

PROFESSIONAL MASTER PROGRAM

Module: BASIC HYDROLOGY

By: Marcelo Villarroel, MSc


EXCERCISE

Calculation of Hydromorphological parameters for a Catchment

Abstract

Hydrological models applications on catchments require the calculation or estimation of some hydromorphological parameters. This is usually made trough manual digitizing on hardcopy cartographic maps. An alternative way to obtain these parameters is to use some GIS procedures (ILWIS 3.x this case). This exercise shows the traditional method for some parameters determination, but within a GIS environment.

Starting

- 
- Open ILWIS
 - Using the Navigator Tab, move to the exercise data folder

Introduction

The exercise works on La Llave catchment, located on the south slope of the Tunari Mountain in Cochabamba. This catchment is about 4 [Km] distant North-West from Vinto Village.

ILWIS is used to calculate the following parameters:

- **Catchment Area**
- **Channel length**
- **Average channel slope**
- **Average slope steepness**
- **Hypsometric Curve**

Channel length is the distance along the main channel, measured from the channel outlet to the farthest point inside the catchment.

Average channel slope, is calculated as:

$$acs = \Delta h / L$$

Where Δh = Height difference between catchment outlet and the farthest point along the main channel.
 L = Main channel length

Average slope steepness, is calculated as:

$$S_m = \frac{1}{DA} * \sum (S_i * DA_i)$$

where S_m = average slope steepness
 DA = total drainage area

The catchment has to be reclassified in several subarea elevation ranges. In this case, ranges every 200 [m] are good enough because of the height differences in the study area.

S_i = average slope for every (reclassified) elevation range.
 DA_i = drainage area of every (reclassified) elevation range.

The exercise aim is to extract these parameters by means of the combined use of GIS maps and tables, using ILWIS. Some of the GIS procedures are quite simple, while others make the most of table and column operations.

Input data visualization

Vector data as input maps are:

- LIMITE** Segment map of the catchment boundary, digitized from cartographic maps.
- CURVAS** Segment map containing contours for the catchment area. They are every 25 [m], digitized from cartographic maps.
- DRENAJE** Segment map of the drainage net, digitized from cartographic maps.

Note: Check domain types of the input maps.
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Catchment area calculation



- Polygonize the segment map **LIMITE**. Uncheck the Auto Correction and Label Points options. Select Unique Identifier option. The new polygon map is also called **LIMITE**. New polygon map has the Pol 1 attribute.
- Get the new polygon map Histogram. The area value corresponds to the catchment area, in [m²]. This value should be 31,466,896.00 [m²].

Channel Length calculation

Channel length calculation is performed using Distance function in ILWIS. Two raster maps are required:

A Source Map, which contains one pixel, the catchment outlet in this case, being the source point for distance measuring along the drainage map. The drainage map acts as the Weight Map. Check ILWIS Help about this function.



- Rasterize segment map **DRENAJE**. Use the same name for the new raster map. Define a new georeference that contains the same coordinate system as the original map.
- The georeference boundaries are:
Xmin 772,895 [m] Ymin 8,081,050 [m]
Xmax 779,350 [m] Ymax 8,090,620 [m]
- Use 10 [m] as pixel size.

In order to make the distance calculation along the raster map **DRENAJE**, this map has to have the weighting value 1.



- Reclassify **DRENAJE** raster map in a new value map, having value 1. Name the new map as **DRENAJE_VAL**. Assign (-1) to the undefined values.
- By screen digitizing over **DRENAJE_VAL**, create a raster map called **OUTLET** with a class domain also called outlet. This new map has only one pixel (the Source Map) located in the RowCol position (870, 547). Farthest distance along the drainage map will be measured using this single-pixel source map. Note this RowCol position for further use.

Now you can go to the raster operation Distance Calculation and use Source and Weighting maps already defined.



- Run Distance calculation operation. Name the new map as **DIST**, with 1 [m] precision.

Once the map is calculated, the Display Options window shows a maximum value. In this case, that value means the maximum distance measured along drainage map as from the catchment outlet. This value should be 11,796 [m].

In order to find the pixel located on the farthest position along the drainage channel, perform the next calculation in the command line of ILWIS main window.



- **max_dist:=dist=mapmax(DIST.mpr)** ↵
- Accept the default options.

This calculation creates a new map **max_dist**, 'bool' domain, where the farthest pixel has the 'True' attribute, and all of the rest has 'False' attribute.

Once you open **max_dist** map, zoom in the window to see the farthest pixel along the drainage network. This pixel is located at RowCol (54,298). Note this position for further use.

Average channel slope calculation

Two values are needed in order to calculate the Average channel slope: the catchment outlet elevation and the elevation of the farthest point along the drainage network.


So far, we only have the contours in a segment map called **curvas**. To obtain the elevation values in a raster format as to calculate slope values, we need to calculate a Digital Elevation Model, DEM.



- Perform the Contour Interpolation operation for **curvas** segment map.
- Name the resulting map as **dem**. Use previous georeference **drenaje** to preserve pixel size and boundaries.
- Use 1 [m] precision for the calculation.

Having DEM in a raster format, the elevation value for a given pixel position is feasible. One straight way is simply looking by zooming in a view map window overlaying the **drenaje** segment map on the **dem**, and locating the elevation for the pixels at the catchment outlet and the farthest point over the drainage net. With a hand calculation we can finally get the desired slope value.

If we do not want to make hand calculations, and like to use some automated operations within ILWIS instead, we can extract values using the RASVALUE function. This way, we calculate the average channel slope with a single pocket calculator line:




- In the ILWIS command line, type:
$$? (rasvalue(dem,54,298)-rasvalue(dem,870,547))/mapmax(dist) ↵$$
- This expression calculates the elevation difference between catchment outlet and the farthest point in the drainage net. The difference is divided by the distance to that extreme point.
- The average channel slope has to be 0.11
- Check related functions and syntax in the ILWIS Help.

Break the dependency for all the maps already calculated. Type **breakdep *.*** in the ILWIS command line.

Average slope steepness calculation

As described in the Introduction section, we need to reclassify the elevation map in 200 [m] elevation ranges.



- Calculate the slope map for the study area from **dem**. Name the resulting map as **pend**. Use a precision of 0.1
- Open **dem** and note the maximum and minimum values from the Display Options window. They are: 3,325 [m] y 5,025 [m].

According to these values, we can reclassify the elevation in the next ranges:

Upperbound [m]	Name
3400	<3400
3600	3400-3600
3800	3600-3800
4000	3800-4000
4200	4000-4200
4400	4200-4400
4600	4400-4600
4800	4600-4800
5200	>4800

pend map extends over the study area boundary. So, we have to cut that map to fit the slope area within the **limite** map.



- Rasterize polygon map **limite** using the same name for the output map. Georeference has to be 'drenaje' as the used by **dem** map.
- Cut **pend** map with **limite**. Name the resulting map as **pend_cut**:

```
pend_cut=iff(isundef(limite),?,pend) ↵
```



- Same way, cut **dem** map to a new **dem_cut**.
- Reclassify **dem_cut** map with a 'class group' domain according previous elevations ranges list. New map is **dem_200**. New domain has also the same name 'dem_200'.

Now is possible to obtain slope values for every elevation range, as this is required by the average slope steepness expression described in the introduction section.



- Use the Cross operation using **dem_200** map with **pend_cut** map. Also, create a cross table named 'cross'.

As from this table, we can calculate the average slope values for each elevation range area, and also the total average slope steepness for the study area.

For that final purpose, we need to create another table having the aggregated values for each elevation range.



- Create a new table 'sm', with domain 'dem_200'.
- Use 'Join' column option to insert the 'pend' column from 'cross' table. You have to use 'Aggregate' option while using 'Average' function to get the average slope values grouped by elevation ranges 'dem_200'. These values have to be weighted by the number of pixels for each elevation range. By this weighting type, the calculated average slope value is more accurate. The new column name can named as 'si', according the introduction section.
- Use a precision of 2 digits for the new calculated values of 'si', and accept the default values for the remaining column options.
- Next, using the 'Join' option insert each area value of the elevation ranges from 'cross' table.
- In a new column, calculate the product of the slope and the area, as:

product:=si*Area ↵

- Within the table, calculate the final average slope steepness:

? sum(product)/sum(Area) ↵

- That value should be 0.5, or 50%.

Hypsometric curve calculation

Hypsometric curve can be useful to find out some water storage and water yield characteristics as to try to relate catchments with similar hydromorphological characteristics

Formerly, it was used to do this by measures on topographic hard copy maps using a planimeter or simply by counting area units within the grid lines.

Maps and tables created up to here have all the data required to calculate the hypsometric curve, in a more precise manner.

Hypsometric curve is a representation of accumulated catchment area vs. Topographic elevation.



- In the 'sm' table calculate a new column that accumulates each elevation range area. Use Cumulative option from Columns menu. Name the column as 'area_acum'.
- Calculate a new column 'porc_area_acum' with the next expression:
$$\text{porc_area_acum} := \text{area_acum} / \text{sum}(\text{Area}) * 100$$
- Create another column containing average values for the elevation ranges 3300,3500,3700,3900,4100,4300,4500,4700 and 4900. Name this column as 'value_avg'.
- Plot the hypsometric curve from the table, with 'porc_area_acum' column in X axis, and 'value_avg' for Y axis.

Hypsometric curve will show as follows:

