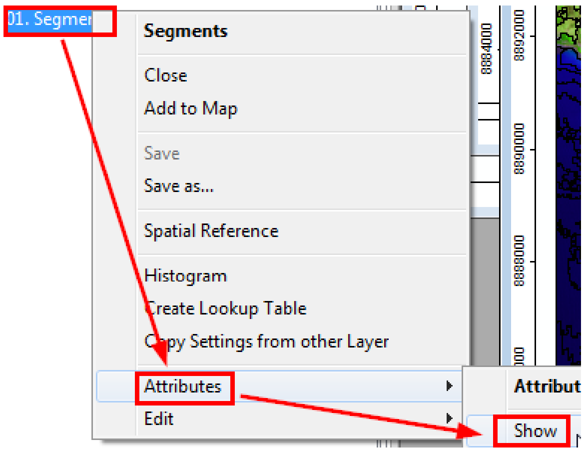


Double click on the resulting segmentation polygon file and display it over the image map display. In the **settings tab** change the fill style to opaque





View the attribute table for the segmentation. Right click on the segmentation file and Select:
Attributes>Show.

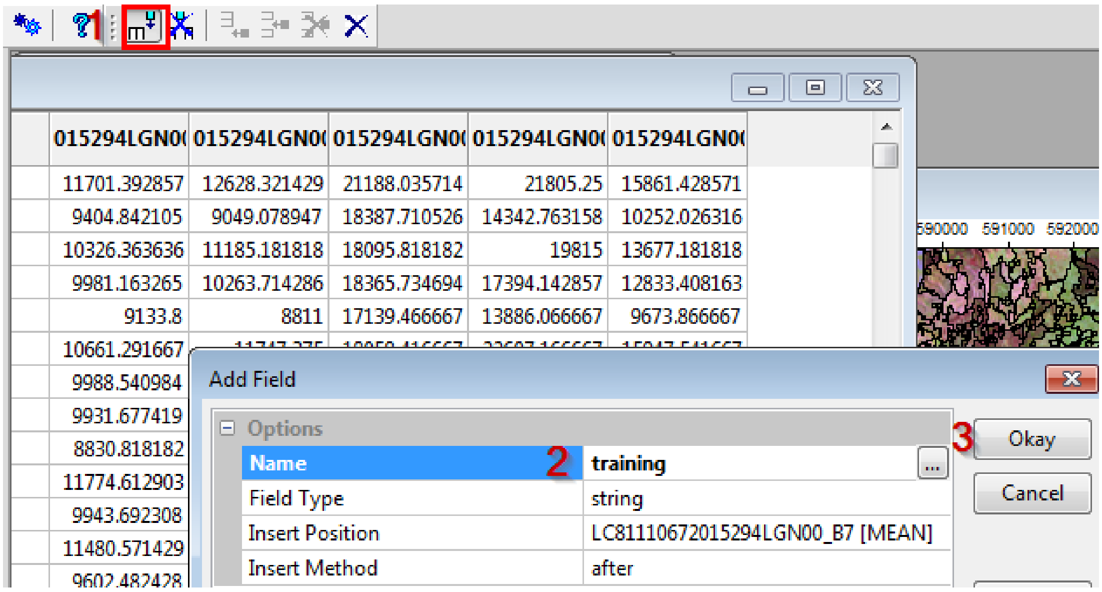


We now want to add a new '**Training'** attribute to the table. We will then be able to select polygons and enter into the new '**Training'** attribute the land cover type of a polygon.

This process is called training because we are training the classification how to identify all regions land cover type based on a number of representative sites

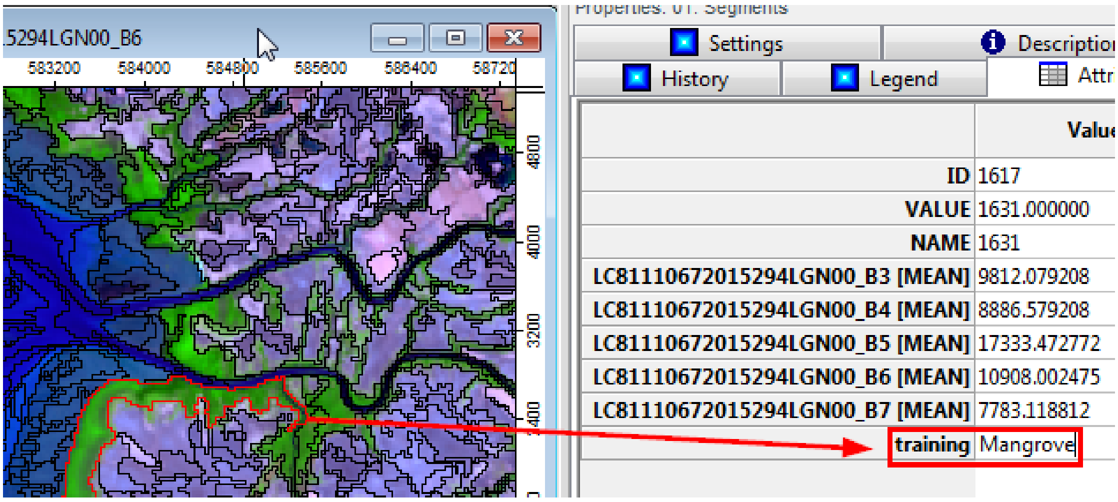
To add the new Training attribute:

1. Click the add attribute button
2. Enter '**training'** as the attribute name
3. Click OK.

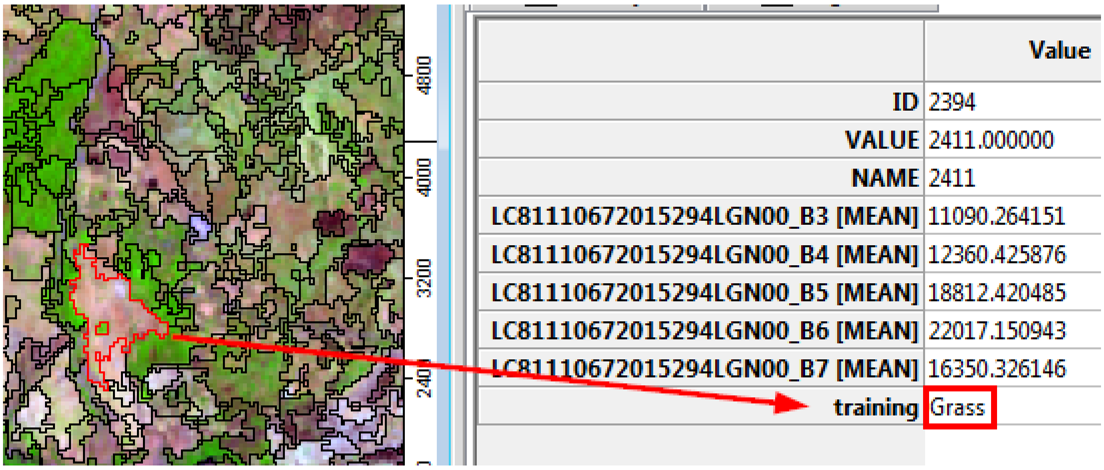


Now you can start the process of selecting training sites. Click on a single polygon and open the attribute tab. You will see a number of attributes for the selected polygon including all the mean band values for the bands used in the segmentation and lastly the new attribute **'Training'.**

In the example below a mangrove polygon is selected to Mangrove has been entered as the training attribute. This is our first "Training Site'.



Carry on selecting a number of training sites (5-10) for each land cover class. For example below a grass polygon has been selected.



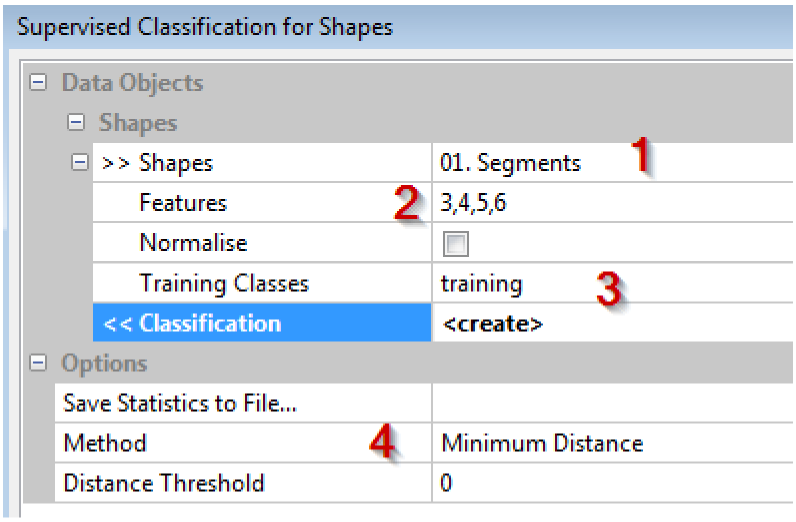
For this exercise create training sites for seven:

1. Forest
2. Mangrove
3. Open Forest
4. Grass
5. Bare ground
6. Mud Flat
7. Ocean

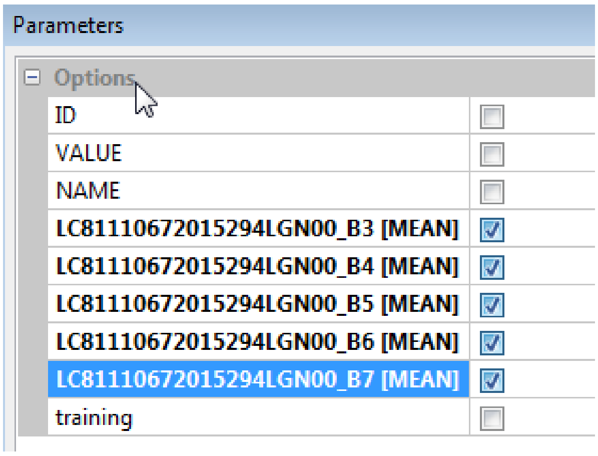
Once you believe you have a representative sample of polygons selected for each land cover class we can conduct our supervised classification:

Use: Shapes>Table>Supervised Classification for Shapes

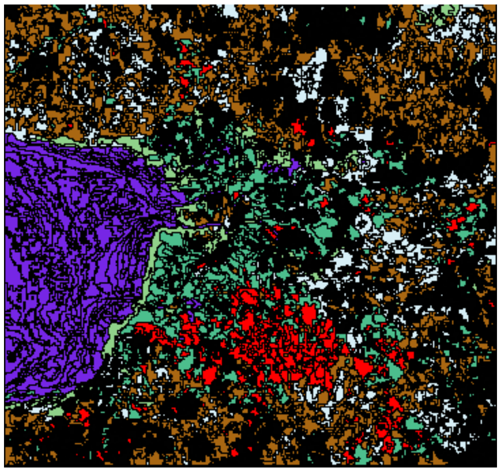
1. Select the segment polygon file for the input
2. Select a bands 3,4,5,6 as our input features
3. Select the training attribute as our input training classes
4. Choose Minimum Distance as the training algorithm



For step 2 you will get a pop-up window where you check the bands you wish to use.



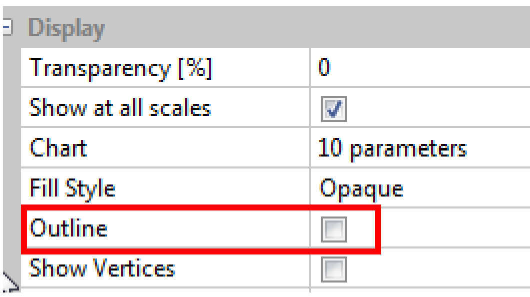
The resulting output polygon classification will be coloured randomly:



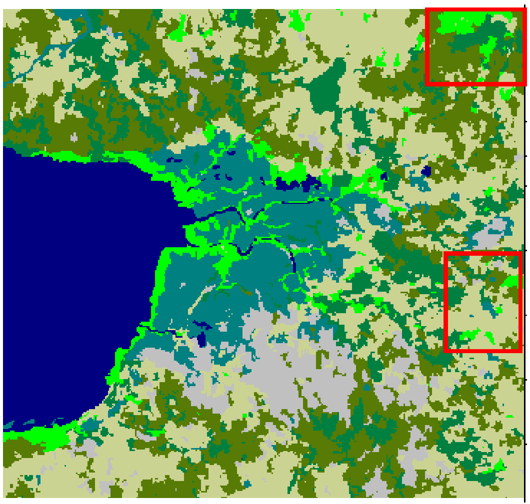
Open the Lookup table and change the colours appropriately.

COLOR	NAME	DESCRIPTION	MINIMUM	MAXIMUM
	Grass		1.000000	1.000000
	Bare		2.000000	2.000000
	Ocean		3.000000	3.000000
	Mud Flat		4.000000	4.000000
	Mangrove		5.000000	5.000000
	Open Forest		6.000000	6.000000
	Forest		7.000000	7.000000

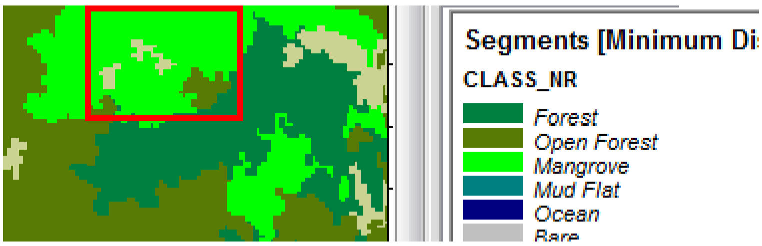
In the settings deselect the Outline value.



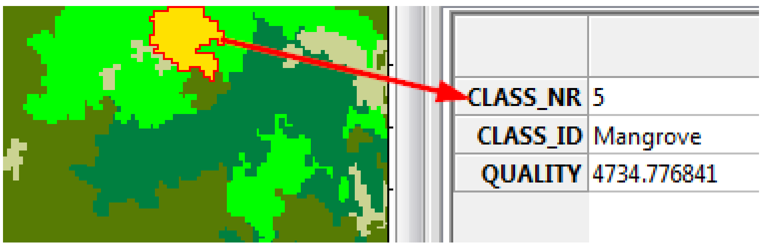
The resulting image classification looks good but we can see there are some clear errors where some mountain forests have been classified as mangroves.



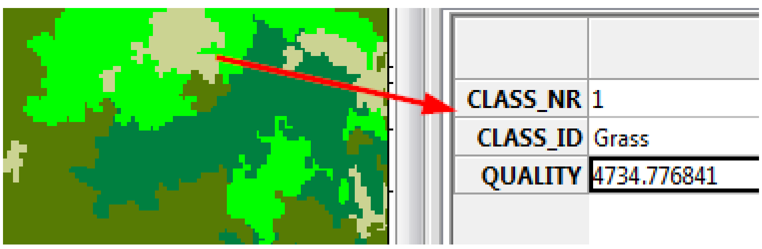
Part of the power of Segmentation classification is that it is easy to manually edit incorrectly classified polygons. We can manually edit these mangrove segments to change them to their appropriate land cover class. For example below is an area of forest incorrectly classified as mangrove.



Select one of the incorrectly classified polygons:



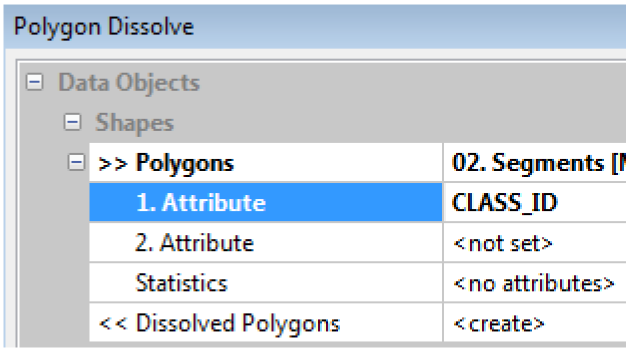
Change the 'Class_NR' (Number value) and 'Class_ID' name to the correct land cover, ie Grass.



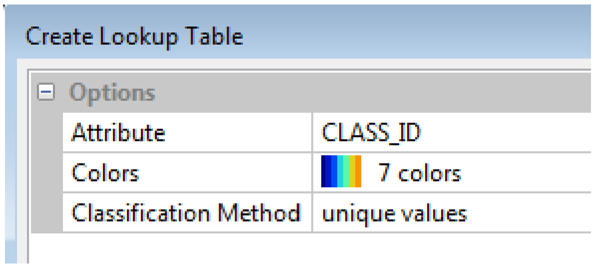
Once you have edited the image we can now look at some area statistics for the classification. First we need to conduct a polygon dissolve:

Use: Geoprocessing>Shapes>Polygons>Dissolve

Choose Class ID as the attribute to dissolve all polygons on:



We first need to create a look-up table for the dissolved polygons so we can get area statistics for each land cover class and not each polygon. Right click on the new dissolved polygon data file in the Data table and select **create look-up table**. Set the classification method to unique values;

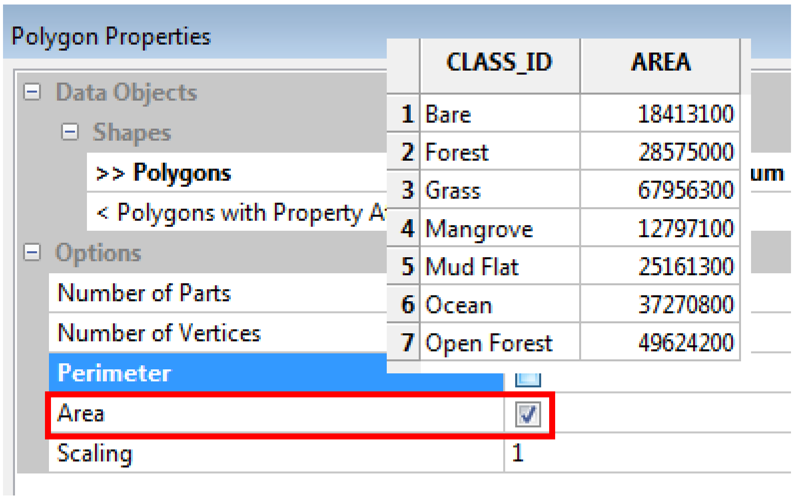


Now create an area property for our dissolved polygons.

Use: Shapes>Polygons>Polygon Properties.

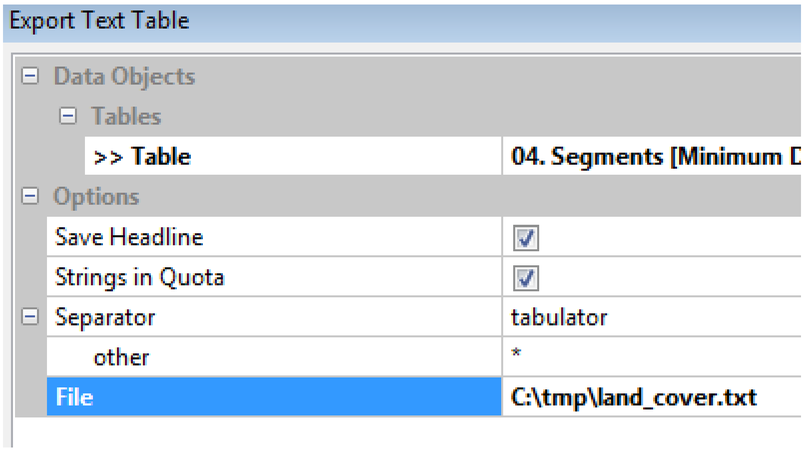
Select out dissolved classification segments as the input file and **Area** as the output static we want.

Right click on the segmented file and select **Attributes>Show** to see the new AREA attribute.



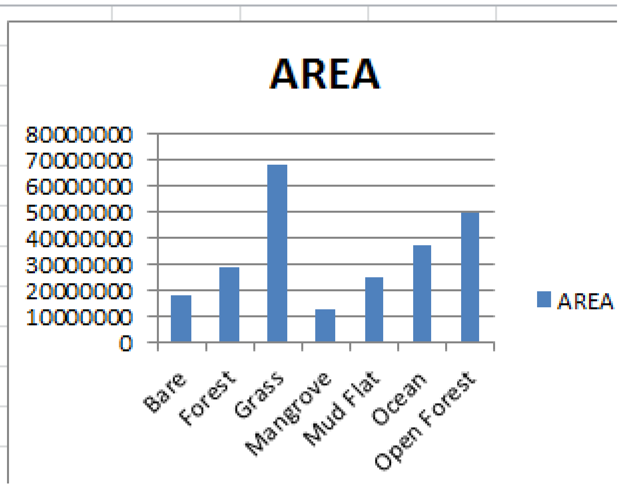
It is possible to export the table for further analysis in other software.

Use**: Geoprocessing> File>Table>Export**



The output text file can then be graphed in excel.

CLASS_ID	AREA
Bare	18413100
Forest	28575000
Grass	67956300
Mangrove	12797100
Mud Flat	25161300
Ocean	37270800
Open Fore	49624200



9. Hydrology and terrain modelling

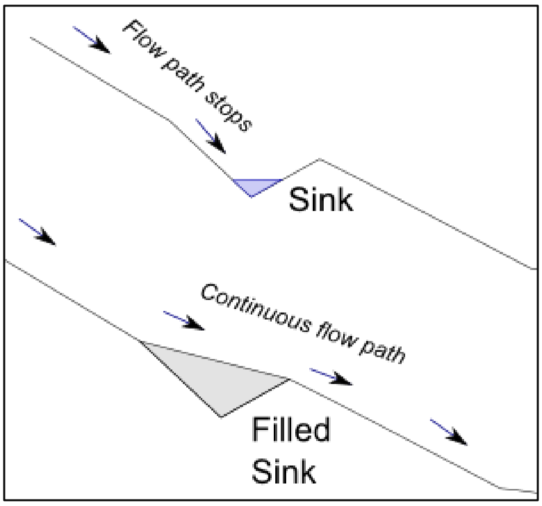
SAGA GIS has some very powerful terrain and hydrological modelling tools. In this section you will learn methods for (1) 3D visualisation, (2) terrain analysis and (3) hydrological analysis.

The data for this section can be downloaded here: West Timor – elevation Data

Access a video tutorial for this section here: sagatutorials.wordpress.com/basic-terrain-analysis/

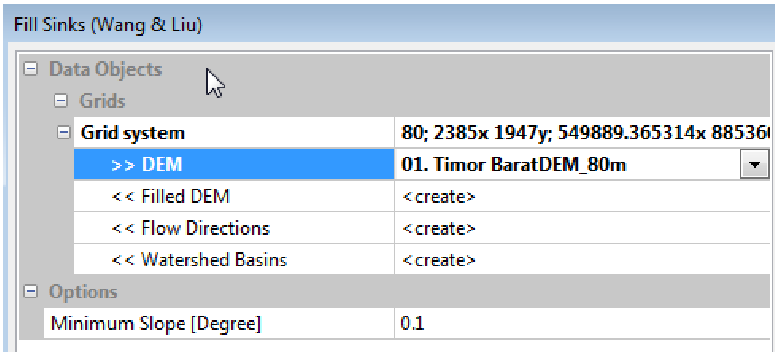
9.1 Create watershed basins – preprocessing

In order to produce hydrological flow models we need to produce an elevation dataset free of 'Sinks' or depressions that would capture the flow of water. The figure to the right is an example of a model with a 'Sink' and the same surface after 'Sinks' are filled and overland flow is continuous.



Add the Timor Barat DEM as the input. The output includes a filled DEM and watershed basins (DAS). To produce a sink filled elevation data:

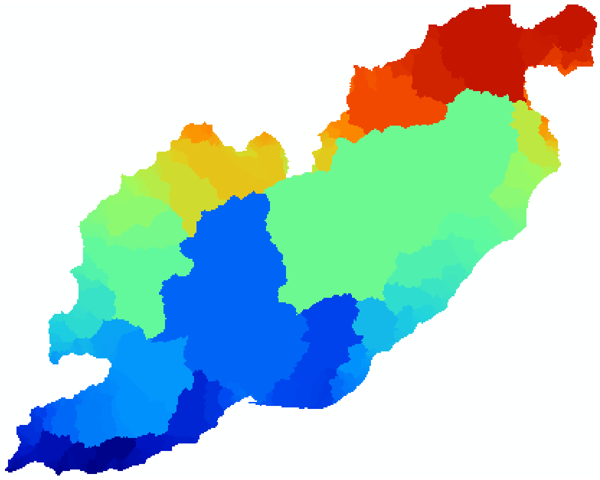
Use: Terrain Analysis>Preprocessing>Fill Sinks (Wang Liu).



Choose the grid system and the DEM grid.
The 'Fill sinks' module produces three new layers:

1. "TimorB_SRTM [no sinks]" , the sink filled grid
2. "Flow directions" the direction of water flow through each cell
3. Watershed basins" or catchments.

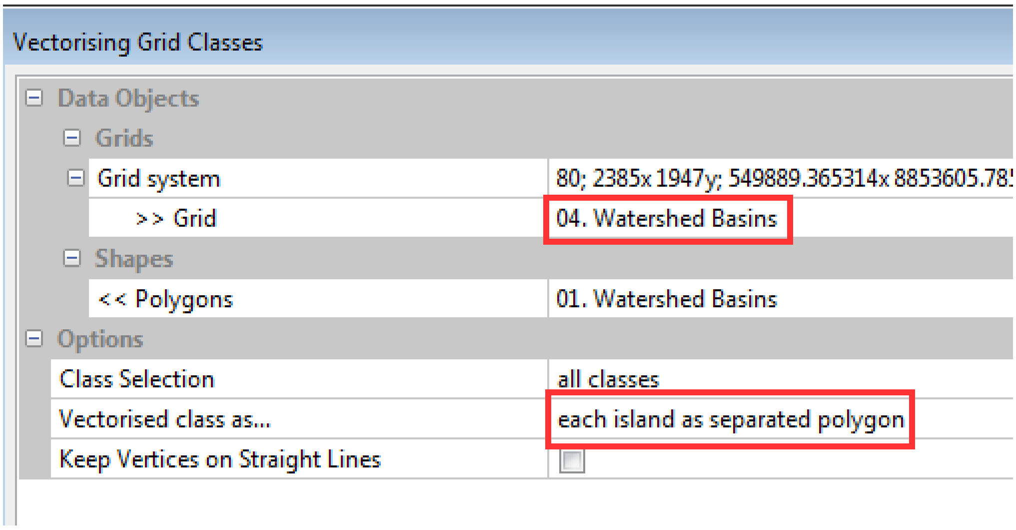
Double click on layer Watershed basins to display it in the map as shown to the right:



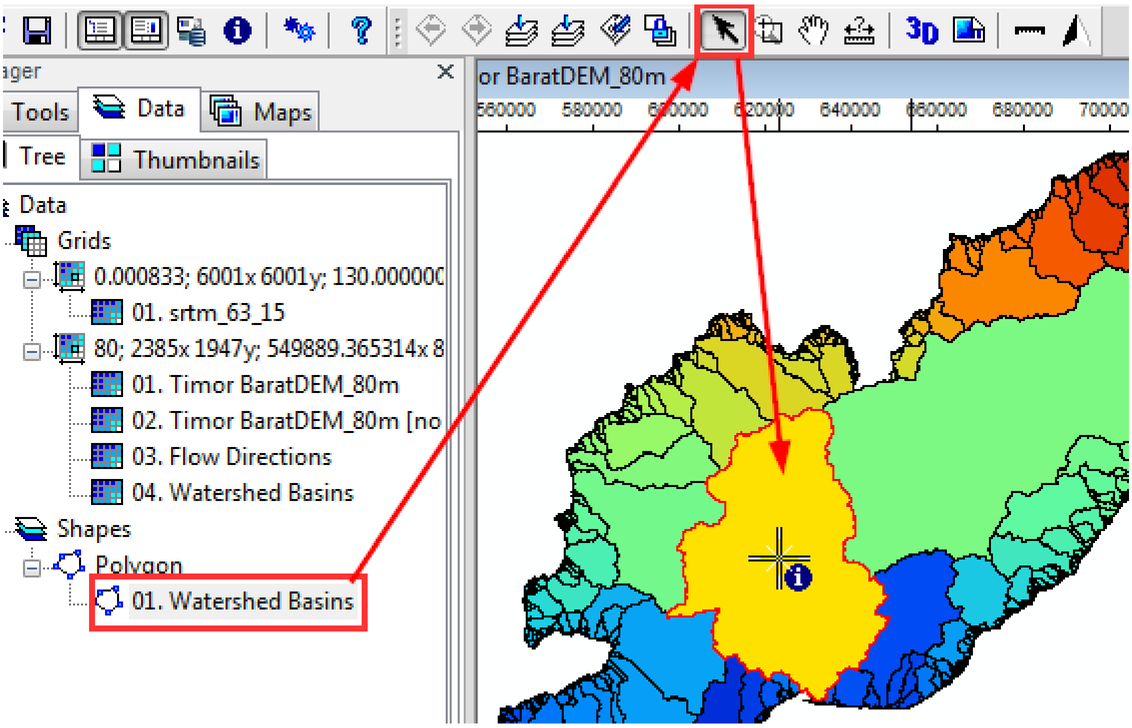
We will conduct further analysis on just one catchment delineated by the fill sink tool. To clip our data to one catchment we must first convert our raster watershed data-set to watershed polygons. To do this:

Use: Geoprocessing>Shapes>Grid>Vectorising Grid Classes

Choose the watershed layer as the input. Select ‘each island as a separate polygon’ under the ‘vectorised class as’ options. This makes sure that each catchment polygon can be selected individually.



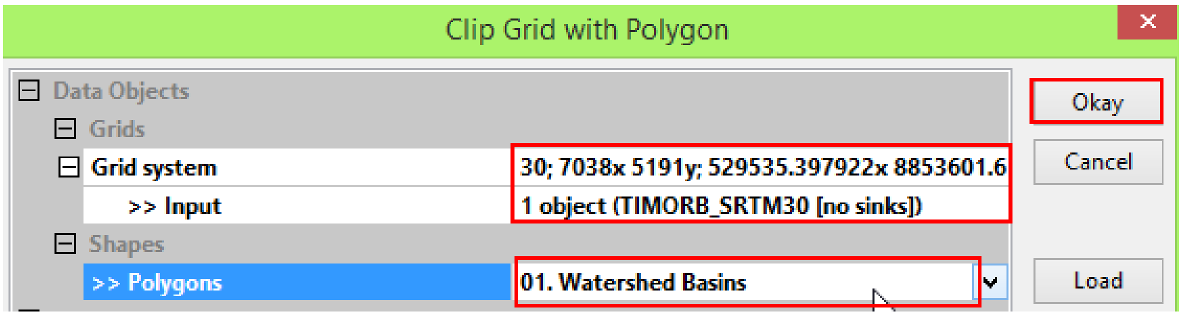
Once the process is complete display the new shape file watershed basin layer and select one of the larger catchments with your cursor tool.



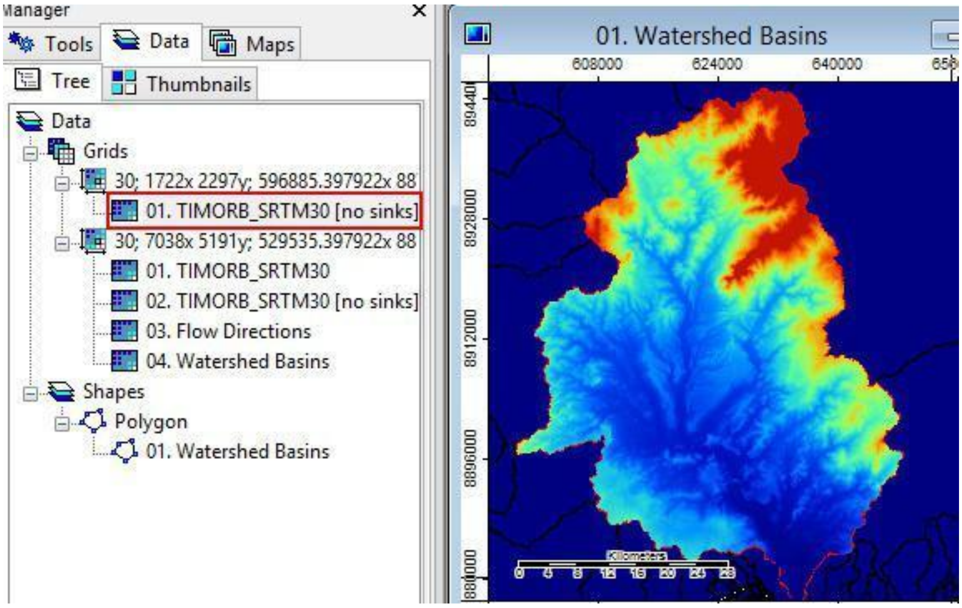
Cut the DEM layer using the selected catchment.

Use: Geoprocessing>Shapes>Grid>Spatial Extent>Clip grid with polygon

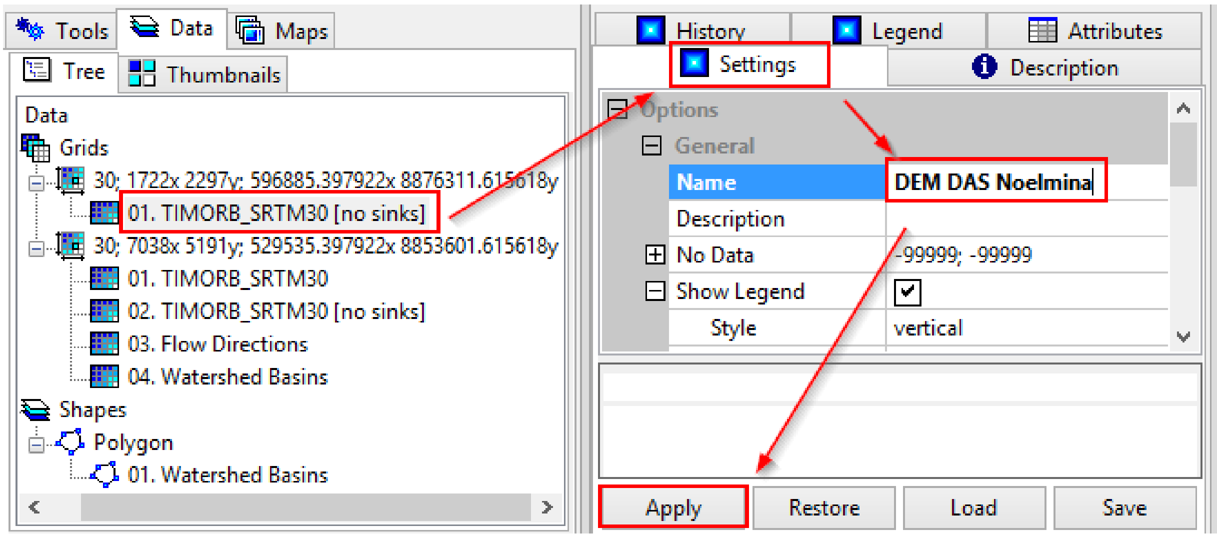
1. Choose the Grid system
2. Select just the DEM as the input layer
3. Choose watershed basins as the input grid



You will notice a new grid system with smaller extents has been made. This is the clipped grid. Double click on the new grid to display it over the Watershed shape file.

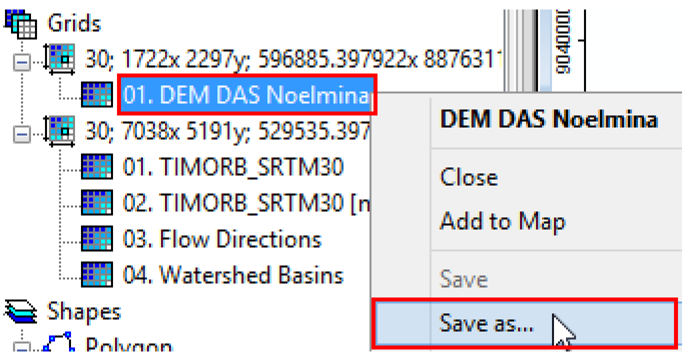


Although it is a new Grid it has taken the name of the old grid. In order to avoid confusion change the name of the new grid in the settings tab. In the example shown here we have called it DEM DAS Noelmina. ‘DAS’ is the Indonesian name for a catchment and Noelmina is the name of the catchment clipped in the example shown.



By right clicking in on the new grid layer it is possible to save it. It will be default save as a SAGA Grid format (.srgd).

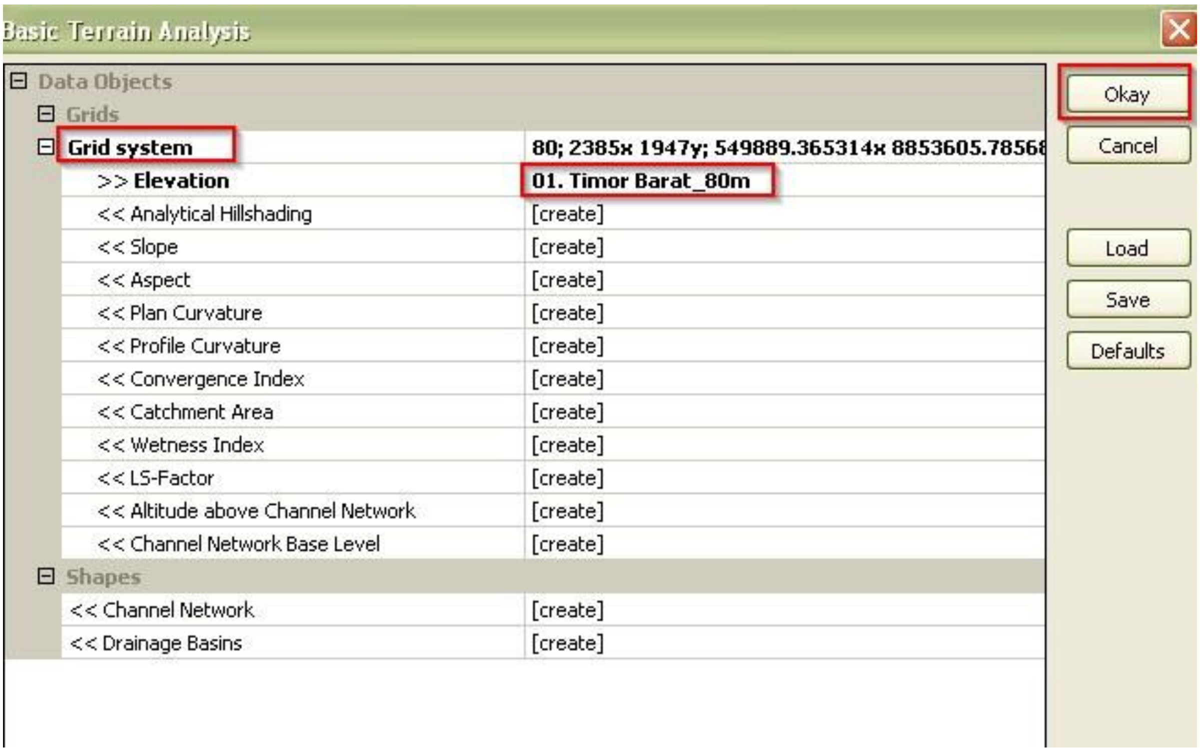
Now we have prepared our catchment we can conduct some further analysis.



9.2 Basic Terrain Analysis

The basic terrain analysis tool is very powerful, automatically producing 16 terrain and hydrological metric outputs.

A new window will then ask you to input the grid system and the elevation grid to use. You will see a list of all the terrain parameters that will be created by this module.

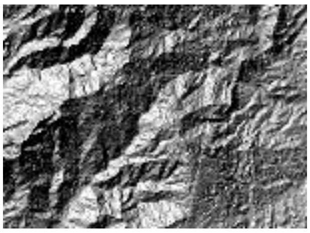


Enter the input elevation Grid, click **OK.**

N**ew** Grids and **Shape** files will appear in the **data Tab.** It may take a minute for the processing of all the grids to complete. Double click each grid to see the result in a map window.

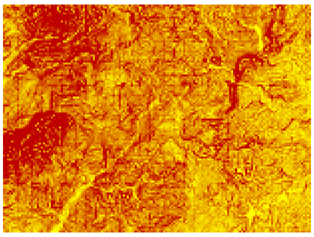
A description of some of the key outputs from this process is shown following.

Basic Terrain Parametres



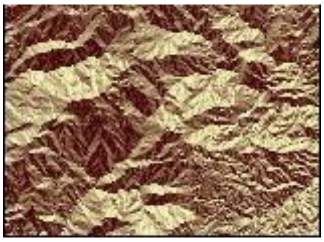
Analytical Hill Shading

Produces a grid shaded as if by sunlight
This is a very useful tool for visualising topography.



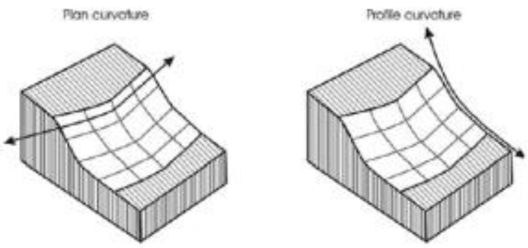
Slope

This creates a grid of slope. You can see the slope value in degrees displayed at the bottom of the SAGA window.



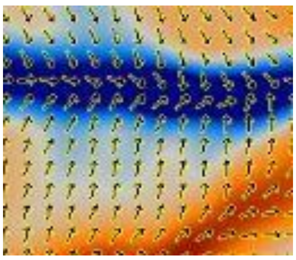
Aspect

This creates a grid of aspect or facing direction. You can see the slope value in degrees displayed at the bottom of the SAGA window.



Plan/Profile Curvature

These grids describe the form of landscape features. These parameters can be useful for modelling landslide risk.

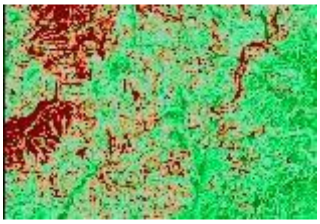


Convergence Index

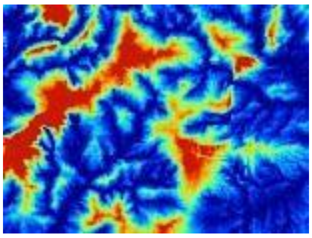
This module calculates an index of convergence/divergence of overland water flow.

Wetness index

Produces a grid showing water accumulation. This can be useful for soil or flood mapping.

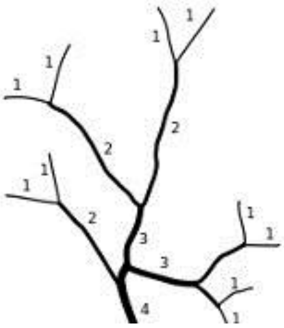


LS Factor
Is a combination of Slope and Slope length which combined are is a key attribute for predicting erosion potential within a landscape.



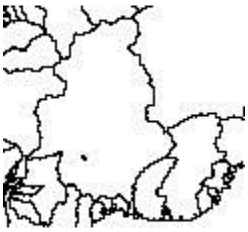
Altitude above channel network

This grid can be useful for potential flood prediction.



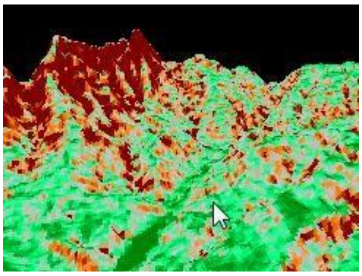
Channels

Produces a vector file of drainage channels. One of the attributes of this data is the Strahler order which is a measure of the order of the stream in the drainage network. This can be useful for understanding potential magnitude of streamflow.



Drainage Basins
Produces a shape file of water catchments (DAS).

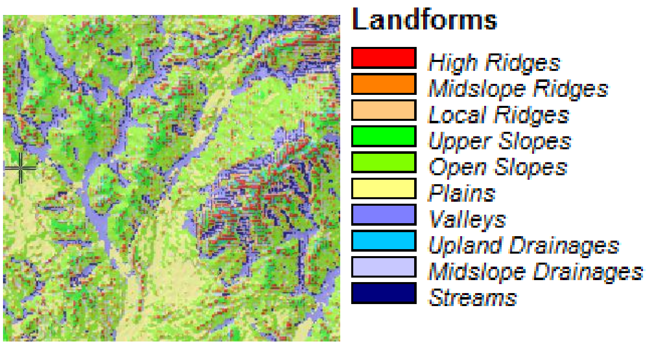
Displaying the terrain parameters in 3D mode will help you understand what they represent.



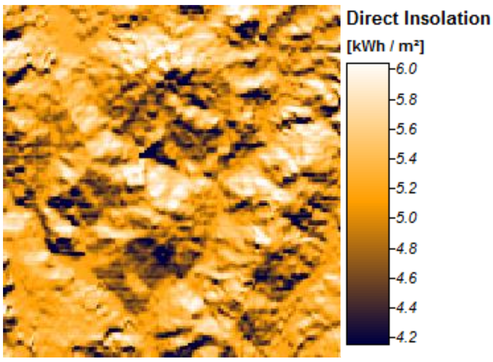
Try exploring other analysis tools

For example:

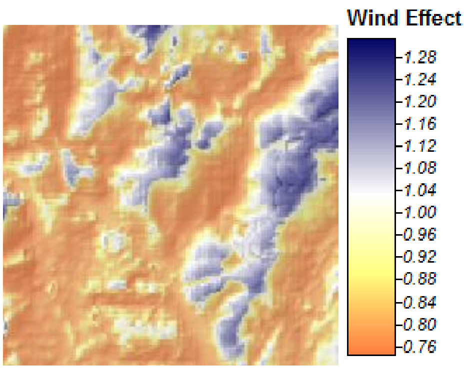
- Landform Classification: (Terrain Analysis > terrain Classification > TPI Based Landform Classification)



- Solar Radiation: (Terrain Analysis > Lighting > Potential Incoming solar radiation)



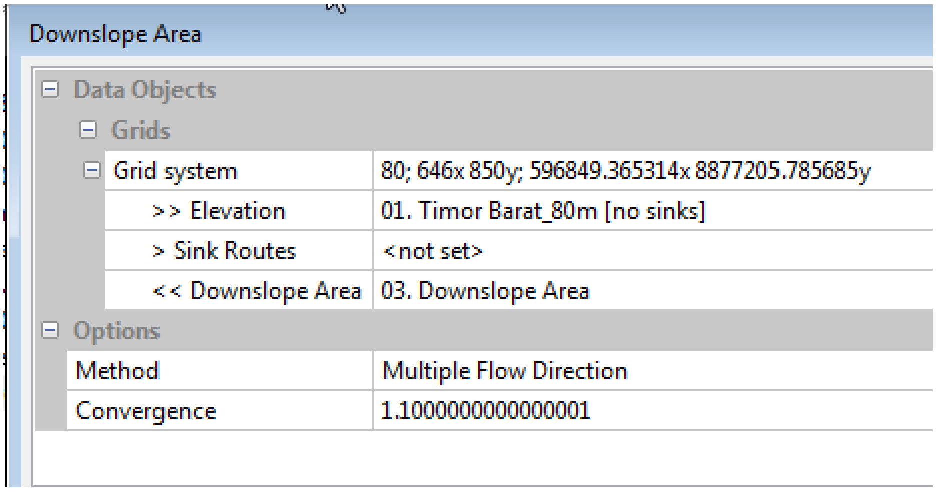
- Wind: (Terrain Analysis > Climate and Weather > Wind)



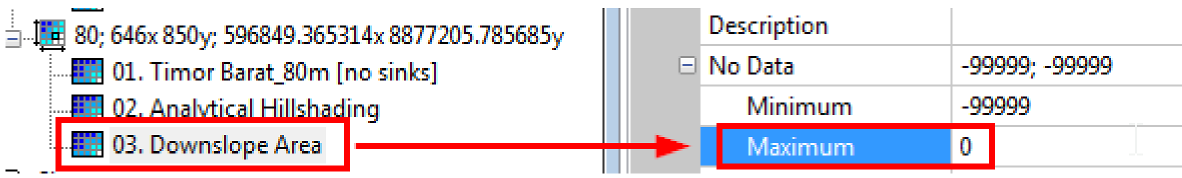
9.3 Hydrological flow modelling

There is a variety of way to assess flow over a landscape in SAGA. This example allows you to interactively initiate points of flow over corrected (Sink Filled) elevation data.

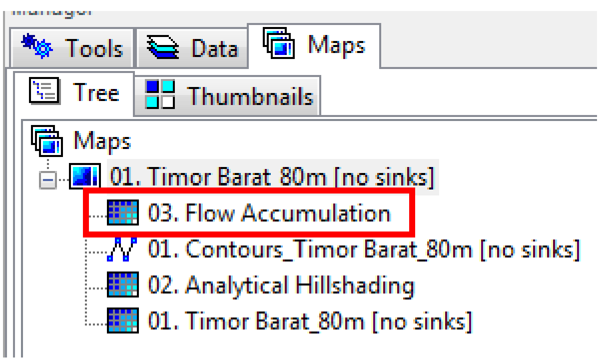
Use: **Geoprocessing> Terrain Analysis>Hydrology>Flow Accumulation >Downslope Area (Interactive)**



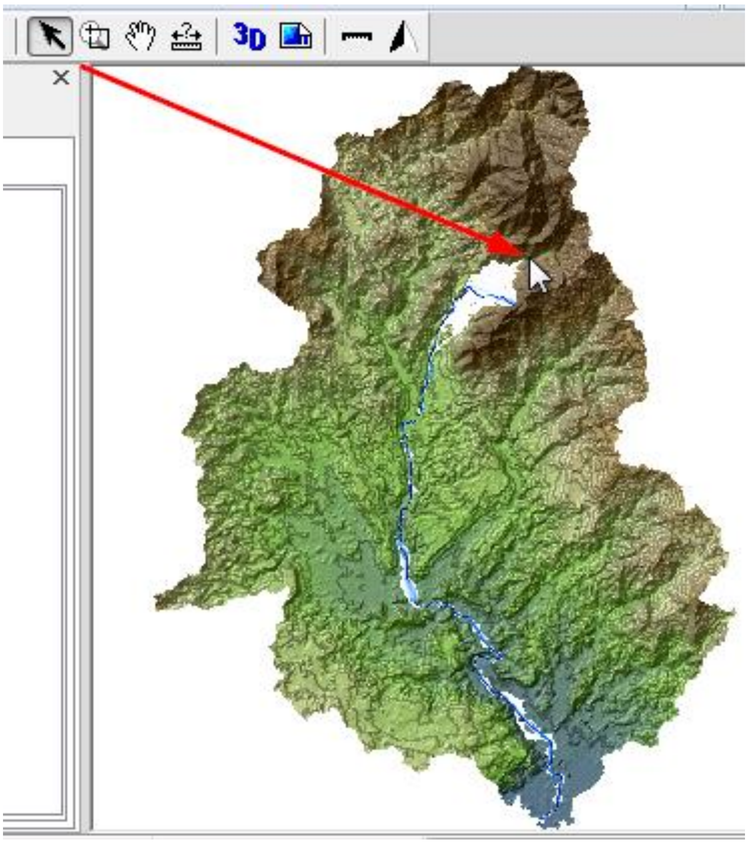
Select the resulting downslope area grid and in the settings tab set the maximum no Data value to 0. This will make the background transparent so you can see flow accumulation over the top of other terrain displayed.



Open the Downslope area grid into a map window over your terrain display



Use the pointer tool to initiate a flow path.



Try viewing this in 3D:

10. Application examples

This section contains tutorials for three practical application examples using techniques and data described in the previous sections: (1) Mapping fire extents, (2) Mapping forest cover change and (3) modelling mining related sediment flows.

Mapping wildfires

Wildfire is common across a variety of landscapes and poses a serious threat to life, property, natural resources and biodiversity. The example in this section is from the tropical savannas of northern Australia where we use an object-based image segmentation technique to quickly mapping an area of savanna grassland fire.

Mapping forest cover change

Landsat imagery provides a unique data set for assessing environmental change over time and has become the primary dataset for hundreds of Land Use and Land cover change (LULCC) studies. The example in this section investigates the extent of forest loss in South East Sulawesi (Indonesia) using recent and historic Landsat imagery.

Assessing potential sediment flows from a field survey of small-scale mining

This application imagines that mine site location data has been collected in the field using a GPS and the coordinate locations entered into excel. This data is then used to look at potential sediment flow paths from these mining points. This tutorial uses elevation data from Indonesian west Timor.

Assessing potential toxic heavy metal flows from satellite imagery

By combining land cover and disturbance data derived from Satellite imagery with elevation data for hydrology modelling we can investigate catchment scale impacts from mining related sediment flow.

4.1 Using Object-Based Image Analysis in SAGA to map fire extent

Savannas landscapes occur in monsoonal climates with short intense wet seasons and a long dry season across the world. This wet-dry flux promotes rapid grass growth followed by a long period of curing resulting in the most fire-prone landscapes in the world. Across northern Australia, on average 19% of the 1.9 million km^2 of tropical savannas burn each year. These Savanna landscapes have evolved over the at least the last 50000+ years through the strategic use of fire by aboriginal people

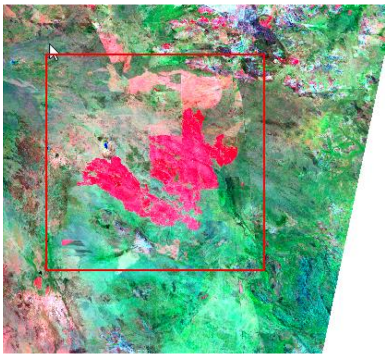
Over the last fifteen years there has been increasing effort to support fire management using satellite-derived fire information to help guide strategic burning programs. This exercise uses Landsat imagery from a savanna region of Northern Australia to illustrate the process of mapping burnt areas to inform operation planning and analysis.

Burnt areas usually show up clearly using a display combination including Landsat 8 band 10. Band 10 is the thermal (Heat) detecting band. Because burnt areas are often black due to charred biomass they absorb and emit a lot of thermal energy thus the good response in Band 10. SAGA can be used to quickly and easily map burnt areas from Landsat imagery using an Object Based Image Analysis processes.

The data for this section: Australia Fire mapping - Landsat 8 Clipped (64mb)

Access fire mapping video tutorials here:
sagatutorials.wordpress.com/mapping-fires-from-satellite-imagery/

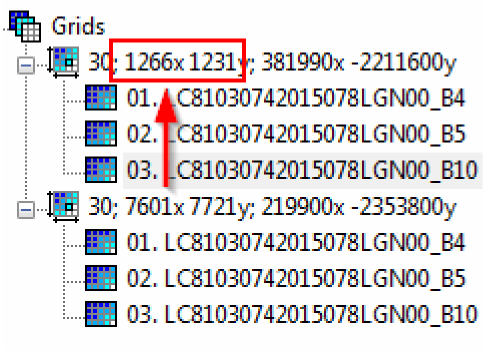
As SAGA works with data loaded into RAM segmentation of very large data sets, such as a whole Landsat scene requires a lot of processing power. The method shown here allows for rapid burnt area assessment for smaller areas and is most appropriate for mapping particular fire events or management regions.



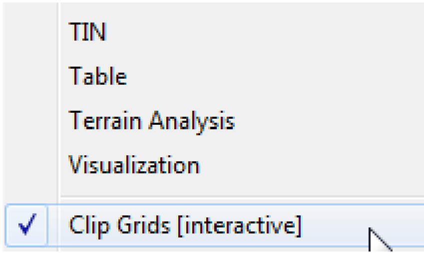
For this exercise, the imagery provided for download includes only bands 4,5 and 10. Import these bands using the Landsat import with options tool using band 10 for red. You will notice the imagery has already been cut to make a smaller file for download however for this exercise you will need to clip this image again to one large burnt area for mapping as shown to the right.

Use: Geoprocessing>Grids>Grid System > Clip Grids interactive

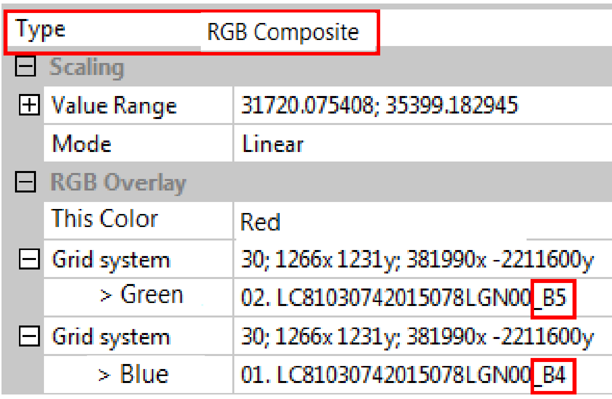
After you have clipped the grid a new grid layer system layer will appear. Look at the number of pixels values to determine the new, smaller grid. The original image will have over 7000 pixels in the width and height; the new clipped image will be smaller than this.



Once you have clipped a grid you need to 'turn off' the Clip Grids interactive tool by deselecting it in the tools menu.

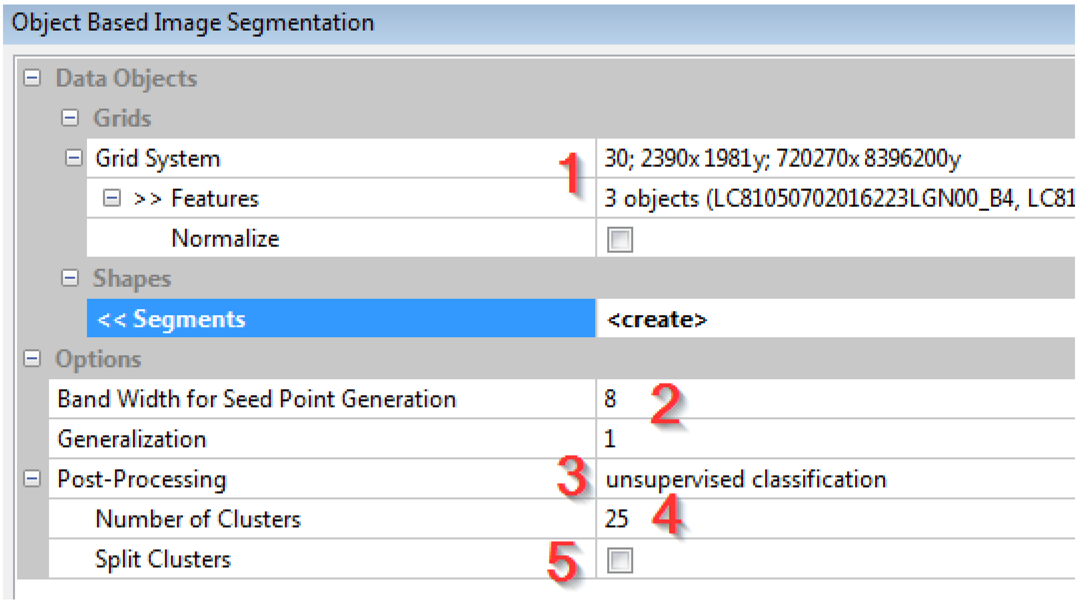


To display the clipped grid first display the **band 10** layer as a map then in the settings window set the display type to **RGB Composite**, >***Blue*** to **Band 4,** and > ***Green*** to **Band 5;** press apply. This will produce an RGB display image.



Now you can run the Segmentation process:

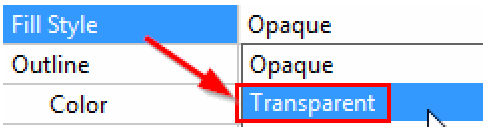
Use**: Geoprocessing > Imagery > Segmentation > OBIA > Object Based Image analysis**



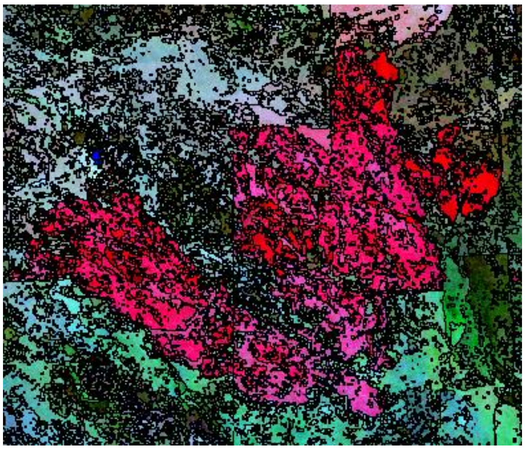
In the dialogue box:

1. Select all the image layers from your clipped dataset.
2. **'Band width for Seed Point Generation':** increasing the size of this number will increase the size and decrease the number of polygons created. In this example of have increased this number to 8 from the default value of 3 to decrease the number of polygons produced. It is worth trying larger band width values to produce datasets with fewer polygons which will be easier to work with subsequently.
3. Select unsupervised classification for the post-processing method.
4. Choose the number of different classes for the polygons.
5. Deselect **'Split Clusters'**. This will allow us to quickly select all polygons of the same class designation.

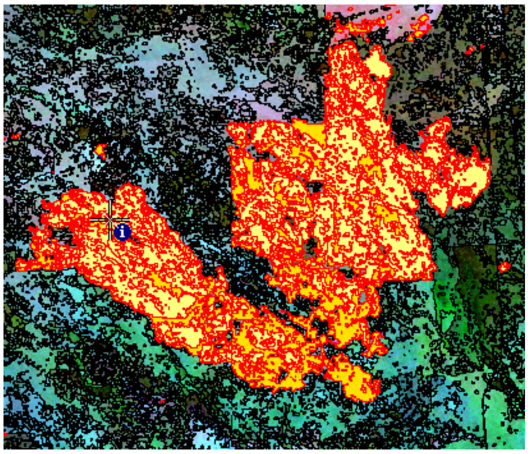
After the classification is finished display the dissolved polygon layer over the satellite imagery and set its fill to transparent



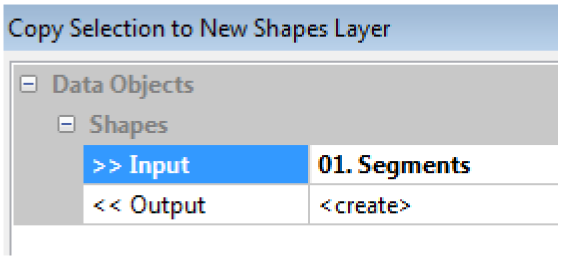
It should look something like this:



Use the pointer tool to select a number of polygons within the burnt area; this should select all burnt area polygons as shown:

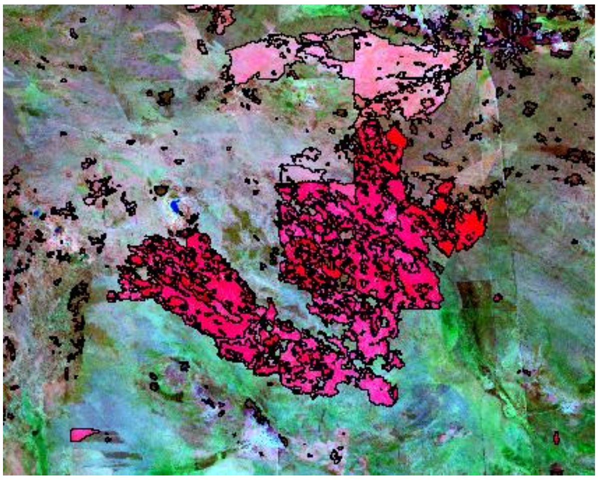


Now we need to copy the selection to a new shapes layer.



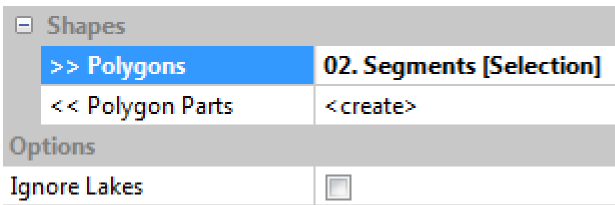
Use: **Geoprocessing> Shapes > Selection > Copy selection to new shapes layer**

You should now have a shape file layer like the image on the right.



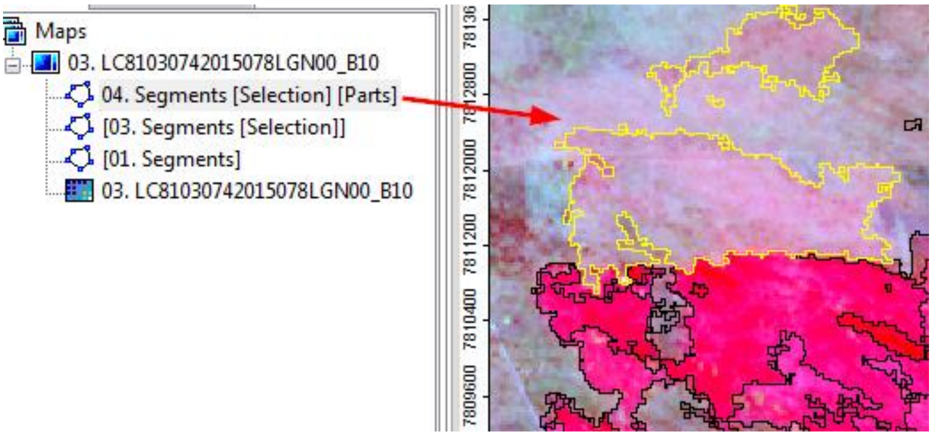
To clean up the section classification we now need to separate the polygons in the new shapes layer so we can edit (Delete) individual polygons.

Use: **Geoprocessing>Shapes > Polygons > Polygon Parts to separate Polygons**

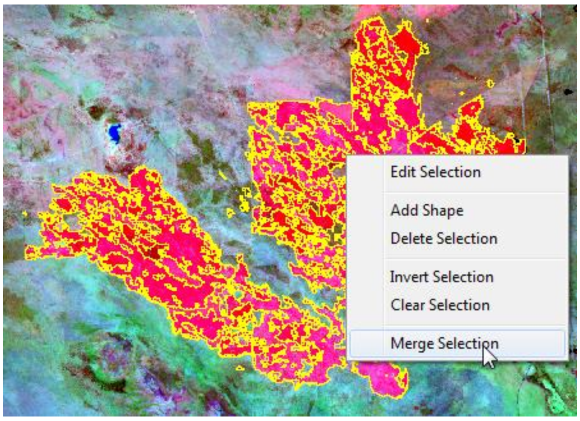


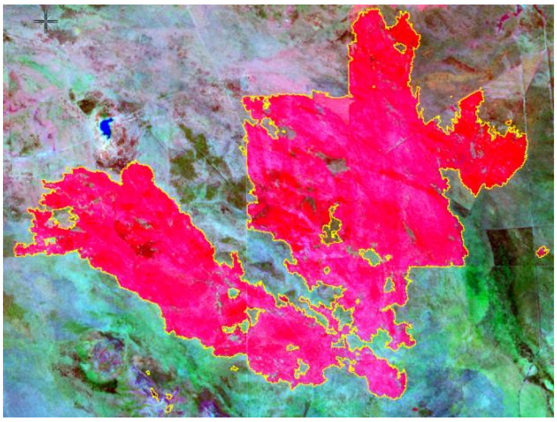
Now display the new 'selection Parts' shape layer over the satellite imagery.

Turn off the old segment layer in the map view by double clicking on it. Now using the pointer tool you can select and delete individual polygons incorrectly mapped.



Once you have cleaned up the classification select all the remaining polygons, right click and "Merge Selection." This will combine all polygons of the same class:





You can now calculate the area burnt in the same way as we did for the previous Sentinel example in **section 8.1.**

10.2 Forest cover change mapping using Image differencing

Over recent years the destruction of the world's tropical forests has become an urgent international issue, particularly with regard to their role as a major carbon sink and stores. Satellite-derived data on land cover and land use has become the accepted baseline source of information for assessing the state of tropical forests.

This example uses an image differences technique to highlight changes in forest cover between satellite image dates. In this case, we are looking at forest cover change in South East Sulawesi.

This section uses: Landsat data from Sulawesi from 1996 and 2015. You can download these data here (219mb). *Only three Landsat image bands are provided to reduce the download size.*

Access land cover change mapping video tutorials here:
sagatutorials.wordpress.com/land-cover-change-image-differencing/

Steps involved:

1. Convert Landsat 8 imagery from 16bit to 8bit data so it is the same as the Landsat 5 imagery
2. Subtract 1996 imagery from the 2015 imagery using Grid Calculator.
3. Conduct unsupervised classification on the differenced bands.
4. Reclassify to aggregate forest cover change classes.
5. Convert forest cover change class to polygons.
6. Edit cover change polygon to remove errors and calculate area

---

Data Preparation Landsat 5 and Landsat 8

***Note**: This is the same data and visualisation process as used in section 6.4.*

Open the Landsat data for the region of Southeast Sulawesi and then open Landsat 8 (2015).

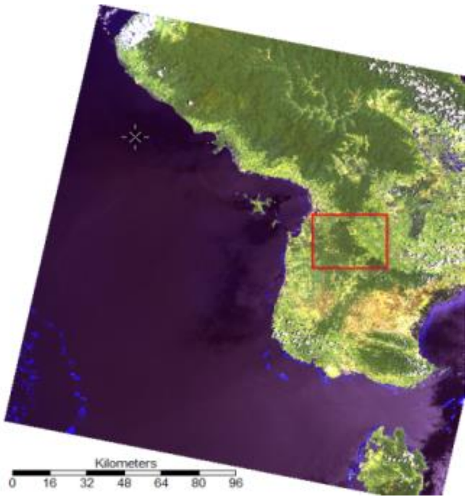
Use: Geoprocessing> Imagery> Landsat> Import Landsat With Options.

For the **Landsat 5 (1996)** image import bands 2,5,6.
For the **Landsat 8 (2015)** image import bands 3,6,7.

Now clip the image to our study area of interest. For this example clip to the area as shown by the red box in the Landsat images to the right. This a region where there has been significant forest cover change. Use the Landsat 8 2015 for the input grids Use the pointer tool to draw a box around the area of interest (Clip Grids).

Use: **Geoprocessing > Grid > Grid System > Clip Grid Interactive**

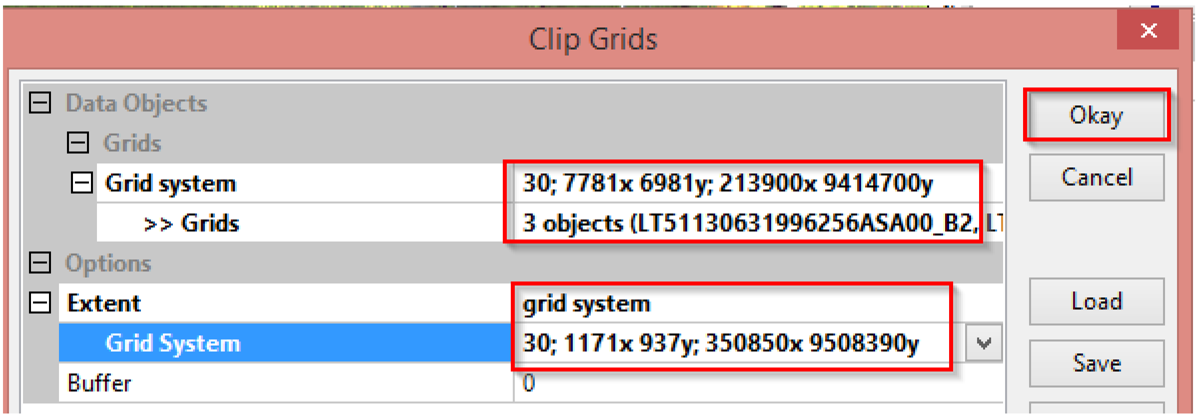
Now clip the 1996 imagery to the same area so they are in the same grid system:



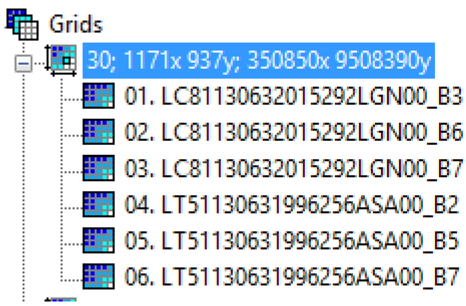
Use: **Geoprocessing > Grids > Clip Grids**.

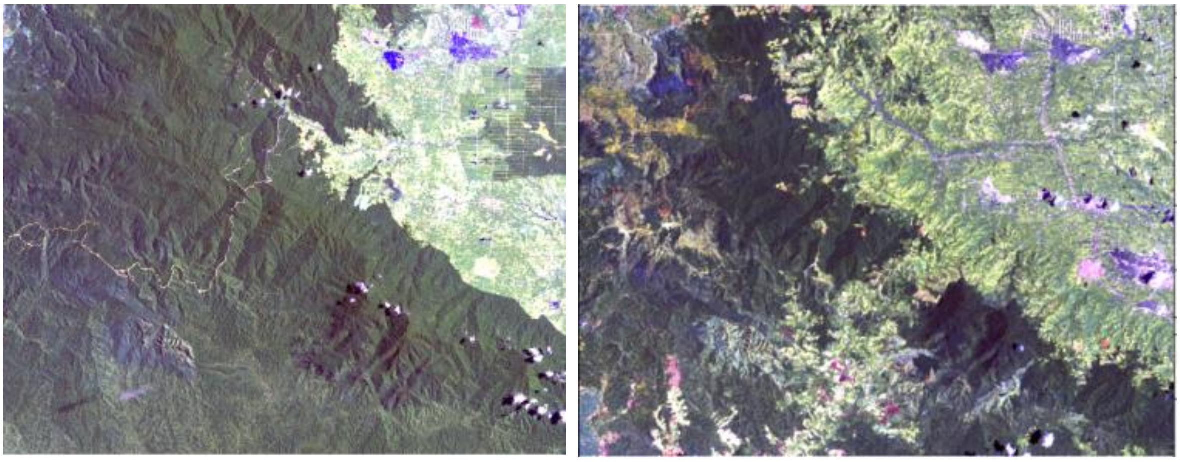
Input the three bands from Landsat 1996.

For **extent** choose 'grid system' and choose the clipped grid system produced with the **Clip Grid Interactive** for the Landsat 8 data. As shown below.



You should end up with one grid system containing all the bands for 1996 and 2015: Display the two image bands as an RGB composite image to visualise the Forest Cover change.



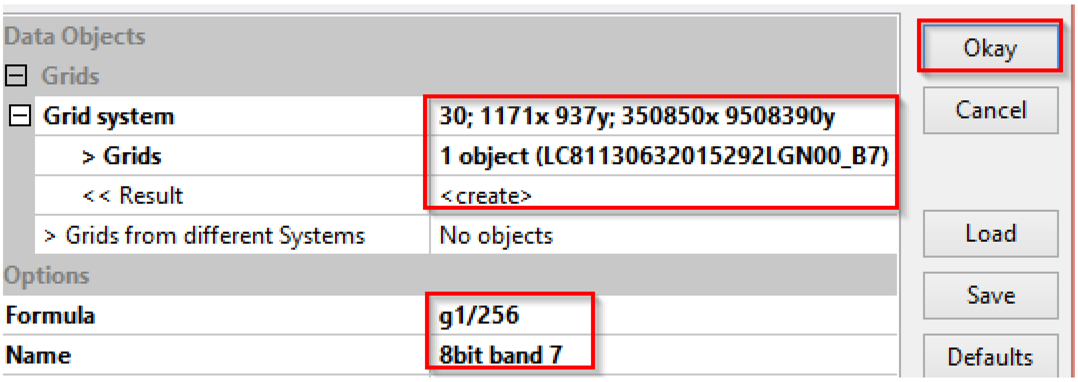


Convert Landsat 8 to 8-bit imagery

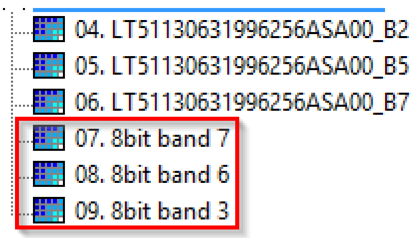
Because we are working between Landsat 5 and Landsat 8 imagery we need to convert the image data format. Landsat 8 imagery is stored as 32-bit data whilst all other is sorted in 8bit format. To do this conversion:

Use: **Geoprocessing > Grid > Calculus > Grid Calculator**.

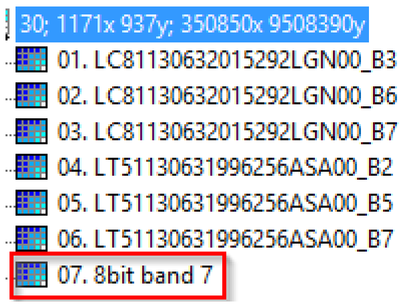
For each 2015 (Landsat 8) grid band use the formula g1/256



The resulting image will be the same as an 8-bit band. Each band (3,5,7) will need to be converted individually.



Once you have converted all bands we can subtract the image bands for the two years from each other.



Note it is necessary that each image is in the same Grid System to be able to conduct the image differencing. The example shown here is based on using imagery already clipped to the same area of interest grid system as shown in the previous land cover change example.

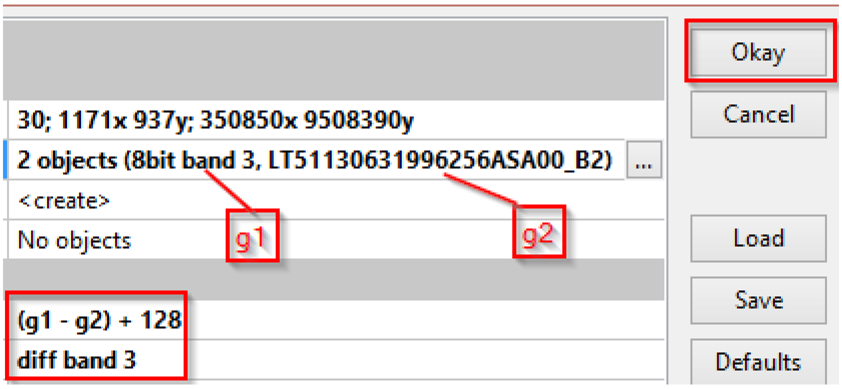
Image Difference

For each band subtract (8bit) 2015 imagery from the 1996 imagery. Because the different Landsat satellites have a different number of bands the same spectral bands have a different band number allocation so for example:
8bit band 3 = band 2 Landsat 1996
8bit band 7 = band 7 Landsat 1996
8bit band 6 = band 5 Landsat 1996

To create the difference image:

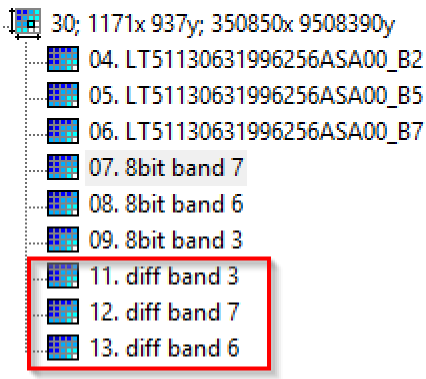
Use: **Geoprocessing>Grid > Calculus > Grid Calculator**

With this calculation formula **(g1 – g2) + 128**. as shown below.



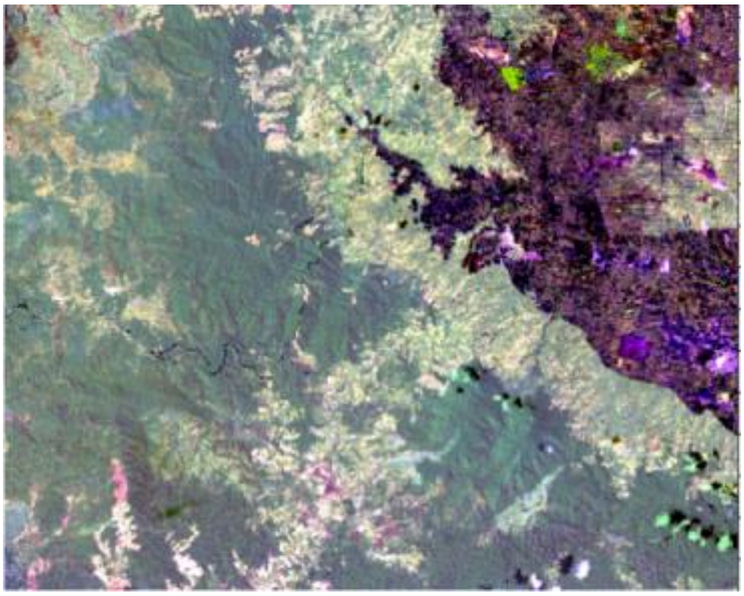
Conduct the image difference for each of the three bands for both image years individually. Remember to change the output grid allocation to **"Create"** after processing each band so as to not over-write the previous process.

When finished you should have a difference grid for the three bands as shown here.



Now display these as a RGB composite as follows: Diff and 7 = red, diff band 6 = green and diff band 3 = blue.

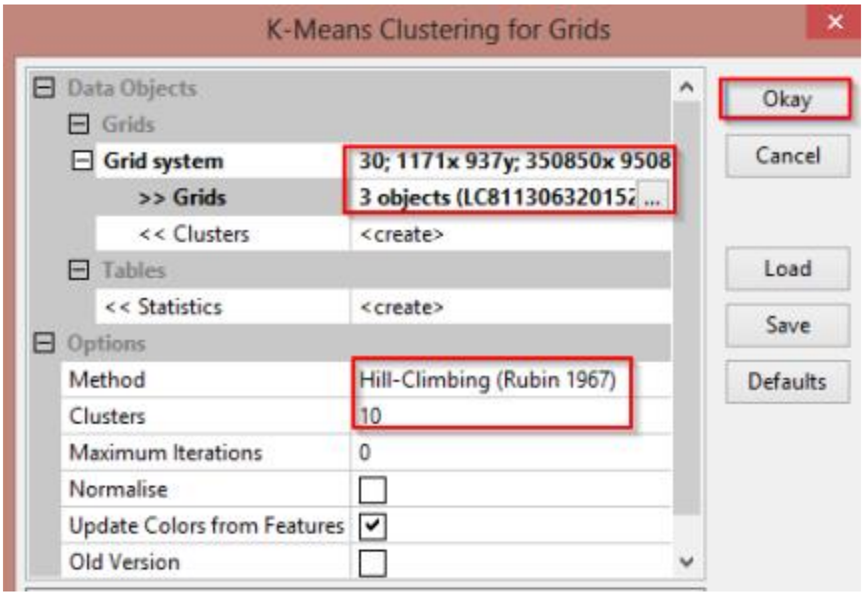
Display the difference image over the original imagery to determine the meaning of the different difference image colours. In this case, we see an image similar to that shown below where the brighter areas are those with reduced forest cover.



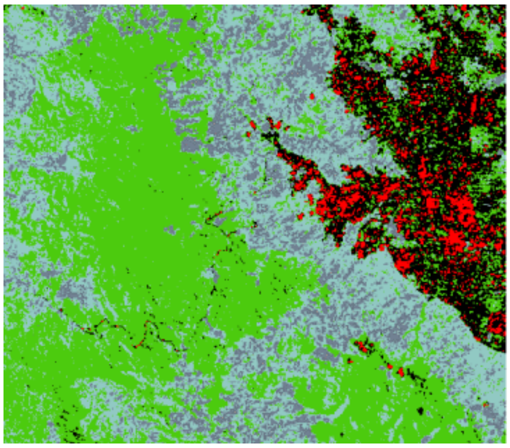
Cluster Analysis

Now run an unsupervised classification on the difference grid to determine areas of change.

Use: **Geoprocessing > Imagery > Classification > Unsupervised > K-Means Clustering Analysis For Grids**

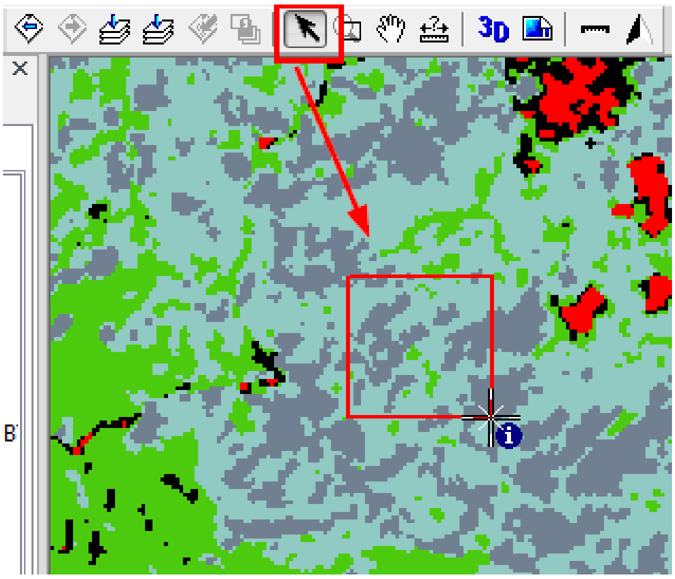


In this case, try setting the number of clusters (Classes) to five. We end up with a classified image similar to that shown to the left:

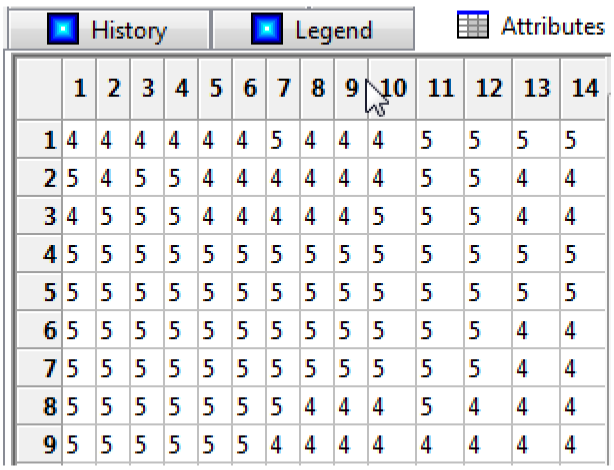


By comparing to the two original images (1996, 2015) we can determine the classes showing forest cover loss.

To assist identifying the classes use the pointer tool to select an area on the classified image and open the attributes tab.



You will see a matrix of numbers representing the class values within you selection area. In the example blow it is showing the forest cover difference classes as 4 and 5. Note for this to work you need to have the correct image (classified grid) selected in the data tab.



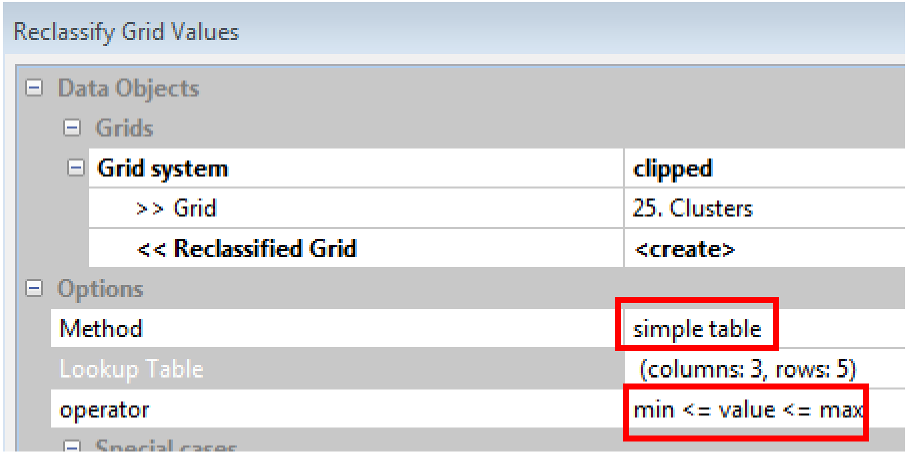
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	4	4	4	4	4	4	5	4	4	4	5	5	5	5
2	5	4	5	5	4	4	4	4	4	4	5	5	4	4
3	4	5	5	5	4	4	4	4	4	5	5	5	4	4
4	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	5	5	5	5	5	5	5	5	5	5	5	5	4	4
7	5	5	5	5	5	5	5	5	5	5	5	5	4	4
8	5	5	5	5	5	5	5	4	4	4	5	4	4	4
9	5	5	5	5	5	5	4	4	4	4	4	4	4	4

Reclassification

Now reclassify the grids so that bands 4-5, the forest cover change classes, become 1 and all other classes become 0.

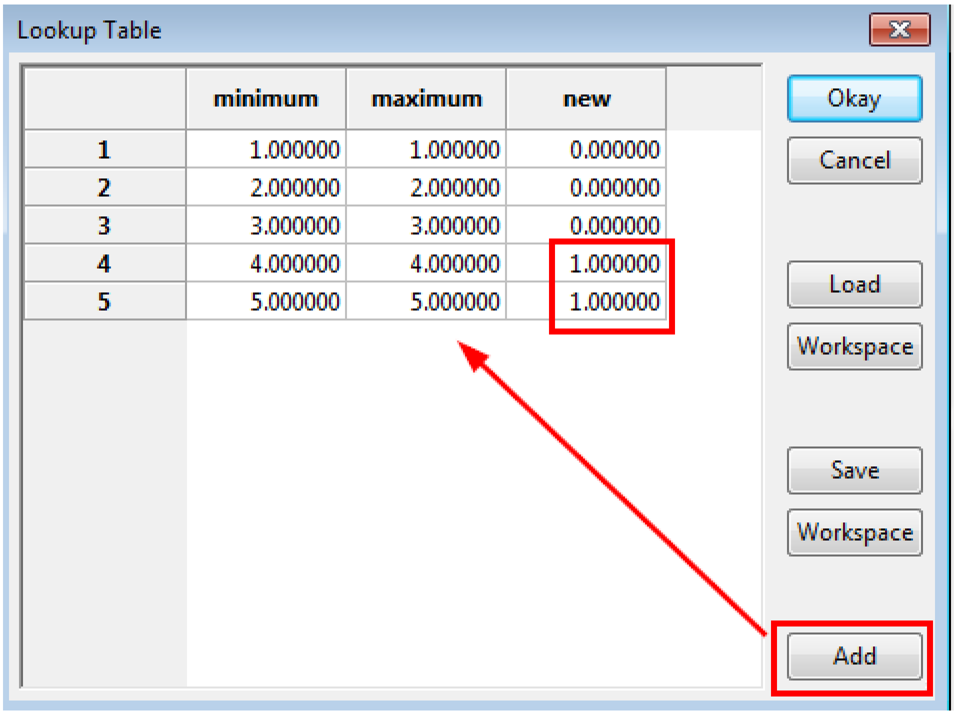
Use: Geoprocessing>Grid>Values>Reclassify

Set 'simple table' as the method and the operator as *'min<=value <+max'*



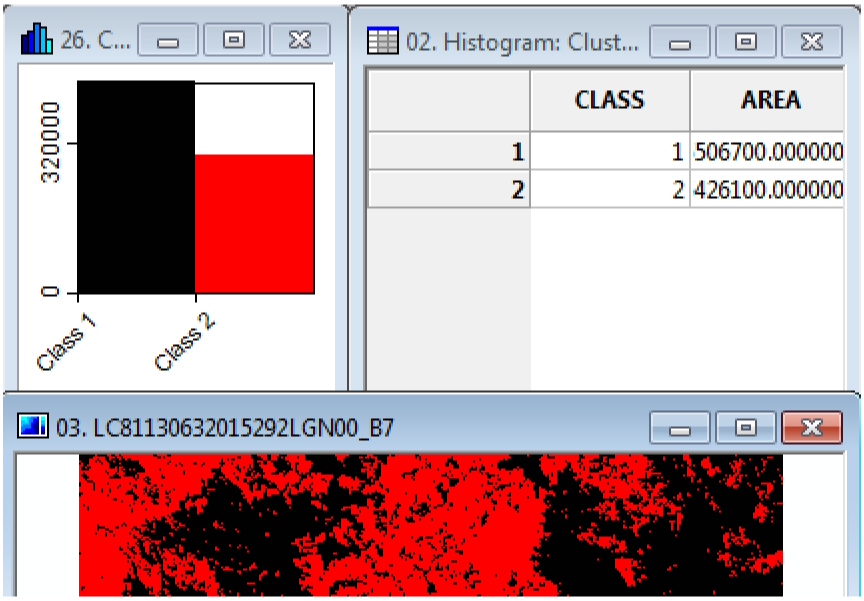
Open the lookup table **(click the selector button next to Colums3, Row3)**

You will need to edit the lookup table to add as many rows as you have classes ie 5. Set the minimum and maximum 1-5 and the new output values for each class. e want our "**new**" forest classes to be 1.



After running the reclassification we are able to look at the histogram values.

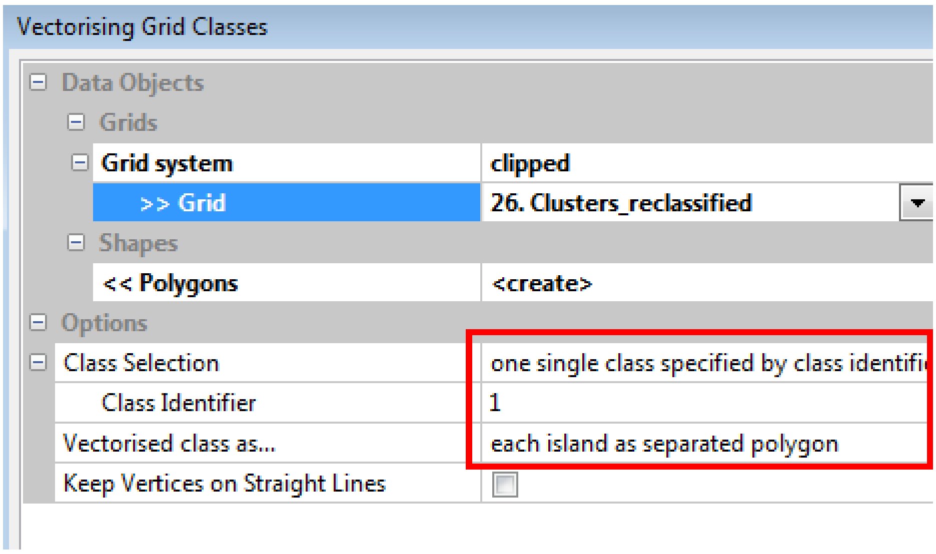
Right click on reclassification grid layer and select histogram
and area tables
Select the histogram and click the table button in the top window bar.



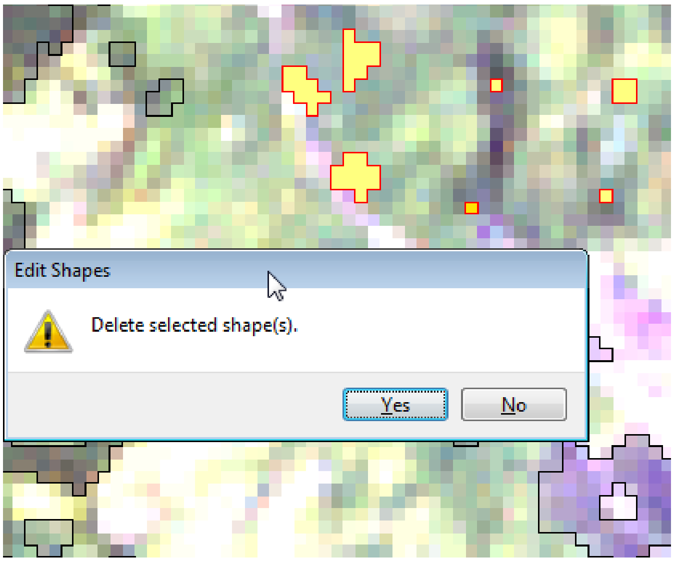
Vectorising grid classes

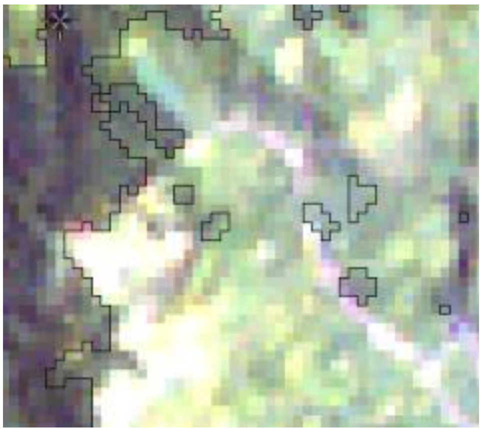
We will now convert the resulting classification to a polygon file to assist assessing the region of deforestation and to calculate total area.

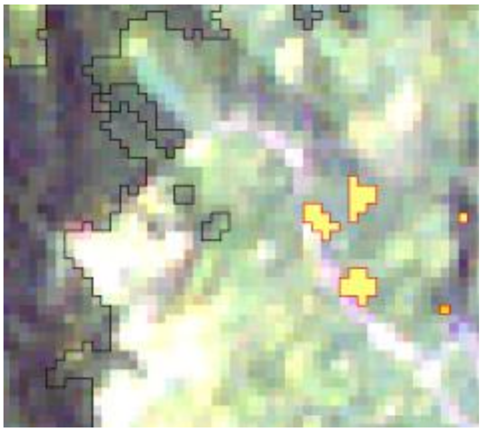
Use: **Geoprocessing>Shapes > Grid > Vectorization > Vectorising Grid Classes**.



Display the resulting polygon classification over the 1996 imagery and set the polygon fill display to transparent. Using the pointer tool it is now possible to manually edit the polygon classification to remove areas mistakenly included in the forest cover change classification.



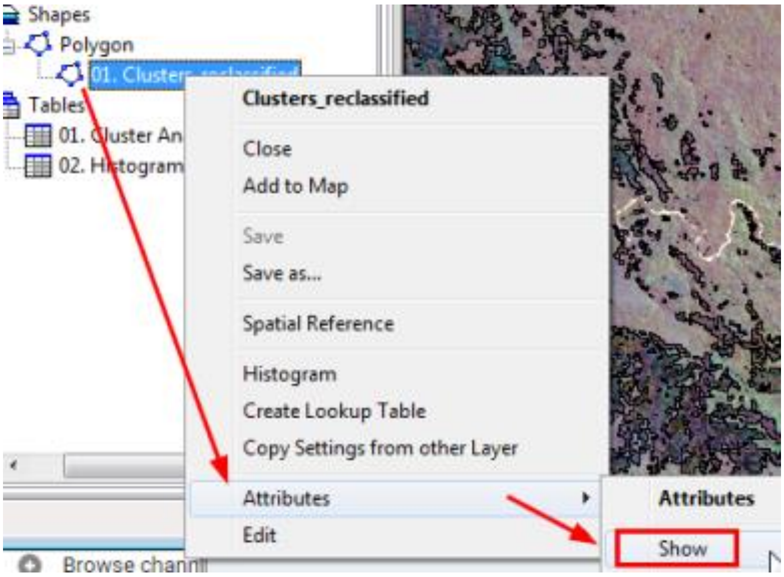


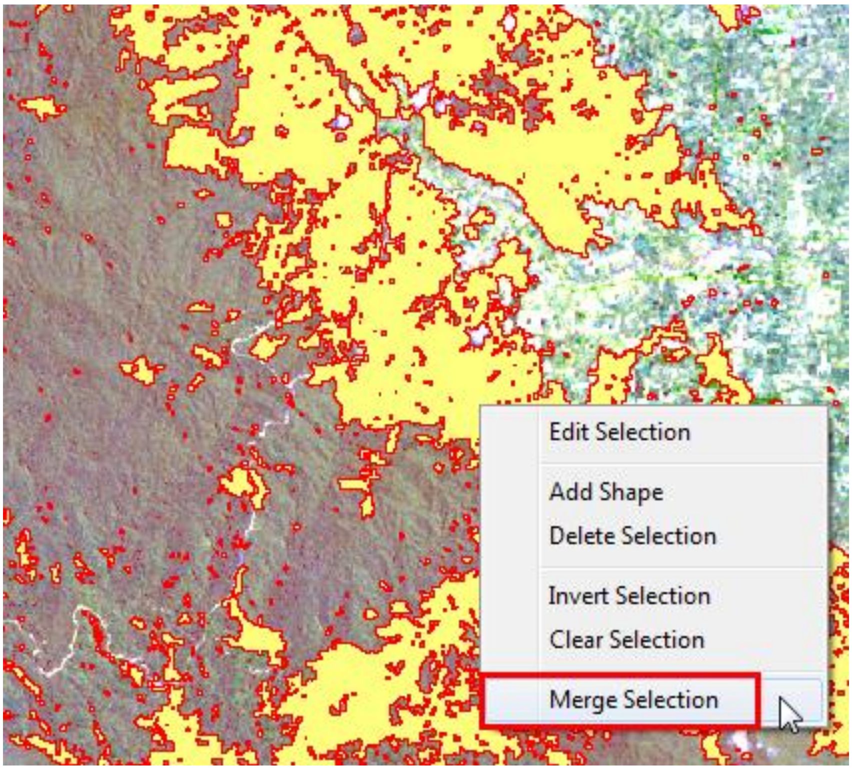


Right click on the polygon layer and under the attributed menu select show. this will open the attribute table. You will see there is currently an entry for each individual polygon. We want to merge these into one polygon that we can calculate the area for.

	ID	VALUE	NAME
1	1	1.000000	Class 1
2	1	1.000000	Class 1
3	1	1.000000	Class 1
4	1	1.000000	Class 1
5	1	1.000000	Class 1
6	1	1.000000	Class 1
7	1	1.000000	Class 1
8	1	1.000000	Class 1
9	1	1.000000	Class 1

To merge all use the pointer tool to drag a box around the whole image to select all polygons. Now right click on the image and select "Merge Selection".





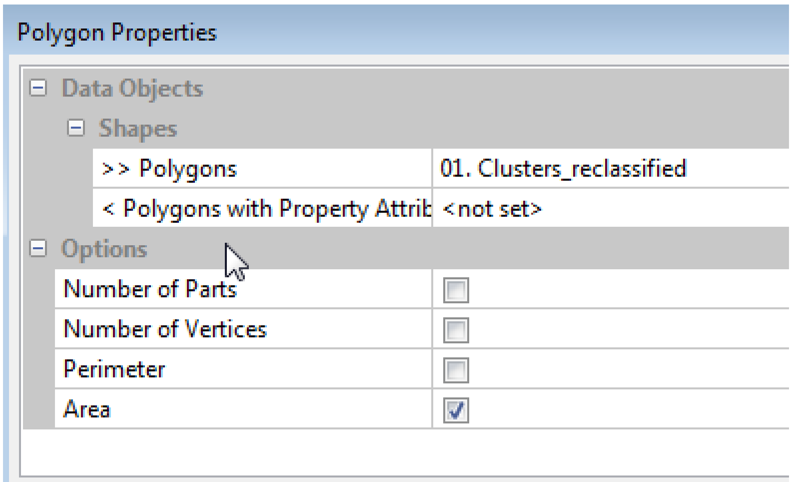
View the attribute table again and you will now see only one polygon:

	ID	VALUE	NAME
1	1	1.000000	Class 1

To calculate the area of this polygon:

Use: Geoprocessing>Shapes>Polygons>Polygon Properties.

Select your merged class (Cluster) polygon layer and tick Area as the output property.



You will then see area appear as a value in the class polygon layer's attribute table.

VALUE	NAME	AREA
1.000000	Class 1	265973400.000000

Land cover change assessment can also be conducted by classifying Imagery into land cover classes for each image date (year) as shown in section 8. This technique allows for a more sophisticated assessment of change between land cover types. This is described in more detail in section 8.2-8.3.

10.3 Assessing sediment flows from a field survey of small-scale mining in west Timor

This tutorial uses data from Indonesian west Timor to explore the impacts of small-scale (artisanal) manganese mining in one catchment.
(https://asm4d.wordpress.com/).

Artisanal and small-scale mining (ASM) involves up to 30 million people worldwide contributing 15-20% of global mineral and metal production. This form of mining is generally defined as a community activity with little capital input or formal recognition, focusing on marginal or small deposits. The number of people involved in ASM has increased substantially over the last ten years as world mineral prices have shot up. Despite its scale this form of mining is often viewed negatively by governments and international agencies due to the potential for adverse environmental and health impacts. However artisanal and small-scale mining does provide poor people direct access to the mineral wealth of their land, providing diversified livelihood's and positively develop community resilience.

This section uses elevation data from west Timor: West_Timor_(SRTM_80m)

The example application described here imagines that location data of mining sites have been collected in the field using a GPS and the coordinate locations entered into excel. This data is then used to look at potential sediment flow paths from these mining points. The process described in this section involves the following steps:

1. Import field data CSV file into SAGA
2. Convert to point data
3. Add erosions potential (LS Factor) values from grid to points
4. Convert points to Grid
5. Use this grid to model flow paths

Import field data CSV file into SAGA

The CSV file used here is included with the west Timor elevation data download.

Load the CSV file by simply dragging and dropping it into SAGA (as shown in **section 7.7**).

Now convert the imported location table to point data:

Use: Shapes>Conversion>Convert table to points

Choose the resulting table layer as the table to be converted and x as your Easting (or Latitude) and Y axis as you Northing (or Longitude) values (as shown in **section 7.7**).

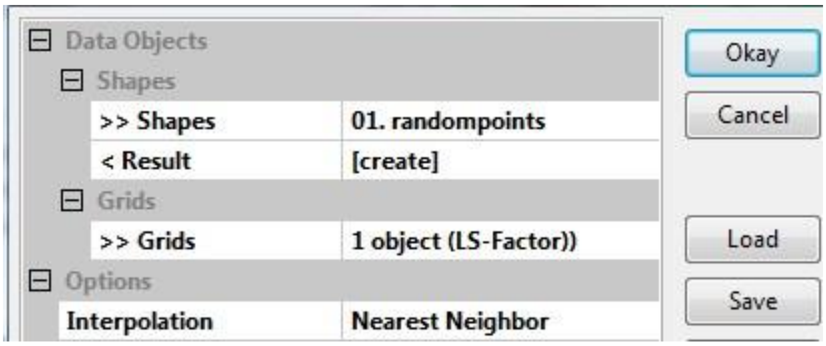
Intersecting Raster and point data

It is possible to add values from terrain grids to point data. For this example we will add Length Slope (LS) factor value to our mine points. As described in **section 9.2** the LS factor is one of the primary measures of erosion potential. We, therefore, will use the LS factor value to weight the sediment flow amount from each point. Use the basic terrain analysis tool to create an LS factor grid for one catchment in the west Timor elevation data following the method is shown in **Section 9**. Then add the LS factor values to the point data:

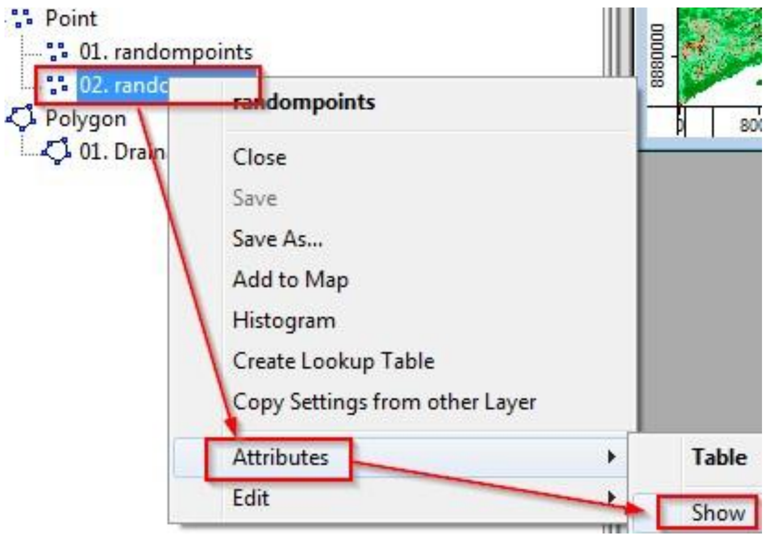
Use: Geoprocessing>Shapes>Grid>GridValues>Add Grid Values to Points.

The module window will then ask for:

- The point shape we want to add the data to.
- The results file (choose [create] to make a new point layer).
- The grid we want to take the parameters data from (This can be multiple grids)
- And the method for extracting the attribute data. Use "Nearest Neighbour"



Check that the new terrain attributes have been added by checking the attribute table: Right click on the new shape file and select **Attribute>>Show.**



A LS-Factor tribute column with values should appear for each point.

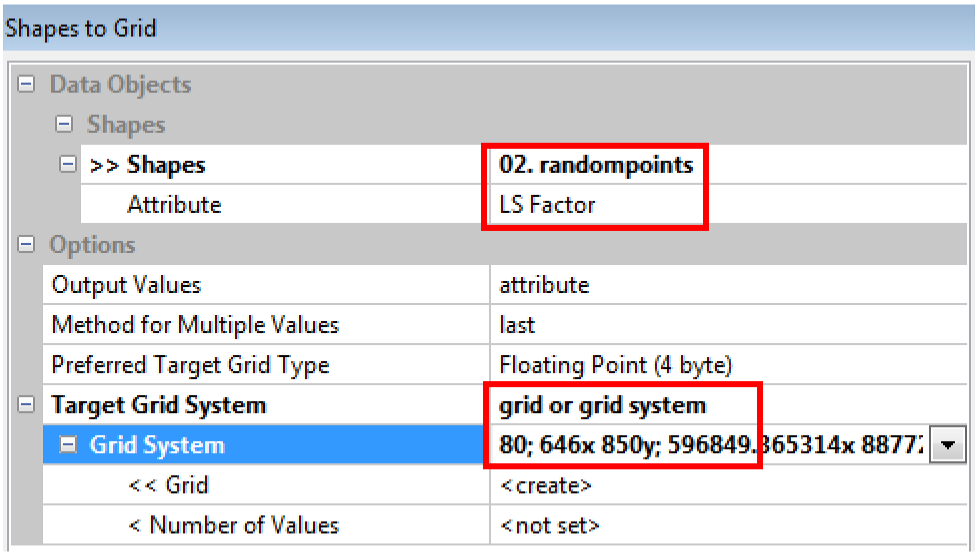
LS-Factor
11.399673
4.236103
8.179164
4.762056
0.443540
0.788774

Visualising Sediment flow.

We will now use these points to visualise sediment flow in the catchment. To do this we first need to make the point data into grid data.

Use: Geoprocessing>Grid>Gridding>Shapes to Grid

Select Random Points as your input grid with LS factor as the output

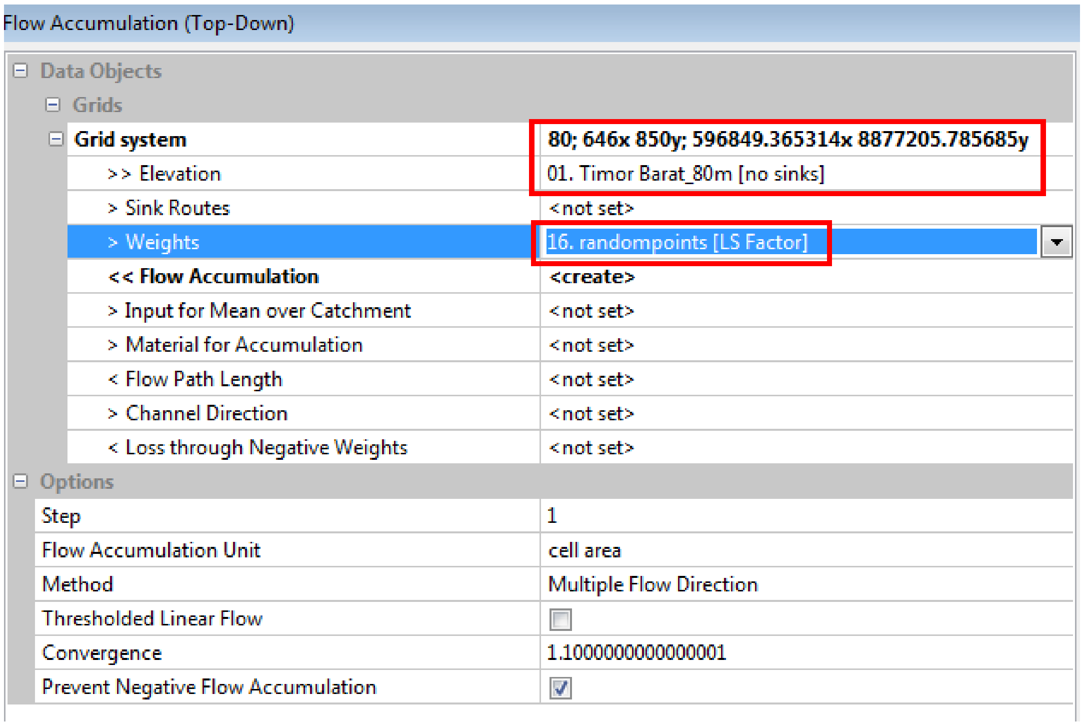


You will now have a new grid (random points (LS Factor)).

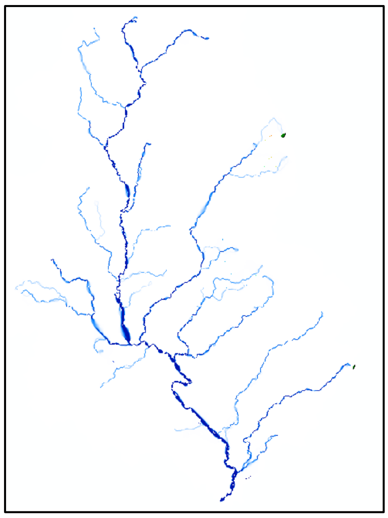
To create a sediment flow grid from these points:

Use: Geoprocessing>Terrain Analysis>Hydrology>Flow Accumulation>Flow Accumulation (Top Down)

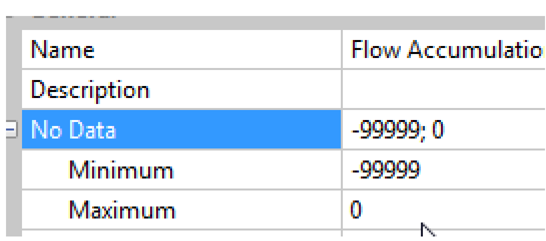
Set the elevation data set to the sink filled catchment elevation grid and the weights to the LS factor grid.



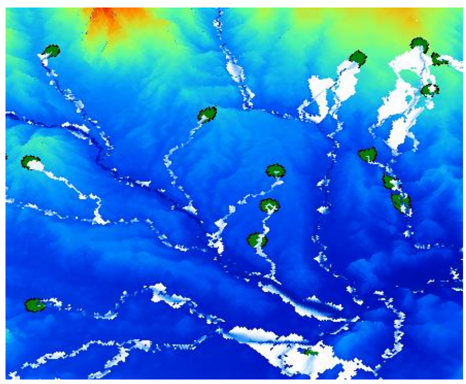
You should see an output grid like this:



Setting the No Data maximum value to 0 in the settings tab allows you to visualize the flow data over your other data.



Try then viewing the output in 3D:



10.4 Assessing potential toxic heavy metal flows from a satellite-based assessment of a small-scale mine area in South East Sulawesi

Artisanal gold mining in the Bombana District of Southeast Sulawesi began with a gold rush in late 2008. From September 2008 until April 2009, official records show that more than 63,000 people flooded into the district from neighbouring areas and beyond the province. Without meaningful guidance from the government, the gold rush quickly led to a variety of unexpected and deleterious social and environmental impacts. Environmental damage has been widespread with increased erosion and river sedimentation from river bank and alluvial mining, the conversion of forest land and markedly reduced downstream river flows and water quality. Since these events and the emergence of community opposition to the poorly regulated ASM activities, government efforts have focused on issuing mining licenses to private companies and restricting ASM activities.

For this exercise, we will be first classifying mining areas from a from a small scale mining region in South East Sulawesi using Object-Based Image analysis segmentation techniques. We will then use this classification for conducting a hydrological analysis of potential heavy metal flows through the lands scape using hydrological modelling tools. The four follow steps will be used in this exercise:

1. Import Landsat Imagery and identify mining areas
2. Classify mining areas using an image segmentation approach
3. Open Digital Elevation Data and Fill sinks
4. Run Flow tracing analysis to identify affected catchments and outflow points

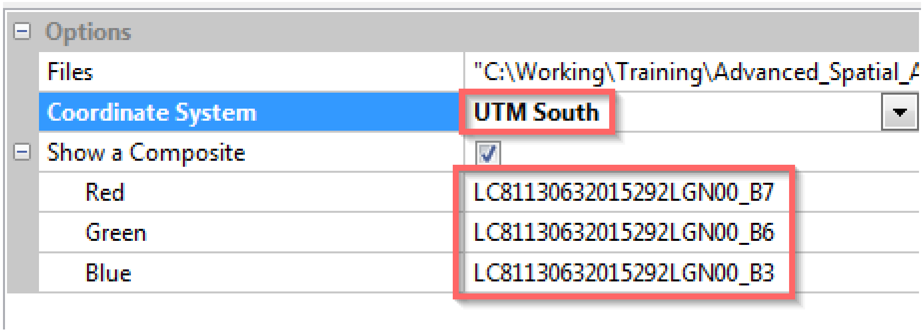
This section uses: Landsat data from Sulawesi from 1996 and 2015. (219mb)

Access a video tutorial here:
https://sagatutorials.wordpress.com/mapping-mines-site-sediment-flows/

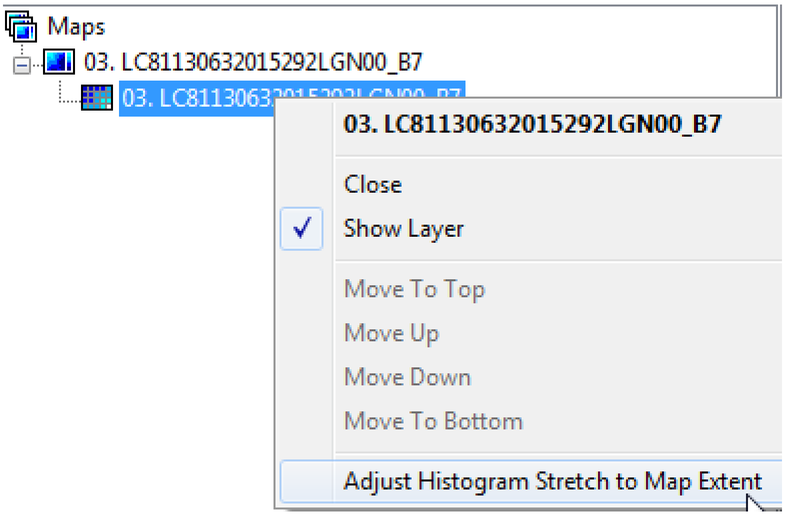
Import imagery

In this exercise we will map the extent of gold mining in Bombana using imagery from October 18 2015. Load bands 3,6,7 from this image date and in the displayed map zoom to the Bombana mining area.

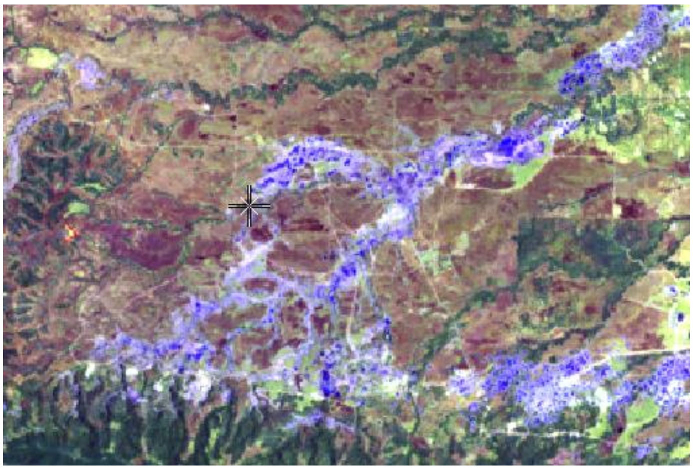
Use: Geoprocessing>Imagery>Landsat Import With options



Zoom to the mining area and in the **Map Tab** right-click on the displayed layer and select **Adjust Histogram to map extent.**



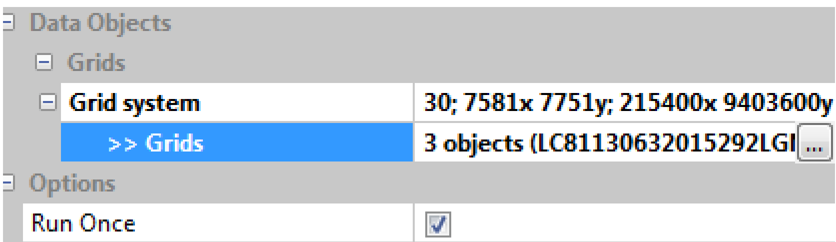
The mining areas should appear clearly as blue. This is a reflectance response from standing muddy water.



Clip imagery to our area of interest
Look carefully at the imagery to identify all the mining areas. We will now cut the imagery to include just the mining area.

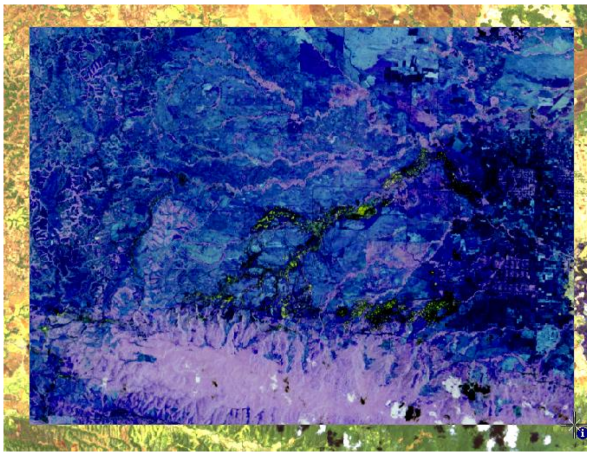
Use: Geoprocessing>Tools>Grid>Grid System>Clip Grid Interactive

Select the grid system and all the loaded grids to clip.

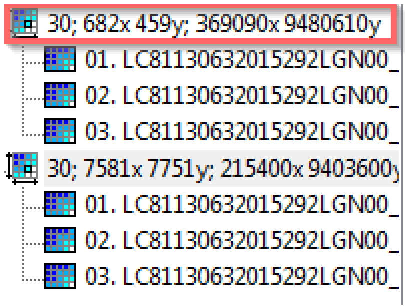


Now use the cursor tool to draw a rectangle around the mining region.

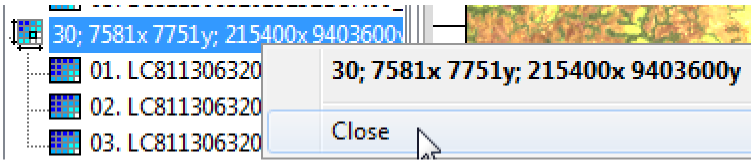
You will next see a box asking you to confirm your selected extent. If your selection was wrong you can select cancel and select your area again.



Once you have made a correct selection your new dataset will appear in the data tab:
You will be able to see which is your new dataset by the smaller extent values in the grid system.

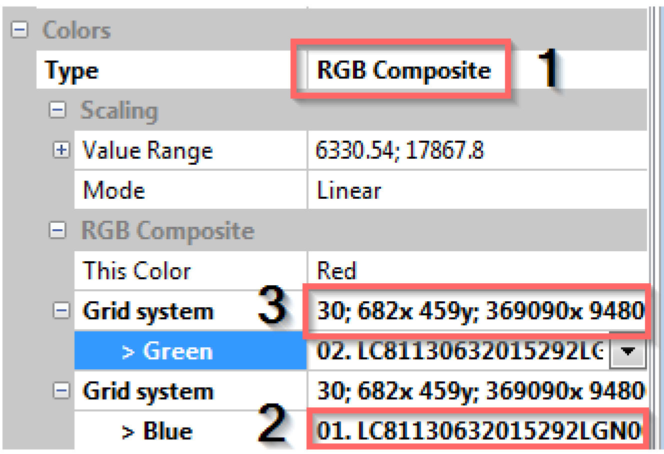


Right click on the larger grid system and close it:



We will not need to work with the full Landsat data again.

To redisplay the new clipped imagery as an RGB composite double click on the band 7 layer to display it then in the properties tab for that band; **(1)** Select RGB composite as the display type **(2)** Blue as Band 3 and **(3)** Green as band 6 then click apply.



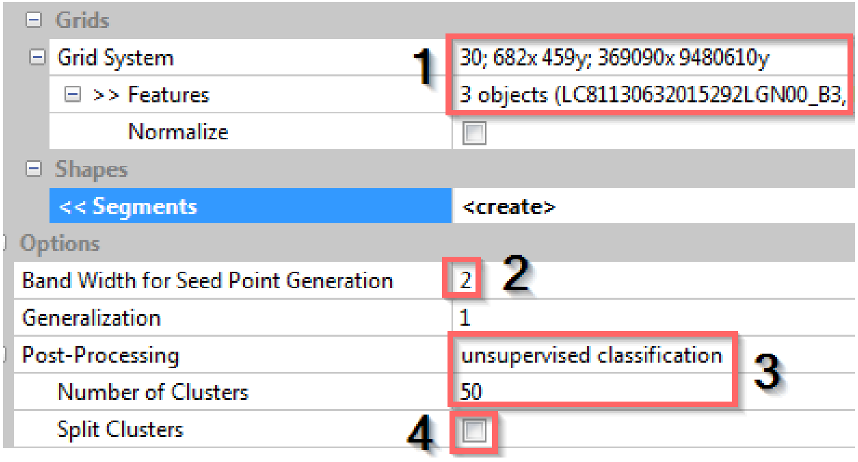
Run Object Based Image Analysis (Segmentation)

Use: Geoprocessing > Imagery > Segmentation > OBIA > Object Based Image analysis

1) Select your cropped data and the three bands.

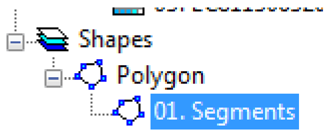
2) Set band width for seed generation to 2. Changing this changes the size of segments produced.

3) Select unsupervised classification and 50 classes for post processing

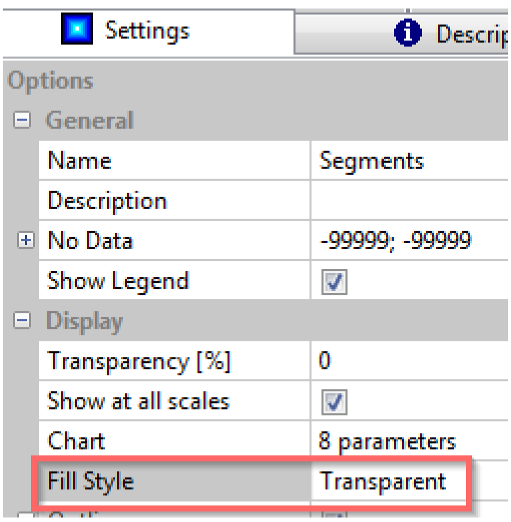


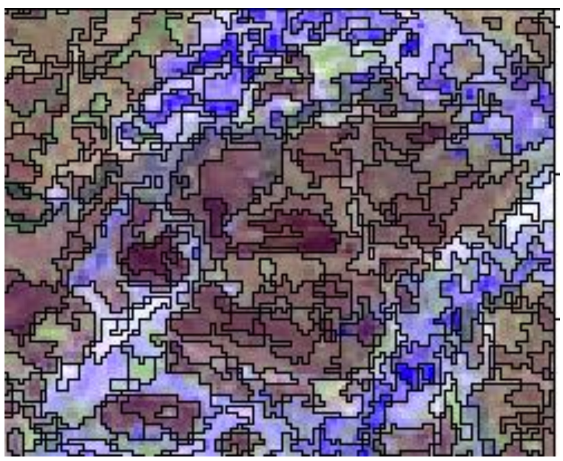
4) Deselect Split clusters. This will mean that we select multiple polygons of the same class.

A new shapes “segments” data set will be produced. Double click on this to display it over your satellite imagery.

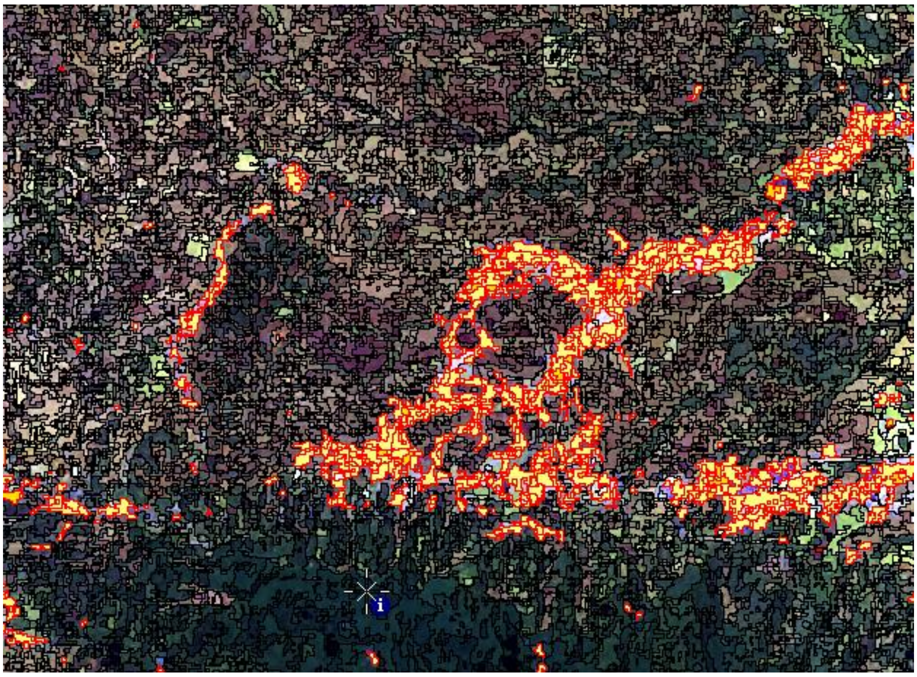


Make the segment shape file transparent so you can view the underlying data in the settings tab. Set the fill style to transparent:





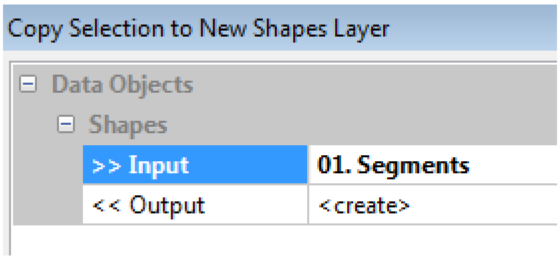
Now using the cursor tool select a number of polygons surrounding mined areas. Selecting one polygon will then select all polygons of the same class. Use the **CTRL** key to select additional polygons.



Select enough polygon classes to capture most of the mined area without too many polygons outside the mined area selected as shown here

Now we need to copy the selection to a new shapes layer.

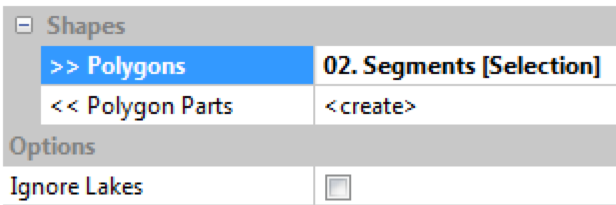
Use: Geoprocessing>Shapes > Selection > Copy selection to new shapes layer



Edit the mine site selection

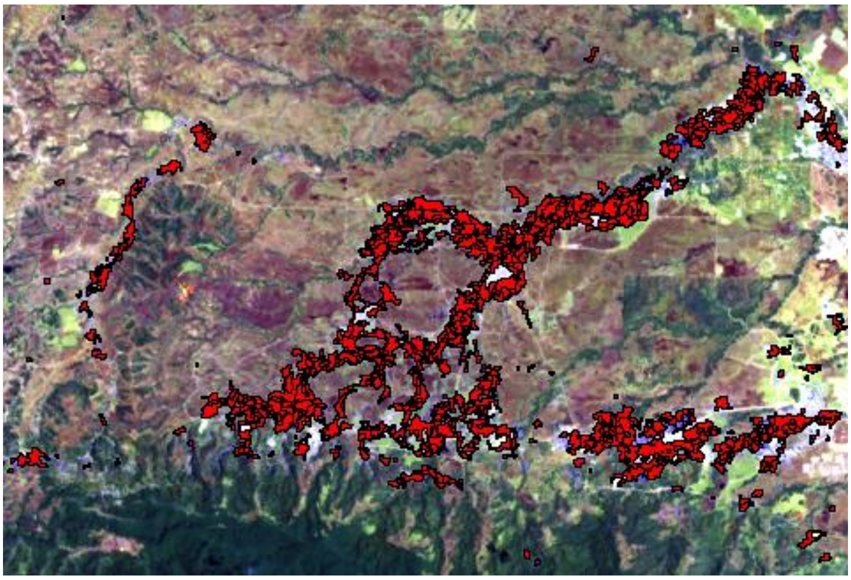
To clean up the section classification we now need to separate the polygons in the new shapes layer so we can edit (Delete) individual polygons.

Use: Geoprocessing>Shapes > Polygons > Polygon Parts to separate Polygons

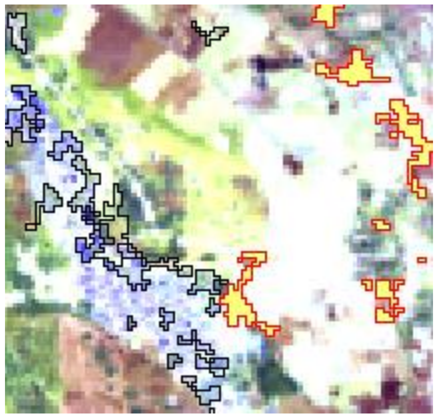


Now display the new 'selection Parts' shape layer over the satellite imagery.

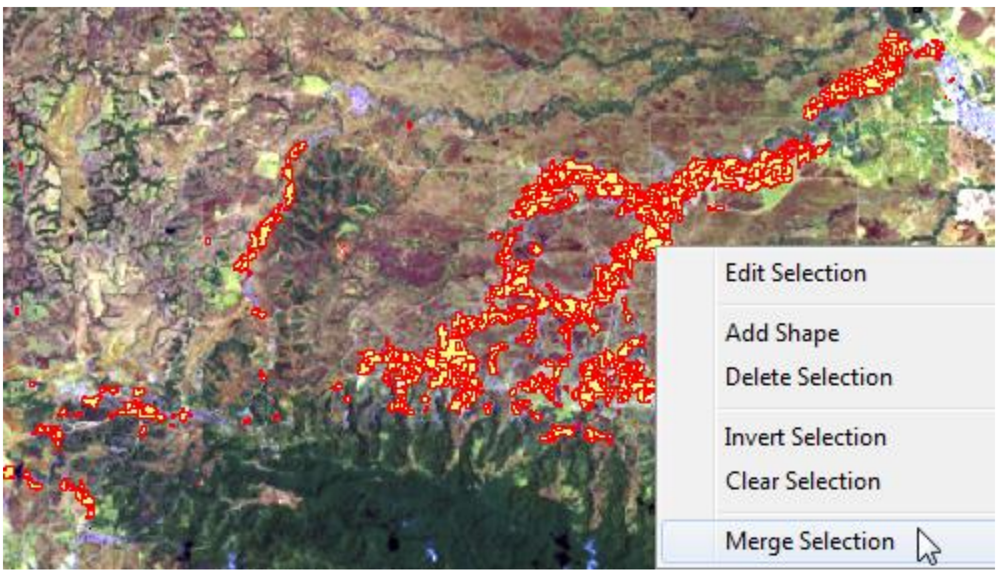
Turn off the old segment layer in the map view by double clicking on it. You should see something like shown here:

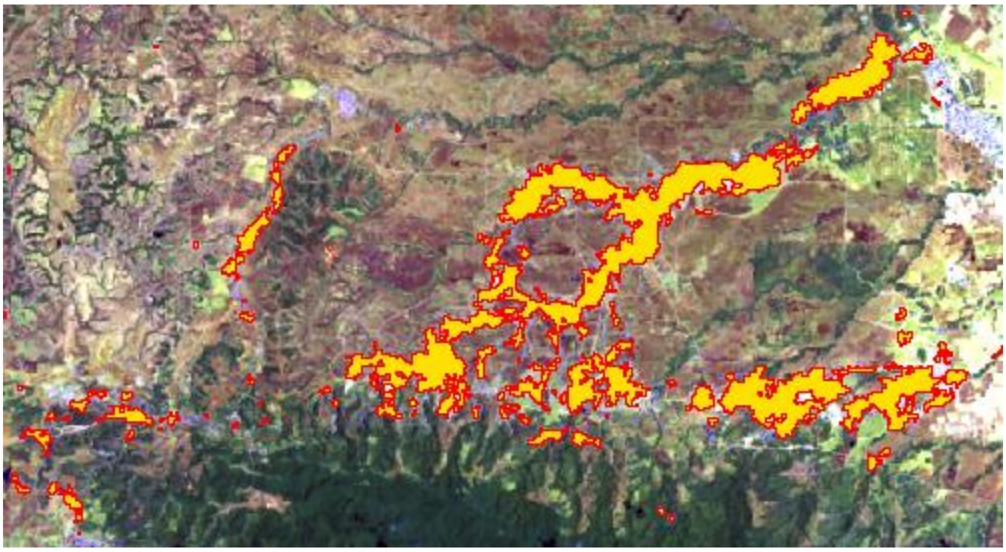


If you now make the polygon selection transparent you can select (Using the cursor tool) and delete incorrect polygons.

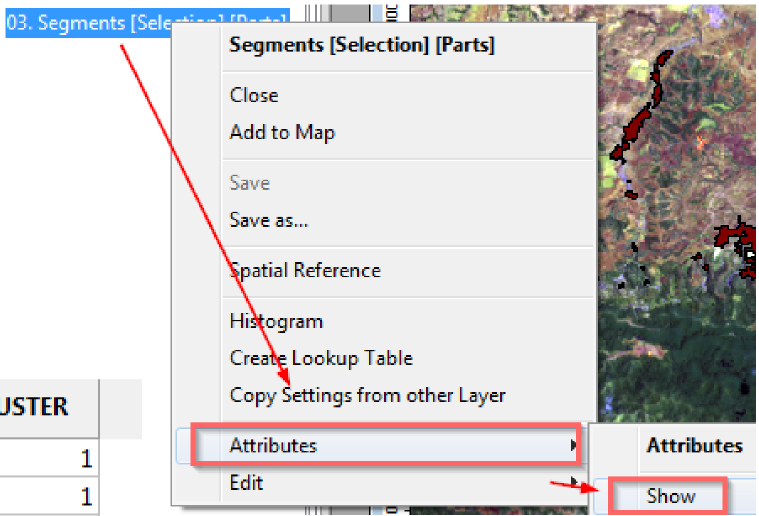


Once you have cleaned up the mine classification select all the mine site polygons then right click to **Merge Selection** into one multi-part polygon.





Once you have done this right click on the Polygon layer in the Data Tab to view the attribute table for the merged mining area classification.

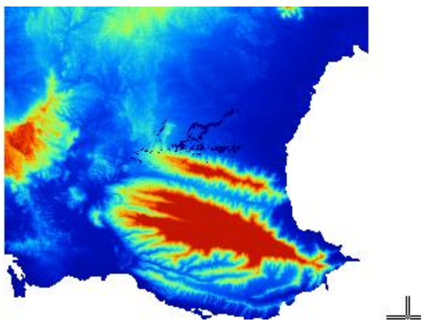


There should only be a few classes (Clusters). Make sure that each cluster has the same value (1) as we will use this as the value to weight the sediment flow analysis.

	CLUSTER
1	1
2	1
3	1
4	1
5	1

Sediment flow analysis

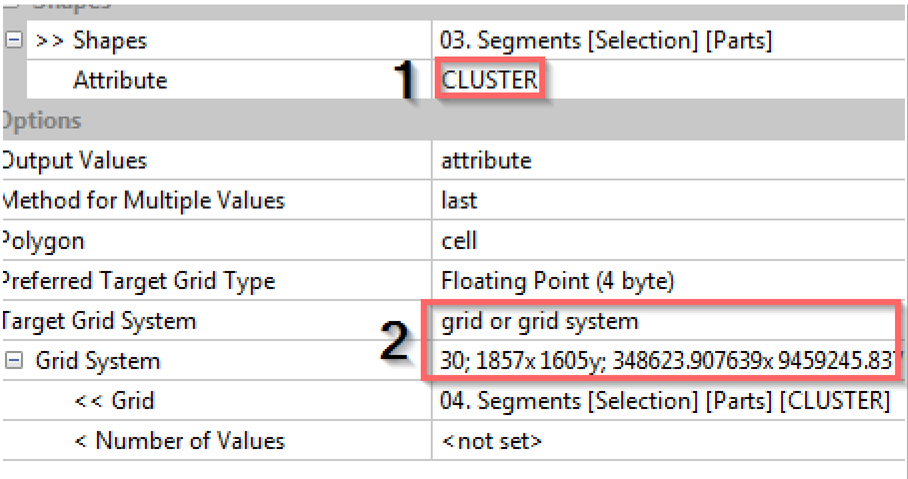
Load the South East Sulawesi DEM grid. We will use this grid when we convert our classified segments to a raster file.



Convert cleaned up classification to raster data

Use: Geoprocessing> Grid>Gridding>Shapes to Grid

1) Select cluster as the attribute value the grid cells will take.
2) Select the loaded DEM grid system as the target output grid system for the new grid.

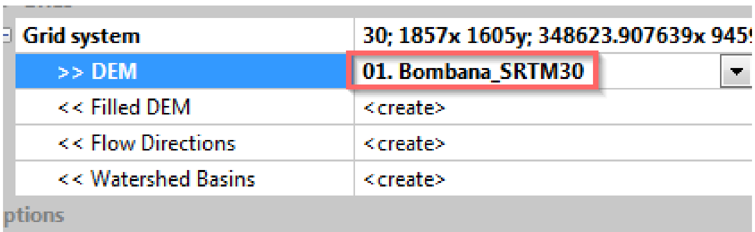


Display the resulting mined area raster grid over the DEM.

Preprocess the DEM

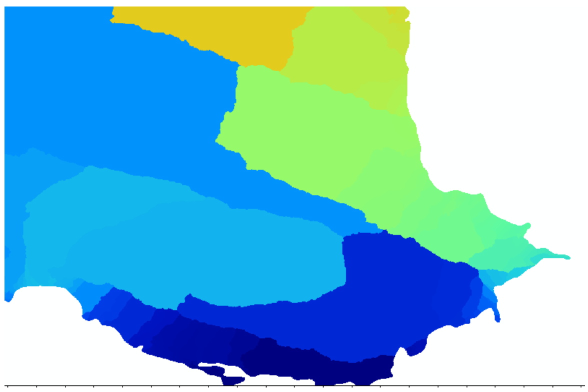
Before we can do a flow analysis we need to fill sinks Fill sink. Remember to produce a sink filled elevation data;

Use: Geoprocessing>Terrain Analysis>Preprocessing>Fill Sinks (Wang Liu).



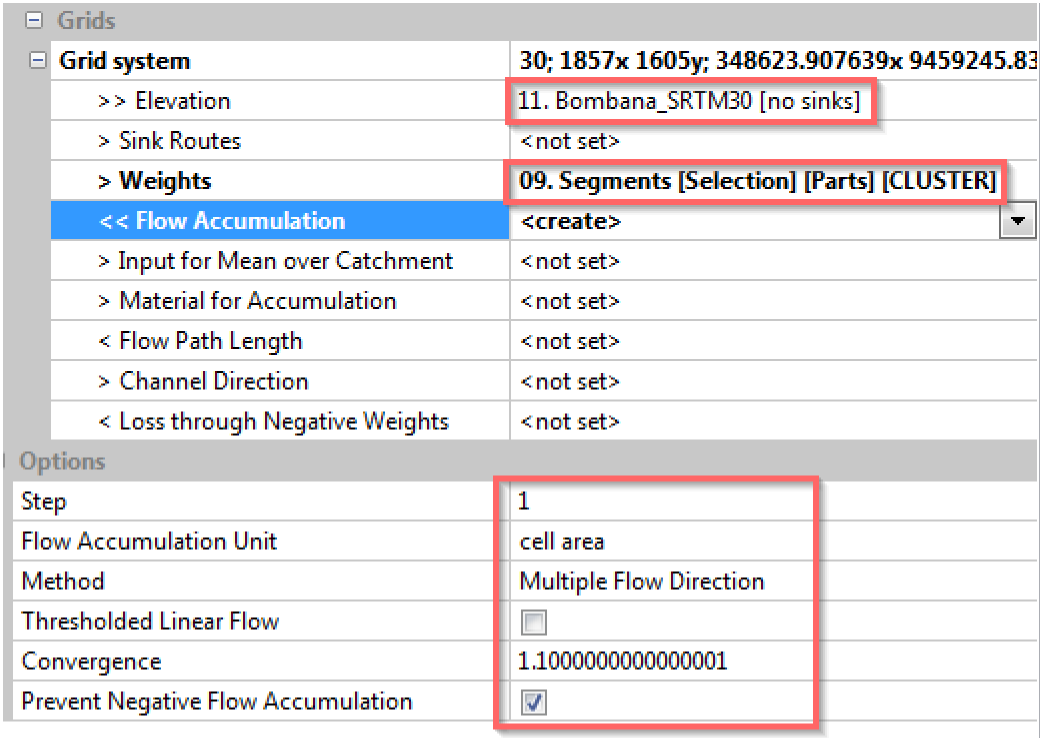
Have a look at the resulting catchment boundary grid.

Can you use this to predict where the sediment form the mine sites will flow?



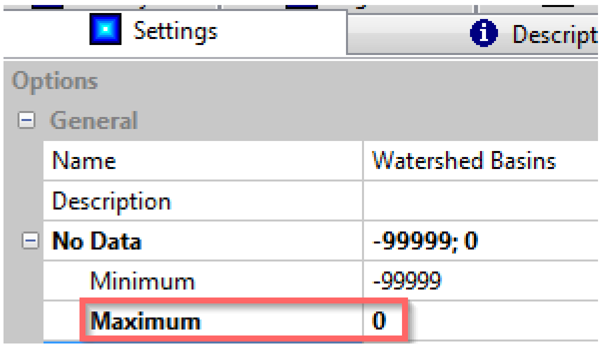
Run flow path tracing.

Use: Geoprocessing > Terrain analysis > Hydrology > Flow accumulation > Flow tracing

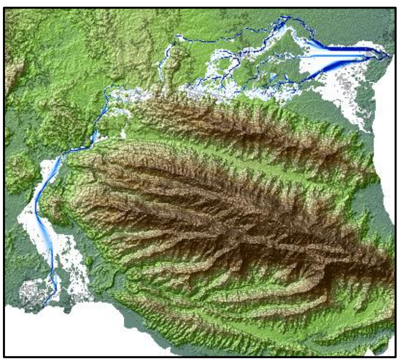


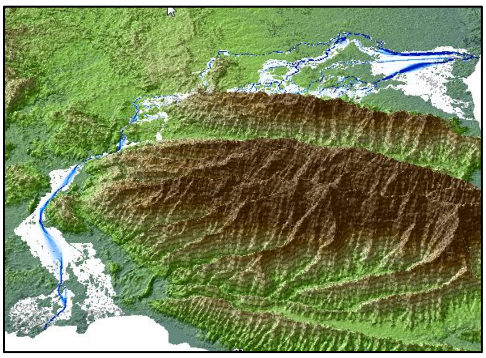
[Note try changing the flow accumulation method you use and see how the results differ]

Double click on the resulting **Flow Accumulation** grid to display the result. To see the flow paths over the elevation data you will need to go into the **Setting Tab** and set the **No Data Maximum** value to 0. This will make the 0 values transparent.



Try displaying the flow paths over a 3D representation of the landscape as shown below.





11. Advanced concepts

This section covers the following concepts:

Tool Chains

SAGA Tool Chains capability allows multiple modules to be joined together to automate and speed up complex processing sequences.

Travel time analysis:

Described are two SAGA-GIS tool chains that automate and simplify some of the processes required for conducting raster based travel time analysis. The tools also allow a degree of interactivity and adaptability supporting the rapid exploration of multiple travel time scenarios through altering continuous variables, such as travel speed as well as adding discrete factors such as barriers, new roads or services.

Error Matrix

An error or confusion Matrix is a technique for comparing changes between two raster (grid) data sets that is commonly used for land cover change analysis.

Atmospheric correction

Imagery reflectance values can be converted to Top Of Atmosphere (TOA) Reflectance (combined surface and atmospheric reflectance) to reduce variability between scenes from different dates through a normalization for solar irradiance.

Troubleshooting

This section should help with some common known issues with SAGA

11.1 Tool Chains

SAGA Tool Chains capability allows multiple modules to be joined together to automate and speed up complex processing sequences. Tool chains are similar to the ARC-Map model builder however instead of a graphic interface SAGA uses an xml file to join processing modules. The easiest way to start creating a tool chain is through exporting a files processing history as an xml file then editing it in Notepad ++ (https://notepad-plus-plus.org/download/). The process is quite easy and, as you get the hang of building tool chains you'll find them incredibly useful.

The SAGA team have created a number of Chain Tools that you can investigate to get an idea of how they work. You will find them in the '\modules\toolchains' folder of your SAGA installation. The following section described two tool chains developed to assist cost distance analysis applications for modelling travel time to services.

You can find a short video tutorial showing the creation of a simple tool chain for processing elevation data at https://sagatutorials.wordpress.com/tool-chains/.The example produces a catchment area polygon file and a high erosion risk grid based on a LS Factor analysis.

11.2 Travel time analysis tools

Modelling travel time to services has become a common tool for evidence-based infrastructure planning to assist improved public service provision. However, most of the travel time modelling tools currently available are in expensive, complex, proprietary GIS software limiting their decentralised application. Improving the accuracy and relevance Travel time analysis requires greater accessibility to, and flexibility in, travel time modelling tools to facilitate the incorporation of local knowledge and the rapid exploration of multiple travel scenarios. The tools described in this section were developed to support simple open source, adaptable, interactive travel time modelling tools allowing greater access to and participation in service access analysis.

This section describes tools developed for SAGA-GIS software that automates and simplifies some of the processes required for conducting raster based travel time analysis. The tools described have been developed as SAGA GIS tool chains. As described in the previous section tool chains link multiple SAGA processes into one tool using simple xml scripting code. The two tools produced are (1) for land cover grid creation and (2) travel time calculation, the latter requiring the output of the first. Separating the two tools allows for simpler and faster execution to test multiple scenarios with the Travel Time Grid creation tool without having to recalculate the base land cover grid each analysis iteration. A flow chart of the processing steps and the connection between the two tool chains is provided at the end of this section.

For this section you can use the data: Travel time analysis - Example-Data (4.2mb)

Screen videos of this application are available here:
sagatutorials.wordpress.com/travel-time/

This work is described in more detail in an article (Fisher et al 2017) available here:
https://ij-healthgeographics.biomedcentral.com/articles/10.1186/s12942-017-0086-8

The data provided for this section includes a vegetation grid, elevation grid, road vectors, destination points and reclassification tables.

Land Cover grid creation

The **Land Cover grid creation tool** combines vegetation, transport infrastructure (roads) and elevation data to produce a raster grid of land cover including rivers and creeks. The land cover grid is used as the basis for the travel time calculation with each land cover type being allocated a potential travel speed value. In the example shown here the vegetation and road data were pre-processed as follows:

- Vegetation data was produced from Landsat 8 imagery and classified into 4 broad classes; Forest, Scrub, Grassland, Bare Land. This data set was produced at a 50-metre grid cell size and becomes the base grid system to which other created data are resampled to.

- Road data was obtained as vector data and attributed into three classes based on infrastructure quality; class 1 national road, class 2 provincial road and class 3 local road.

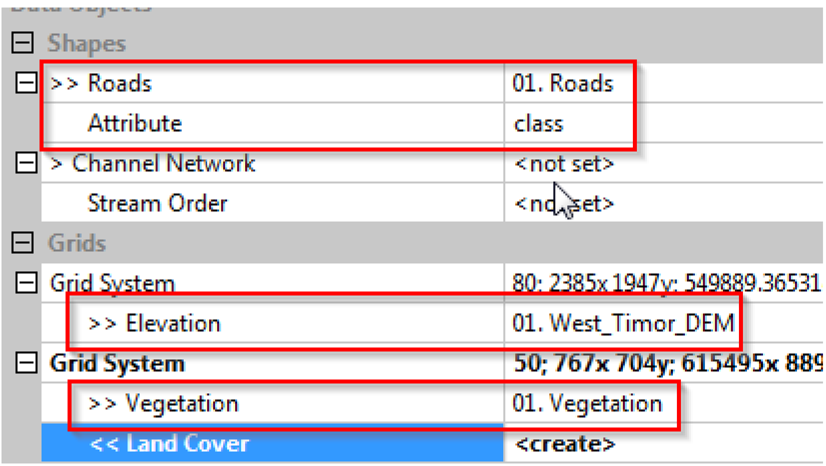
The elevation data is derived from SRTM data and used to create water channel data. The water channel data is created within the Land cover grid creation tool chain in the form of a Strahler order raster layer. The Strahler order is a measure of flow accumulation within a landscape and within the travel time calculation is used to model barriers to travel based on different seasonal scenarios.

Five Strahler classes are produced in the analysis grid with the highest class most likely to be impassable throughout the year.

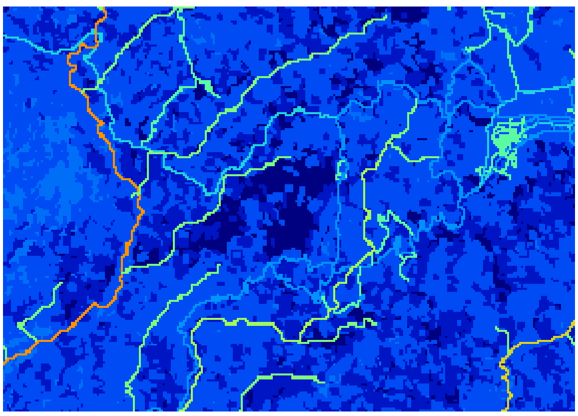
Use: Geoprocessing > Grid>Analysis>Travel Time Analysis>Land Cover scenario offset

The Land Cover grid creation tool input window can be seen here to the left using the inputs:

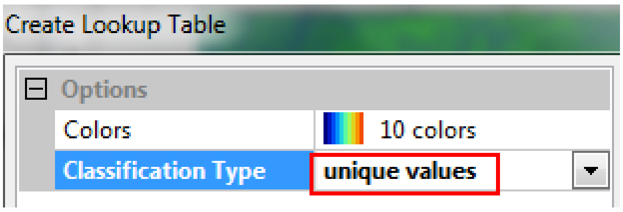
1. Timor_Barat_80m (DEM)
2. Veg (Vegetation)
3. Roads, selecting class as the attribute
4.



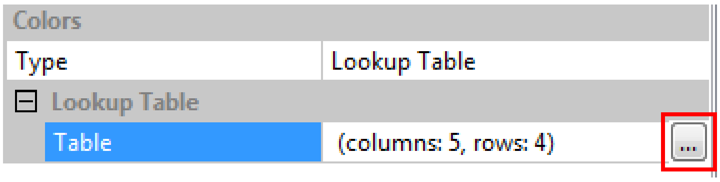
The output grid, shown here, is randomly coloured. It helps to interpret the output if it is re-coloured using a more intuitive colour scheme.



To achieve this right click on the LC grid and select Create Lookup Table. Select **“unique values”** as the **“classification Type”.**

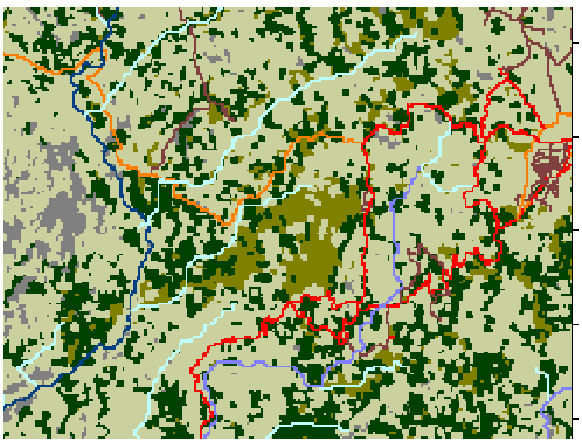


Click **apply** in the **Object Properties Tab** then select **Lookup Table** as **the colour Type**



Finally, Change the colours in the colour lookup table to produce an easily interpretable land cover grid image as shown here.

	COLOR	NAME	DESCRIPTION
1		1	Scrub
2		2	Forest
3		3	Grass
4		4	Rock
5		101	Stream 1
6		102	Stream 2
7		103	Stream 3
8		104	Stream 4
9		105	Stream 5
10		201	Road 1
11		202	Road 2
12		203	Road 3



Travel Time Grid creation

The **Travel Time Grid creation tool** travel time to destination in minutes and this data reclassifies as travel time or remoteness zones. The Travel Time Grid creation tool requires the input of the Land Cover grid, destinations points as vector data, and two reclassification tables.

- The destination data is provided as vector points. These can be edited and moved or new point added after each run of the model to produce new output scenarios based on changing service provision.
- The first reclassification table (see table 1) gives travel speed values for each land cover class calculated as the number of seconds to travel across one grid cell using the formula [Km/h x 180] where 180 is the number of seconds to travel 50 metres at 1 km/h. For the water-way classes (8-12) a very high (>99999) is given to allocate that class as a barrier (not crossable) due to flooding. The travel time values can be altered after each run of the model to produce new output scenarios based on differing travel conditions
- The second table defines a look up table (LUT) recolouring the output grid into travel zones. (table 2). This is optional.

Table 1.

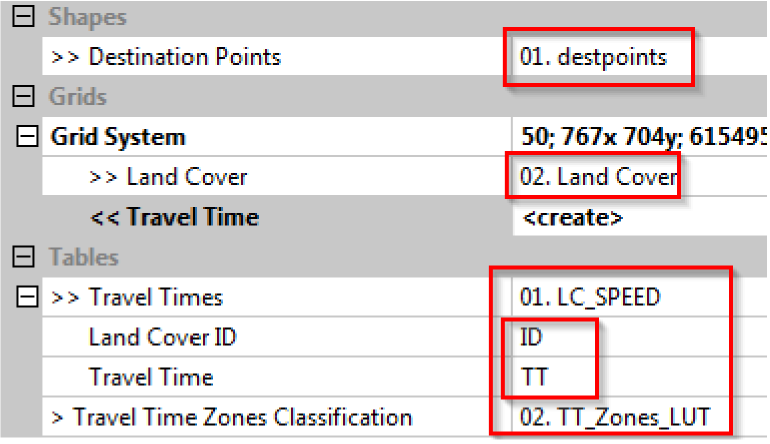
ID	Cover Class	km/h	Travel Time (Sec)
1	Forest	1	180
2	Grass	2	90
3	Bare, Rocky	3	60
4	Scrub	0.75	240
101	Stream Class 1	2	90
102	Stream Class 2	2	90
103	Stream Class 3	2	90
104	Stream Class 4	2	90
105	Stream Class 5	0	99999
201	National Road/Hi-way	50	3
202	Provincial Road	25	7
203	Local Road/Track	10	18

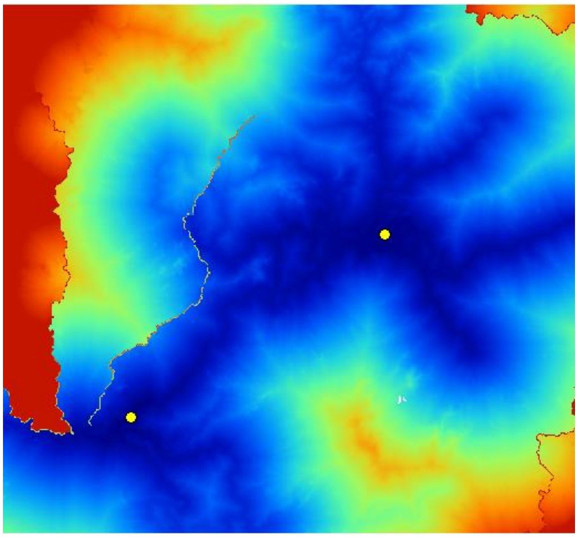
Table 2.

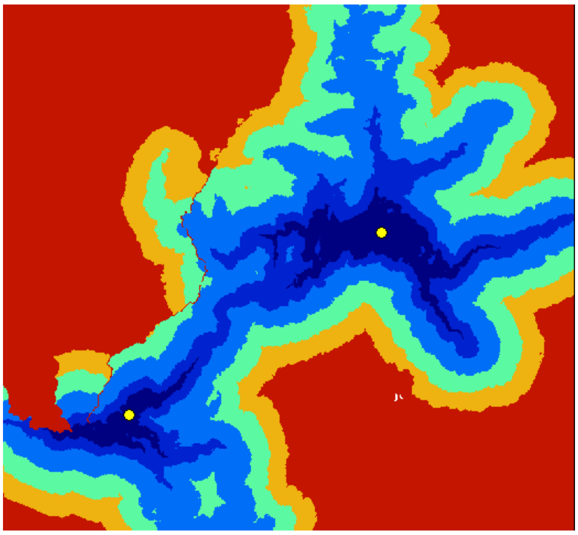
COLOR	NAME	DESCRIPTION	MINIMUM	MAXIMUM
8388608	1	0 - 15 min	0	15
8421440	2	15 - 30 min	15	30
2280084	3	30 - 60 min	30	60
65535	4	60 - 90 min	60	90
33023	5	90 - 120 min	90	120
213	6	120 + min	120	999999

Travel Time grid creation tool input window can be seen here to the left using the inputs:

1. Land Cover Grid derived from the Land Cover grid creation tool.
2. Destpoints (Sestination points)
3. LC_Speed (Table 1)
4. TT_Zones (Table 2)







Output one is the travel time grid showing the distance to destination points in minutes. Output two is the travel time grid reclassified into zones using table 2.

Interactive modelling

Alternative travel time scenarios can be rapidly modelled three ways through: (1) altering the location and number of destination points, (2) changing the travel speed table and (3) editing the Land Cover grid.

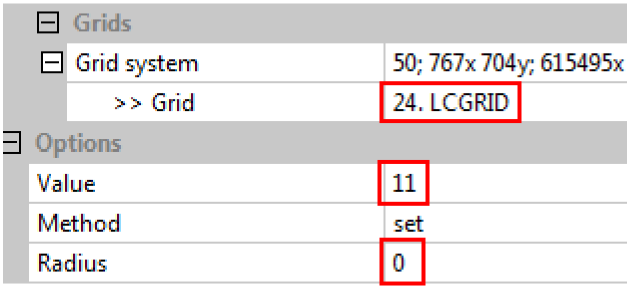
To edit the location and number of destination points select the point data layer on the data tab then use the pointer tool to select a point in the map window, right click and select Edit Selected Point . You can now move or delete the point. To add a point right, with the point data layer on the data tab selected, right click on the map window and select “Add Shape” then select the location on the map where you want to add a new point and hit enter.

To change travel speed values right click on the travel speed table in the data tab to open the table then alter the values in the travel time column. For example, you may wish to make all the travel time values for the waterway classes very high to model travel after a large rainfall event making all stream channels impassable or increase all the walking (non-road) travel times to simulate someone being carried.

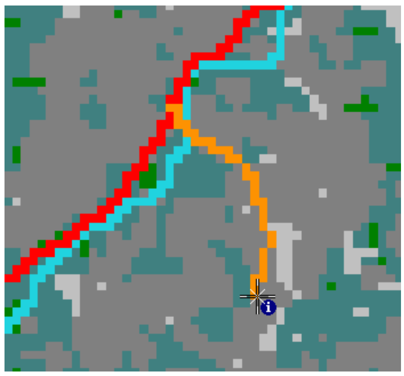
It is also possible to directly edit the Land Cover grid, for example, to reduce travel speeds on sections of road known to be damaged or add new roads and tracks know to exists by planning participants but not otherwise captured in by the road data used in the initial analysis. To alter the Land Cover grid use the "Change Values Interactive:

Use: Geoprocessing>Grid>Values>Change Values Interactive

In the example shown to the right, the new value we wish to "draw" on the land cover grid has been set to 11 so we can draw a new local road. If adding a barrier to travel, ie a new flooded area, set the radius to 1 or more to make a solid line. Note when drawing on the travel grid move the cursor slowly to paint a contiguous line.



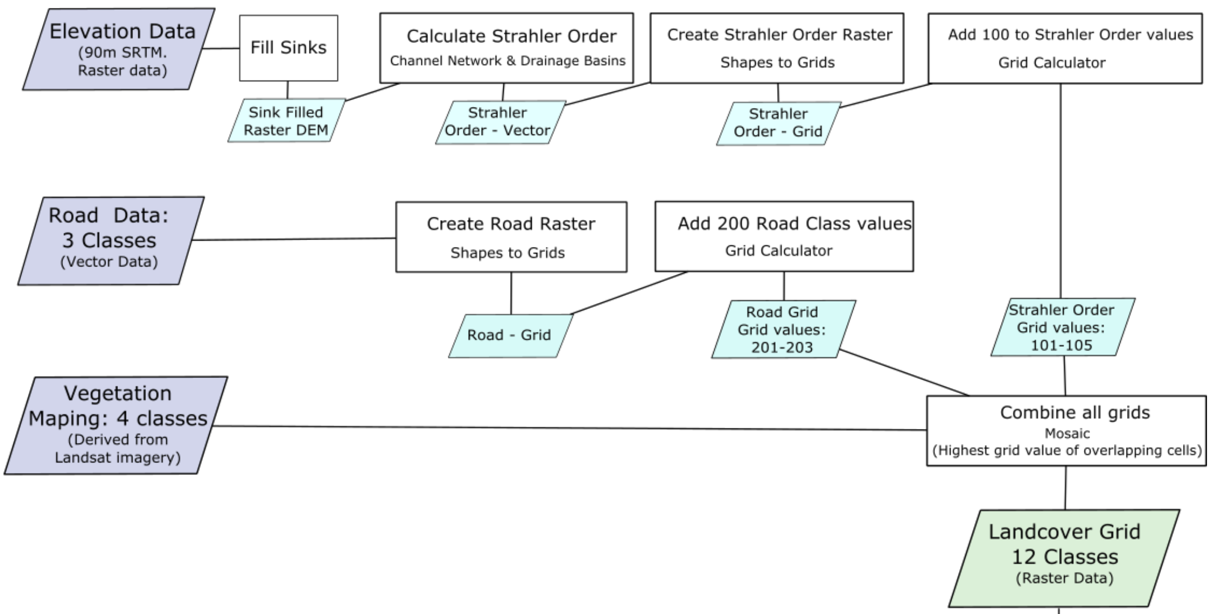
Now use the cursor tool to slowly draw then new cell values across the land cover grid.



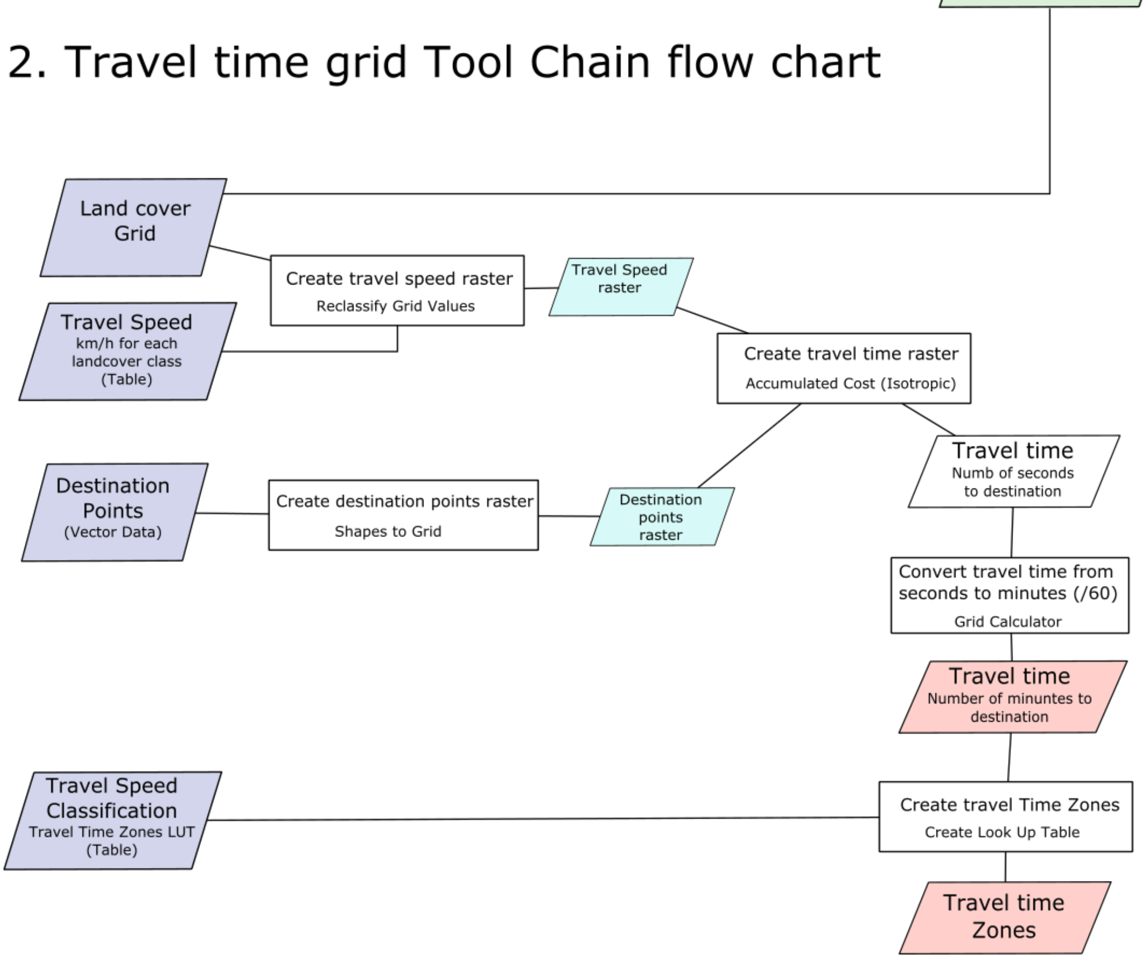
After editing the destination points, travel speed table and/or land cover grid it is possible to directly run the Travel Time Tool again to see new outputs. After each iteration of the model you can save the to output as a map graphic or a GIS file to further compare scenarios.

Fisher, Rohan, and Jonatan Lassa. "Interactive, open source, travel time scenario modelling: tools to facilitate participation in health service access analysis." International Journal of Health Geographics 16.1 (2017): 13.

1. Landcover grid Tool Chain flow chart



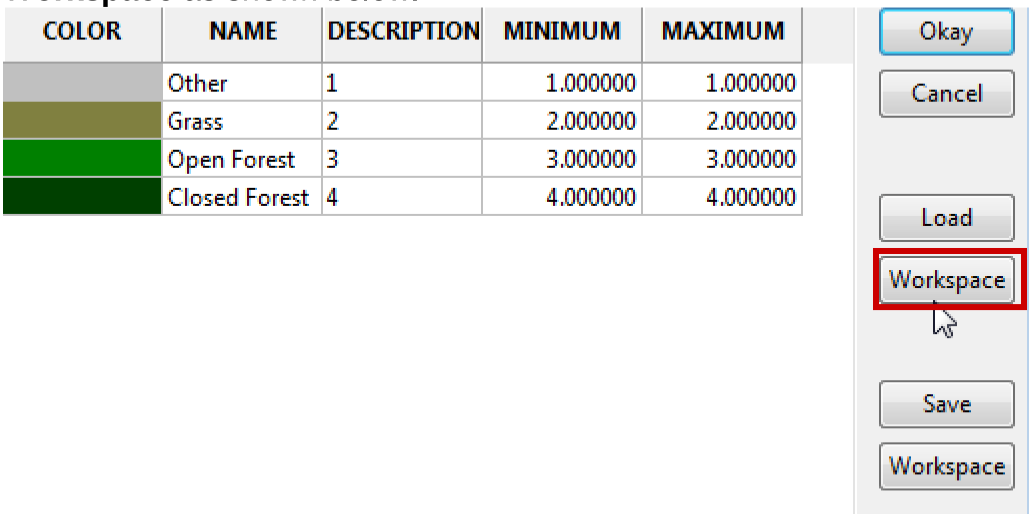
2. Travel time grid Tool Chain flow chart



11.2 Error matrix

An error or confusion Matrix is a technique for comparing changes between two raster (grid) data sets. In order to produce a confusion matrix grid classes must be defined by the lookup table and values of the grid classes for each image year must be the same. We will use classified grids from 1996 and 2015 to create a confusion matrix.

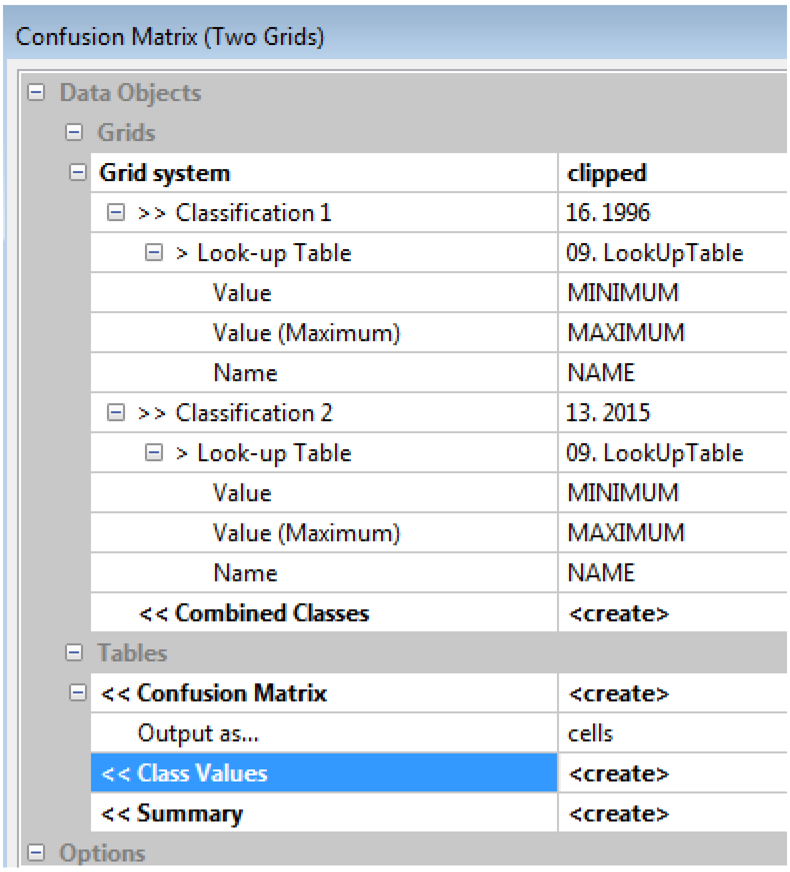
We also need an input look-up table to define the cell class names. Open the lookup table from the colour display input in the settings tab and save the table to **Workspace** as shown below.



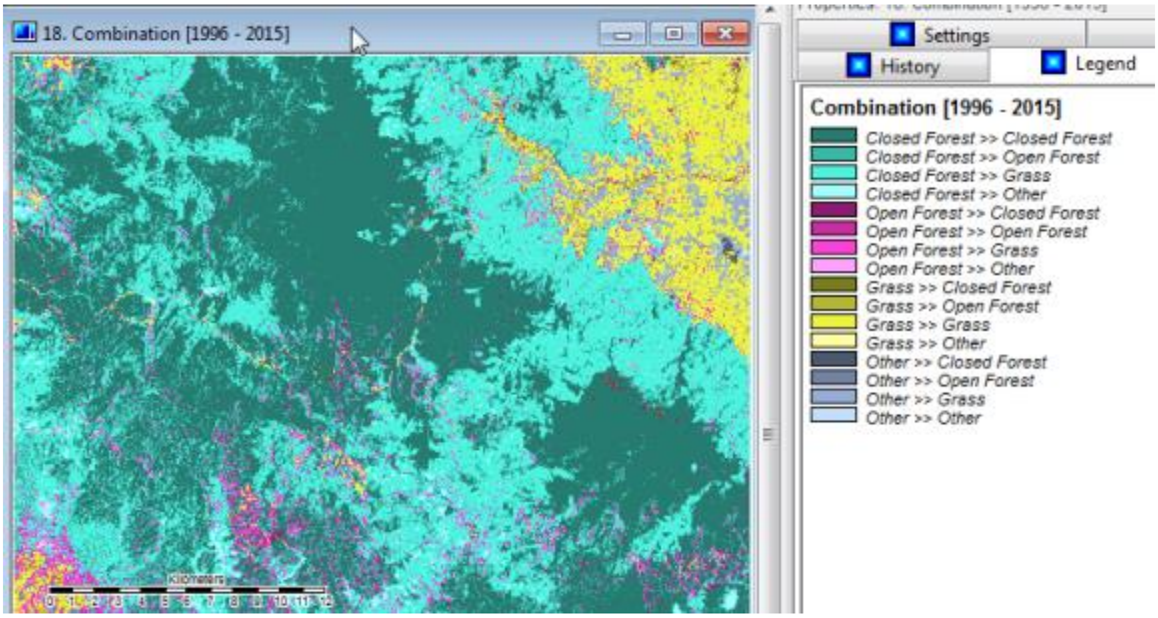
Give the **Workspace** grid a new the name in the example below the table has been given the name “LookUpTable”.
Now we are ready to create the confusion matrix:

Use: Geoprocessing > Imagery > Classification > Confusion Matrix (Two Grids)

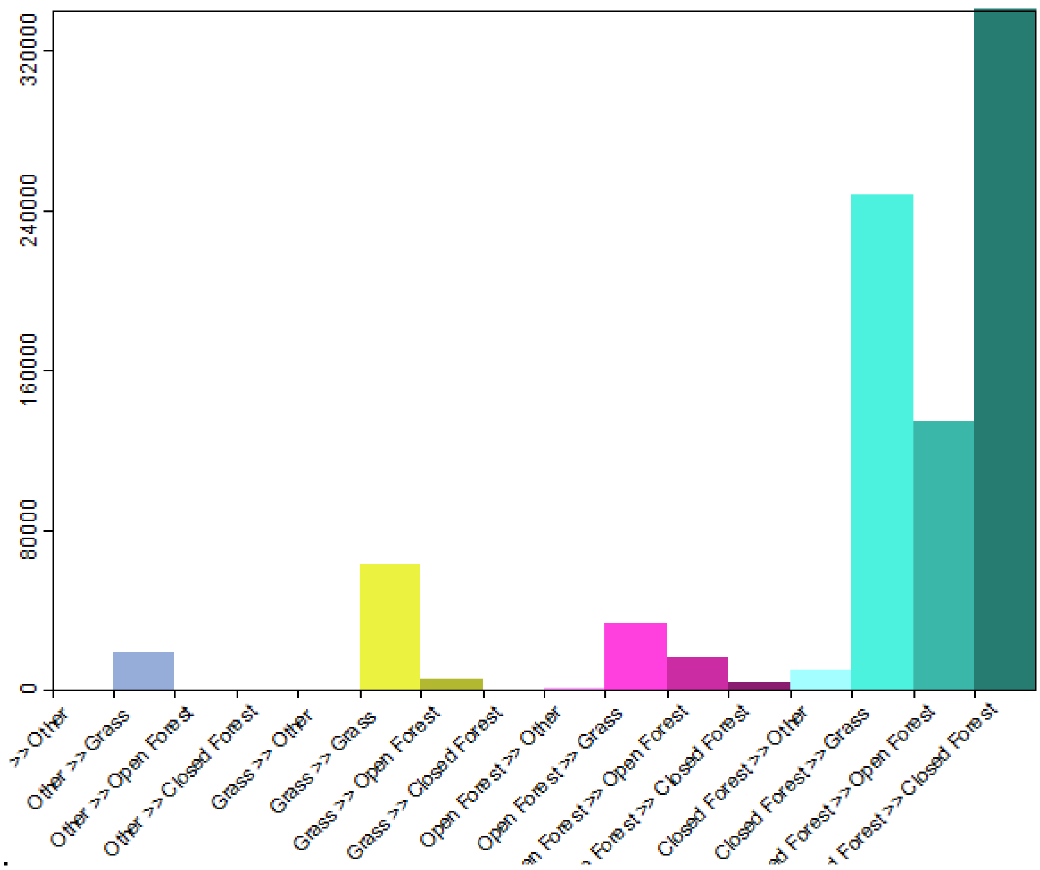
Classification 1 is the 1996 grid, classification 2 is the 2015 grid. The Look-up Table and the **minimum**, **maximum** and **name** values are given.



A new image will appear in the data tab. The image below is an example of what this image looks like with each colour representing a different change trajectory. For example in the image below the light blue colours indicate regions where closed forest has changed to grassland or other.



It is also possible to view the histogram and table for this grid as we did for the cover classifications



.

Opening the table shows you the change trajectory of each land cover type and the area of change.

listogram: Combination [1996 - 2015]

	Name	Other	Grass	Open Forest	Closed Forest	Unclassified
1	Other	401	18852	830	526	0.000000
2	Grass	665	62668	6032	806	0.000000
3	Open Forest	1201	33353	16089	3635	0.000000
4	Closed Forest	10495	247509	133950	339963	0.000000
5	Unclassified	0	0	0	0	0.000000

Land Cover 1996

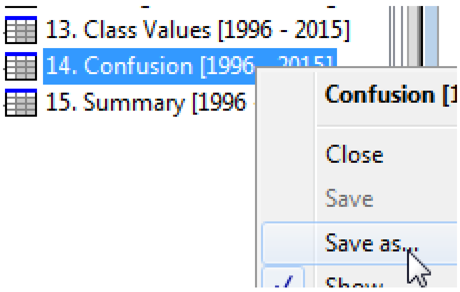
Area Change from Closed forest to grass

Land Cover 2015

Note the values shown in this table are the count of pixels in that class value. To convert to metres square and kilometres square you need to:

1. Multiply the value by 900 – this is the number m2 per 30*30 metre pixel.
2. Divide by 1000000 (One million) to scale it to km2

In the example above the area in km2 change from forest to grass in is 222.7km2. *(247509*900)/1000000*
It is possible at any stage to save a table to a .txt or .csv format for further analysis in excel.

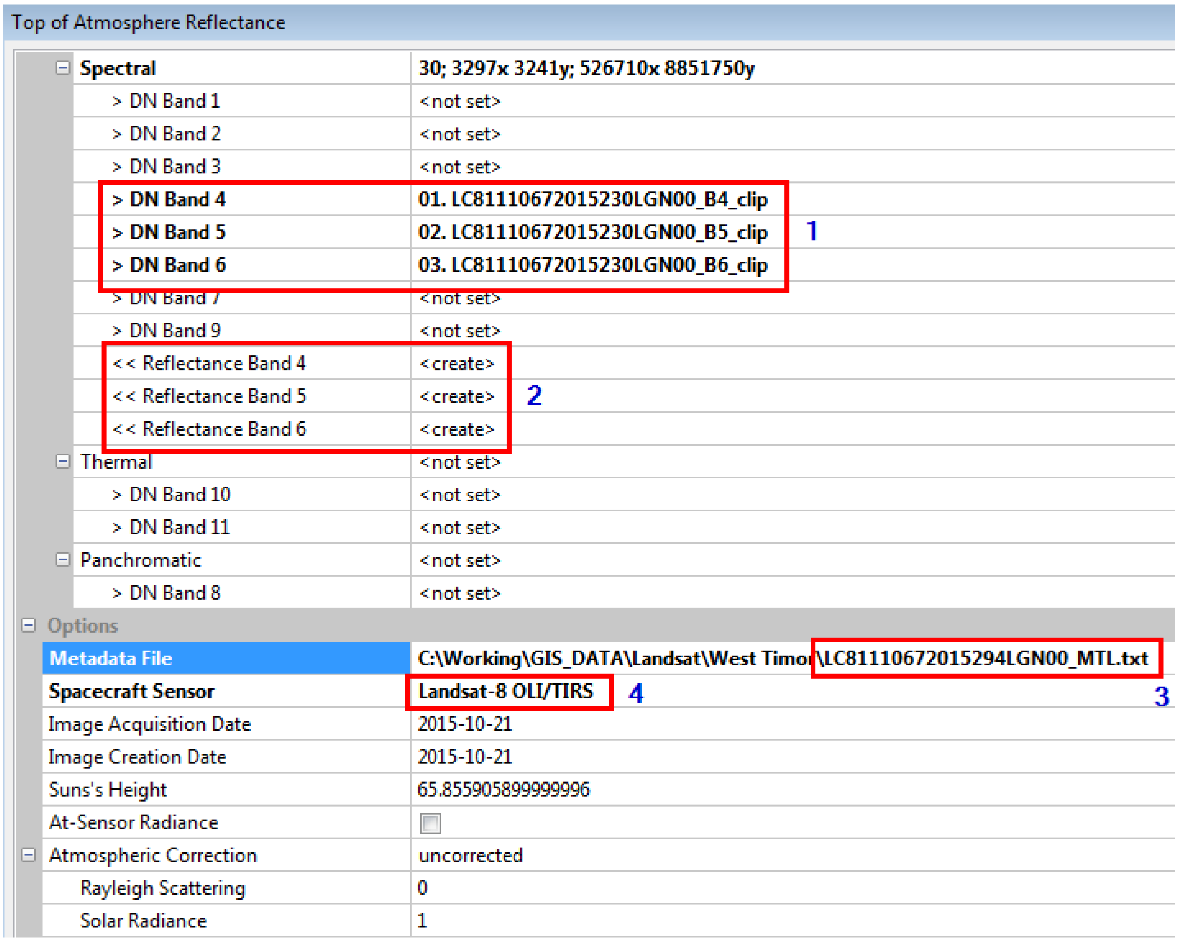


11.4 Atmospheric Correction

Top of Atmosphere correction converts Landsat imagery reflectance by removing variation due to solar irradiance.

Use: Geoprocessing>Imagery>Landsat>Top Of Atmosphere Reflectance

Enter the bands you wish to correct tool the will automatically create corrected bands
Load the meta data txt file that comes with Landsat scene downloads (This contains TOA correction details). Make sure you have the right Landsat sensor selected.



11.5 Troubleshooting

This section should help with some common known issues with SAGA. Other question or queries should be directed to the SAGA development team through the source forge forum: https://sourceforge.net/p/saga-gis/discussion/

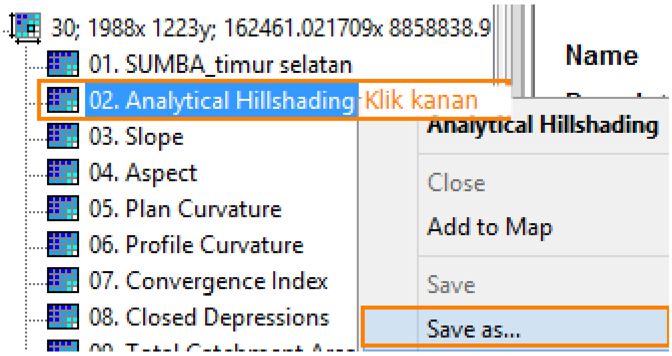
SAGA Crash!

Due to the fact that SAGA runs via your computer's RAM allocation, large data sets can cause an overload crash. There are three ways to deal with this:

1) Working with a computer with a good RAM allocation.
2) Clip larger data-sets to your area of interest. Avoid, for example, working on full Landsat Scenes if unnecessary.
3) Save your data and associated project as you go to avoid losing your work.

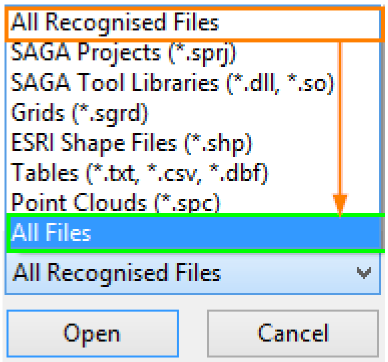
To save an individual grid just right click and choose save as.

To save all produced data and the associated project structure use File>Save Project from the top of the menu.



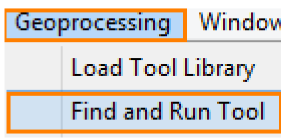
Opening unrecognised files

Most files can be opened by dragging and dropping them into SAGA. If you try and open a file and it does not appear in the chosen window select “All Files”.

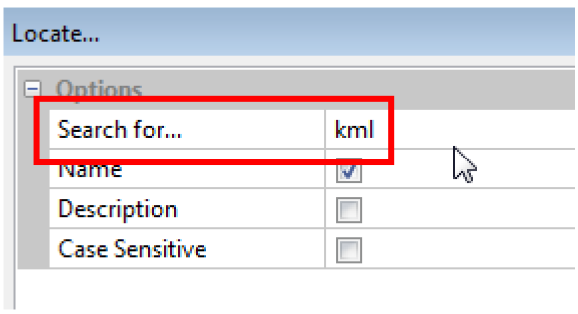


Finding Geoprocessing tools

If you can’t find the tool you are after or have an idea of the process you want to conduct and are not sure where it is within the SAGA menu structure use:

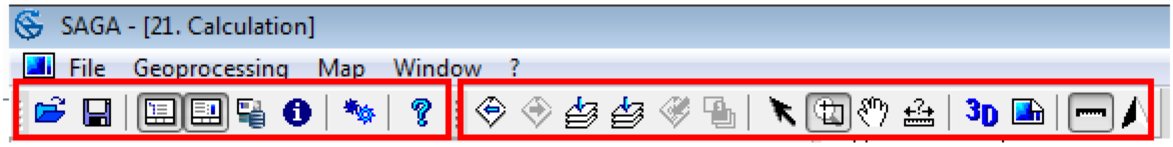


Geoprocessing>Find and Run tool
Enter a name or keyword related to the tool you wish to find then select the tool from the resulting list.

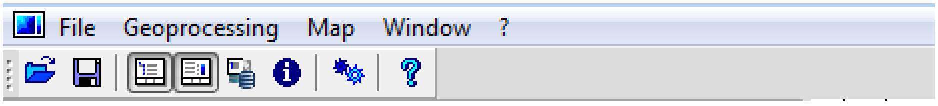


Losing the Navigation toolbar

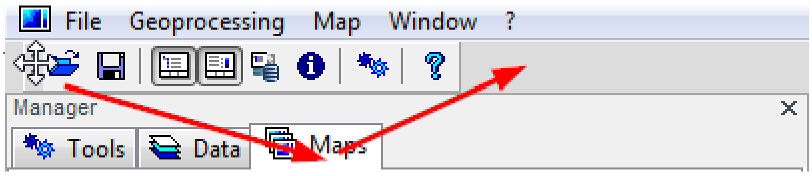
Usually, you have two tool bars under the top menu as shown below.



Occasionally the navigation tool bar may not appear

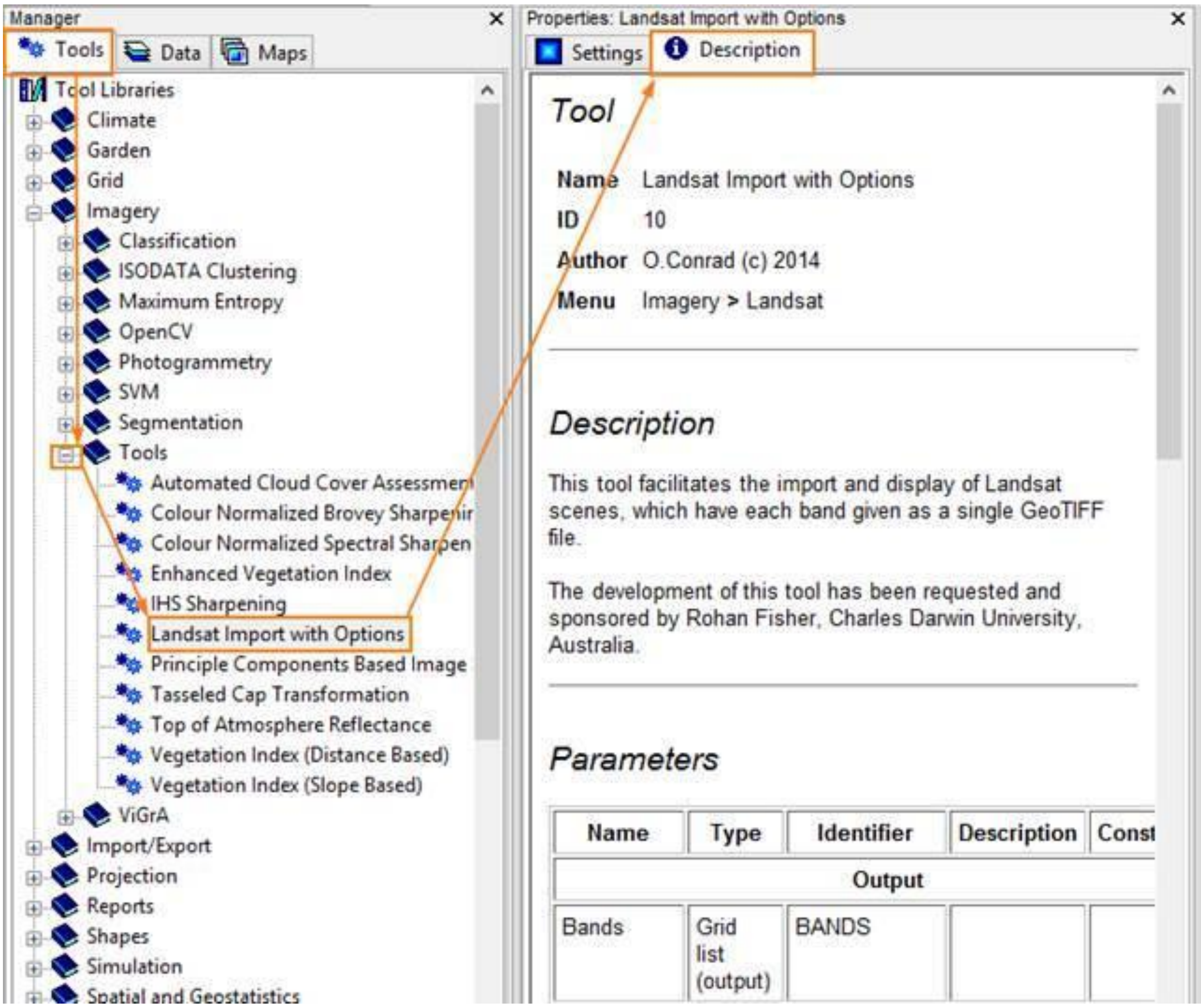


The easiest way to make it reappear is to simply drag the existing tool bar out of the toolbar area and drop it back in again.



Finding more information about geoprocessing modules.

All geoprocessing modules have an accompanying description of how they were derived and often with references to papers describing in detail the algorithms behind them. This can be found using the tools tab, selecting a tool and the description Tab.


Manager
Tools
Data
Maps
Tool Libraries
Climate
Garden
Grid
Imagery
Classification
ISODATA Clustering
Maximum Entropy
OpenCV
Photogrammetry
SVM
Segmentation
Tools
Automated Cloud Cover Assessmen
Colour Normalized Brovey Sharpenir
Colour Normalized Spectral Sharpen
Enhanced Vegetation Index
IHS Sharpening
Landsat Import with Options
Principle Components Based Image
Tasseled Cap Transformation
Top of Atmosphere Reflectance
Vegetation Index (Distance Based)
Vegetation Index (Slope Based)
ViGrA
Import/Export
Projection
Reports
Shapes
Simulation
Spatial and Geostatistics
Properties: Landsat Import with Options
Settings
Description
Tool
Name Landsat Import with Options
ID 10
Author O.Conrad (c) 2014
Menu Imagery > Landsat
Description
This tool facilitates the import and display of Landsat scenes, which have each band given as a single GeoTIFF file.
The development of this tool has been requested and sponsored by Rohan Fisher, Charles Darwin University, Australia.
Parameters
Name
Type
Identifier
Description
Const
Output
Bands
Grid list (output)
BANDS