

Soil erosion modelling

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Summary

Soil erosion modelling, described here, is based on the methods explained by Morgan (Morgan, 1986; Morgan and Finney, 1984). The model tries to encompass some of the recent advances in understanding of erosion processes. The model separates the soil erosion process into a water phase and a sediment phase. It considers soil erosion to result from the detachment of soil particles by raindrop impact and the transport of those particles by overland flow.

Getting started

The data for this case study are stored on the ILWIS 2.1 CD-ROM in the directory d:\appguide\chap24. If you have already installed the data on your hard-disk, you should start up ILWIS and change to the subdirectory where the data files for this chapter are stored, c:\ilwis21\data\appguide\chap24. If you did not install the data for this case study yet, please run the ILWIS installation program (see ILWIS Installation Guide).



- Double-click the ILWIS program icon in the ILWIS program group.
- Change the working drive and the working directory until you are in the directory c:\ilwis21\data\appguide\chap24.

Now you are ready to start the exercises of this case study.

The study area

The sub watershed of Sitla Rao is selected to run the erosion model. It is located in the western part of Doon valley, Dehradun District, Utter Pradesh in India. The subwatershed belongs to the Asan river system which is a tributary of Yamuna river. The area lies approximately between 77°45'33" and 77°57'46" East longitudes and 30°24'39" and 30°29'05" North latitudes, covering approximately 55 km². The altitude varies from 440 to 2300 m asl. The climate is characterised by hot summers and cold winters. The rainfall varies from 1600 to 2200 mm, depending on elevations, most of which falls in the rainy season (June-August). The area is characterised by having East-West oriented mountain range belonging to the Middle Mountains of Indian Himalayas, a chain of erosional hills, extensive piedmont and river valleys. Land cover/land use is characterised by forest, grazing land and agriculture. In the lower elevation forest type is dominated by sal trees (*Shorea robusta*) while in the higher elevations the forest is of mixed type. Main crops are rice, wheat, maize and sugarcane.

24.1 Map digitizing

The material used in this exercise comprises two maps (Map1 and Map2) containing village locations (points), roads (segments) and the watershed area (polygon). These 2 maps, available in two PostScript files (Map1.eps and Map2.eps), need to be printed in a A4 size landscape paper, before digitizing. In ILWIS, these data are entered and stored as separate digital files as point file, segment file and polygon files.



- Create a Coordinate system file by selecting **Create** under **File** in the ILWIS main menu. A dialog box will open.
- Enter a file name and enter the minimum and the maximum values for the X and the Y coordinates as follows:
Minimum X = 764090
Maximum X = 784720
Minimum Y = 3364830
Maximum Y = 3376870
- Create a georeference file by selecting **Create** under **File** in the ILWIS main menu. Call it Sitlarao.

24.1.1 Creating a segment map

In the next exercise you will create a segment map comprising the lines of the road network in the area. Although not always necessary, we will assume that a network analysis will be carried out later. The individual segments will therefore be connected to each other.



- Select File, Create, Create Segment Map from the main menu.

The Create Segment Map dialog box is opened. Note that it is possible to either create a Coordinate System and a Domain or to select one that already exists. In the previous exercise, you already created a coordinate system.



- Type a name (Road) for the segment map. Select the coordinate system you have created.
- Click the Create Domain icon in the list box Domain.

The Create Domain Window is now opened. In this box the name and the type of the domain for the map can be defined



- Type Road in the text box Domain Name. Accept Class as the domain type. Click the OK button of this box.
- The Domain window is opened.
- Close the Domain window.
- Click OK in the Create segment map window.
- Click OK in the Display option window and accept the defaults.



Why is the domain type class selected and not, for example, the domain type identifier or value?

The Segment Editor map window and Add Segments command box are now opened. The segment editor works in Select Mode, Move Points Mode, Insert Mode and Cut.

To start digitizing main roads, a new class must be added to the domain which can be done as follows



- Click the menu command Edit and select Insert Code.

- Select **New** from the list in the **Edit** box **Value**. Type **Main road** in the **Add Item** box **name**. Type a short code, for example, **Mr** in the text box **Code**; select a suitable colour (red). Click **OK**.
- Click the **OK** button in the **Edit** box.

You are now ready to start digitizing the individual line segments.

24.1.2 Creating a point map

In this exercise, you will create a point map showing the locations of villages.



- Place the map on the digitizer and reference it if you have not done so.
- Select **File, Create Point Map** from the main menu.
- Type **Villages** in the **Map Name** text-box of the **Create Point Map** dialog box and select the appropriate **Coordinate System**.
- Click the **Create Domain** icon in the domain text box. Type **Villages** in the text-box of **Domain Name**. Select **Class** for the domain type. Click **OK** and close the **Domain** window.
- Click the **OK** button in the **Create Point Map** dialog box.
- The **Display Options - Points** dialog box is now opened. Accept the defaults by clicking on the **OK** button.
- Click the **Exit** button in the button bar to save your work and leave the editor window.

24.1.3 Creating a polygon map

In this exercise, you will create a map with information on the various areas (polygons) on the map.



- Reference the watershed boundary map to the digitizer.
- Click on the menu **File**. Select **Create** and **Create Segment Map**. The **Create Segment Map** dialog box is opened.
- Type **Boundary** to digitize the watershed boundary and the river

boundary which will be common for all the maps. Select an appropriate coordinate system.

- Create a Domain with the domain type Class and click OK.
- Close the Domain window and click OK from the Create Polygon Map dialog box. The Display Options - PolygonMap is opened.
- Click OK.



- Digitize the boundary lines. Make sure to snap all segments.
- Check segments.
- Polygonize the segments and create a polygon map Boundary.
- Check the polygons in the polygon editor.

! You have now digitized the polygons of the whole watershed boundary and the polygon of river. The segments of these polygons are common to all the maps (soil map, land use map, etc.) and it is thus not necessary to digitize these boundaries again if you are digitizing the polygons of soil or land use maps. It is thus suggested to copy the polygon map containing the watershed boundary and the river boundaries into a soil and a land use polygon map. If you want to digitize soil polygons, the polygon soil map (copied from boundary map) can be opened and edited. Similarly the polygon land use map can be opened and edited.

24.2 Rasterization

Raster maps can be generated from vector data (segment, polygon or point map). For the output raster map, an existing georeference has to be selected or a new one can be created. The georeference determines the pixel size and the number of lines and columns of the output map. It uses a coordinate system. A georeference file stores the relation between lines and columns of a raster map (row,col) and coordinates (X,Y).



- Select Rasterize, Polygons to raster from the operations list. A dialog box will be opened.
- Enter the input polygon map name, the output raster map name and the geoReference file you have created (Sitlara0).

- Click OK.

Display the newly created raster map. Check that the pixel size is 30 m.

24.3 Attribute data and map generation

Upon completion of this exercise you should be able to generate attribute maps from attribute table. It should be also possible to carry out table calculation and generate maps.

24.3.1 Working with an attribute table

In order to generate attribute maps you should have a raster map. A table should be also available which is linked to the map. An attribute table can be created and edited by making use of column operations.

A soil attribute table is provided to you in which new data have to be entered. Once the attribute data are entered, table calculation can be performed.



- Display the `Soil` table by double clicking on the soil table icon. The table window will be opened. You will notice that the first column shows the soil map units, the second column shows the number of polygons. Similarly area and perimeter are given in meters. Some soil attributes are also given.
- To add the attribute `pH` of surface soil, select `Add Column` from the `Columns` in the `Table` window. Enter the column name (`pH`) and select domain type `Value`. Define the range for the value which will be from 1 to 14 for `pH`. Enter 0.1 for the precision. The column `pH` will appear in the table.

Enter the `pH` values per soil mapping unit.
- Update the table `Soil` by creating columns and entering the values for stoniness, bulk density (`DB`) of top soil, moisture storage (`MS`) capacity, etc. Once the table is updated, close the table window.

24.3.2 Linking an attribute table to a map and generating attribute maps

Once you have created and entered all the attributes in a table it can be linked to a raster map and attribute maps can be created.



- Select the `Soil` map from the map list and click on the right mouse button. Select **Properties** from the list. The raster map properties window will be opened.
- If the map is **Read Only**, cross out the small box and click **OK**. If a small box appear with an option for attribute table click on the small box and select the `Soil` table. Click **OK**.

The table `Soil` is linked to the map `Soil`. The attribute map can be now easily created. Suppose you want to create a map which shows only the pH of the top soil follow the steps as shown below:



- Select the `Soil` map from the list and double click it. A display dialog window will be opened.
- Click on the small box in front of **Attribute** and select **pH** from the list. Click **OK**.

The map showing pH of the top soil is displayed. Check with the left mouse button to see map units having different pH values.

The above example shows you how to display an attribute map but an attribute map showing only pH can be also created as follows:



- Type following command in the command line of ILWIS main menu:
`pH=Soil.Soil.pH`
 press **Enter** and click **OK**. A dependent raster map is created.
- Select the newly created `pH` map and display it.

Above example shows you how to edit and update a soil table, how to link it to the raster map `soil` and how to generate attribute maps. Update similarly the `Landuse` table.



- **Create** and enter the values for crop cover management factor (C), percentage rainfall contributing to interception (A), ratio of actual to potential evapotranspiration (`Et_Eo`), and rooting depth (`Rd`).
- Close the table and link it to the map `Landuse`.

Table 24.1: Soil attribute table, Sitla Rao Watershed, Doon valley, Dehradun, India

Soil map unit	Number of polygons	Area (m ²)	Perimeter (m)	Drainage class	Surface texture	Soil depth class
H11	10	2449561	21471.11	Well drain	Gravelly loam	Shallow
H12	3	2829484	17464.67	Well drain	Loam	Deep
H13	1	246370.4	2083.426	Well drain	Gravelly loam	Deep
H21	6	2977356	23721.54	Well drain	Loam	Deep
M1	5	1070312	14000.2	Exc. drain	Gravelly sandy loam	Shallow
M2	1	5713150	25924.82	Exc. drain	Gravelly sandy loam	Shallow
M3	3	535729.9	7638.436	Exc. drain	Gravelly sandy loam	Shallow
P11	4	2198135	17447.36	Well drain	Gravelly loam	Deep
P12	6	6610258	39331.77	Well drain	Loam	V. deep
P21	6	4503889	36091.89	Well drain	Gravelly sandy loam	V. deep
P22	6	5277803	37355.96	Well drain	Sandy loam	Deep
river	1	6125919	62227.91	?	?	?
V1	2	9911202	37076.93	Well drain	Loam	Deep
v2	9	4213459	44254.8	Exc. drain	Loamy sand	Deep
V3	4	652134	12927.86	Well drain	Sandy loam	Deep

Table 24.1: Soil attribute table, Sitla Rao Watershed, Doon valley, Dehradun, India (cont.)

Soil map unit	pH (top soil)	Stoniness %	ls fact	Bulk density (g/cm ³)	Moisture storage capacity	k fact
H11	6.6	40	4	1.3	0.18	0.45
H12	6.5	20	4.3	1.3	0.18	0.5
H13	7.2	50	4.5	1.4	0.2	0.4
H21	6.8	20	4	1.3	0.2	0.48
M1	7.5	90	6	1.2	0.26	0.45
M2	7	90	6.5	1.2	0.25	0.43
M3	6.8	90	5.5	1.2	0.25	0.4
P11	6.8	35	3.5	1.4	0.18	0.35
P12	6.6	15	3.2	1.3	0.2	0.4
P21	7.2	10	2.5	1.3	0.2	0.36
P22	7.4	5	2.6	1.2	0.28	0.38
river	?	?	?	?	?	?
V1	6.8	0	1.2	1.3	0.2	0.41
v2	7	5	1	1.4	0.1	0.3
V3	6.8	40	1.5	1.2	0.15	0.35

Table 24.2: Land use attribute table, Sitla Rao Watershed, Doon valley, Dehradun, India

Land use	Nr. of polygons	Area (m ²)	Perimeter (m)	C	P	A %	Et/Eo	RD
Baren land	1	798323.8	5353.084	1	1	0	0.05	0.01
Degraded sal forest	1	509458.6	3285.896	0.03	0.8	20	0.8	0.1
Dense mixed forest	6	1018976	11598.38	0.01	0.8	20	0.9	0.1
Dense sal forest	9	10187900	61882.41	0.004	0.8	20	0.9	0.1
High intensity cultivation	2	12390900	40016.91	0.3	0.6	43	0.85	0.07
Low intensity cultivation	8	14804600	74801.55	0.5	0.7	30	0.6	0.05
Open mixed forest	1	6384172	21197.06	0.05	0.8	15	0.8	0.1
Open sal forest	8	3008305	21895.18	0.006	0.8	15	0.8	0.1
Orchard	2	55880	1091.753	0.007	0.8	20	0.9	0.1
River	1	6135076	62286.28	0	0	?	?	?

24.4 Generation of DTM and its applications

Upon completion of this exercise you should be able to generate a digital terrain model (DTM), a slope map and various applications related to DTM, based on the digitized contour lines. It is also possible to generate slope exposition from a digital terrain model.

Terrain slope plays quite an important role not only on its influence in soil formation and development but also on degradation of land, caused by soil erosion. Having other erosion parameters being constant, we can assume that higher the slope gradient larger is the risk of soil erosion. Thus it is very important to compute slope gradient. Terrain slope gradient is one of the most important parameters in soil erosion modelling in GIS. It is also essential in many land use planning exercises.

24.4.1 Digitizing the contours map

If you want to digitize a contour map you should begin by georeferencing the map on the digitizer table by using the same coordinate system and georeferencing done for all the maps related to the case study to ensure the same map and the pixel size. Detail about digitizing can be referred to the digitizing exercise for this case study (segment digitizing, with domain type *Value*). For this exercise, however, a segment file called *Contour* is available.

24.4.2 Interpolating the contours

Once you have digitized contour lines, stored as a segment file, the next step is interpolation of the segments by which a raster map (digital elevation map) is

created with certain pixel size. The size of the pixel is defined in the georeference file



- Select **Interpolation, Contour Interpolation** from **Operations** in the main menu. A dialog box is opened.
- Enter input contour segment map name, output raster map name and georeference file name. Keep the domain type as **Value**.
- The value range and the precision required can be defined, depending on your data. Click **OK**.

Display the output map and check the pixel values which indicate the terrain height. If interpolation result is satisfactory break the dependency of the map

24.4.3 Computation of height difference maps

Once you have digital elevation map you can compute slope gradient. For this purpose height differences need to be computed in X and Y directions since overall slope gradient is a function of height differences over horizontal distances in both X and Y directions.



- Select **Image Processing, Filter** from the **Operation** list in the main ILWIS menu. A **Filtering** dialog window will be opened.
- Select the input raster map (height map), filter type as **Linear** and the filter **dfdx**.
- Give a name (dx) for the output raster map.
- Accept the default values and click **OK**.

The filtering operation with the filter **dfdx** will compute height differences in west-east direction where the positive value in the resulting map indicates the increase of height, the negative value indicates the decrease of height and zero indicates no difference. Perform filtering in north-south direction and store the result in a map called **dy**.

24.4.4 Generation of a slope map

Slope can be generated either in percentage values or in degrees or radians. In some erosion models slope percentage values are required as input data (Universal Soil Loss Equation) while some models demand slope degrees as input values.



- In the command line of the main ILWIS menu, enter the following formula:

```
Slope_p=( (hyp(dx,dy) ) / 30 ) * 100 ) ↵
```

- This will give a slope map in percentage. Note that the value 30 in the formula refers to the pixel size.
- To compute slope in degrees following formula needs to be entered:

```
Slope_d=raddeg( atan( Slope_p / 100 ) ) ↵
```

You have noticed that slope in degrees is simply conversion of slope percentage values into degrees. In this case you have to compute first slope in percentage.

-
- ! Can you think of an equation by which you can compute slope in degrees directly from the dx and dy maps?. Write down the formula and convert it into an ILWIS map calculation command and generate the slope map in degrees.
-

If you display the map you will also notice that the whole screen is covered by the slope value whereas the watershed boundary is smaller.



- Mask using MapCalc the areas belonging to watershed and store the final slope map in a file called Slope.

(Hint: use the map Soil to mask the area).

24.4.5 Generation of a rainfall map based on DTM

In an area with known variations of annual rainfall, caused by elevation differences DTM can be used to generate rainfall map. Assuming that no rain shadow area exists in the watershed, a regression analysis of annual rainfalls with different elevations can be performed and if the correlation coefficient is found to be high enough an equation can be derived to compute rainfall map from elevation data.

In the Sitla Rao watershed good correlation was found between annual rainfall and elevation differences (r value of 0.743). Thus an equation can be derived to compute a rainfall map as follows:

$$\text{Rain} = 1384.2 + 0.329 * \text{Elevation} \quad [24.1]$$



- Translate the equation into the map calculation command and generate the map `Rain`.
- Mask the rainfall map so that only the watershed area is displayed.

24.4.6 Classification of the rainfall map

If you display the rain map you will notice that every pixel will have certain value indicating the amount of rainfall. It will be ideal to classify or group the rainfall amounts into certain classes which can be done by creating a domain with type `Class`.



- Select **Create, Create Domain** from the **File** in the main menu. A dialog box is opened.
- Enter a domain name (`Rain`). Select **Class** as type and click on **Group**. A domain editing dialog box will be opened.
- Select **Edit, Add item**. Enter upper bound for the rainfall value (1600) and enter 1600 mm as name and click **OK**.
- Add items for other rainfall values for 1700, 1800, 1900, 2000, 2100 and 2200 as explained above. Close the domain editor window when all the values are added with proper class names.


The class domain is created. Now you can classify the map `Rainfall` into a rainfall class map.



- Classify the map and generate a rainfall class map using the command line in the main ILWIS menu:

```
Rainclas=clfy(Rain,Rain)↵
```


If you display the map `Rainclas` you will notice that it is a class map and not a value map. To be able to use the rainfall data in erosion modelling a value map is required. For this purpose an attribute table needs to be created for the map `Rainclas`. In the attribute table a column needs to be created with rainfall values. It can be created as follows:



- Select **File, Create, Create Table** from the main menu.
- Enter a name for the table (`Rainfall`) and select the domain `Rain` from the list. The table will be opened.
- Add a column called `Rainfall`, with domain `Value` and precision 1. The column will be shown.
- Enter the corresponding values of rainfall for different rainfall classes.
- Create a rainfall value map by entering following command:
`Rainfall=Rainclas.Rainfall.Rainfall`

where `rainfall` is the output map, the second `rainfall` in the command is the table and the third `rainfall` is the column in the table.

Based on the climatic data it seems that the number of average rainy days in a year appear to be 75 days in the lower elevations while the average rainy days are 95 in Mussoorie.



- Generate a map which shows annual rainy days as a function of elevation as follows:

<u>Elevation</u>	<u>Number of rainy days</u>
up to 700m elevation	75
from 701-1200m	85
more than 1200m	95

24.5 Generation of rainfall energy and the rate of soil detachment by raindrop impact

Upon completion of this exercise you should be able to generate a map indicating the rate of soil detachment by raindrop impact. You should be also able to compute kinetic energy of rainfall which is dependent on annual rain and rainfall intensity.

24.5.1 Generation of rainfall energy map

Kinetic energy of rainfall (E) in J/m^2 is dependent on the amount of annual rain (R) and the rainfall intensity (I). It can be derived by the following equation:

$$E = R * (11.9 + 8.7 * \log(10I)) \quad [24.2]$$

For computing the rainfall energy, the rainfall map generated earlier in the exercise can be used. For rainfall intensity take the value of 25 mm/hr for Sitla Rao watershed and generate the rainfall energy map in map calculation by typing the following command in the command line:

$$E = R * (11.9 + 8.7 * \log(25)) \quad [24.3]$$

24.5.2 Estimation of the rate of soil detachment

Soil detachment is a function of soil detachability index defined as the weight of soil detached from the soil mass per unit of rainfall energy.

It can be computed by using following equation:

$$F = K * (E * e^{(-0.05 * A)}) * 1.0 * 10^{-3} \quad [24.4]$$

where F is the rate of soil detachment in kg/m^2 , K is the soil detachment index and A is the percentage rainfall contributing to permanent interception.



- Generate attribute maps of soil detachability index (hint: Soil table) and percentage rainfall contributing to permanent interception (hint: Landuse table).
- Translate the above equation into ILWIS MapCalc command and generate the soil detachment rate map.
- Display the map, and if there are no unknown pixels in the map, release the disk space and break the dependency.

24.6 Generation of overland flow map

The objective of this exercise is to generate a map indicating the volume of overland flow.

Overland flow (Q) is dependent on moisture storage capacity (MS) of surface soil which can be derived from field capacity. It is also dependent on the soil bulk density (BD). Moreover it is dependent on rooting depth (RD) of various cover types, the ratio of actual to potential evapotranspiration (E_t/E_o), the amount of annual rain (R) and the number of rainy days (R_n). It can be explained by following equations:

$$Q = R * \exp(-R_c / R_o) \quad [24.5]$$

where

$$R_c = 1000 * MS * BD * RD * (E_t / E_o) * 0.5 \quad [24.6]$$

$$R_o = R / R_n \quad [24.7]$$

24.6.1 Calculation using MapCalc



- As shown by the above equations 6 maps are required. From the attribute tables linked to the corresponding maps (*Soil*, *Landuse*, *Rainfall* and map showing the number of rainy days) generate the required attribute maps.
- Compute formulas (24.6) and (24.7) in MapCalc.
- Compute the volume of overland flow by translating the equation (24.5) into ILWIS command and store the result in a file. If necessary, break dependency of the file.

24.6.2 Calculation by means of map crossing

The computation of overland flow (above) makes use of map calculations. Other option is by means of map crossing of the maps *Soil* and *Landuse* by which a cross table and a cross map can be generated. In this way it is not necessary to generate all the attribute maps. Most of the calculations can be performed in the table itself.



- Select Raster Operations, Cross from the operations list. Enter

first and the second maps to cross (Soil and Landuse). Enter a name for the output table Soilland. Give same name for the output map. Click Show and OK.

The cross table is opened. In this table the necessary attributes from the Soil and the Landuse tables should be joined so that table calculations can be performed.

Note: Before joining the columns from other tables it is strongly advised to break the dependency of the newly created cross table and the cross map



- Open the cross table Soilland.
- Select Columns, Join from the menu.
- Select table Soil and column Ms. Accept the default values for key column and the output column name.
- Click OK twice.

The column Ms will be added to the cross table. It is also advisable to break the dependency of the column by changing the column properties which can be done by double clicking the column Ms.



- Join other relevant columns (Bd, Rd, Et_Eo) from the tables Soil and Landuse and break the dependencies.
- Compute the product of Ms, Bd, Rd and the square root of Et_Eo, and multiply by 1000. Store the result in a column and name it RC.
- Generate an attribute map (RC2) based on the column RC in the cross table. Click OK twice.
- Compute overland flow volume and store in a map (Q2).



- Which map unit of land use has the highest possible volume of overland flow?
 - Which soil unit has the lowest volume of overland flow? Explain the reason.
-

24.7 Generation of transport capacity of overland flow

The objective of this exercise is to generate a map indicating the transport capacity of overland flow.

24.7.1 Estimating the transport capacity

Transport capacity of overland flow (G) is dependent on the volume of overland flow (Q), crop cover management factor (C) and the topographic slope factor (S). It can be calculated by using following equation:

$$G = C * Q^{2.0} * \sin(S * 10^{-3}) \quad [24.8]$$



- Generate crop cover management factor map from the attribute Landuse table.
- Write down in a piece of paper above equation into an ILWIS command line.

Note: Please keep in mind that the trigonometric function Sin in ILWIS assumes the value in radians instead of degrees. The slope value (S) should be thus converted into radians by adding an ILWIS command Degrad.

The command line to compute transport capacity of the overland flow can be rewritten as follows:

$$G = C * \text{sq}(Q) * \sin(\text{degrad}(S)) * 0.001 \quad [24.9]$$

Note: The unit of the result is in kg/m².

24.8 Estimation of soil erosion

Soil loss estimation is calculated from the transport capacity of overland flow (G) and the estimated rate of soil detachment (F). If the transport capacity is higher than the rate of soil detachment, the soil detachment value will be taken as the soil loss. Similarly, if the rate of soil detachment is higher than the transport capacity of overland flow, the value of the transport capacity will be considered for the soil loss.

24.8.1 Soil loss estimation

Since the lower value of the transport capacity of overland flow and the estimated rate of soil detachment is taken, use the minimum function MIN in ILWIS.



- Compute the soil loss. The command will be as follows:
$$\text{Soilloss} = \min(G, F) \downarrow$$
- Display the map `Soilloss` and check the results.
- As the unit of the values shown in the result is kg/m^2 , convert the data to make it into tons/ha. Store the soil loss map in tons/ha in a file (`Erosion`) with domain type `Value`, precision 1.

24.8.2 Soil loss estimation per land use class

It will be interesting to see soil erosion per land use class. For this purpose it is necessary to cross the maps `Landuse` and `Erosion` and aggregate the soil loss values per land use classes.



- Create a new map changing the precision of `Erosion` into 10 or 20 before the crossing.
- Cross the maps `Landuse` and `Erosion` and enter a name for cross table. It is not necessary to create a cross map.
- Display the cross table you have created. Once the cross table is opened, soil loss aggregation can be performed per mapping unit.
- Select `Columns, Aggregation` from the cross table menu list. A dialog box is opened. Select the column `Erosion` and the function `Average`. Select `Group by Landuse`. Select output table `Landuse` and enter an output column name (`Avg_soilloss`).
- Open the table `Landuse` and break the dependency of the column `Avg_soilloss`.
- Compute the standard deviation of the soil loss per land use class and add the column (`Std_soilloss`) in table `Landuse`. Also break its dependency.

-
- ! - Which land use type has the highest estimation of soil loss?
 - Which land use type has the lowest estimation of soil loss?
 - What do you think is the main reason for having higher soil loss estimation in low intensity agriculture as compared to high intensity agriculture?
 - If soil loss of 20 tons/ha is taken as the tolerable amount of soil losses considering the fact that many areas lie in the hilly to mountainous terrain, which land use/land cover types are still at higher risk?
-

24.8.3 Soil loss estimation per soil map unit

The same procedure can be applied to the soil map to calculate the soil loss estimation per map unit.



- Update the table `Soil` by computing and adding average soil loss and the corresponding standard deviations.
 - Break the dependencies of the columns in table `Soil`.
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- ! - Which soil map unit has the lowest and which map unit has the highest soil loss estimation?
 - Which units have soil loss estimation of more than 20 tons/ha?
 - What is the main reason for having higher soil loss?
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24.9 Display of maps and adding annotations

Upon completion of this exercise you should be able to display vector data such as drainage lines, river, road network, villages etc. on a raster or a polygon map, and add legend and annotations. The annotations make the map easier to read.



- Display a raster or a polygon map. It may be even better to use a polygon map to get a better result when printing it. Display the polygon map `River`.
- Display the drainage lines and the road infrastructure, the village locations and the village names on the map.
- Display the legend (`Layers`, `Add Annotation`, `Legend`).

- Add titles and subtitles, scale bar, north arrow sign, grid lines, box, etc.

If you find that the map view needs to be extended especially after you have added grid coordinates it can be done as follows:



- Select Options, Extend Window from the Annotation Editor window.
- Select Extend by Percentage.
- Extend the map view, for an example, by 10 percent in all the directions.

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