Universal Soil Loss Equation (USLE)

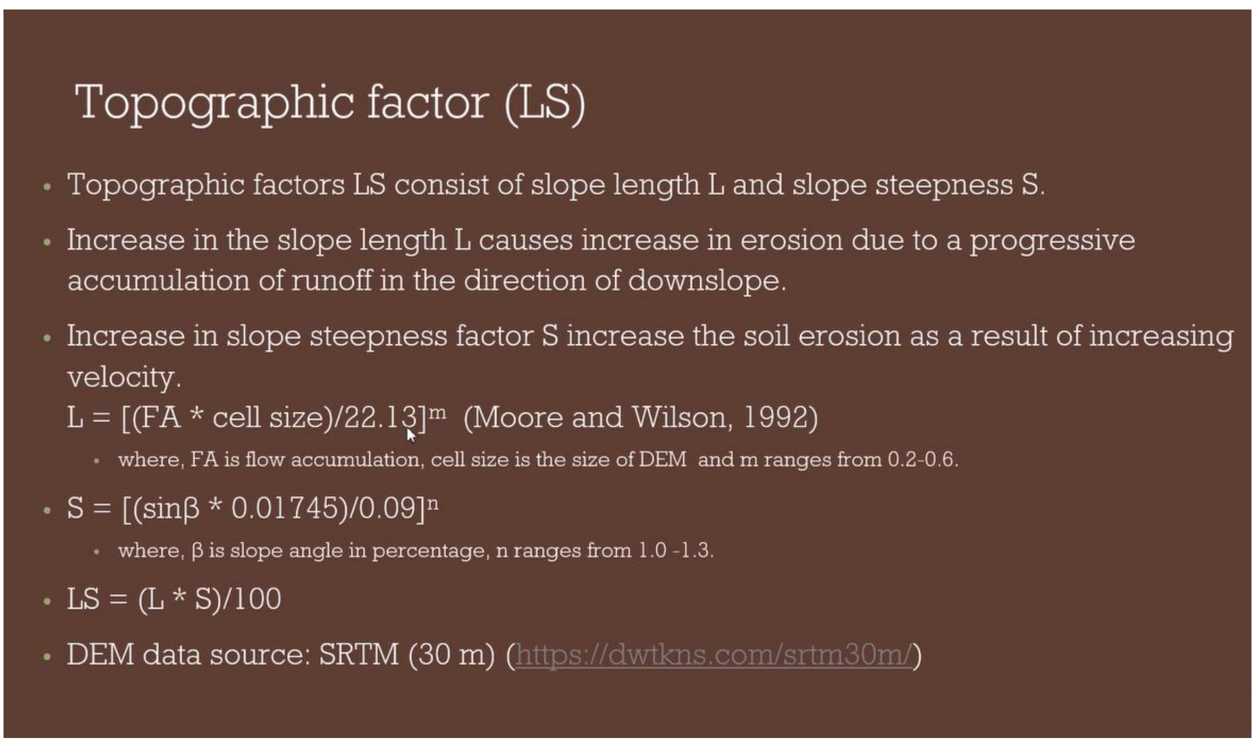
Introduction

The Universal Soil Loss Equation (USLE) is a widely used mathematical model that describes soil erosion processes.

$$\boldsymbol{A = R \times K \times LS \times C \times P \left(metric\colon \frac{\frac{tonnes}{ha}}{yr} \right)}$$

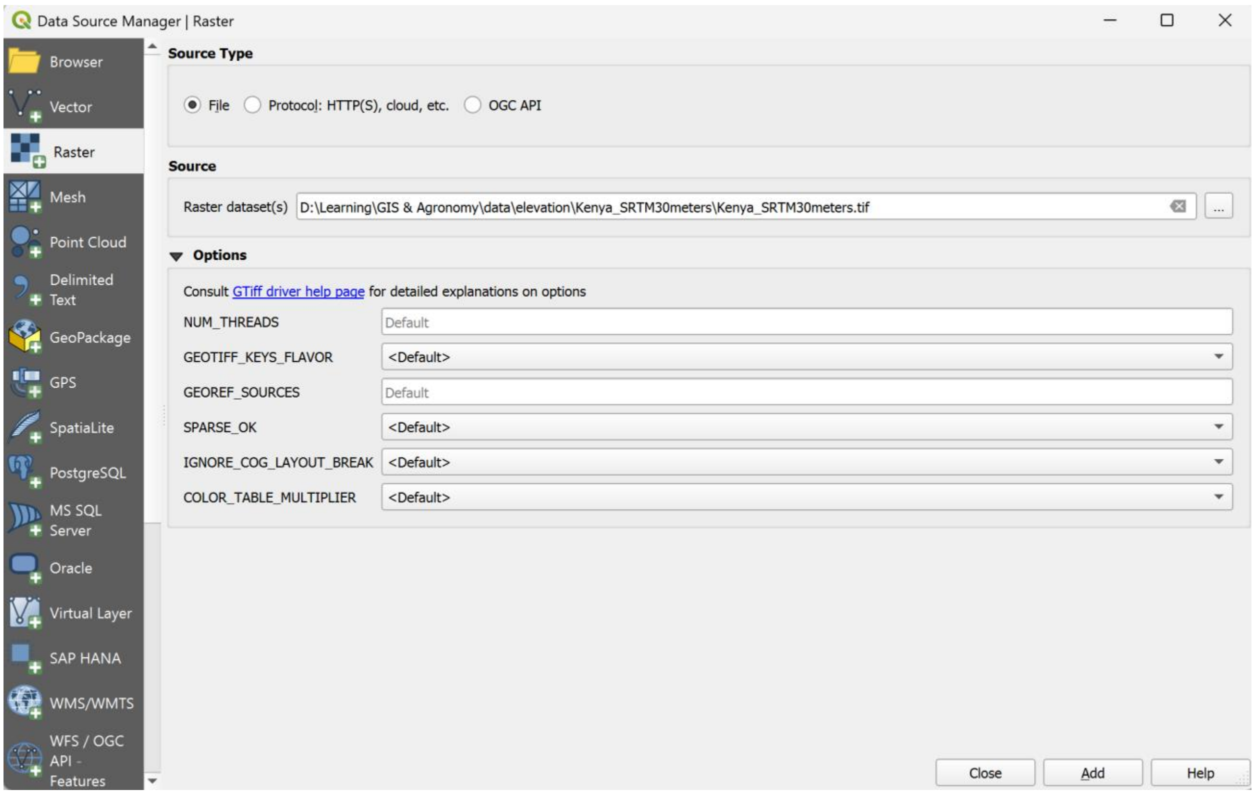
- ✓ R - rainfall Erosivity
- ✓ K - soil erodibility;
- ✓ L - slope length;
- ✓ S -slope steepness;
- ✓ C - cover and management;
- ✓ P - support practice.

This tutorial uses the LS factor, derived from SRTM DEM.

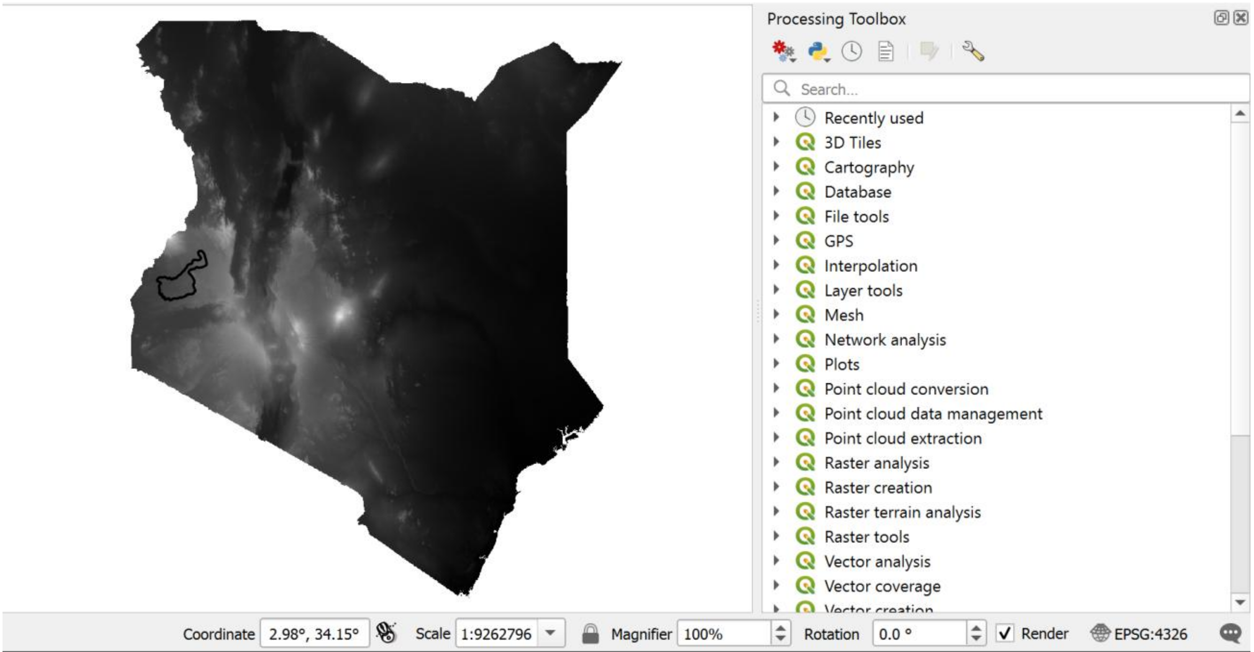


Step 1: Load the Data

- ✓ Open **QGIS**.
- ✓ Load the **SRTM DEM** raster layer:
  - Go to **Layer > Add Layer > Add Raster Layer**.

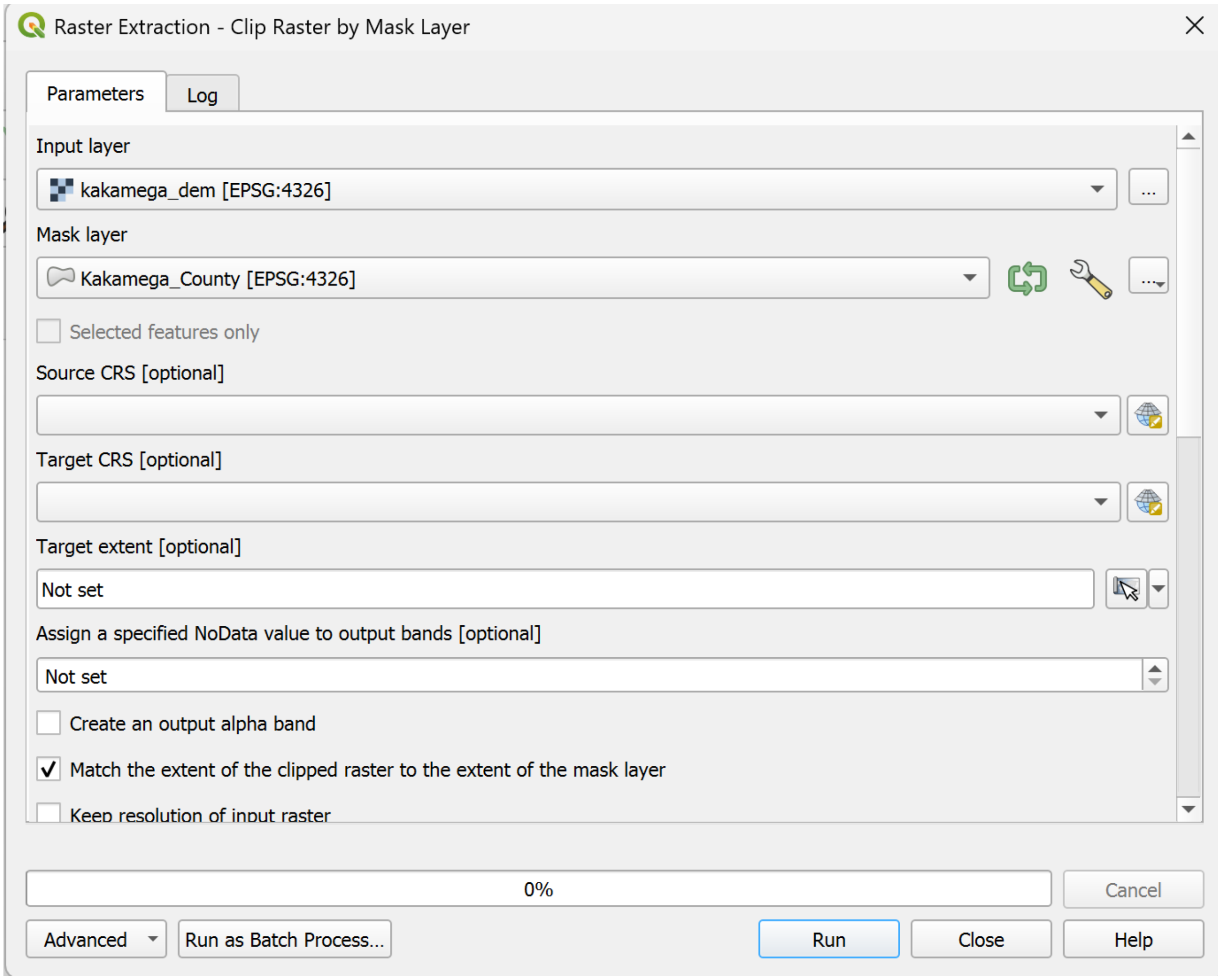


  - Browse and select your SRTM DEM file (e.g., .tif).

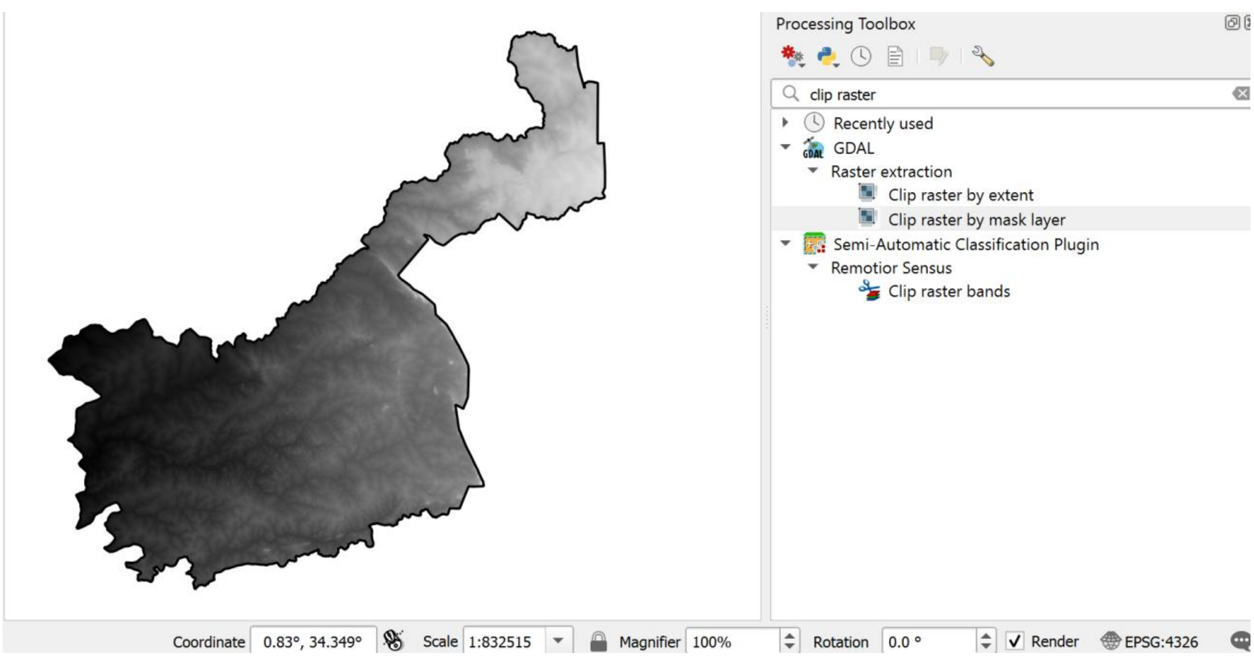


Step 2: Clip the DEM to Your Area of Interest

1. Load your **area of interest (AOI)** boundary shapefile.
2. Use the **Clip Raster by Mask Layer** tool:
    - Go to **Raster > Extraction > Clip Raster by Mask Layer**.
    - Input Layer: Your SRTM DEM.
    - Mask Layer: Your AOI shapefile.
    - Check **Match the extent of the mask layer** and **Keep resolution of input raster**.
    - Choose an output file path and run the tool.



The raster file will automatically be added to the map

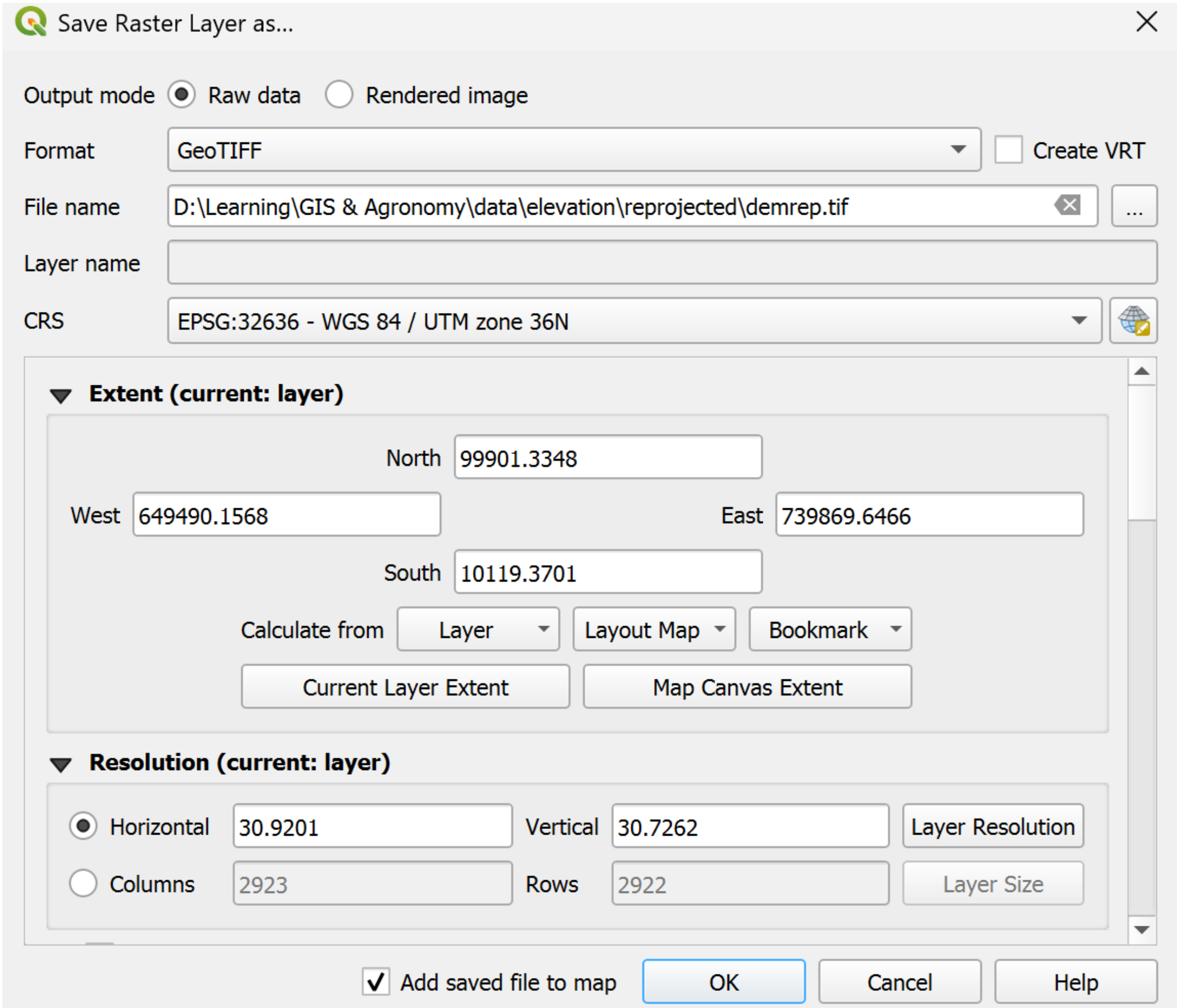


Reproject the Data in QGIS

To ensure accurate mapping and spatial analysis, you should reproject your data into a suitable projected coordinate system based on your area of interest.

Steps:

1. Right-click your layer in the Layers Panel
2. Select Export → Save Features As…
3. In the CRS (Coordinate Reference System) section, click the Select CRS button
4. Search and select a projection based on the location of your area of interest:
    - For areas north of the equator, such as Kakamega, use:
        - EPSG:32636 – WGS 84 / UTM Zone 36N
    - For areas south of the equator, use:
        - EPSG:32736 – WGS 84 / UTM Zone 36S
5. Choose an appropriate output file name and save location
6. Click OK to save the reprojected layer



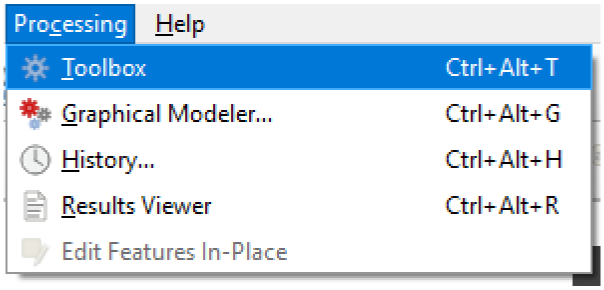
Fill sinks in the DEM

The first step is to fill the sinks in the DEM. Sinks are artificial depressions that trap the water and prevent flow to the outlet.

1. Start QGIS Desktop with GRASS.

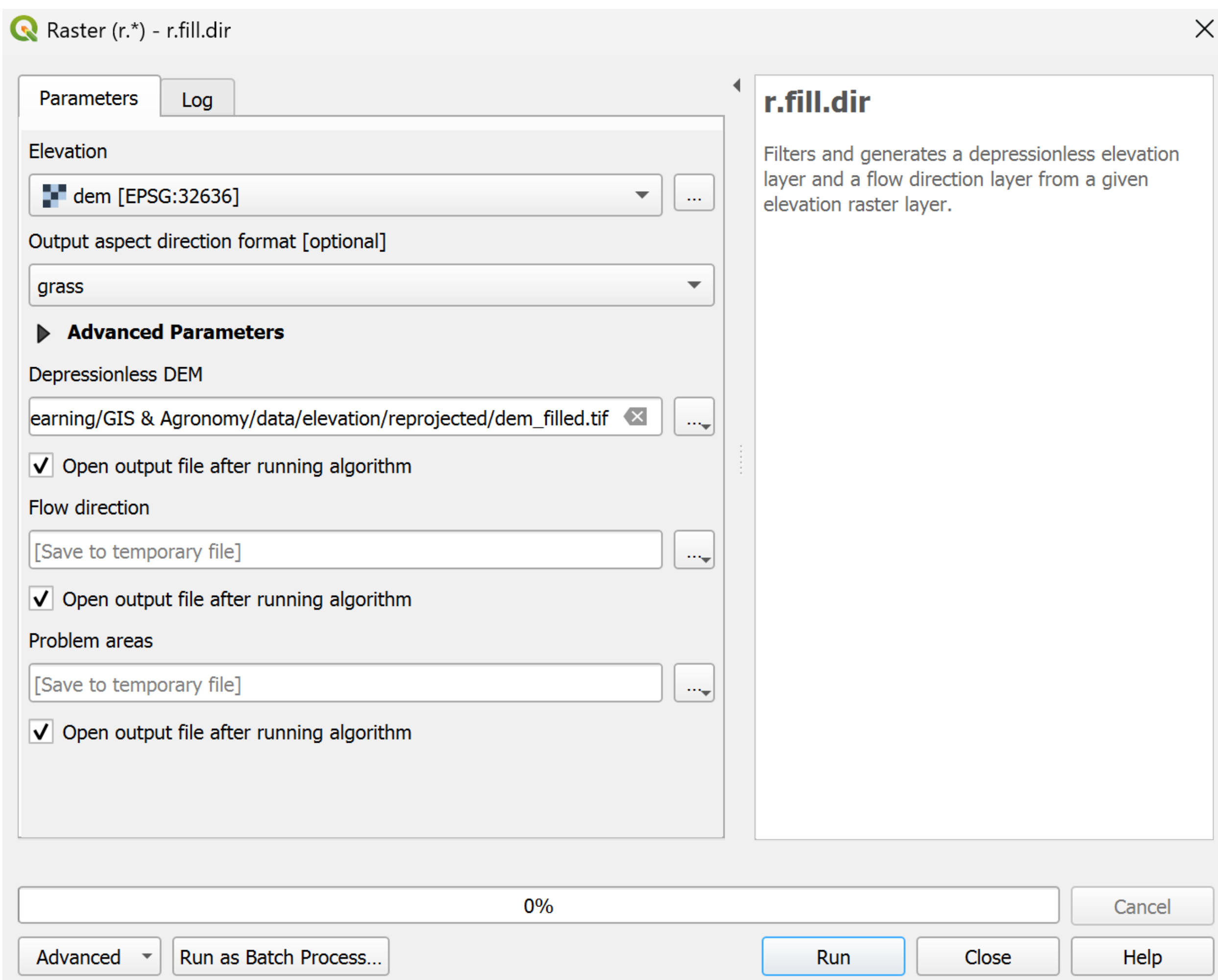
2. Add *dem.tif* to the *Layers* panel.

3. Open the *Processing Toolbox* panel: in the main menu go to Processing | Toolbox.



4. In the Processing Toolbox choose to **GRASS | Raster (r.*) | r.fill.dir**.

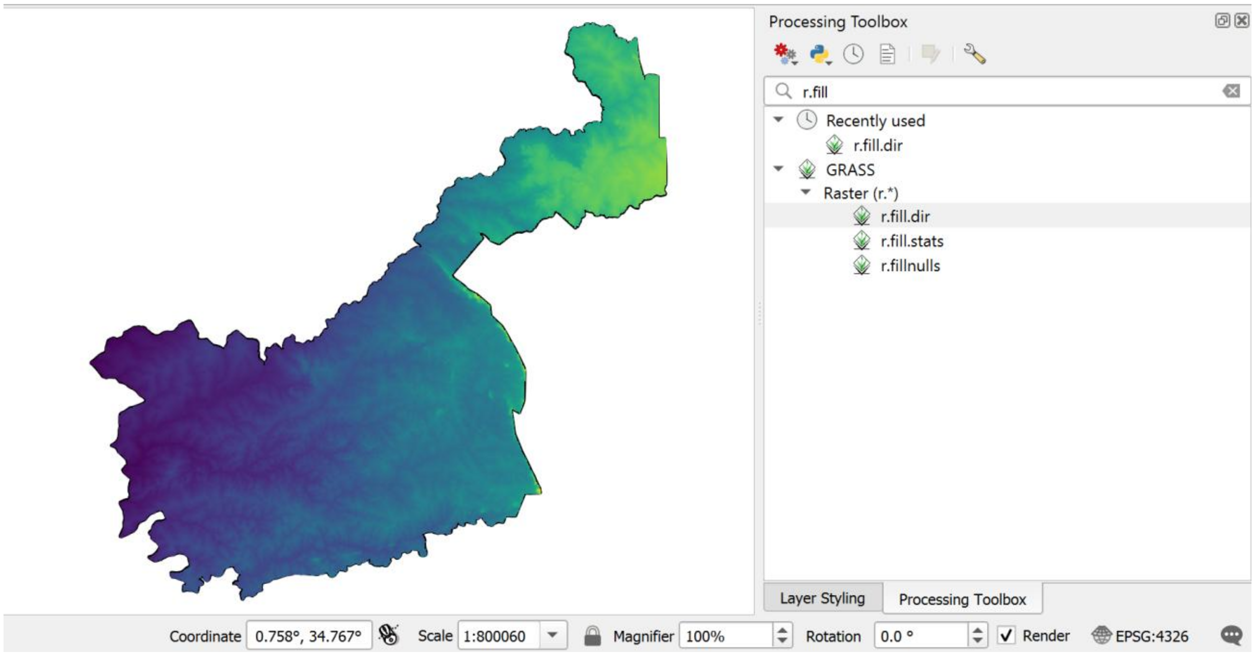
5. In the *r.fill.dir* dialogue choose the *DEM* layer as *Elevation*. Keep the default *Output aspect direction format* as *grass*. Save the *Depressionless DEM* as *DEM_filled.tif* (make sure to choose a GeoTiff) and uncheck the other output layers, because we don't need them.



6. Click *Run*. *Close* the dialogue after processing. Processing will take a while. Ignore the red warnings in the log.

More info about the algorithm can be found here.

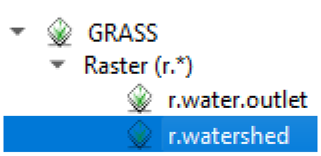
7. Remove the *DEM* layer from the *Layers* panel so we only have the *DEM_filled* layer there to proceed with.



3. Calculate flow accumulation and flow direction

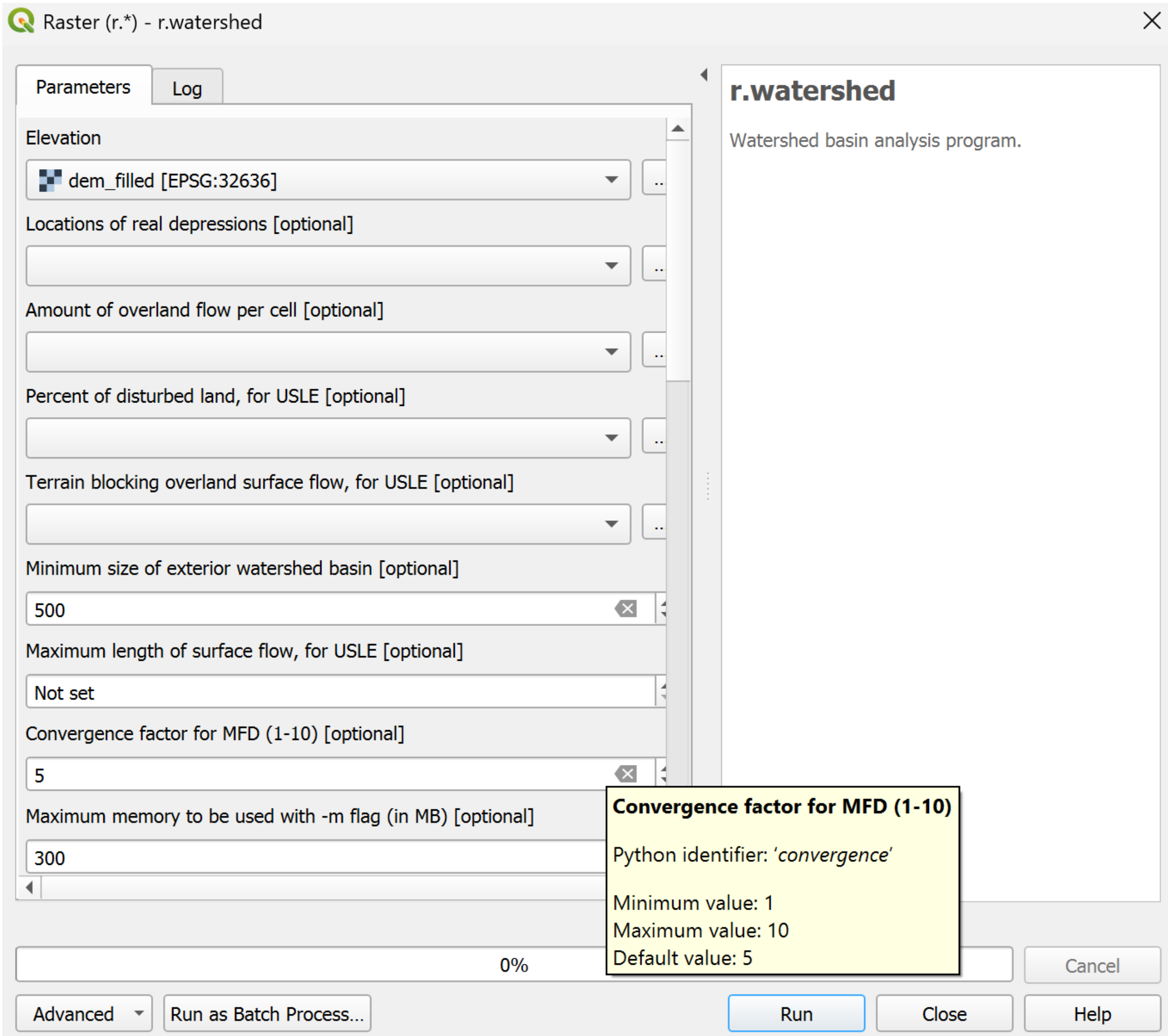
The next step is to calculate the accumulation of water over the filled DEM.

1. In the Processing Toolbox choose **GRASS | Raster (r.*) | r.watershed**.



The *r.watershed* tool has a lot of settings. Check the GRASS manual page for this tool to learn more about the settings of the algorithms.

2. In the *r.watershed* dialogue choose *DEM_filled* as *Elevation*. Set the *Minimum size of exterior watershed basin* to 500 pixels and check the box to *Enable Single Flow Direction (D8) flow*. Save the *Number of cells that drain through each cell* to *accumulation.tif* and save the *Drainage direction* to *flowdir.tif*. Uncheck the other outputs, we don't need them.



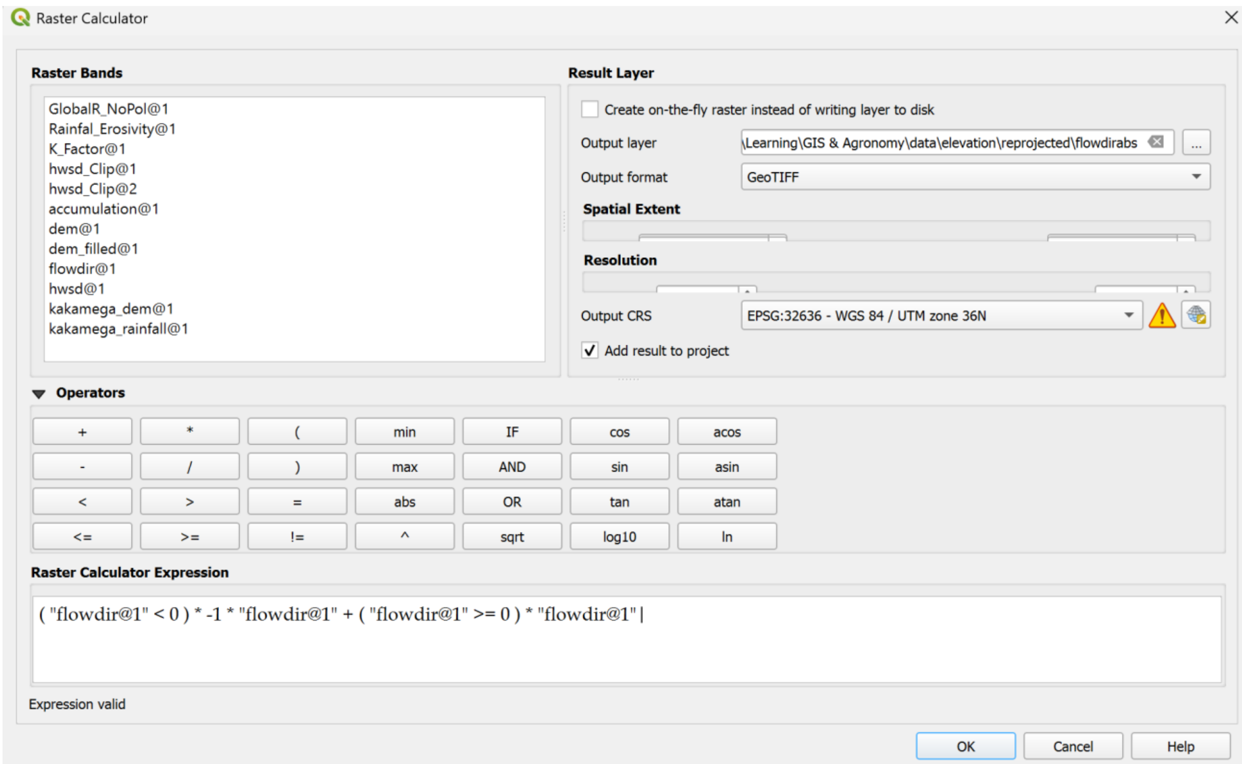
3. Click *Run*. *Close* the dialogue after processing. Ignore the warnings in red.

The flow direction layer is encoded using the GRASS definition: Drainage is 8 directions numbered counter-clockwise starting from 1 in north-east direction. The value 0 indicates that the cell is a depression area. Negative values indicate that surface runoff is leaving the boundaries of the current geographic region. The absolute value of these negative cells indicates the direction of flow. Therefore we need to convert the *flowdir* layer to absolute values.

4. In the main menu go to **Raster | Raster Calculator**.

5. In the Raster Calculator compose the following equation:

("flowdir@1" < 0) * -1 * "flowdir@1" + ("flowdir@1" >= 0) * "flowdir@1"

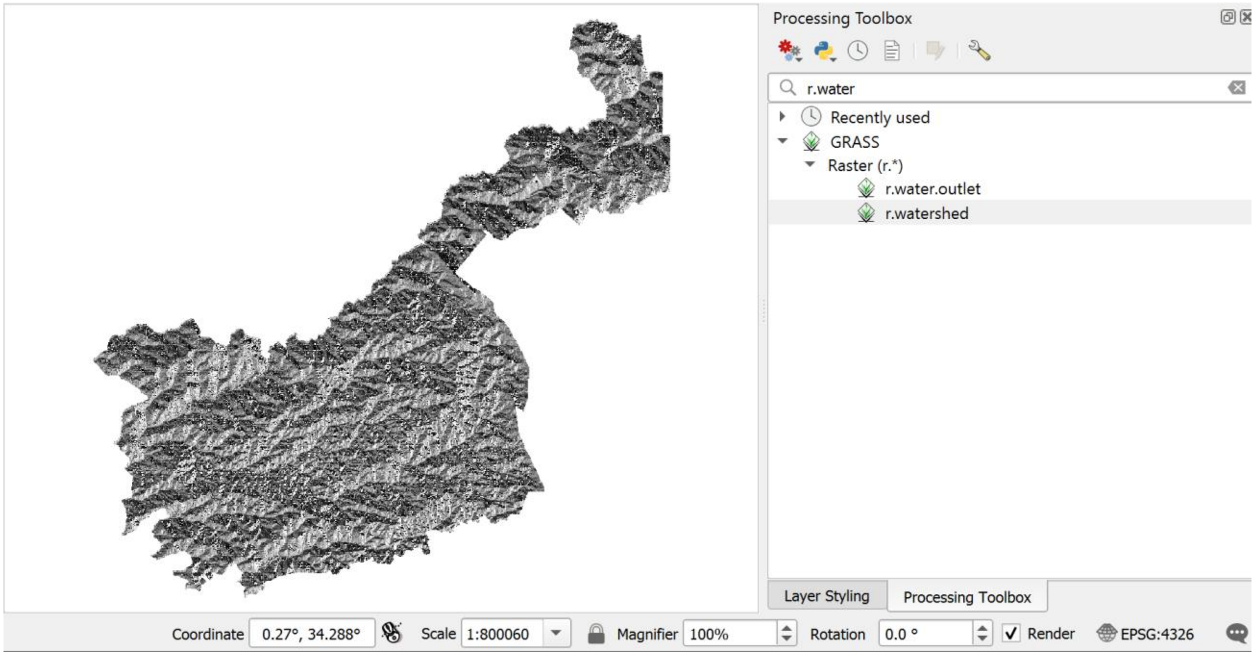


This equation is a condition which reads as: if the flow direction values are less than zero then the result is Boolean True (1), else Boolean False (0). Multiply this with -1 and the flow direction. In this way the first part of the equation results in the absolute values of the negative flow directions. Then we add the condition if the cells are larger than or equal to zero, give Boolean True (1), else Boolean False (0) and multiply this with the flow direction values. This means that non-negative flow direction values will keep their original value.

6. Save the result as *flowdirabs.tif* and click *OK*.

Normally we would style the flow direction result with a directional grid, but that's not part of this tutorial.

7. Remove the original *flowdir* layer from the *Layers* panel.

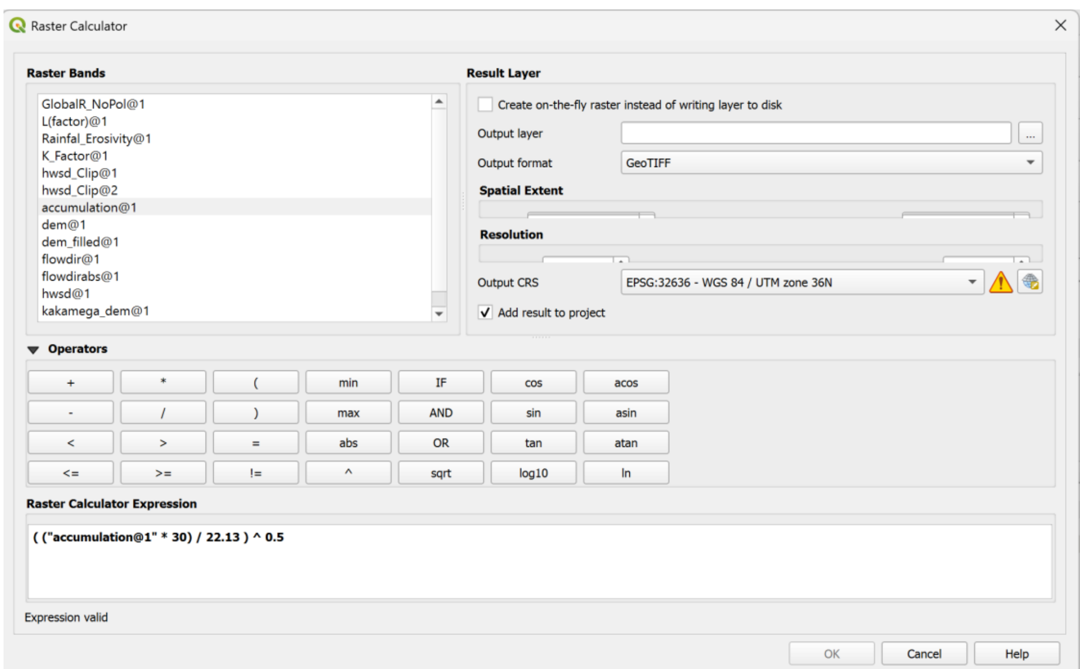


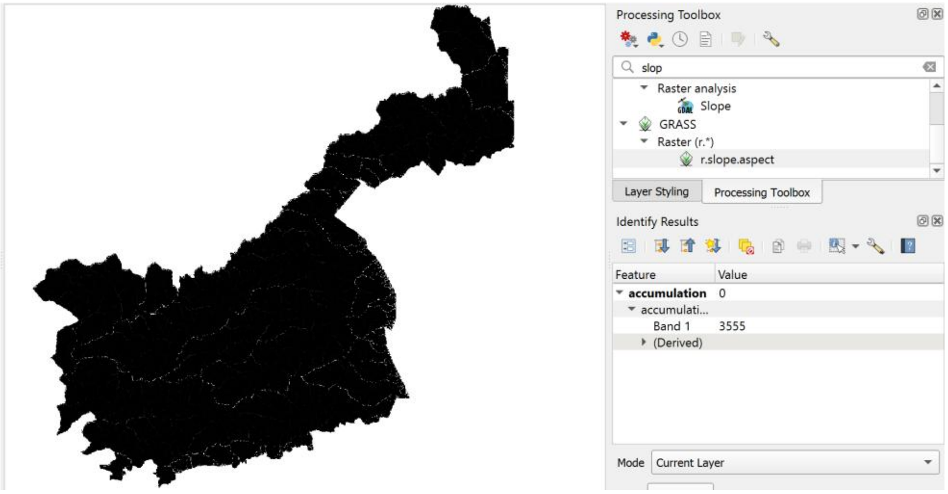
Calculate L

Open raster calculator and input the following formula

$$L = \left[\frac{FA * cell\ size}{22.13}\right]^m \text{(Moore and Wilson, 1992)}$$

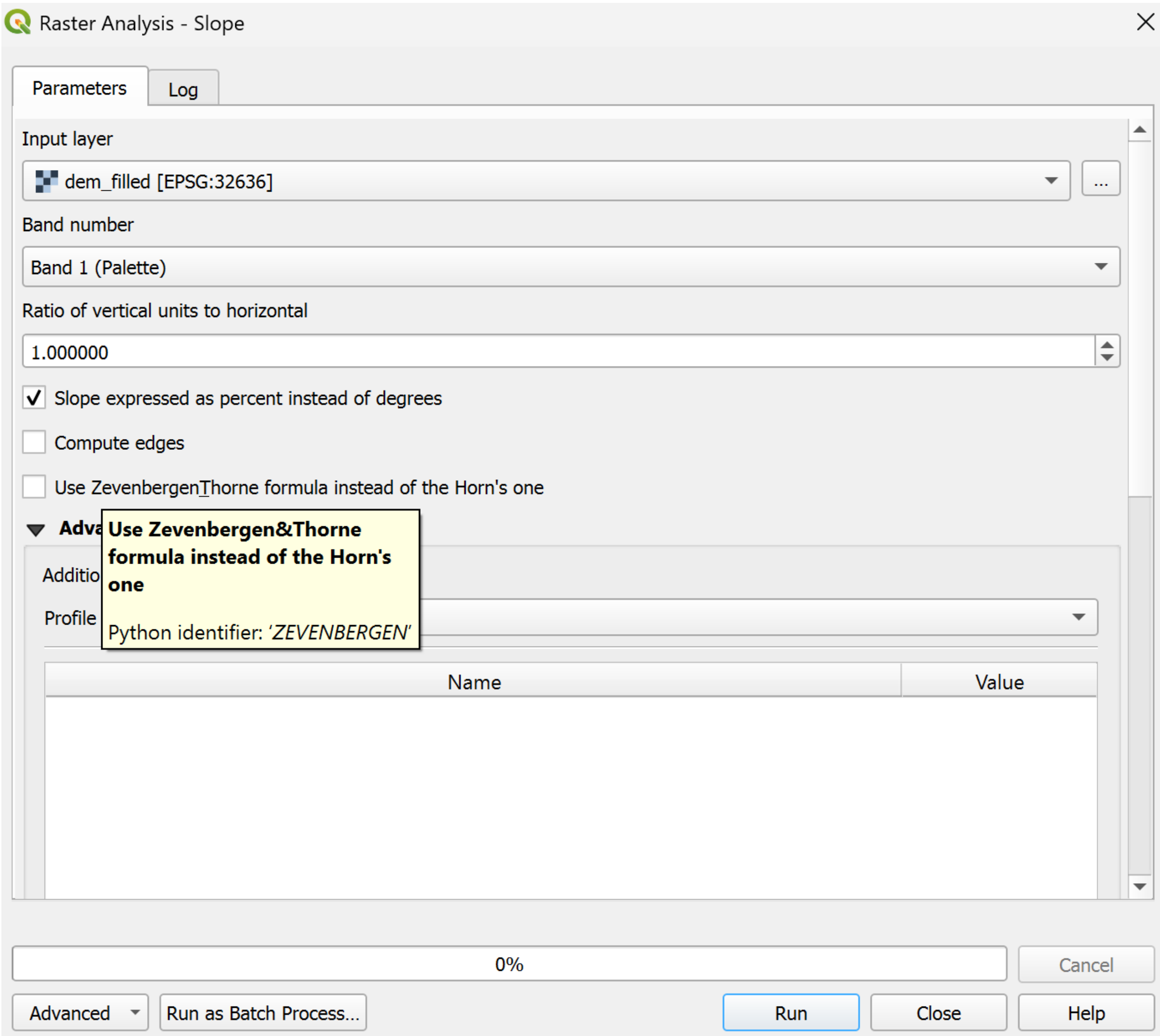
where, FA is flow accumulation, cell size is the size of DEM and m ranges from 0.2-0.6.



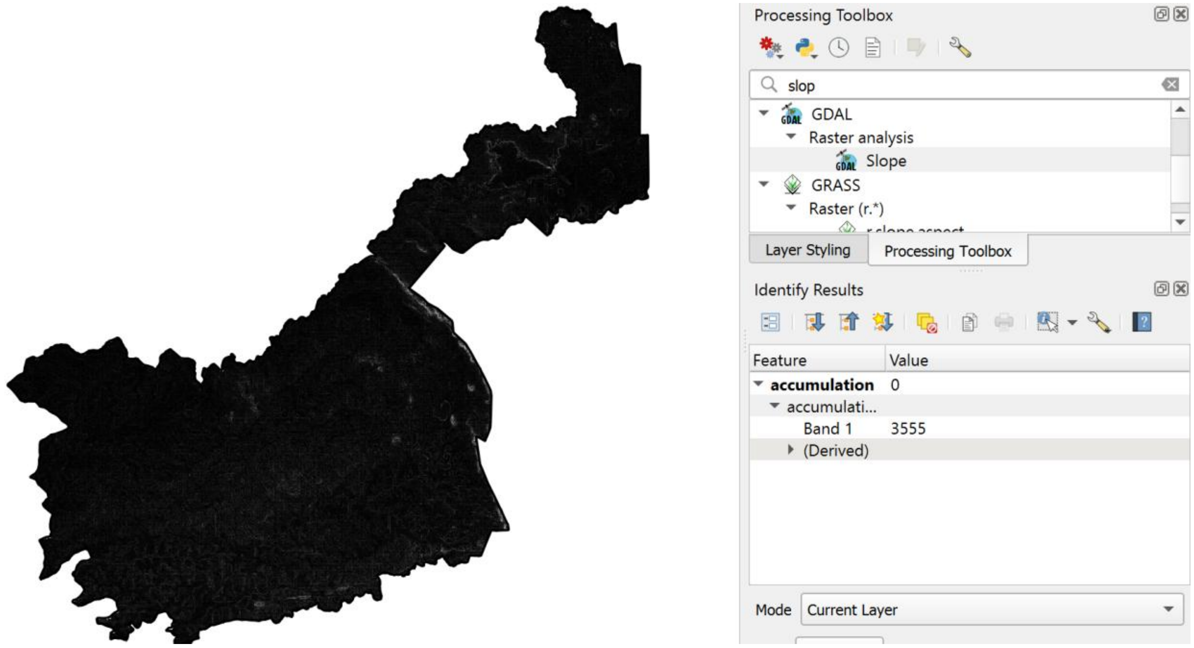


Calculate Slope from DEM

- In the top menu, go to **"Raster"** > **"Analysis"** > **"Slope…"**.
- In the **Slope** tool dialog:
  - **Input layer**: Select your loaded DEM.
  - **Output file**: Choose a name and location to save the slope raster.
  - **Output format**: Choose format (e.g., GeoTIFF).
  - **Z factor**: Leave as 1.0 unless working with non-meter elevation or geographic CRS.
  - **Slope expressed as**:
    - Choose **Degrees** (°) for angle,
    - Or **Percent rise** for steepness ratio.

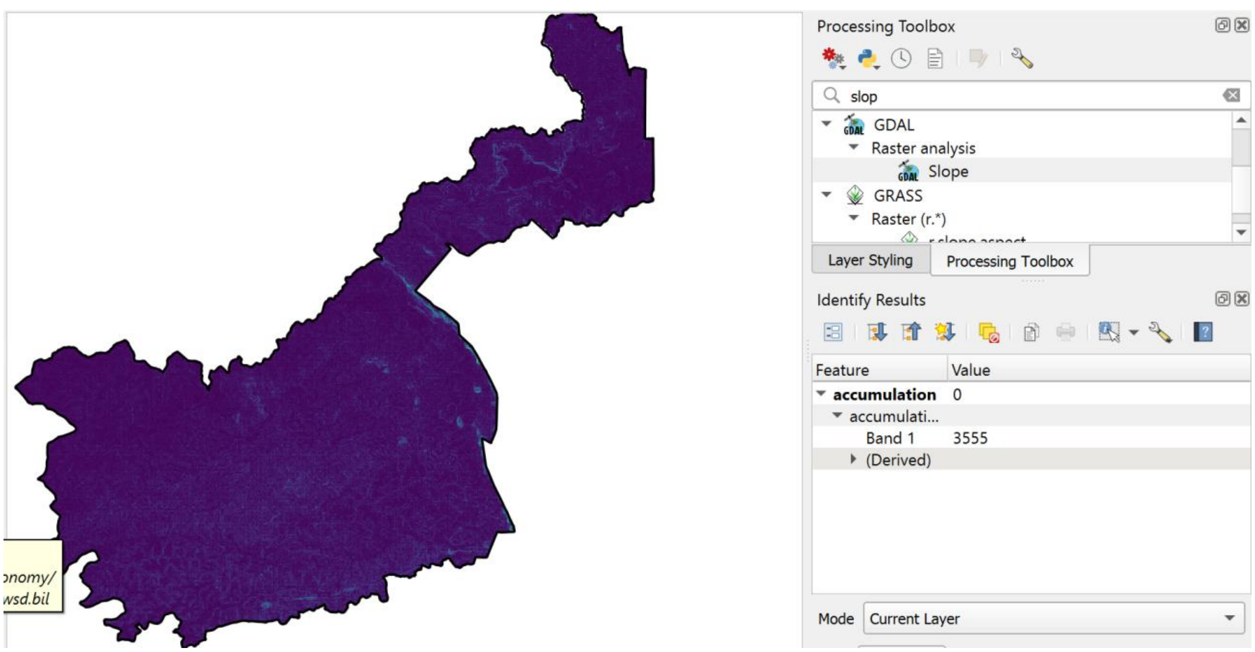


- Click **"Run"** to process.
- After completion, the slope raster will be automatically added to your map.



Style the Slope Output (Optional but Recommended)

- Right-click on the slope layer > **"Properties"** > **"Symbology"**.
- Choose a suitable **color ramp** (e.g., "Viridis" or "Elevation").
- Set **classification mode** (e.g., Equal Interval, Quantile) to better visualize slope ranges.
- Click **"Apply"**, then **"OK"**.



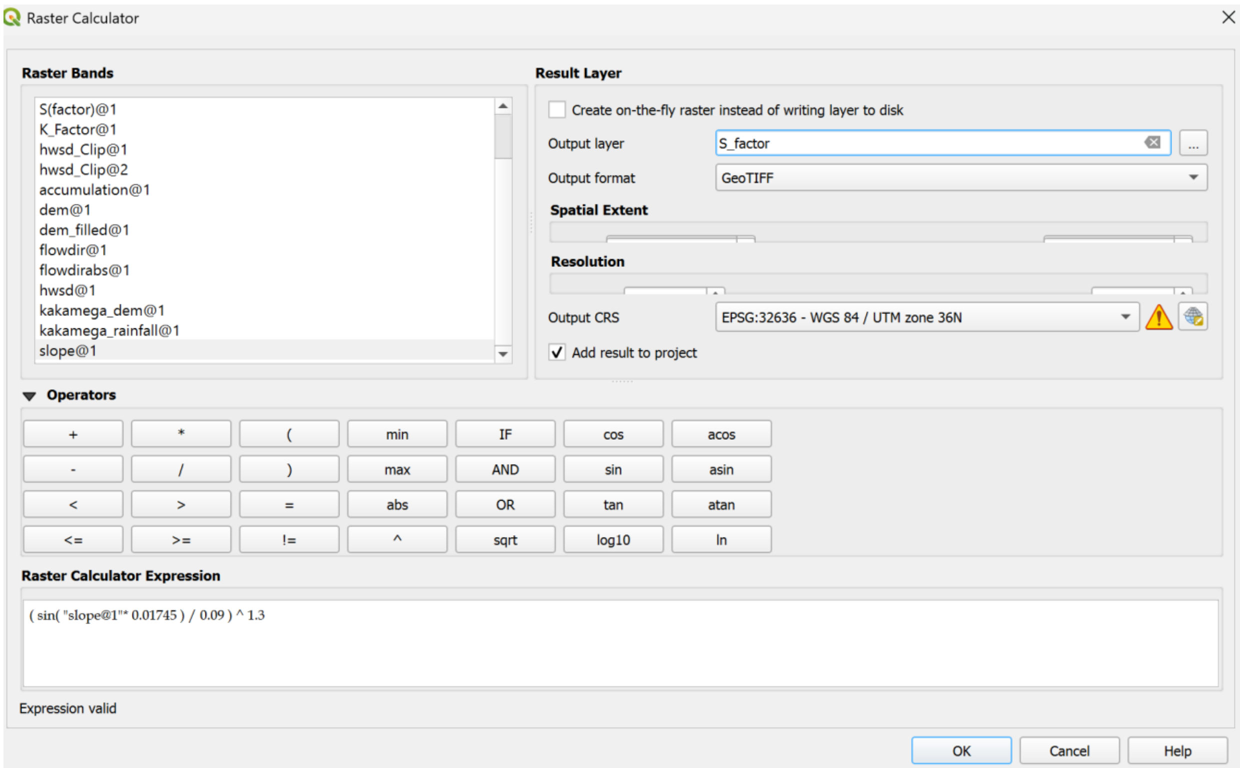
Step 4: Compute S Factor

Formula:

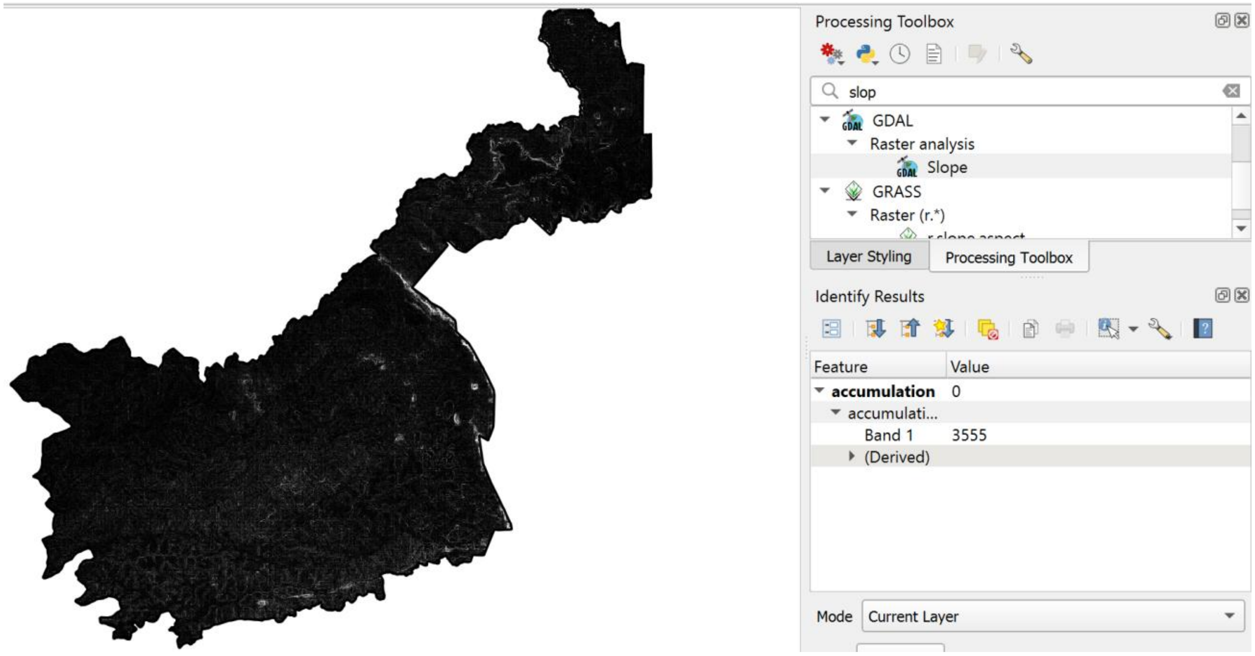
$S = \left[\frac{\sin ß * 0.01745}{0.09}\right]^n$ where, ß is slope angle in percentage, n ranges from 1.0-1.3.

QGIS Raster Calculator expression:

(sin("slope_percent@1" * 0.01745) / 0.09) ^ 1.3



Save as S_factor.tif okay the S_factor will be added to map



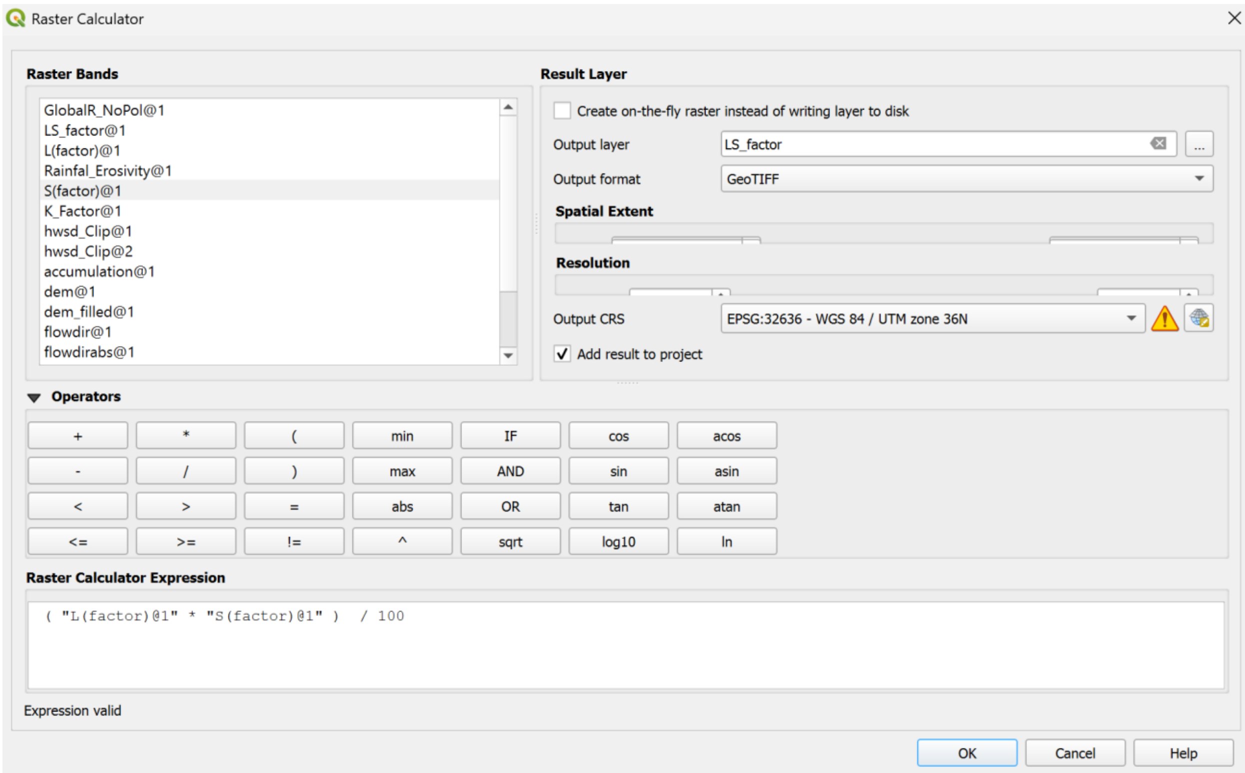
Step 5: Compute LS Factor

Formula:

$$LS = \frac{L \cdot S}{100}$$

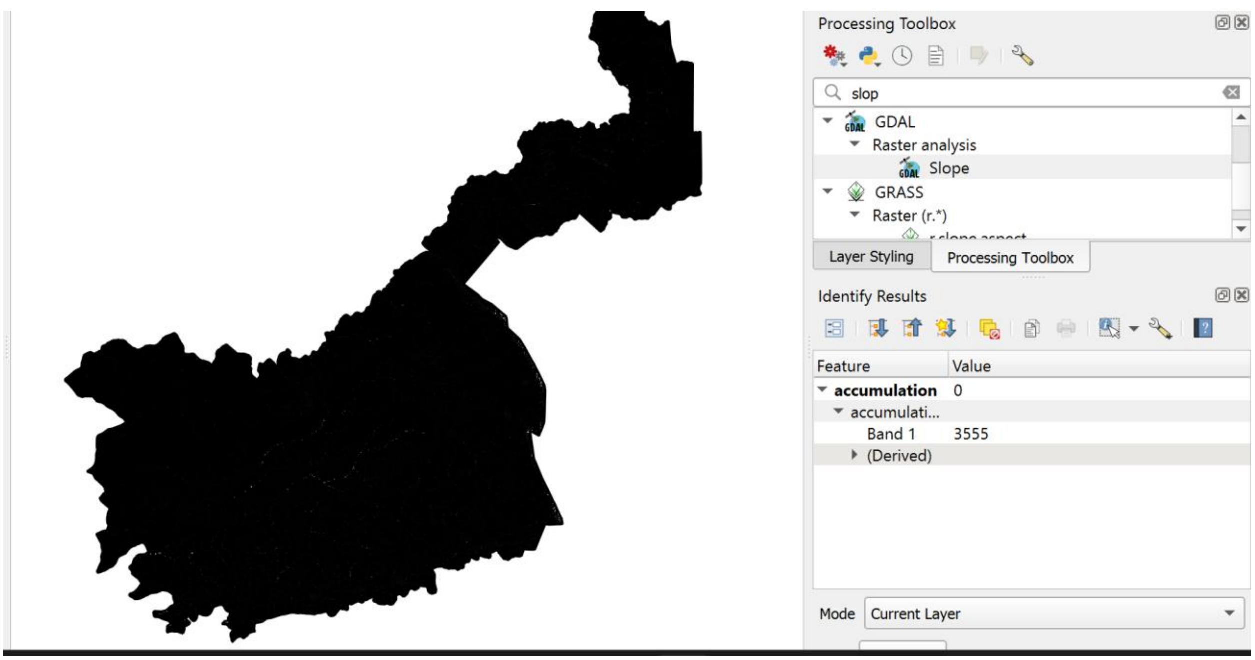
Raster Calculator expression:

$$(\text{L\_factor@1} * \text{S\_factor@1})/100$$



Save as LS_factor.tif

Results will be added automatically



Final Map Preparation

$$Go\ to\ Project\ \rightarrow\ New\ Print\ Layout$$

Insert:

✓ Title

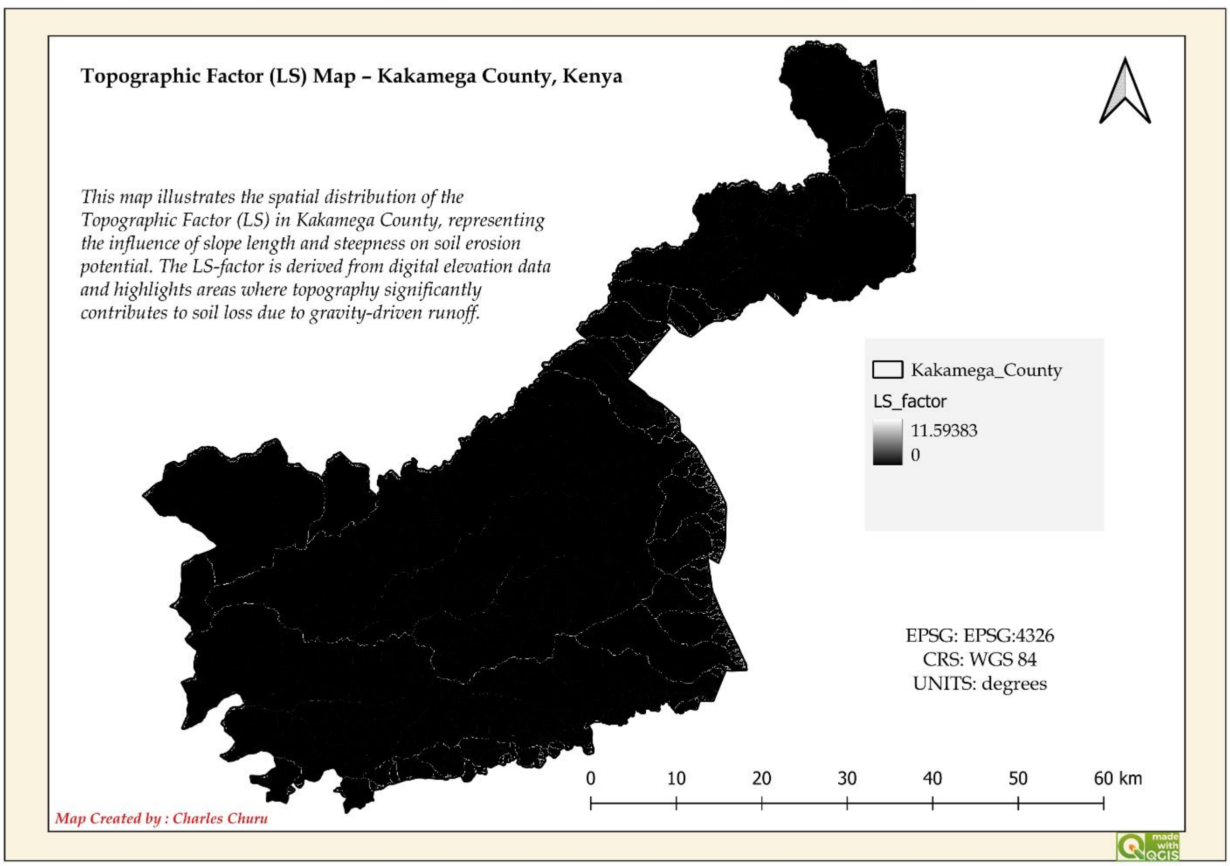
✓ Legend

✓ Scale bar

✓ North arrow

✓ Labels (use on a case-by-case basis)

Export the map as PDF, JPEG, and PNG Final Output



You now have ready a high-resolution map of the Topographic Factor (LS) to be used in further USLE-based soil erosion modeling in QGIS