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# Landslide susceptibility mapping: A remote sensing based approach using QGIS 2.2 (Valmiera)

Technical manual

Metz, L. and Bear-Crozier, A.N.



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## **Department of Industry**

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Secretary: Ms Glenys Beauchamp PSM

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# 1 Introduction

This manual outlines a methodology for landslide susceptibility mapping using the freely available and open source Quantum GIS software package (QGIS) coupled with multispectral remotely sensed satellite imagery.

## 1.1 How to use this manual

Instructions throughout the manual have been colour coded in order to assist the user as they address each step of the procedure. The colour code is defined below:

- Green text refers to 'selectable' features that the user can click on using a mouse (e.g. the 'register' button on the Earth Explorer web page).
- Purple text directs you through menu items encountered during the procedure (e.g. the 'system properties' tab in Windows).
- Red text refers to data the user can enter (e.g. a filename, a command etc.).
- Orange text refers to existing file names.
- Blank lines left in the instructions indicate 'optional fields' and are not mandatory.

## 1.2 Directory structure

The storage device accompanying this manual contains training materials and has the following directory structure (Table 1.1):

*Table 1.1 Directory structure for training materials*

Directory	Content
base_data	Vector environmental condition files, Digital Elevation Model (DEM) and examples
inventory	Examples
processing	Reclassifying rule text files and examples
weighting	Weighting calculation spreadsheet and examples

Each directory contains a sub-directory which displays examples of the expected outputs.

## 2 Background

### 2.1 Landslide susceptibility mapping

Landslides are a complex geological hazard triggered by a combination of factors depending on their magnitude and type (Figure 2.1). There are a number of methodologies employed for landslide susceptibility mapping around the world. The method adopted should vary according to the individual characteristics of the landslide being considered.

The method of landslide susceptibility mapping adopted here was developed using an existing method, the InfoVal method (van Westen, 1997), adapting it for use with the open source software QGIS. QGIS was chosen as the GIS system due to its use by other natural hazard scientists in Papua New Guinea and in the region, and because it is free and open source.

The bivariate statistical model is employed here and is suitable for investigating debris flows greater than 10,000 m<sup>2</sup> in surface area that can easily be spotted using satellite imagery. It is suitable for use with satellite data of pixel resolution less than 30 m<sup>2</sup> and with landslide factor inputs (e.g., geology, slope angle, slope aspect, drainage, etc.) of similar resolution. It is important to note that the quality of landslide susceptibility maps produced using this method is highly dependent on the quality of input data.



*Figure 2.1 The Tumbi Quarry landslide, Hides and Komo area, Papua New Guinea which occurred January 24<sup>th</sup> 2012 killing more than 25 people. (Source: Telegraph United Kingdom).*

### 2.2 Bivariate statistical method

The bivariate statistical method of landslide susceptibility mapping has been used by many authors (van Westen, 1997; Vijith et al. 2009; Nandi and Shakoor 2010; Bednarik et al. 2012). It involves simple calculations of ratios of total landslide area to total non-landslide area for various contributing factors to landslides.

This method requires a landslide inventory with spatial footprints, GIS information layers of the contributing factors to landslides (e.g. geology, slope angle, slope aspect, drainage, etc.) and GIS software.



This method relies on four main assumptions (Guzzetti et al. 1999; Guzzetti et al. 2012).

1. Slope failures leave discernible morphological or spectral features; most of them can be recognized, classified and mapped both in the field and through remote sensing.
2. The morphological signature of a landslide depends on the type (i.e. rock fall, slide, flow, etc.) and the rate of motion of the mass movement.
3. Landslides do not occur randomly or by chance. Slope failure is controlled by mechanical laws that can be determined empirically, statistically or in a deterministic fashion.
4. The geological principle of uniformitarianism infers that “the past and present are keys to the future.” I.e. landslides are more likely to occur under the conditions that led to past instability.

Any potential contributing factor to landslide occurrence can be tested using the bivariate statistical method using the following input data sets:

- Digital elevation model (preferably digital terrain model (DTM)) for investigation of slope angle/degree and slope aspect.
- Geology (lithological data)
- Rainfall data

Other important inputs for consideration include:

- Seismic data
- Drainage
- Soil properties
- Distance from rivers
- Distance from fault lines
- Land cover

The bivariate statistical method is described as follows:

1. Weights are calculated using the following hazard index method and described further in Table 2.1 (van Westen, 1997):

$$W_i = \ln \left( \frac{Denclas}{Densmap} \right) = \ln \left( \frac{\frac{Area(S_i)}{Area(N_i)}}{\frac{\sum Area(S_i)}{\sum Area(N_i)}} \right)$$

2. Landslide areas are compared with parameter maps to isolate landslide areas in each parameter class. The areas of each individual parameter class are recorded, as well as the areas of the landslides within them. The total area of the area of interest and the total area of landslides in the area of interest are also calculated. Landslide density values for each parameter class and the total landslide density for the area of interest are calculated. The density ratio for each parameter is calculated and the natural log of this value is calculated. This produces weightings for each parameter class.



3. To create the weighting maps for each data type, a new file must be created for each data type, and each parameter value is replaced with the weighting that was calculated.
4. To produce the final map, all individual weighting maps for each data type are summed together, to find the final susceptibility values for the area.

*Table 2.1 Parameters in weighting formula*

<b>Wi</b>	<b>The weight assigned to a parameter class</b>
densclas	The landslide density within the parameter class
desnmap	The landslide density within the entire map
Area (Si)	Area containing landslides in a parameter class
Area (Ni)	Area (total) in a parameter class



## 3 Data Inputs

It is essential that the projection and pixel size of all data inputs is consistent. For the examples provided in this manual the projection is 'WGS 84 / UTM zone 55S: EPSG Projection' and the pixel size is 4.97727m<sup>2</sup>.

### 3.1 Digital elevations models: DTM versus DSM

There are two kinds of digital elevation models (DEMs), digital terrain models (DTMs) and digital surface models (DSMs). DTMs represent the bare ground surface and do not include buildings and trees. These models represent a closer estimate of the actual land elevation. DSMs include buildings and trees. For landslide susceptibility mapping, a DTM is more suitable if one is available. DEMs were previously primarily produced by interpolating contour maps that may have been originally produced by direct survey of the land surface. Now, DEMs are more frequently produced using remote sensing.

Using DEMs with coarse resolutions (grid sizes larger than 50 m) are likely to result in landslide susceptibility maps where larger areas are classified as unconditionally stable or unstable (Claessens et al. 2005). Using DEMs with finer resolution will give better results.

### 3.2 Remote sensing

Various forms of remote sensing data can be used to identify landslides for the purpose of creating a landslide inventory (Table 3.1). Optical imagery is the cheapest available option due to the availability of free Landsat data through the USGS. However, if resources allow, SAR data and higher resolution optical imagery can also be used. Existing aerial photography is also worth pursuing if available, but commissioning aerial photography can be prohibitively expensive. A more detailed discussion of spatial data for landslide susceptibility assessment can be found in van Westen et al. (2008).

*Table 3.1 Remote sensing data commonly used in landslide susceptibility studies*

Satellite	Sensor	Swath (km)	Nadir spatial resolution (m)	Date acquired
Landsat-5	TM Multispectral	185	30	
Landsat-7	ETM+Panchromatic	185	15	
	ETM+Multispectral	185	30	
Landsat-8	ETM+Panchromatic	185	15	
	ETM+Multispectral	185	30	

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## 4 Building a landslide inventory

For input into the landslide susceptibility map, landslide inventories must record the spatial extent of landslides, point databases will not suffice.

### 4.1 Using satellite imagery data

In the absence of an existing database, techniques using satellite imagery can be used to detect landslides for the purpose of building a landslide inventory (Table 4.1).

*Table 4.1 Summary of remote sensing data sources and methods used for building a landslide inventory*

Data source	Method	Explanation	Advantages	Disadvantages
Multispectral data (IKONOS, Quickbird, SPOT, ASTER, Landsat)	Manual interpretation	Use appearance (context, shape & size) to delineate landslides	Most accurate (expert knowledge); immediate vector output file	Time consuming; subjective; non-repeatable; person needs to manually trace the landslide
Multispectral data (IKONOS, Quickbird, SPOT, ASTER, Landsat)	Image thresholding	Use band ratios (such as NDVI) to pick up spectral properties of landslides	Can be used as part of manual interpretation, simple & rapid, band ratios reduce illumination variability, can be applied with panchromatic data	Determination of threshold values may be subjective, landslides do not have unique properties – non-landslides may be incorrectly identified
ALOS PALSAR	Change detection	Measures how the vertical position of an area has changed between two or more time periods (using Synthetic Aperture Radar)	Automatically creates polygons, no need to trace; rapid	Requires expensive software, may incorrectly identify forestry or other land clearing as landslides, may not pick up landslides where there has not been a significant change in elevation

One of the main inhibitors of accurate landslide identification using satellite imagery is the problem of land cover changes. Land cover changes, such as farming or clearing land for development, have similar optical properties as landslide footprints. While using satellite radar (SAR) land cover changes can appear as a change in elevation of land surface which could then be interpreted as a landslide (Joyce et al. 2009).

Manually identifying landslides can be completed with any resolution of multispectral (or panchromatic in some cases) remote sensing data. However, different resolutions of satellite imagery are suitable for different purposes. Landsat, with 30 m pixels, is more suited to regional scale (larger area, less detailed) studies, while higher resolution data such as IKONOS & Quickbird (80 cm panchromatic/3.6 m multispectral and 60 cm panchromatic/2.4 m multispectral pixels, respectively) is more suited to



identifying smaller landslides for larger scale (smaller area, more detailed) studies. Landsat is unlikely to detect smaller landslide types such as rock falls, and it may be more difficult to classify landslide types using that resolution of data, even if detection is possible.

Manual interrogation of satellite data is typically analysed using multi-temporal multispectral or panchromatic images (e.g. Landsat) semi-transparently overlaid over a DEM-produced hill shade. Criteria for landslide identification include NDVI (see section 4.2) values between 0.1 and 0.5, a soil-coloured appearance in true colour optical imagery and greater slope values.

## 4.2 Normalised Difference Vegetation Index (NDVI)

NDVI is the Normalised Difference Vegetation Index, an indicator of the presence or absence of live green vegetation in an area (Tarpley et al. 1984). It is calculated using the formula:

$$NDVI = \frac{NIR - VIS}{NIR + VIS}$$

Where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively. The higher the NDVI value (ranging from -1 to 1), the denser and more healthy the vegetation is in that area. In the case of identifying landslides, NDVI values for landslides can range between 0.1 and 0.9 (where the landslides have become revegetated). Unfortunately, due to the nature of the index, landslides are spectrally similar to other areas of lesser vegetation, such as gardens, areas burnt by bushfires or deforested land. However, calculating NDVI values is a useful tool to identify potential areas of landslide that can then be further investigated using morphological characteristics.

In the Landsat data that is used in this manual to detect landslides, the bands that correspond to the NIR and VIS are as follows (Table 4.2):

Table 4.2 Landsat bands which correspond to the spectral reflectance measurements used to detect landslides

Spectral Reflectance Measurement	Wavelength (µm)	Landsat 5 (µm)	Landsat 8 (µm)
Near Infra-red (NIR)	0.73-1.1	Band 4 (0.76-0.90)	Band 5 (0.85-0.88)
Visible (VIS)	0.4-0.68	Band 3 (0.63-0.69)	Band 4 (0.64-0.67)



# 5 Quantum GIS (QGIS)

## 5.1 Downloading and installing QGIS

To download QGIS, go to <http://www.qgis.org/en/site/> and click **Download Now**. Go to the **Download for Windows** window and under For New Users select **QGIS Standalone Installer Version 2.2**.

Depending on your operating system, install the 32 bit or 64 bit version. To discover which version of operating system you are using, go to the **Control Panel** and look at **System** properties.

In some systems it is helpful to make sure that QGIS is installed in a folder that does not include spaces as this can cause problems on some systems (e.g. **ProgramFiles** instead of **Program Files**).

This manual is written for Version 2.2 Valmiera.

## 5.2 File extensions adopted in this manual

A number of file types are used throughout this manual and the extensions are described in Table 5.1.

*Table 5.1 Description of file extensions used throughout manual*

Extension	Use
.tif	TIFF file (raster)
.shp	Shapefile (vector)
.qgis	Project file
.tar.gz	Compressed file



# 6 Landsat Data

## 6.1 Downloading Landsat data

To download Landsat data, you must set up an account on the Earth Explorer webpage. To do this, go to <http://earthexplorer.usgs.gov/> and click **Register** in the top right-hand corner. This will lead you to a webpage where you will have to pick a username, password and fill in details about yourself and why you wish to use the data.

After you have registered, log in to the webpage. You will now be able to search for and download Landsat data.

In this manual we will focus on the Porok landslide (Table 6.1). To search for the Landsat data for the Porok landslide:

1. Select **Decimal** under the **Coordinates** tab.
2. Now select **Add Coordinate**
3. Type **Latitude: -6.05101**
4. Type **Longitude: 145.021**

Table 6.1 Gera and Porok landslides, Papua New Guinea

Landslide	Date	Latitude/Easting	Longitude/Northing
Gera	8th April 2008	-6.05101	145.021
Porok	23rd February 2012	-6.03706	145.031

An alternate way to search for data is to search according to path and row. To search for Landsat data for the Porok landslide by path and row, click the **Path/Row** tab and fill in:

- **Type: WRS2**
- **Path: 98**
- **Row: 64.**
- Then select **Show**.

A marker will now appear near Mt Hagen, signifying the centre of the image that has been searched for. For more information about WRS (Worldwide Reference System) go to [http://landsat.usgs.gov/worldwide\\_reference\\_system\\_WRS.php](http://landsat.usgs.gov/worldwide_reference_system_WRS.php).

Landsat is available for a range of dates (Table 6.2). Once you have identified the area using either of the above methods:

5. Select the **Date Range** tab
6. Search from **02/23/2008** (US date format) until the present day.



7. Select **Data Sets**. This will take you to another window.
8. Click on the plus sign next to **Landsat Archive** to expand the list of Landsat satellites.
9. Check the box next to **L8 OLI/TIRS** (for different time periods, different Landsat satellites should be used).
10. Now click Results.

*Table 6.2 Landsat dates in use*

Instrument	Dates in use	WRS
Landsat 1	23/07/1972 – 6/01/1978	1
Landsat 2	5/03/1978 – 22/01/1981	1
Landsat 3	5/03/1978 – 31/03/1983	1
Landsat 4	16/07/1982 – 14/12/1993	2
Landsat 5	1/03/1984 – 5/06/2013	2
Landsat 6	Mission failed	N/A
Landsat 7	15/04/1999 – present (note from 31/05/2003 SLC failure makes data have lines through it)	2
Landsat 8	11/02/2013 – present	2

You can also search for other data by address, month, shape file and many other search criteria. In the window there should now be a list of images with a small thumbnail of the image and some details (Figure 6.1). These identify the data that fit the search criteria.



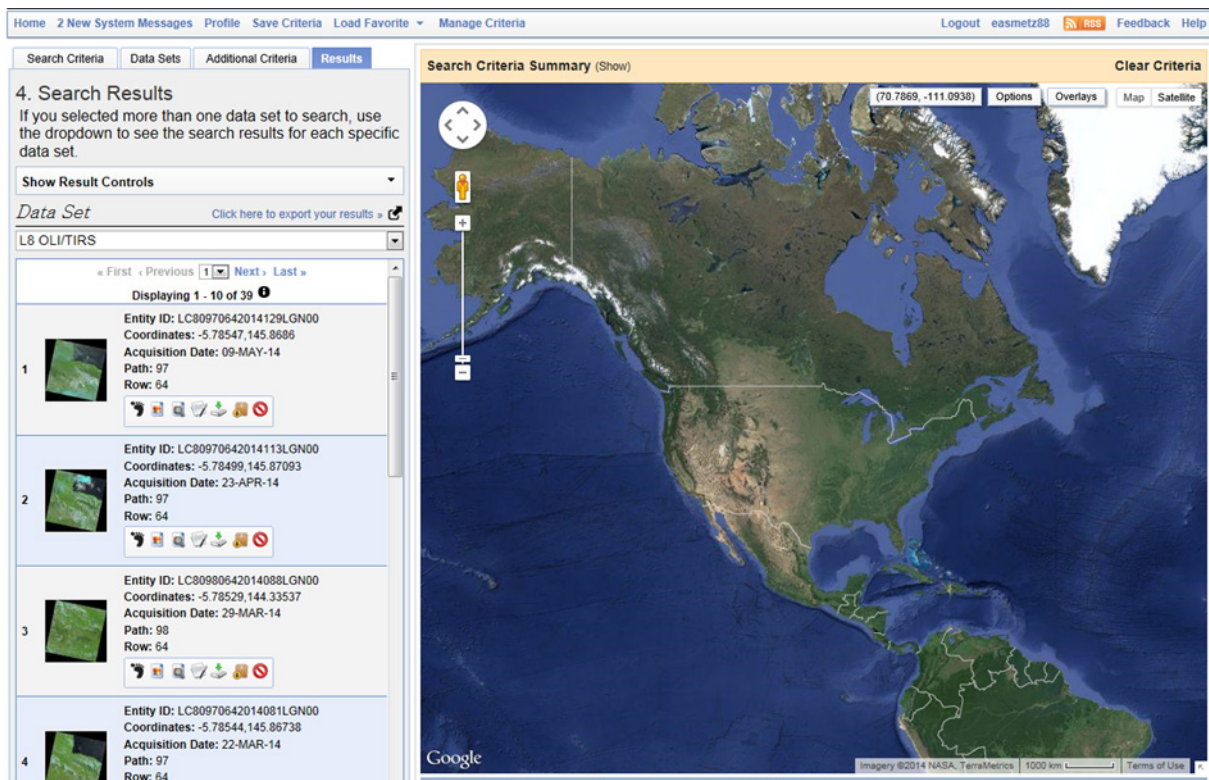


Figure 6.1 Screenshot of the Earth Explorer web tool for sourcing Landsat imagery. Users can view footprints of available Landsat imagery (foot icon), view previews of the data (picture icon) and download datasets (green arrow icon) (Source: <http://earthexplorer.usgs.gov/>).

For this example, we will download **Entity ID: LC80980642014088LGN00** with the acquisition date of 29th March, 2014.

To download:

11. Select **Download Options** on the **LC80980642014088LGN00** entry
12. The **Download Options** window will appear.
13. Select **Level 1 GeoTIFF Data Product (969.8 MB)**
14. Select **Download Option** button. A **Download Scene** window will appear.
15. Select **Download** and save the **LC80980642014088LGN00.tar.gz** file to the **Training/Inventory/Landsat** folder.

## 6.2 Unzipping Landsat data

After the file has finished downloading, you must now unzip it to access its contents. If you do not have an unzipping program installed you can use 7-Zip which you can download from <http://www.7-zip.org/> for free. Download the appropriate 32-bit or 64-bit program for your computer (as in chapter 5.)

After you have downloaded and installed 7-Zip, open the program:



1. Navigate to the folder in which you saved the **Landsat .tar.gz** file (**Training/Inventory/Landsat/LC80980642014088LGN00\_B1.tar.gz**).
2. Select the **.tar.gz** file
3. Select **Extract** to extract it into the **Training/Inventory/Landsat** folder.
4. Navigate to the **Training/Inventory/Landsat** folder again in 7-zip. The file will now be a **.tar** file. This requires another level of extraction.
5. Select the **.tar** file and click the **Extract** button again. The file will now contain all the bands of the Landsat image.
6. The **.tar** and **.tar.gz** files are no longer needed so they can now be deleted.

## 6.3 Decoding Landsat file names

Upon first look, Landsat file names may look complex. However, they contain important information about the time, place and satellite on which the data was recorded. A typical Landsat8 file name will look like this (Table 6.3):

**LC80980642014088LGN00\_B1.tif**

The table below describes each component of this file name.

Table 6.3 Description for each component of the Landsat filename

Landsat satellite & sensor	WRS Path	WRS Row	Year of acquisition	Day of acquisition year	Ground Station Identifier & Version	Band
LC8	098	064	2014	088	LGN00	B1
Landsat 8 (OLI-TIRS sensor)	Path 98	Row 64	Year 2014	The 88 <sup>th</sup> day of that year	Landsat Ground Network	Band 1

For more information on Landsat identifiers go to:

- [https://lta.cr.usgs.gov/landsat\\_dictionary.html](https://lta.cr.usgs.gov/landsat_dictionary.html) - entity\_id.

## 6.4 Useful website for Landsat data

Table 6.4 Table of useful website for viewing and downloading Landsat data

Website	Comment
<a href="http://landsat.usgs.gov/tools_latlong.php">http://landsat.usgs.gov/tools_latlong.php</a>	A tool allowing you to convert the Latitude/Longitude coordinates of an area into the WRS-2 Path/Row that the area is in. This is useful to narrow down search results on the USGS page
<a href="http://earthexplorer.usgs.gov/">http://earthexplorer.usgs.gov/</a>	A website allowing you to search and download Landsat data
<a href="http://landsat.usgs.gov/band_designations_landsat_satellites.php">http://landsat.usgs.gov/band_designations_landsat_satellites.php</a>	A website detailing the wavelength ranges of Landsat bands



# 7 Creating a landslide inventory

## 7.1 Loading and viewing a DEM

DEMs are helpful in differentiating landslides from other land cover changes with similar optical properties (see Chapter 4.) Now you will learn to load and view a DEM.

1. Open QGIS by double clicking on the **QGIS Desktop 2.2.0** icon on the desktop.
2. To load the raster DEM select **Layer**
3. Select **add Raster Layer**. This opens a window. If QGIS has not automatically gone to the **base\_data** folder, navigate to it.
4. Select the file **png\_dem.tif**
5. Select **Open**. Your DEM should load.
6. Select **Project**
7. Select **Save As** and navigate to the **base\_data** folder.
8. Name this file as **base\_data.qgs**.
9. Select **Save**.

## 7.2 Reprojecting a raster

To be able to make correct calculations later on, the DEM must now be reprojected into the Universal Transverse Mercator (UTM) Coordinate Reference System (CRS) so the pixels are measured in metres (instead of degrees as they are in the WGS 84 CRS).

1. Select **Raster**
2. Select **Projections**
3. Select **Warp (Reproject)** and fill in the parameters as indicated in (Table 7.1).

Table 7.1 Input parameters for Warp (Reproject) window (DEM reprojection)

Parameter	Input
Input file	png_dem.tif
Output file	png_dem_UTM.tif [navigate to base_data folder and save it there]
Source SRS	EPSG:4326 [WGS 84]
Target SRS	EPSG:32755 [WGS 84/UTM Zone 55S]
Resampling method	Cubic
Load into canvas when finished	Check box provided



4. `gdalwarp -overwrite -s_srs EPSG:4326 -t_srs EPSG:32755 -r cubic -of GTiff C:\Training\base_data\png_dem.tif C:/Training/base_data/png_dem_UTM.tif`
5. Select **Ok**. The reprojected DEM should appear on the screen.

## 7.3 Creating a hillshade

A hillshade is a DEM with shadows applied to it to simulate the effect of the sun's rays over the varied terrain of the land. It allows the viewer to visualise slope angles more effectively.

1. Confirm that the reprojected DEM (**png\_dem\_UTM.tif**) is still loaded
2. Select **Raster**
3. Select **Analysis**
4. Select **DEM (Terrain models)** and fill in the parameters as indicated in (Table 7.2).

Table 7.2 Input parameters for DEM Terrain models (Hillshade)

Parameter	Input
Input file (DEM raster)	png_dem_UTM.tif
Output layer	hillshade.tif (navigate to base_data folder and save)
Z factor (Vertical exaggeration)	1.0
Scale (ratio of vert. units to horiz.)	1.0
Azimuth of the light	35° (90° perpendicular direction of mountains)
Altitude of the light	45°
Load onto canvas when finished	Check box provided

5. `gdaldem hillshade C:/Training/base_data/png_dem_UTM.tif C:/Training/base_data/hillshade.tif -z 1.0 -s 1.0 -az 35.0 -alt 45.0 -of GTiff`
6. Select **Ok**. The hillshade will now appear on the screen.

## 7.4 Loading and viewing Landsat data

To be able to create a landslide inventory, you need to load and view remote sensing imagery. Landsat is free through the USGS, so we will be using this to make our landslide inventory. We will be creating stacked files with individual bands. Details on how to download Landsat imagery can be found in Chapter 6.

To load Landsat data:

1. Select **Raster**
2. Select **Miscellaneous**
3. Select **Merge**. This opens a Merge window.
4. Click **Select...** (next to Input files) to open a **Select files to merge** window



5. Navigate to **Inventory**
6. Select **Landsat**
7. Select **LC80980642014088LGN00** to select the files (by holding ctrl down while selecting them)

**LC80980642014088LGN00\_B1.tif**

**LC80980642014088LGN00\_B2.tif**

**LC80980642014088LGN00\_B3.tif**

**LC80980642014088LGN00\_B4.tif**

**LC80980642014088LGN00\_B5.tif**

8. Select **Open** on the **Select files to merge** window.
9. Click **Select...** next to **Output file**
10. Navigate to **Inventory**
11. Select **Landsat**
12. Select **LC80980642014088LGN00**
13. Save the file as **LC80980642014088LGN00\_RGB**
14. Select the checkbox for **Layer stack**
15. Select the checkbox for **Load onto canvas when finished**

An example **Merge** window is shown in Figure 7.1.

16. Select **Ok**.
17. When the layer has loaded, right click on the layer in the **Layers** sidebar and from the drop down menu select **Properties**.
18. A **Layer Properties** window will appear
19. Select the **Style** tab
20. In the **Band Rendering** box select **Multiband Colour** from the dropdown list next to **Render type**.
21. Then match the **Red Band** with **Band 4**, the **Green band** with **Band 3** and the **Blue band** with **Band 2** from the respective drop down menus.
22. Select **Apply**. The image on the screen should now appear in true colour
23. To make the image brighter with more contrast select the **Colour rendering** box
24. Change the **brightness** to **145**
25. Change the **contrast** to **70**
26. Select **Apply**. The image is now ready for viewing.

Repeat steps 21 – 46 with all downloaded Landsat data.



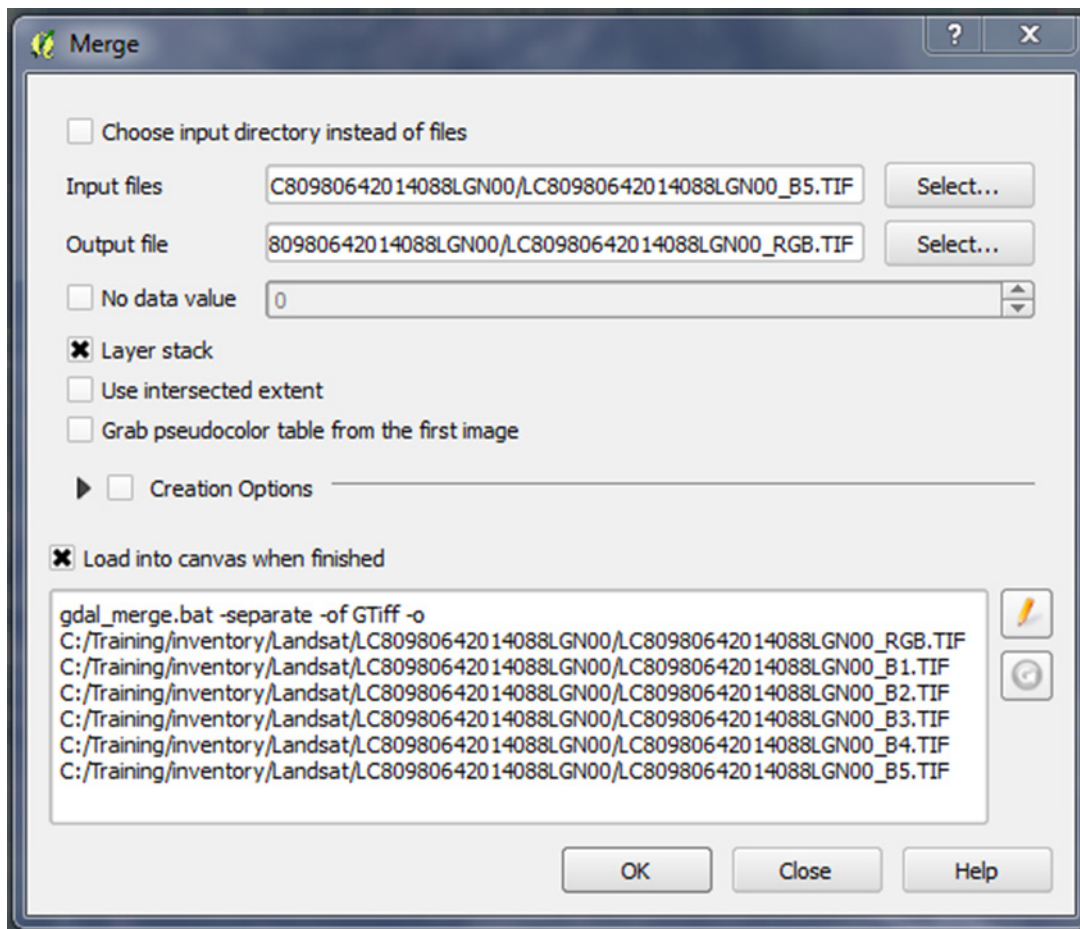


Figure 7.1 Example Merge window for Landsat data

## 7.5 Calculating NDVI ratios

For this example we will calculate NDVI for Landsat imagery from January 2009.

1. Select **Layer**
2. Select **Add Raster Layer**
3. An **Open a GDAL Supported Raster Data Source** window will appear.
4. Navigate to the folder: **Training/Inventory/Landsat/ LC80980642014088LGN00**
5. Load bands 4 (**LC80980642014088LGN00\_B4.tif**) and 5 (**LC80980642014088LGN00\_B5.tif**) of Landsat data by selecting the files and clicking **Open**.

Landsat 8 data will use bands 4 & 5 to calculate NDVI, previous Landsat mission data will use bands 3&4.]

6. Select **Raster**
7. Select **Raster Calculator**

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8. In the **Raster calculator expression** box write the expression:

**$((\text{Band 5 file} - \text{Band 4 file}) / (\text{Band 5 file} + \text{Band 4 file}))$**

E.g:

**$(\text{LC80980642014088LGN00\_B5@1} - \text{LC80980642014088LGN00\_B4@1}) / (\text{LC80980642014088LGN00\_B5@1} + \text{LC80980642014088LGN00\_B4@1})$**

9. Navigate to the **Training/Inventory/Landsat/LC80980642014088LGN00** folder and name it **LC80980642014088LGN00\_NDVI.tif**

10. Select **Ok**.

An example of the **Raster Calculator** window for this example is shown in Figure 7.2.

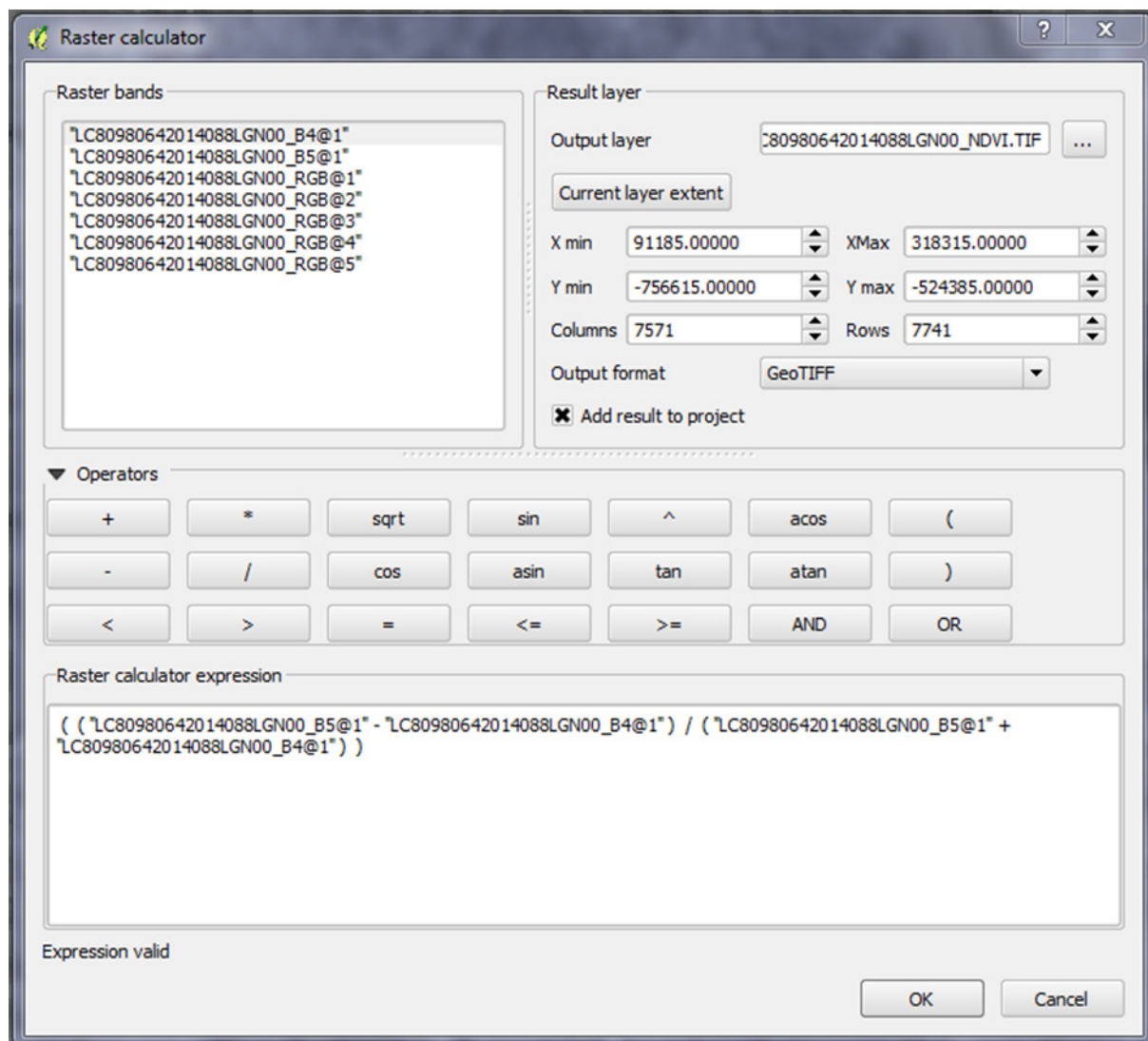


Figure 7.2 Example Raster Calculator window showing raster calculator expression

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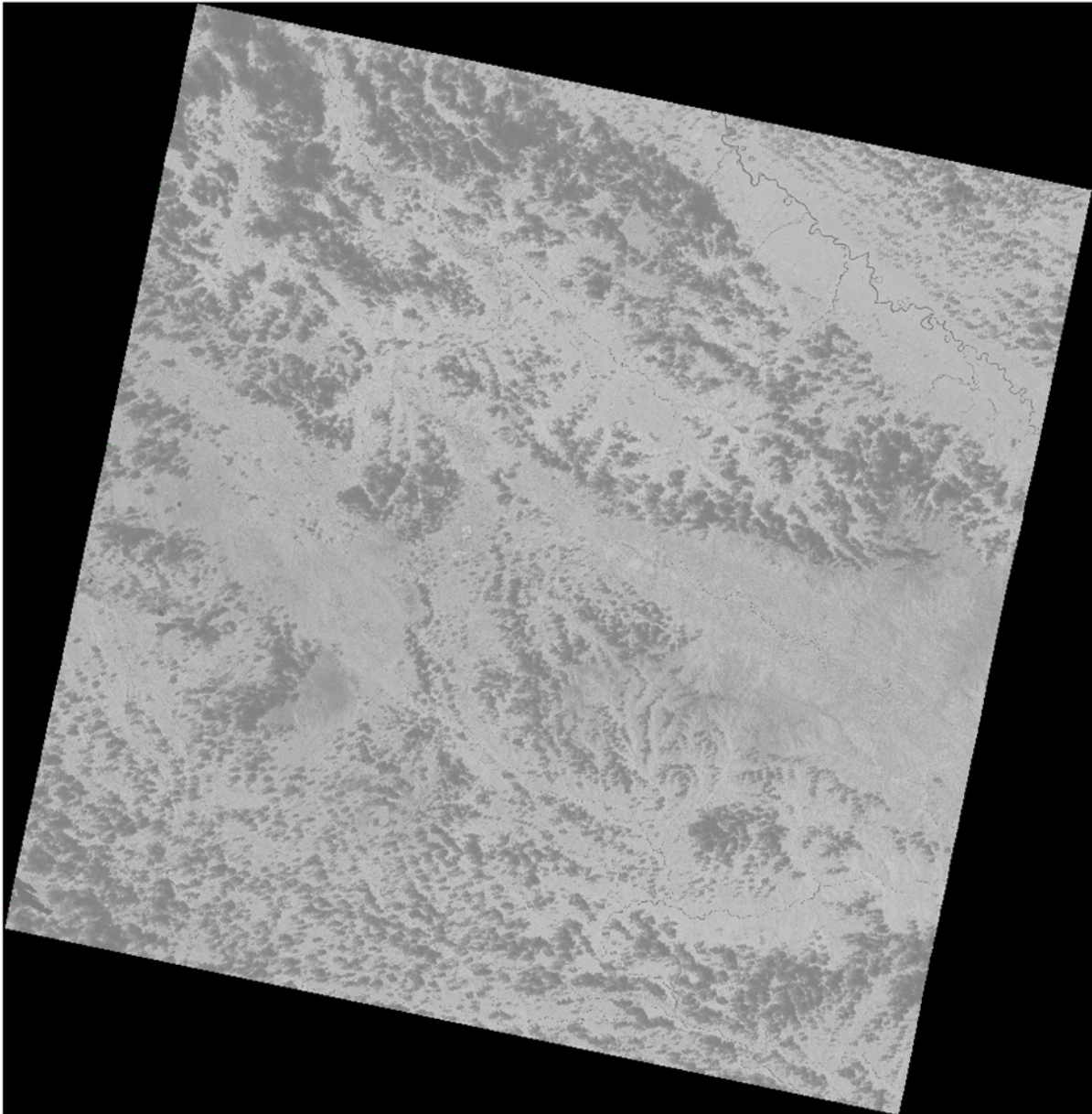
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11. A new file named **LC80980642014088LGN00\_NDVI.tif** will appear in the **Layers** window.
12. Repeat this for the rest of the Landsat imagery in the **Training/Inventory/Landsat** folder.

Darker areas of this file show areas with lower NDVI values. Landslide areas will be medium grey (values between 0.1 and 0.5), while water and clouds (see the cloud shapes scattered across the image) appear dark grey and medium-dark grey respectively (Figure 7.3).



*Figure 7.3 Landsat image configured by raster calculator for NDVI values.*



## 7.6 Making a raster layer transparent

To be able to view the hillshade behind the optical imagery and better identify landslides, we must make the Landsat file semi-transparent.

1. Double click on the layer (in the sidebar) which you wish to make transparent. In this case click on one of the Landsat files. This will take you to **Properties**.
2. Select the **Transparency** tab
3. In the **Global Transparency** box slide the slide bar to the percentage of transparency required (**30%** is recommended).
4. Press **Apply** and then **Ok**.

Repeat this for all of the Landsat files. If needed, reorder the layers in the sidebar so that the Landsat layers are on the top and the hillshade is on the bottom.

## 7.7 Creating the landslide polygons

To construct the landslide inventory, a new layer needs to be added in which to create the landslide polygons.

1. Select **Layer**
2. Select **New**
3. Select **New Shapefile Layer**. A window will pop up (Figure 7.4).
4. In the **Type** box, select **Polygon**.
5. Specify CRS [Coordinate Reference System] (in this instance it was **EPSG:32755 - WGS 84/UTM zone 55S**).
6. To add a Date, fill in the **Name** field in the **New attribute** box with the word **Date**. For **Type**, click the drop down menu and select **Date**.
7. Click **Add to attributes list**.
8. To add a Classification/Type field, type **Classification/Type** in the **Name** field in the **New attribute** box. For **Type**, select **Text data** from the drop down menu.
9. Click **Add to attributes list**.
10. To add a Population Displaced field, type **Population Displaced** in the Name field in the **New attribute** box. For **Type**, select **Whole number** from the drop down menu.
11. Click **Add to attributes list**.



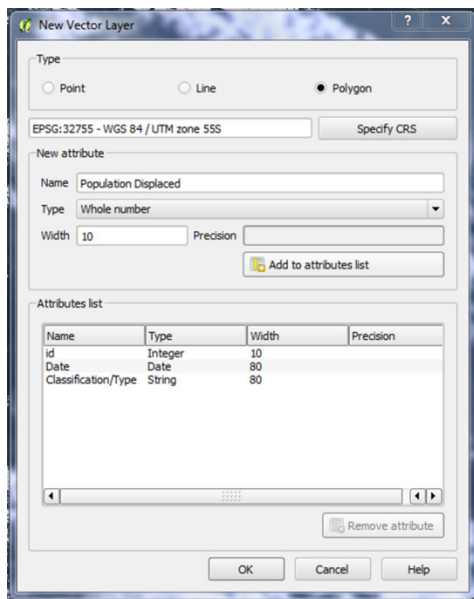


Figure 7.4 Example New Vector Layer window for creating landslide polygons

The attributes Date, Classification Type and Population Displaced will now be seen in the Attributes list box. Create more attributes as needed. Suggestions include volume, trigger mechanism, wetness of slide mass, secondary effects and rate of movement.

12. Press **OK**. A **Save As** window will pop up.
13. Name the file (e.g. **landslide\_12.shp**) & choose a directory to save it in (e.g. **Training/Inventory/Landslide**). The layer will now appear in the **Layers** sidebar.
14. Select the layer in the layers window
15. Select **Layer**
16. Select **Toggle Editing**. The Editing toolbar will now be activated.
17. Locate the Porok landslide at Easting: 281760 Northing: 9332335. Here it is displayed in NDVI and true colour (Figure 7.5).



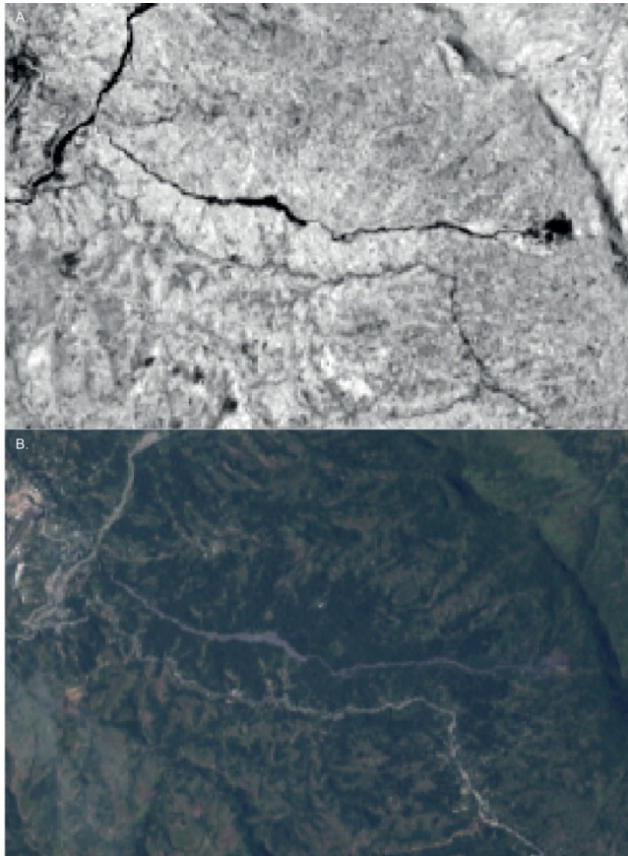


Figure 7.5 Aerial imagery of the Porok landslide, Papua New Guinea A) Porok landslide region in NDVI; B) Porok landslide region in true colour.

18. Make sure that the layer (**landslide\_12**) is still highlighted in the Layers window.
19. Click **Add Feature** in the Editing toolbar.
20. Now use the mouse to trace the edge of the landslide feature to outline it (click to add a point, click again to add next point).
21. Right click when you finish tracing the feature. A box will appear asking you to fill in the attributes.
22. Give the feature a unique landslide ID, date, classification/type and population displaced if the information is known.
23. If the area needs to be reshaped use the **Node** tool in the editing toolbar.
24. Save by clicking the **Save Layer Edits** button on the Editing toolbar (Important – the outline will not be saved if you don't click the **Save Layer Edits** button).
25. When finished, deselect the **Toggle Editing** feature.
26. If you make a mistake and wish to delete a polygon or a node, go to **Select Single Feature** button, and then press the **Delete Selected** button in the editing toolbar.
27. To change the colour of the polygons, double click on the layer in the Layers sidebar to bring up the **Layer Properties** window.
28. Click the **Style** tab and choose a style or colour for the polygon to be.
29. To put a "hole" in the polygon (e.g. when a landslide bifurcates and then joins again) click **Add Ring** either under **Edit** in the top bar of QGIS, or in the toolbar. Then point and click to outline the area.



## 7.8 Merging the landslide shapefiles

To create the complete landslide inventory, the landslide shapefiles from different years need to be merged together into one shapefile. If your landslide inventory is contained in one shapefile, this step may be omitted.

1. Confirm that all landslide shapefiles are in the same directory, with no other non-landslide files in that directory.
2. Select **Vector**
3. Select **Data Management Tools**
4. Select **Merge Shapefiles to one**
5. A **Merge Shapefiles** window will appear. Add parameters as indicated in Table 7.3 and Figure 7.6.

Table 7.3 Input parameters for Merge shapefiles tool used to merge all landslide shapefiles into one directory

Parameter	Input
Shapefile type	Polygon
Input files	Path to directory of files to be merged
Output shapefile	Landslide.shp
Load canvas onto map when finished	Check the box

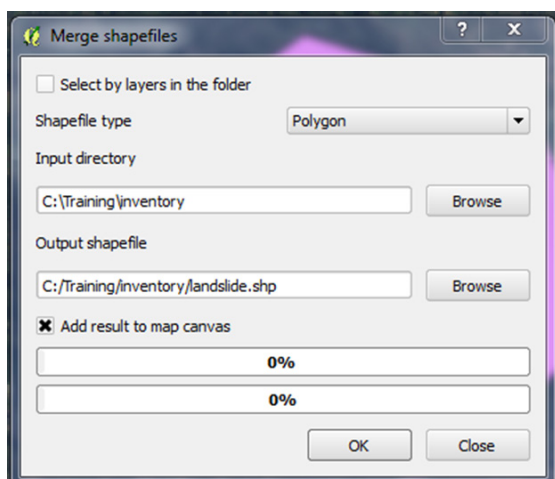


Figure 7.6 Example Merge Shapefiles window



6. Press **OK**. The merged file will now appear on the screen.

Note: if the merge has failed, check that all the original files are in the same CRS and that none are currently marked as being edited. A layer is shown to be being edited when an image of a pencil appears next to the file name in the Layers sidebar.

The landslide inventory is now complete.

Optional additional processing:

If any of the shapefiles have polygons that overlap with each other then:

7. Select **Vector**
8. Select **Geoprocessing**
9. Select **Union tool** to merge the shapefiles one at a time.

To dissolve any intersections between merged files:

10. Select **Vector**
11. Select **Geoprocessing Tools**
12. Select **Dissolve**.



# 8 Processing input data

In this section we will determine which environmental conditions contribute most to landslide susceptibility using an example for the Simbu region, Papua New Guinea.

## 8.1 Calculating slope angle

Slope angle is a measure of the steepness of the slope.

1. Open a new QGIS session
2. Save this session as **processing.qgis** in the **processing** folder.
3. Select **Raster**
4. Select **Analysis**
5. Select **DEM (Terrain models)** and fill in the parameters as indicated in Table 8.1 and Figure 8.1.

Table 8.1 Input parameters for DEM Terrain models (Slope angle)

Parameter	Input
Input file (DEM raster)	png_dem_UTM.tif
Output file	slpang.tif (navigate to base_data)
Mode	slope
Scale (ratio of vert. to horiz.)	1.00
Load onto canvas when finished	Check box indicated



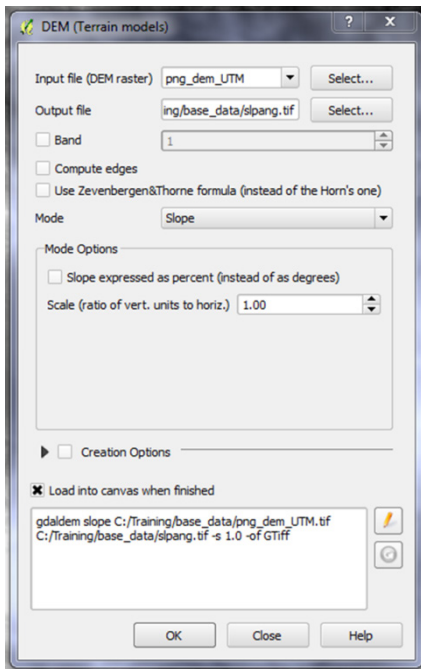


Figure 8.1 Example DEM (Terrain models) window

6. `gdaldem slope C:/Training/base_data/png_dem_UTM.tif C:/Training/base_data/slpang.tif -s 1.0 -of GTiff`
7. Press **OK**.

The image will now load onto the map.

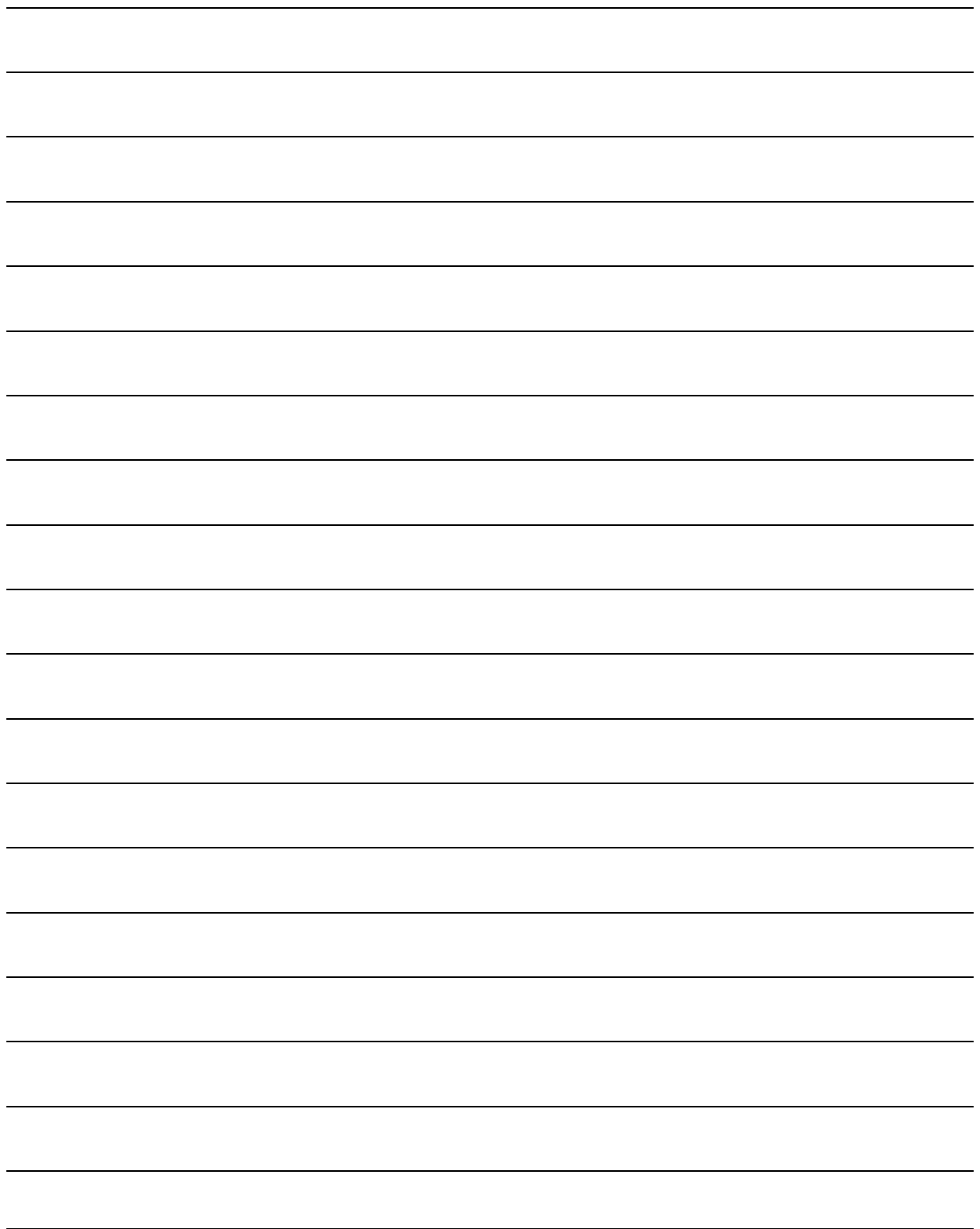
## 8.2 Calculating slope aspect

Slope aspect is the direction the slope is facing (i.e. northeast = 45°, south-southwest =202.5°)

1. Select **Raster**
2. Select **Analysis**
3. Select **DEM (Terrain models)** and fill in the parameters as indicated in Table 8.2.

Table 8.2 Input parameters for DEM Terrain models (Slope aspect)

Parameters	Input
Input file (DEM raster)	png_dem_UTM.tif
Output file	slpang.tif (navigate to base_data)
Mode	aspect
Return 0 for flat (instead of -9999)	Check box indicated
Load onto canvas when finished	Check box indicated



4. `gdaldem aspect C:/Training/base_data/png_dem_UTM.tif C:/Training/base_data/slpsp.tif -zero_for_flat -of GTiff`
5. Press **OK**.

The image will now load onto the map.

## 8.3 Reprojecting a vector

### 8.3.1 Rainfall

1. Select **Layer**
2. Select **Add Vector Layer** (Figure 8.2)
3. Add the file **rainfall\_sim\_region.shp** from the folder **base\_data**.
4. Right click on the **rainfall\_sim\_region** file in the Layers window
5. Click Save As and fill in the parameters as indicated in Table 8.3.

Table 8.3 Input parameters for Save Vector Layer As tool used to reproject rainfall shapefile

Parameters	Input
Format	ESRI Shapefile
Save as	Rainfall_sim_UTM.shp (in base_data_
CRS	Selected CRS WGS84/UTMzone 55S (Click Browse)
Add saved file to map	Check box indicated

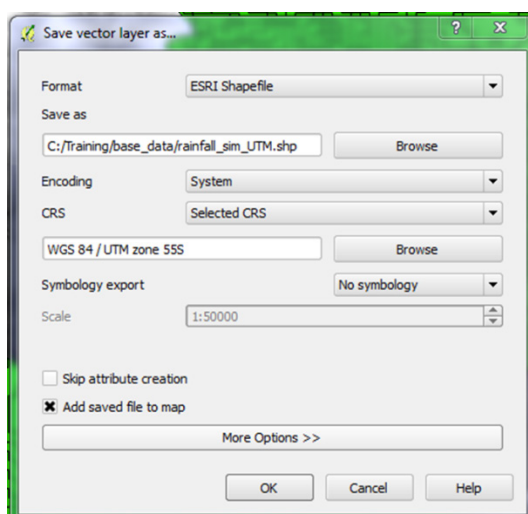


Figure 8.2 Example Save Vector Layer As window

6. Repeat this for the **geology\_sim\_region.shp** file, renaming it **geology\_sim\_UTM.tif**.



## 8.4 Converting from vector to raster

To be able to effectively calculate ratios of landslide area to non-landslide area, we must convert vector files to raster format. As the DEM-derived slope factors are already in raster format there is no need to complete this step for those files.

### 8.4.1 Rainfall

1. Select **Raster**
2. Select **Conversion**
3. Select **Rasterize (Vector to Raster)** and fill in the parameters as indicated in Table 8.4.

Table 8.4 Input parameters for Rasterize (Vector to Raster) used to convert rainfall vector data to raster

Parameters	Input
Input file (Shapefile)	rainfall_sim_UTM
Attribute field	RAINFALL
Output file for rasterised vectors (raster)	Rainfall_sim_UTM.tif (in base_data)
Raster resolution in map units per pixel	Check box indicated
Horizontal	4.97722 (same pixel size as png_dem_UTM)
Vertical	4.97722
Load onto canvas when finished	Check box indicated

4. `gdal_rasterize -a RAINFALL -tr 4.97722 4.97722 -I rainfall_sim_UTM C:\Training\base_data\rainfall_sim_UTM.shp C:/Training/base_data/rainfall_sim_UTM.tif`
5. Click the edit button

To ensure the new file is converted to eight bit unsigned integer (Byte) format:

6. Insert the red text into the script already in the box:

```
gdal_rasterize -ot Byte -a RAINFALL -tr 4.97722 4.97722 -I rainfall_sim_UTM C:\Training\base_data\rainfall_sim_UTM.shp C:/Training/base_data/rainfall_sim_UTM.tif
```

7. Press **OK**.

The rainfall raster will now load on to the map.



## 8.4.2 Geology

1. Select **Raster**
2. Select **Conversion**
3. Select **Rasterize (Vector to Raster)** and fill in the parameters as indicated in Table 8.5.

Table 8.5 Input parameters for Rasterize (Vector to Raster) used to convert geology vector data to raster

Parameter	Input
Input file (Shapefile)	geology_sim_UTM
Attribute field	ROCKTYPE
Output file for rasterised vectors (raster)	geology_sim_UTM.tif (in base_data)
Raster resolution in map units per pixel	Check box indicated
Horizontal	4.97722 (same pixel size as png_dem_UTM)
Vertical	4.97722
Load onto canvas when finished	Check box indicated

4. `gdal_rasterize -a ROCKTYPE -tr 4.97722 4.97722 -l geology_sim_UTM C:\Training\base_data\geology_sim_UTM.shp C:/Training/base_data/geology_sim_UTM.tif`
5. Click the edit button
6. To ensure the new file is converted to eight bit unsigned integer (Byte) format.
7. Insert the red text into the script already in the box:  
`gdal_rasterize -ot Byte -a ROCK TYPE -tr 4.97722 4.97722 -l geology_sim_UTM C:\Training\base_data\geology_sim_UTM.shp C:/Training/base_data/geology_sim_UTM.tif`
8. Press **OK**.

The geology raster will now load on to the map.

## 8.4.3 Changing the appearance of rasters

To change the appearance of the rainfall\_sim\_UTM raster file:

1. Right click on the file in the Layers sidebar
2. Select **Properties** (a **Layer Properties** window will appear)
3. Select the **Style** tab

To view the full range of information in the raster file:

4. Select **Min / max** in the **Load min/max values** box in the corner of the **Layer Properties** window
5. Select **Load**
6. Select **Apply**

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Now the **Min & Max values** in the **Band Rendering** box will reflect the actual minimum and maximum values of the raster file.

7. To change the colour of the raster from grayscale to blue:
8. Check the box next to **Colorize** in the **Colour rendering** box
9. Select the coloured box on the right hand side of **Colorize**. A **Select Colour** window with a rainbow of colours will appear.
10. Select the colour that you wish to use (e.g. blue)
11. Select **OK**.

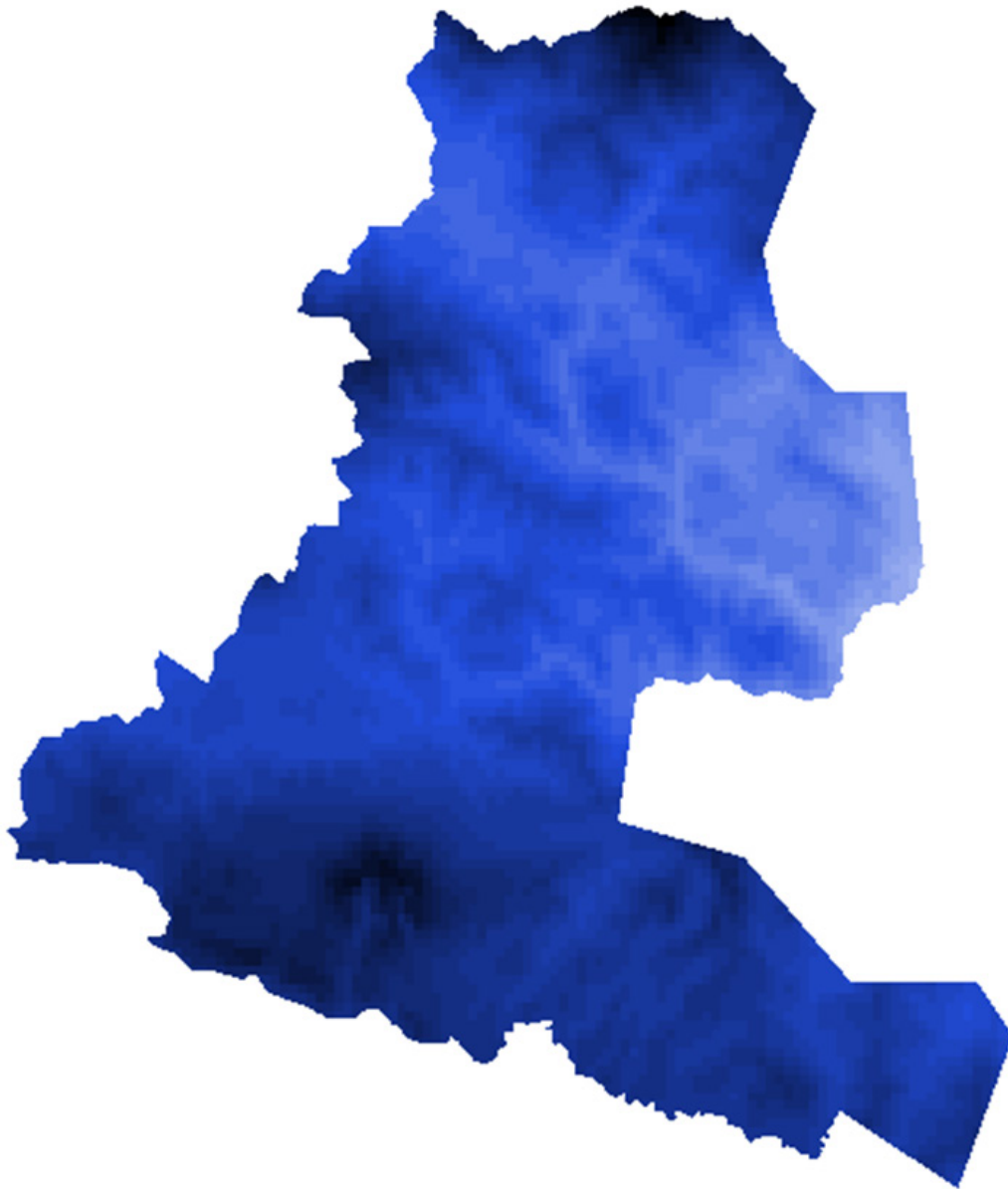
The **Select Colour** window should disappear. The raster should now fade from blue to white, with dark blue values associated with lower levels of rainfall, and light blue to white values associated with higher values of rainfall (Figure 8.3).

To change the appearance so that the darker blue represents higher rainfall values and the lighter blue represents lower rainfall values:

12. Select the drop down menu next to **Colour gradient** in the **Band rendering** box.
13. Select **White to black**
14. Click **Apply**



15. Repeat the geology\_sim\_UTM raster file



*Figure 8.3 Rainfall raster dataset colourised blue to reflect higher rainfall areas (dark blue) and lower rainfall areas (light blue).*

## 8.5 Clipping rasters to the study area

### 8.5.1 Slope aspect

1. Select **Raster**
2. Select **Extraction**
3. Select **Clipper** and fill in the parameters as indicated in Table 8.6.



Table 8.6 Input parameters for Clipper used to clip Slope aspect raster to the study area

Parameter	Input
Input file (raster)	slpasp.tif
Output file	slpaspC.tif (in processing)
No data value	400 (and check box indicated)
Clipping mode	Mask layer (Check box indicated)
Mask layer	rainfall_sim_UTM
Load onto canvas when finished	Check box indicated

```
gdalwarp -dstnodata 400 -q -cutline C:\Training\base_data\rainfall_sim_UTM.shp -crop_to_cutline -of GTiff C:/Training/base_data/slpasp.tif C:/Training/base_data/slpaspC.tif
```

4. Press **OK**

### 8.5.2 Slope angle

1. Select **Raster**
2. Select **Extraction**
3. Select **Clipper** and fill in the parameters as indicated in Table 8.7.

Table 8.7 Input parameters for Clipper used to clip Slope angle raster to study area

Parameter	Input
Input file (raster)	slpang.tif
Output file	slpangC.tif (in processing)
No data value	255 (and check box indicated)
Clipping mode	Mask layer (Check box indicated)
Mask layer	rainfall_sim_UTM
Load onto canvas when finished	Check box indicated

```
gdalwarp -dstnodata 255 -q -cutline C:\Training\base_data\rainfall_sim_UTM.shp -crop_to_cutline -of GTiff C:/Training/base_data/slpang.tif C:/Training/base_data/slpangC.tif
```

4. Press **OK**

### 8.5.3 Creating a polygon of the DEM area

1. Select **Vector**
2. Select **Research Tools**
3. Select **Polygon from layer extent** and fill in the parameters as indicated in Table 8.8.



Table 8.8 Input parameters for Polygon from layer extent for creating polygon of the study area

Parameter	Input
Input layer	png_dem_UTM (load onto canvas first)
Output polygon shapefile	study_area.shp (in base_data)
Add result to canvas	Check box indicated

### 8.5.4 Rainfall

1. Select **Raster**
2. Select **Extraction**
3. Select **Clipper** and fill in the parameters as indicated in Table 8.9.

Table 8.9 Input parameters for Clipper used to clip rainfall raster to study area

Parameter	Input
Input file (raster)	Rainfall_sim_UTM.tif
Output file	rf_study_area.tif (in processing)
No data value	255 (and check box indicated)
Clipping mode	Mask layer (Check box indicated)
Mask layer	study_area
Load onto canvas when finished	Check box indicated

```
gdalwarp -dstnodata 255 -q -cutline C:/Training/base_data/study_area.shp -crop_to_cutline -of GTiff
C:/Training/base_data/rainfall_sim_UTM.tif C:/Training/processing/rf_study_area.tif
```

4. Press **OK**.

### 8.5.5 Geology

1. Select **Raster**
2. Select **Extraction**
3. Select **Clipper** and fill in the parameters as indicated in Table 8.10.

Table 8.10 Input parameters for Clipper used to clip geology raster to study area

Parameter	Input
Input file (raster)	geology_sim_UTM.tif
Output file	geo_study_area.tif (in processing)
No data value	255 (and check box indicated)
Clipping mode	Mask layer (Check box indicated)
Mask layer	study_area
Load onto canvas when finished	Check box indicated



```
gdalwarp -dstnodata 255 -q -cutline C:/Training/base_data/study_area.shp -crop_to_cutline -of GTiff C:/Training/base_data/geology_sim_UTM.tif C:/Training/processing/geo_study_area.tif
```

4. Press **OK**.

## 8.6 Reclassifying rasters into parameter classes using r.reclass

For the next step, the rasters will need to be reclassified into integer (whole number) parameter classes. This will allow us to calculate the influence of each parameter on landslide susceptibility.

### 8.6.1 Slope angle

Slope angle values in the file **slpangC.tif** are in the range  $0^\circ < x < 90^\circ$ , but there are no slopes greater than  $75^\circ$  found in this DEM. Parameter classes for slope angle used are presented in Table 8.11.

Table 8.11 Parameter classes for reclassifying slope angle using r.reclass

ID. No	Slope angle range (°)
1	0-14
2	15-29
3	30-44
4	45-59
5	60-74
6	75-90

1. Select **Processing**
2. Select **Toolbox**.
3. Type **r.reclass** in the search bar
4. Alternatively, expand the GRASS commands menu and scroll down until you find the **r.reclass** tool.

Select **r.reclass** and fill in the parameters as indicated in Table 8.12.

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Table 8.12 Input parameters for *r.reclass* used to reclassify Slope angle raster

Parameter	Input
Input raster layer	slpangC.tif
File containing reclass rules	C:\Training\processing\slpang_reclass.txt [navigate to processing]
Output raster layer	slpang_study_area.tif (in processing)
Open output file after running algorithm	Check box indicated

5. Press **OK**.

A layer called **Output raster layer** will appear in the Layers sidebar. Right-click on this layer and **Remove** it.

6. Select **Layer**
7. Select **Add Raster Layer**
8. Browse to the file that you just created in (**C:\Training\processing\slpang\_study\_area.tif**)
9. Click **Open**.
10. Right click on the **slpangC** file that has just appeared in the Layers sidebar,
11. Select **Properties** from the drop-down menu. A Layer Properties window will appear.
12. Click on the **Style** tab.
13. Select **Min/Max** in the Load min/max values box
14. Click **Load**
15. Click **Apply** and **OK**.

## 8.6.2 Slope aspect

Slope aspect values in the file **slpaspC.tif** are in the range  $0 < x < 360^\circ$ . This method will divide it up into the following parameter classes (Table 8.13):

Table 8.13 Parameter classes for reclassifying slope aspect using *r.reclass*

ID No.	Slope aspect range ( $^\circ$ )
1	0-44
2	45-89
3	90-134
4	135-179
5	180-224
6	225-269
7	270-314
8	315-359



1. Select **Processing**
2. Select **Toolbox**
3. Select **r.reclass** and fill in the parameters as indicated in Table 8.14.

Table 8.14 used to reclassify Slope aspect raster

Parameter	Input
Input raster layer	slpaspC.tif
File containing reclass rules	C:\Training\processing\slpasp_reclass.txt [navigate to processing
Output raster layer	slpasp_study_area.tif (in processing)
Open output file after running algorithm	Check box indicated

### 8.6.3 Rainfall

Rainfall has already been reclassified into parameter classes in the Vector to Raster process. The parameter classes are as follows (Table 8.15):

Table 8.15 Parameter classes for reclassifying rainfall using r.reclass

ID.No.	Rainfall (mm) per year
12	2100-2200
13	2200-2300
14	2300-2400
15	2400-2500
16	2500-2600
17	2600-2700
18	2700-2800
19	2800-2900
20	2900-3000
21	3000-3100
22	3100-3200

This can be viewed by right clicking on the **rainfall\_sim\_UTM.shp** file in the **Layers** sidebar and selecting **Open Attribute Table**.



## 8.6.4 Geology

Geology has already been reclassified into parameter classes in the Vector to Raster process. The parameter classes are as follows (Table 8.16):

Table 8.16 Parameter classes for reclassifying geology using *r.reclass*

ID No.	Geological description
12	Arkose & rudite
13	Siltstone
14	Layered limestone
15	Limestone
23	Massive shale
30	Greywacke
31	Interlayered volcanics (lava, minor tuff)
33	Interlayered volcanics (lava, tuff, volcanic derived minor conglomerate & sandstone)
35	Intrusive igneous (granodiorite, tonalite)
36	Gabbro
41	Swamp and scree deposits

This can be viewed by right clicking on the [geology\\_sim\\_UTM.shp](#) file in the **Layers** sidebar and selecting **Open Attribute Table**.

## 8.7 Calculating weightings

### 8.7.1 Calculating the total area of each parameter class

1. Select **Processing**
2. Select **Toolbox**
3. Select **GRASS commands**
4. Select **Raster**
5. Select **r.report** and fill in the parameters indicated in Table 8.17.

Table 8.17 Input parameters for *r.report* used to calculate the total area of each parameter class

Parameter	Input
Raster layers to report on	slpang_study_area
Units	me
Number of fp subranges to collect stats from	255
Output report file	slpang_study_area



6. Select **Run**.
7. Repeat this process for **slpasp\_study\_area.tif**, **rf\_study\_area.tif** and **geo\_study\_area.tif**.

### 8.7.2 Clipping rasters to the area of the landslide inventory

1. Overlay the merged landslide layer and the parameter that you wish to calculate (this example uses **slpangcl.tif**).

Important: Ensure that all raster layer, polygon layer & project CRSs are consistent.

2. Select **Raster**
3. Select **Extraction**
4. Select **Clipper** and fill in the parameters as indicated in Table 8.18 and Figure 8.4.

Table 8.18 Input parameters for Clipper used to clip raster to the study area

Parameter	Input
Input file (raster)	slpang_study_area
Output file	slpang_LS.tif (in processing)
No data value	255 (and check box indicated)
Clipping mode	Mask layer (Check box indicated)
Mask layer	Landslide
Load onto canvas when finished	Check box indicated

```
gdalwarp -dstnodata 255 -q -cutline C:\Training\inventory\landslide.shp -crop_to_cutline -of GTiff C:\Training\processing\slpang_study_area.tif C:/Training/processing/slpang_LS.tif
```

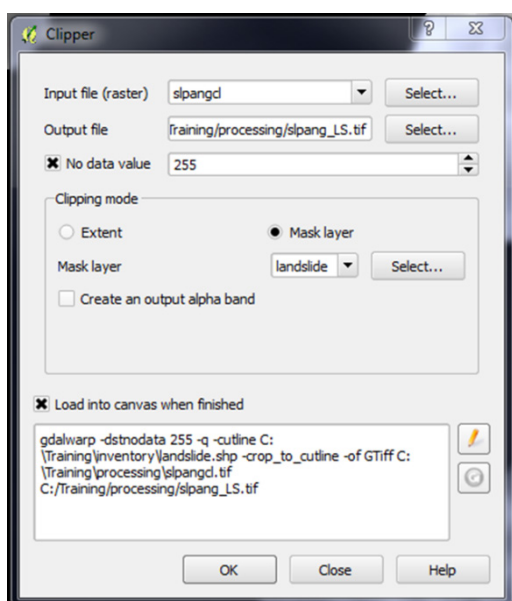


Figure 8.4 Example Clipper window



### 8.7.3 Calculating the area of landslides for each parameter

1. Select **Processing**
2. Select **Toolbox**
3. Select **GRASS commands**
4. Select **Raster**
5. Select **r.report** and fill in the parameters indicated in Table 8.19.

Table 8.19 Input parameters for r.report used to calculate the area of landslides for each parameter class

Parameter	Input
Raster layers to report on	slpang_LS
Units	me
Number of fp subranges to collect stats from	255
Output report file	slpang_LS

6. Select **Run**. A window will appear (Figure 8.5)

#### r.report

```

+-----+
| Category Information | square|
| #|description | meters|
+-----+
| 1-1.8|from to . . . . .| 643,543|
| 1.8-2.6|from to . . . . .| 870,036|
| 2.6-3.4|from to . . . . .| 246,657|
| 3.4-4.2|from to . . . . .| 51,782|
| 4.2-5|from to . . . . .| 10,606|
+-----+
| TOTAL | 1,822,624|
+-----+

```

Figure 8.5 Example of an r.report

7. Repeat this step for **slpasp\_LS.tif**, **rf\_LS.tif** and **geo\_LS.tif**.



## 8.7.4 Using the weighting spreadsheet to calculate ratios and weightings

Use the excel spreadsheet weighting.xlsx to calculate the ratios and weightings by filling in the areas calculated through this process. Repeat for

- slpang\_LS.tif,
- slpang\_study\_area.tif,
- slpasp\_LS.tif,
- slpasp\_study\_area.tif,
- rf\_LS.tif,
- rf\_study\_area.tif,
- geo\_study\_area.tif
- geo\_LS.tif.

## 8.8 Applying the weightings to parameter classes

### 8.8.1 Slope angle

1. Select **Processing**
2. Select **Toolbox**
3. Select **r.reclass** and fill in the parameters as indicated in Table 8.20.

Table 8.20 Input parameters for r.reclass used to reclassify Slope angle

Parameter	Input
Input raster layer	slpang_study_area.tif
File containing reclass rules	C:\Training\weighting\slpangLS_reclass.txt
Output raster layer	slpangwt.tif (in weighting)
Open output file after running algorithm	Check box indicated

4. Press OK.

### 8.8.2 Slope aspect

1. Select **Processing**
2. Select **Toolbox**

Select **r.reclass** and fill in the parameters as indicated in Table 8.21.



Table 8.21 Input parameters for *r.reclass*

Parameter	Input
Input raster layer	slpaspcl.tif
File containing reclass rules	C:\Training\processing\slpaspLS_reclass.txt
Output raster layer	slpaspwt.tif (in weighting)
Open output file after running algorithm	Check box indicated

3. Press OK.

### 8.8.3 Rainfall

1. Select **Processing**
2. Select **Toolbox**
3. Select **r.reclass** and fill in the parameters as indicated in Table 8.22.

Table 8.22 Input parameters for *r.reclass*

Parameter	Input
Input raster layer	rfC.tif
File containing reclass rules	C:\Training\processing\rainfall_LS_reclass.txt
Output raster layer	rfwt.tif
Open output file after running algorithm	Check box indicated

4. Press **OK**.

### 8.8.4 Geology

1. Select **Processing**
2. Select **Toolbox**
3. Select **r.reclass** and fill in the parameters as indicated in Table 8.23.

Table 8.23 Input parameters for *r.reclass*

Parameter	Input
Input raster layer	geoC.tif
File containing reclass rules	C:\Training\processing\geologyLS_reclass.txt
Output raster layer	geowt.tif
Open output file after running algorithm	Check box indicated



4. Press **OK**.

## 8.9 Adding final weightings together

1. Select **Layer**
2. Select **Add Raster Layer**
3. Select **angwt.tif** and **aspwt.tif** to open files
4. Select **Raster**
5. Select **Raster Calculator**
6. In the **Raster calculator** expression box write the expression:

**"angwt@1" + "aspwt@1" + "rfwt@1" + "geowt@1"**

7. In the **Result layer** box, select the '...' button next to the **Output layer** field, navigate to the **weighting** folder and name it **allwt.tif**.
8. Click **OK**.

A new file named **allwt.tif** should show up in the Layers window.

Note – if QGIS crashes when all the layers are added together, add them together one at a time.

## 8.10 Composing a map

### 8.10.1 Composer Manager

Now that the analysis has been completed, you will learn how to make a map. QGIS allows you to create multiple maps using the same map file. For this reason, it has a tool called the Composer Manager.

1. Select **Project**
2. Select **Composer Manager**. A **Composer manager** window will appear.
3. Set drop down menu to **Empty Composer**
4. Select **Add**. A **Composer title** window will appear.
5. Fill in the blank field and name this project **Chimbu**.
6. Click **OK**.
7. Click **Show**. A **Chimbu** window will now appear.
8. To navigate to this file again select **Project**
9. Select **Print Composers**
10. Select **Chimbu**

### 8.10.2 Basic map composition

1. Select the values in the Composition tab in the side bar to the parameters indicated in Table 8.24.



Table 8.24 Input values for Composition tab of map composer

Parameter	Input
Pre-sets	A4 (210x297mm)
Orientation	Landscape
Export resolution	300 dpi

To add a map:

2. Select **Layout**
3. Select **Add Map**. While this is activated, click and drag a box on the blank page. The map will appear on the page.

You can move the map by clicking and dragging it around, or resize it by clicking and dragging the boxes in the corners. Be sure to leave margins along the edges, and a space along the top for the title.

4. Select **Composer**
5. Select **Save project**

### 8.10.3 Adding a title

1. Select **Layout**
2. Select **Add Label**

When you click on the page, a label will now appear. This label can now be moved and resized just like adding a map in item 7.3.2.

To edit properties of the title

3. Select the **Item Properties** tab in the sidebar. Text can be changed in the **Main properties** box.

### 8.10.4 Adding and customising a legend

1. Select **Layout**
2. Select **Add Legend**

When you click on the page, a legend will now appear. Move it to where you want it by clicking and dragging.

### 8.10.5 Adding a logo

1. Select **Layout**
2. Select **Add Image**.



3. When you click on the page, a box will now appear. Move it to where you want it by clicking and dragging. You can also resize it.
4. On the **Item properties** tab, in the **Main properties** box click the ... button that is next to the word **Path**. This will bring up a **Select svg or image file** window.
5. Navigate to the folder that the image file of the logo is in and press **Open**.
6. The logo will now appear.

### 8.10.6 Adding a scalebar

1. Select **Layout**
2. Select **Add scalebar**.
3. When you click on the page, a scalebar will now appear. Move it to where you want it by clicking and dragging. You can also resize it.
4. If you want to change the unit of measurement, go to the **Item properties** tab, and go to the drop down menu in the **Units** box.
5. If you want to change the style of the scalebar, go to the drop down menu next to **Style** in the **Main properties** box.

### 8.10.7 Exporting a map

1. Select **Composer**
2. Select **Export as Image or Export as PDF** (depending on whether you want to save it as an image or a PDF). A window will pop up.
3. Navigate to the folder you wish to save it in, name it and click **Save**.

The image or PDF will now be saved in that location.



## 9 Quality management

Prior to commencing the weighting process, partition the landslide inventory, keeping a random 25% aside to validate the final map.

1. Select **Vector**
2. Select **Research**
3. Select **Random Selection**
4. Select the Input Vector Layer **LS\_UTM**
5. Select the Percentage of Features **25%**.
6. Select **Layer**
7. Select **Save Selection as Vector File**, naming this file as **Sample2**.
8. Open the attribute table for the LS\_UTM file and invert the selection.
9. Select **Layer**
10. Select **Save Selection as Vector File**.



# References

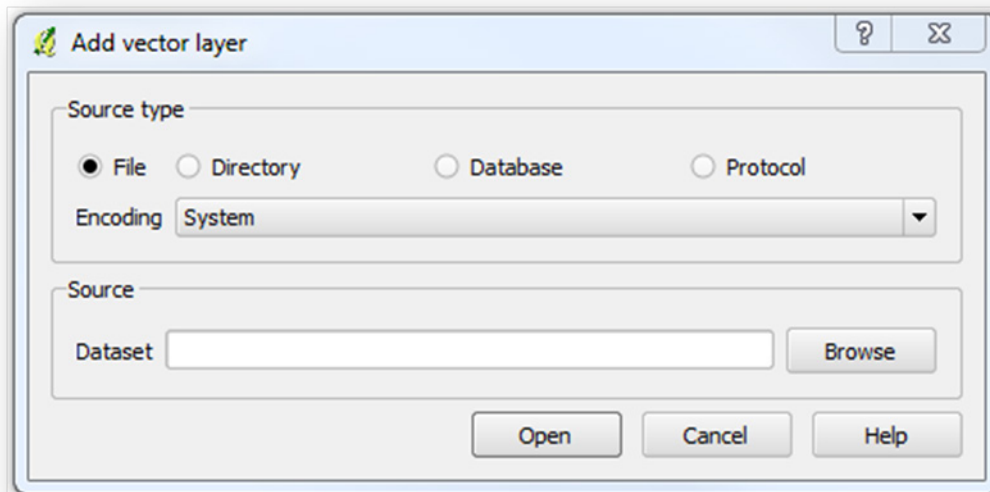
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# Appendix A QGIS Basics

For a complete step by step manual on how to use QGIS see: <http://manual.linfiniti.com/>

## A.1 Loading a vector dataset

1. Select Layer
2. Select Add Vector Layer
3. Select Browse to navigate to the file (Appendix Figure A.1).
4. Click Open.



Appendix Figure A.1 Example Add Vector Layer window

## A.2 Reprojecting a layer

### A.2.1 Raster

5. Select **Raster**
6. Select **Projections**
7. Select **Warp(Reproject)**
8. Fill in required parameters
9. Press **OK**.

## A.2.2 Vector

10. Select **Vector**
11. Select **Data Management Tools**
12. Select **Define current projection**
13. Fill in required parameters
14. Press **OK**.

## A.3 Loading a colour scheme

15. Double click on the layer e.g. DEM (in the layers window) to bring up the **Properties** window.

On the Style tab:

16. Select **Load Style** and locate the file **Wikicarto\_2.0.qml**.
17. Select **Open** and **Apply**.
18. Press **OK**.

## A.4 Useful tips and tools

The Identify button is useful to identify features in shapefiles or pixel values in rasters. To identify a feature or a pixel:

19. Select the file in the Layers sidebar
20. Select the pixel or feature you wish to identify in the main window. A window will pop up with information about the feature or pixel.
21. Double click on a layer in the Layers sidebar to bring up the Layer Properties window.
22. To view the attribute table of a vector layer in the Layers sidebar, right click on the layer to bring up a drop down menu, and then click on Open Attribute Table.