CHAPTER 24

Soil erosion modelling

By:
Dhruba P. Shrestha
Soil Science Division,
International Institute for Aerospace Survey and Earth Sciences (ITC),
P.O. Box 6, 7500 AA Enschede, The Netherlands.
Tel: +31 53 4874264, Fax: +31 53 4874379, e-mail: SHRESTHA@ITC.NL

Summary

Soil erosion modelling, described here, is based on the methods explained by Morgan (1986); Morgan, 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 3.0 CD-ROM in the directory D:\Data\ILWIS 2.1 Applications Guide Data\chap24 (where D is the drive letter of the CD-ROM drive). 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. If you did not copy the data for this case study from the CD-ROM to your system yet, please do this before continuing. It is also possible to download the data from the ILWIS Internet site at http://www.itc.nl/ilwis/.

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- Double-click the ILWIS icon on the desktop.
- Use the Navigator to go to the directory where the data files for this chapter are stored.

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 sub watershed 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 km^2. The altitude varies from 440 to 2300 m asl. The climate is characterized 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 characterized by having an East-West oriented mountain range belonging to the Middle Mountains of the Indian Himalayas, a chain of erosional hills, extensive piedmont and river valleys. Land cover/land use is characterized 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 section comprises two maps. Map1 contains villages and roads and Map2 (optional exercise) contains contour information. In ILWIS, these data are entered and stored as separate digital files; as point file (for village locations) and as segment files (for roads, contour lines).

Both maps are available in Adobe Acrobat PDF format (`Map1&2.pdf`) and need to be printed in landscape format on A4 paper before digitizing.

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- Create a coordinate system file by selecting Create, Coordinate System from the File menu of the Main window. The Create Coordinate System dialog box will open.
- Enter Coordinate System Name `Sitlarao` and select the option "`CoordSystem Projection`".
- 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
- Select the other parameters: for Projection select `UTM`, for Ellipsoid select `Everest (India 1956)` and for Datum select `Indian (India, Nepal)`. Make sure the Northern Hemisphere check box is selected and type `44` for UTM zone.
- Similarly, create a georeference file `Sitlarao`. The georeference

Type should be GeoRef Corners and the Coordinate System should be the one you have just created. For the Pixel size type 30 m. The X and the Y coordinates will be copied from the coordinate system file.

24.1.1 Creating a point map

In this exercise, you will create a point map showing the locations of villages. It is also possible to create a coordinate system and a domain or to select objects that already exist.

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- Select Create, Point Map from the File menu of the Main window.
- In the Create Point Map dialog box, type Villages in the Map Name text box and select the Coordinate System file you have created in the previous exercise.
- Click the Create Domain button next to the drop-down list box. Type Villages in the Domain Name text box, accept Class for the domain type and click OK. The Domain Class editor appears.
- Close the domain editor and click the OK button in the Create Point Map dialog box.

The Point editor is opened and the village locations can be digitized but in order to do so the printed map has first to be fixed on the digitizing table and the map should be referenced so that the system knows where you have put the map on the digitizing table.

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- Exit the Point editor for the moment.
- Place Map1 (the map with the village locations) on the digitizer and reference it if you have not done so. (Note: the digitizer should have been set up correctly beforehand).
- Village locations can now be digitized. Open and edit the point map you have created and digitize the villages. Also enter the village names.
- Exit the Point editor when all the villages are digitized and save your work.

24.1.2 Creating a segment map

In this 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.

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- Select Create, Segment Map from the File menu of the Main window.
- Type a name (Road) for the segment map. Select the coordinate system you have created.
- Click the Create Domain icon next to the drop-down list box. Type Road in the text box Domain Name, accept Class as the domain type and click OK. The Domain Class editor is opened.
- Close the domain editor and click OK in the Create Segment Map dialog box.

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

The Segment editor and Add Segments command box are now opened. The Segment editor works in Select Mode, Move Points Mode, Insert Mode and Split/Merge Mode. To start digitizing the main roads, a new class must be added to the domain which can be done as follows:

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- In the Segment editor, open the Edit menu and click Insert Code.
- Select Class Name <new> from the list in the Edit box.
- In the Add item to Domain dialog box, type Main road in the text box Name, type a short code, for example MR, in the text box Code, select a suitable Color (Red) and click OK.
- Click the OK button in the Edit dialog box.

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

24.1.3 Changing the properties of maps

For this case study a number of digital maps are already provided such as the segment maps of contour and drainage lines and the polygon maps of soil and landuse information. Please note that the coordinate system of the supplied maps is Unknown. In this exercise, you will change the properties of the maps and connect them to the coordinate system you have created.

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- In the Catalog, click segment map `Contour` with the right mouse button and select Properties from the context-sensitive menu. The Properties sheet will be displayed.
- Change the coordinate system from `Unknown` to the coordinate system you have created. Accept all other defaults and click OK.
- Similarly, change the coordinate system of other maps (`Drainage`, `Soil` and `Landuse`) from coordinate system `Unknown` to the coordinate system `Sitlarao`.

24.2 Rasterization

Raster maps can be generated from vector data (point, segment or polygon maps). 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).

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- In the Operation-tree, expand Rasterize and double-click the Polygon to Raster operation. The Rasterize Polygon Map dialog box will be opened.
- Enter the input Polygon Map (for example `Soil`), the Output Raster Map name and the GeoReference file you have created.
- You can display the rasterized map if you like by clicking the Show button (optional) or just define the dependent output map by clicking the Define button.

Check the properties of the rasterized map and verify 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 tables, carry out table calculations and generate maps.

24.3.1 Working with an attribute table

In order to generate attribute maps a table should be 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 calculations can be performed.

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

Soil map unit	Number of polygons	Area (m^2)	Drainage class	Surface texture	Soil depth class
H11	10	2449561	Well drain	Gravely loam	Shallow
H12	3	2829484	Well drain	Loam	Deep
H13	1	246370.4	Well drain	Gravely loam	Deep
H21	6	2977356	Well drain	Loam	Deep
M1	5	1070312	Exc. drain	Gravely sandy loam	Shallow
M2	1	5713150	Exc. drain	Gravely sandy loam	Shallow
M3	3	535729.9	Exc. drain	Gravely sandy loam	Shallow
P11	4	2198135	Well drain	Gravely loam	Deep
P12	6	6610258	Well drain	Loam	V. deep
P21	6	4503889	Well drain	Gravely sandy loam	V. deep
P22	6	5277803	Well drain	Sandy loam	Deep
river	1	6125919	?	?	?
V1	2	9911202	Well drain	Loam	Deep
V2	9	4213459	Exc. drain	Loamy sand	Deep
V3	4	652134	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 %	Bulk density (g/cm^3)	Moisture storage capacity	k fact
H11	6.6	40	1.3	0.18	0.45
H12	6.5	20	1.3	0.18	0.50
H13	7.2	50	1.4	0.20	0.40
H21	6.8	20	1.3	0.20	0.48
M1	7.5	90	1.2	0.26	0.45
M2	7.0	90	1.2	0.25	0.43
M3	6.8	90	1.2	0.25	0.40
P11	6.8	35	1.4	0.18	0.35
P12	6.6	15	1.3	0.20	0.40
P21	7.2	10	1.3	0.20	0.36
P22	7.4	5	1.2	0.28	0.38
river	?	?	?	?	?
V1	6.8	0	1.3	0.20	0.41
V2	7.0	5	1.4	0.10	0.30
V3	6.8	40	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)	C	A	E_t/E_0	RD
Barren land	1	786600	1.000	0	0.05	0.01
Degraded sal forest	1	492300	0.030	20	0.80	0.10
Dense mixed forest	6	1053900	0.010	20	0.90	0.10
Dense sal forest	9	9887400	0.004	20	0.90	0.10
High intensity cultivation	2	12099600	0.300	43	0.85	0.07
Low intensity cultivation	8	9184500	0.500	30	0.60	0.05
Open mixed forest	1	6710400	0.050	15	0.80	0.10
Open sal forest	8	8530200	0.006	15	0.80	0.10
Orchard	2	53100	0.007	20	0.90	0.10
River	1	6012000	0.000	?	?	?

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- Display the `Soil` table by double-clicking it in the Catalog. The `Soil` table will be opened. You will notice that the first column shows the soil map units and the second column shows the area in m^2. Some other soil attributes are also given.
- To add the attribute `pH` of surface soil, select the Add Column option from the Columns menu in the table window.
- Enter the Column Name `pH` and accept the default `Value` Domain. Define the Value Range (which will be from `1` to `14` for `pH)`, enter `0.1` for the Precision and click OK. The column `pH` will appear in the table.
- Enter the pH values per soil mapping unit (use Table 24.1).
- Update the `Soil` table by creating columns and entering the values for stoniness, bulk density of topsoil (`BD`), moisture storage capacity (`MS)`, soil detachability index (`K`), etc. Close the table window once the table is updated.

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

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

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- In the Catalog, click raster map `Soil` with the right mouse button and select Properties from the context-sensitive menu. The

Properties sheet will be displayed.

- In the Properties sheet, select the check box Attribute Table and choose the `Soil` table from the drop-down list box. If the map is Read Only, first select the General tab and deselect the Read Only check box.

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

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- In the Catalog double-click raster map `Soil`. The Display Options – Raster Map dialog box will be opened.
- Click the Attribute check box and select attribute column `pH`. Accept all other defaults and click OK.

The map showing the pH of the top soil is displayed. Check with the left mouse button if the map units have different pH values. The above example shows you how to display an attribute map but an attribute map showing only pH values can also be created as follows:

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- Type the following formula on the Command line of Main window:

  `pH = Soil.Ph` ↵

- The Raster Map Definition dialog box is opened. Press Show. The dependent raster map `pH` is created and the Display Options dialog box is opened.
- Click OK to display the newly created `pH` map.

The example above has shown you how to edit and update a `Soil` table, how to link it to the raster map `Soil` and how to generate attribute maps. Similarly, update the `Landuse` table.

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- Create and enter the values for crop cover management factor (`C`), percentage rainfall contributing to interception (`A`), ratio of actual to potential evapotranspiration (`Et_E0`), and rooting depth (`RD`).
- Close the table and link it to raster map `Landuse`.

24.4 Generation of a 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 DTMs, 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 the higher the slope gradient the larger 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 contour map

For details about digitizing refer 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 to interpolate the segments by which a raster map (digital elevation map) is created with a certain pixel size. The size of the pixels is already defined by the georeference you have created.

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- Select Interpolation, Contour Interpolation from the Operations menu in the Main window. The Contour Interpolation dialog box is opened.
- Select segment map `Contour` as input map, type an Output Raster Map name (`Elevation`) and select the GeoReference you have created. Keep the Domain type as `Value`.
- The Value Range and the Precision required can be defined, depending on your data.

Display the output map and check the pixel values, which indicate the terrain heights. Break the dependency of the map if the interpolation result is satisfactory.

24.4.3 Computation of height difference maps

Once you have a digital elevation map you can compute slope gradients. 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.

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- Open the Filtering dialog box by double-clicking the Filter operation in the Operation-list.
- Select input Raster Map `Elevation` and select the Linear filter `dfdx`.
- Give a name (`Dx`) for the Output Raster Map, accept all other defaults and click Show.

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 a 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.

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- On the Command line of the ILWIS Main window, enter the following formula:

  `Slope_p = 100*HYP(Dx,Dy)/30` ↵

  This formula will generate a slope map in percentages. Note that the value 30 in the formula refers to the pixel size.
- To compute the slope in degrees, enter the following formula:

  `Slope_d = RADDEG(ATAN(Slope_p/100))` ↵

You have noticed that slope in degrees is simply a conversion of slope percentage values into degrees. In this case you have to compute first the slope in percentages. Also, the value in radians needs to be converted into degrees by using the function RADDEG. Notice that the trigonometric function ATAN returns real values in radians.

! Can you think of an equation by which you can compute the 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 notice that the whole screen is covered by slope values whereas the watershed boundary is smaller.

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- Use MapCalc to mask the areas belonging to the watershed and store the final slope map in a map called `Slope`. (Hint: use the map `Soil` to mask the watershed area).

24.4.5 Generation of a rainfall map based on a DTM

In an area with known variations of annual rainfall, caused by elevation differences a DTM can be used to generate a 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 a 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:

$$\text{Rainmap} = 1384.2 + 0.329 \cdot \text{Elevation} \qquad [24.1]$$

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- Translate equation 24.1 into a map calculation formula and generate the map `Rainmap`.
- Mask the `Rainmap` so that only the watershed area is displayed. Call the output map `Rain`.

24.4.6 Classification of the rainfall map

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

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- Select Create, Create Domain from the File menu in the Main window. The Create Domain dialog box is opened.
- Enter a Domain Name (`Rain`). Accept the domain Type `Class`, select the Group check box and click OK. The Domain Group editor is opened.
- Select Edit, Add Item. Enter Upper Bound `1600` for the rainfall value, enter `1600 mm` as Name and click OK.

- Add items for the rainfall values 1700, 1800, 1900, 2000, 2100 and 2200 as explained above. Close the Domain Group editor when all the values are added with proper class names.

The domain group is created. Now you can classify the map Rain into a rainfall class map.

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- Classify the Rain map and generate a rainfall class map using the Command line of the Main window:

  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:

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- In the Main window open the File menu and select Create, Table.
- Enter a name for the table (Rainclas), select the Domain Rain and click OK. The table will be opened.
- Add a column called Rainfall, with Domain Value with Value Range 0 – 2500 and Precision 1.
- Enter the corresponding values of rainfall for different rainfall classes.
- Create a rainfall value map by entering the following command:

  Rainfall = Rainclas.Rainclas.Rainfall ↵

  where Rainfall is the output map, Rainclas is the input map, the second Rainclas is the input table and the second Rainfall is the column in the table Rainclas.

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

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

Elevation	Number of rainy days
up to 700 m	75
from 701-1200 m	85
more than 1200 m	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 also be able to compute kinetic energy of rainfall, which is dependent on the annual amount of rain and the rainfall intensity.

24.5.1 Generation of a 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, established by Wischmeier and Smith (1978):

$$E = R \cdot (11.9 + 8.7 \cdot \log_{10} \cdot I) \qquad [24.2]$$

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.

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 the following equation:

$$F = K \cdot (E \cdot \exp^{(-0.05 \cdot A)}) \cdot 1.0 \cdot 10^{-3} \qquad [24.3]$$

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.

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- Generate attribute maps of soil detachability index K (hint: use the `Soil` table) and percentage rainfall contributing to permanent interception A (hint: use the `Landuse` table).
- Translate equation 24.3 into an ILWIS MapCalc command and generate the soil detachment rate map F.
- Display the map, there should be no unknown pixels in the map

anymore.

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_0), the amount of annual rain (R) and the number of rainy days (R_n). It can be explained by the following equations:

$$Q = R \cdot \exp^{(-R_c / R_0)} \qquad [24.4]$$

where:

$$R_c = 1000 \cdot MS \cdot BD \cdot RD \cdot (E_t / E_0)^{0.5} \qquad [24.5]$$

$$R_0 = R / R_n \qquad [24.6]$$

24.6.1 Calculation using MapCalc

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- As shown by the equations above 6 maps are required. From the attribute tables linked to the corresponding maps (`Soil`, `Landuse`, `Rainfall` and the map showing the number of rainy days `Rn`) generate the required attribute maps.
- Compute formulas 24.5 and 24.6 in MapCalc. Call the output maps `Rc` and `R0`.
- Compute the volume of overland flow Q by translating equation [24.4] into an ILWIS formula and store the result in a map `Q`. If necessary, break the dependency of the file.

24.6.2 Calculation by means of map crossing

The computation of overland flow (above) makes use of map calculations. Another option is by crossing 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.

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- In the Operation-tree, expand Raster Operations and double-click the Cross operation. In the Cross dialog box enter the 1st Map

Soil and 2nd Map Landuse to cross. Enter a name for the Output Table (Soilland), give the Output Map the same name and show the result.

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

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- In the cross table Soilland open the Columns menu and select the Join command. The Join Wizard is opened.
- Select table Soil and column MS and accept the default values for key column and output column name.

The column MS will be added to the cross table Soilland.

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- Join other relevant columns (BD, RD, Et_E0) from the tables Soil and Landuse.
- Compute the product of MS, BD, RD and the square root of Et_E0, and multiply by 1000. Store the result in a column RC.
- Generate an attribute map RC2 based on the column RC in the cross table.
- Compute the volume of overland flow and store the result 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), the crop cover management factor (C) and the topographic slope factor (S). It can be calculated by using the following equation:

$$G = C \cdot Q^{2.0} \cdot \sin S \cdot 10^{-3} \qquad [24.7]$$

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- Generate map C (the crop cover management factor map) from the attribute table Landuse.
- Write down on a piece of paper equation 24.7 into an ILWIS formula.

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

The MapCalc formula to compute transport capacity of overland flow (G) can be rewritten as follows:

G = C * SQ(Q) * SIN(DEGRAD(S)) / 1000 [24.8]

Note: The unit of the result is in kg/m^2.

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- Calculate map G.

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 as 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.

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- Compute the soil loss. The formula will be as follows:

  Soilloss = MIN(G,F) ↵
- 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 ton/ha. Store the soil loss map in ton/ha in a file Erosion with domain Type Value and with a Precision of 1.

24.8.2 Soil loss estimation per land use class

It will be interesting to see the 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.

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- Cross the maps Landuse and Erosion and enter a name for the 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.
- In the cross table, open the Columns menu and select Aggregation. The Aggregate Column dialog box is opened.
- Select the Column Erosion and the Function Average. Select the check box Group by and the column Landuse.
- Select the Output Table check box and type Landuse as output table name.
- Enter an Output Column name (Avg_soilloss) and click OK.
- Compute the standard deviation of the soil loss per land use class and add column Std_soilloss to table Landuse.

!

- 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 a higher soil loss estimation in low intensity agriculture as compared to high intensity agriculture?
- If a soil loss of 20 ton/ha is taken as the tolerable amount of soil loss 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 soil map unit.

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- Update the table Soil by computing and adding the columns average soil loss and the corresponding standard deviations.

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- Which soil map unit has the lowest and which soil unit has the highest soil loss estimation?
- Which units have a soil loss estimation of more than 20 ton/ha?
- What is the main reason for having higher soil losses?

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, rivers, roads, villages, etc. on a raster or a polygon map, and create a layout.

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- Display the raster map `Erosion`. To get a better result when printing, convert the raster map into a polygon map with the Raster to Polygon operation (Tip: for an even better result classify the erosion map by converting the value domain into a class domain before making polygons. Classes can be 0 – 10 ton/ha, 11 – 20 ton/ha, 21 – 30 ton/ha, etc.).
- Add polygon map `River` (which can be masked from the `Soil` or `Landuse` polygon map).
- Add also the drainage lines (segment map `Drainage`), the road infrastructure (segment map `Road`) and the village locations including the village names (point map `Villages` and annotation text layer `Villages`). Grid Lines or Graticules can be also added.

Now all the layers are displayed in the map window. Furthermore, all layers appear in the Layer Management pane (left hand side of the map window). To save the map view:

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- Open the File menu in the map window and select Save View As.

Finally, a layout can be created. A layout is a virtual sheet of paper on which you can insert annotation objects. Annotation objects such as a legend, a scale bar, a north arrow, etc. make the map easier to read.

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- In the map view open the File menu and select the Create Layout command. The Set Scale dialog box appears.
- In the Set Scale dialog box change the scale to `1:120000` and click

OK. The Layout editor will be opened.

In this stage of creating a layout, you can change the page setup and choose the paper size, orientation (portrait or landscape) and margins. The page setup can still be changed later if needed, but you may have to rearrange all items in the layout if you change the size or orientation of the paper.

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- From the File menu of the Layout editor, select Page Setup. The Page Setup dialog box is opened.
- Make sure the Paper Size is A4, change the Orientation to `Landscape` and click OK. The orientation of the layout is now changed into landscape.
- Add a Scale Bar, a North Arrow, a Map Border, a map title and other necessary information. It is also possible to add the map coordinates along the map borderline, to add other map views on different scales or to add pictures/bitmaps.
- The map layout can be saved and the map can be printed, when everything is finalized and you are satisfied with the result.

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Dr. S. K. Saha
Agriculture and Soils Division
Indian Institute of Remote Sensing
4 Kalidas Road
P.O. Box 135
Dehradun 248001, India
Fax: +91 135 741987

References

Morgan, R.P.C, Morgan, D. D. V. and Finney, H. J. (1984). A predictive model for the assessment of soil erosion risk. *J. Agric. Engng. Res.*, 30: 245-253.

Morgan, R.P.C. (1986). *Soil erosion and conservation*. Longman Scientific and Technical, England. 298 p.

Wischmeier W. H. and D. D. Smith, (1978). *Predicting rainfall erosion losses- a guide to conservation planning.* USDA Agriculture Handbook No. 537, Washington D. C., USA 58 p.