CHAPTER 23

Cibodas: the erosion issue

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Summary

In this area, the Cibodas Biosphere Reserve, West-Java, Indonesia, estates and annual rainfed dryland cultivation is practised in often steep sloping areas. Irrigated wetland rice and vegetables mainly occupies more flat land on lower elevation. Based on previous studies vegetable growing on the sloping land causes erosion. It means that sloping areas in the buffer- and transition zone can be categorised as fragile areas. In order to protect the Cibodas Biosphere Reserve from degradation in one hand and to anticipate a calamity down stream of the watershed areas on the other hand, the buffer- and transition zone should receive more attention.

Getting started

The data for this case study are stored on the ILWIS 2.1 CD-ROM in the directory d:\appguide\chap23. 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\chap23. If you did not install the data for this case study yet, please run the ILWIS installation program (see ILWIS Installation Guide).

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- 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\chap23.

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

23.1 The Cibodas Biosphere Reserve

The Cibodas Biosphere Reserve is located in the province of West Java, Indonesia and lies within the administrative districts (Kabupaten) Bogor, Cianjur and Sukabumi. The Biosphere Reserve has a core area, the Gudung Gede-Pangrango National Park (approximately 150 km^2), a buffer zone partly surrounding the core area (approximately 48 km^2) and a transition area that is strongly influenced by human activities. The altitude ranges from about 300 m to over 3000 m. The Gudung Gede-Pangrango has a mean annual rainfall between 3000 and 4200 mm. The wettest season is from October until may, coinciding with the NW monsoon; in the driest months (June to September) the average monthly rainfall drops below 100 mm. The annual average temperature varies from 18° to 10°.

The soils on the higher slopes of the mountains are Andosols derived from the underlying igneous rocks and volcanic ashes. On the lower slopes the soils become more weathered with a mixture of Andosols and Latosols the latter with a high clay content. Lower down deeply weathered Latosols are the dominant soil type. Soils in the upper mountain forest have high moisture content resulting from the heavy precipitation, which retards biological activity and chemical weathering and producing a characteristic peaty soil.

23.2 Available data

The data set available for this study case is:

`Admin`	Map with the administrative units of the Cibodas area derived from a digital elevation model (DEM).
`Cbrb`	Raster map with the boundary of the Cibodas Biosphere Reserve. This map is a base map to be used in MapCalc operations or to resample other raster maps with a different georeference or map size.
`Contour`	Map with the contour lines digitized from existing topographical maps.
`Landuse`	Land use map of the study area, derived from the classification of multispectral image, improved with an air photo-interpretation and fieldwork.
`Rfstat`	Point map with the location of 35 rainfall stations.
`Raindata`	Table with the rainfall distribution in the area.
`Soil`	Map with the soil types found in the study area.
`Terrain`	Map with the terrain units identified in the study area.

23.3 Erosion calculation

The factors causing erosion which comprise: climate, soil properties, vegetation/cover and management practices are considered for estimating soil loss. To do that estimation, the USLE equation is used here:

$$A = R * K * SL * C * P \qquad [23.1]$$

where,

A = USLE calculation.

R = Rain erosivity.

K = Soil erodability.

SL = Slope steepness and length.

C = Cover.

P = Management Practices.

23.3.1 Rain erosivity (R) calculation

Calculate the rain erosivity for the CBR, using point-data map of the 35 rainfall stations and the yearly rainfall data for each of the 35 rainfall stations (rfs). The equation to be used to calculate R is:

$$R = 38.5 + 0.35 * P \qquad [23.2]$$

where,

R = Rain erosivity (Joule/m^2).

P = Annual rainfall (mm/year).

First you have to prepare the rainfall map.

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- Make a rainfall distribution map (mm/year), using the Moving Average method for the interpolation of the rainfall data of each rfs-point. To do so, select the pointmap `Rfstat`. Select the suitable attribute, column `Yearly`, from the table `Raindata`. Select Linear Decrease as weight function with n=5 (power value or weight exponent). The Limiting Distance should be large enough to include most stations, for example 20000.
- Enter an output name `Raindist` for the rainfall map.
- Use as georeference `Georef`. The domain should be Value.

Use the same georeference (`Georef`) and pixel size (`50 m`), otherwise other maps previously calculated cannot be combined (or you have to resample).

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- Smooth the rainfall map by applying an appropriate filter (e.g. Majority, Median, Average).
- It is also possible to create a filter to improve the result.

! Which filters give the best results?

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- Reduce the filtered rainfall distribution map to the map size of the CBR boundaries only.
- Use MapCalc and apply the boundary map `Cbrb` to cut off the outer area. Name the new rainfall map `Raincbr`.

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- Apply in MapCalc the Rain erosivity equation to get the rain erosivity map. Name the output map `Rfactor`.

23.3.2 Soil erodability (K) calculation

In the Cibodas Biosphere Reserve five different soil classes can be distinguished:

– ReLi: Grey Regosols and Lithosols.

– AnRe: Association of Yellow Brown Andosols and Regosols.

– La1: Brown Latosols.

– La2: Yellow Brown Latosols.

– LaRe: Ass. of Brown Latosols and Grey Regosols.

The erodability of the soil is determined by the following soil properties: organic matter content, percentage of silt and fine sand, percentage of sand, soil texture and permeability.

In the Cibodas Biosphere Reserve the soil erodability is from low to very low (Table 23.1) (see K-factor in the table `Soil`).

Table 23.1: Soil information in the Cibodas Biosphere Reserve

Code	Texture	Soil_depth	Depth (cm)	K_factor
ReLi	Sandy loam	Very shallow	< 30 cm	0.166
AnRe	Loam	Shallow	30 - 60 cm	0.230
La1	Silt loam	Deep	60 - 90 cm	0.236
La2	Clay loam	Very deep	> 90 cm	0.237
LaRe	Clay	Very deep	> 90 cm	0.316

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- Open the table `Soil`.
- Add the columns of table 23.1 by creating new columns and selecting appropriate domains for each column.
- Calculate the soil erodability map using the soil map `Soil` and attribute `Kfactor` in the table `Soil`. Name the output map `Kfactor`.

23.3.3 Slope steepness and length (SL) calculation

(1) For slope steepness up till 21 %, the original USLE formula for estimating the slope length and slope steepness will be used. The equation is:

$$SL = (L/72.6) * (65.41 * \sin(S) + 4.56 * \sin(S) + 0.065) \qquad [23.3]$$

where,

SL = Slope length and slope steepness factor.

L = Slope length (m).

S = Slope steepness (radians).

(2) For slope steepness of 21 % or more, the Gaudasasmita equation will be used:

$$SL = (L/22.1)^{0.7} * \left(6.432 * \sin(S^{0.79}) * \cos(S)\right) \qquad [23.4]$$

where,

SL = Slope length and slope steepness factor.

L = Slope length (m).

S = Slope steepness (radians).

To create a digital elevation map of the Cibodas Biosphere Reserve use will be made of the segment contourline map Contour. In fact, this map contains isolines and, therefore, also called an isoline segment map.

Interpolation can be done via the option InterpolSeg in the operation list, where you have to enter a Contour map. But it is also possible to perform the interpolation through selecting Operations, etc., where you have to perform the same activities.

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- For interpolation of the segment contourline map, select Operations, Interpolation, Contour Interpolation in the Menu bar to open the Contour Interpolation dialog box. Select as contour map Contour. Click Show to see the results directly. Select an appropriate georeference Georef. Optionally you can describe the new map. Name the new output map Demtot.
- Check the results of the map (altitude in metres) by moving the mouse over the map and hold the left button.
- Optionally, in Layer Management you can add the segment contourline map and check if the values of the contourlines are corresponding with the values of the DEM map.
- Reduce the map Demtot to the map size of the CBR boundaries only, by using MapCalc and applying the boundary map Cbrb to cut of the outer area. Name the new elevation map Dem.

To calculate the slope percentages of the map Dem, ILWIS uses two steps:

1. First applying digital gradient filters dfdx and dfdy to create two so called x-gradient and y-gradient map.
2. Next these two gradient maps are used to derive differences in elevation in all directions in the construction of a slope map.

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- Create a slope map (in percentages) Slope from the digital elevation map Dem.
- Double click Filter in the operations list and enter the raster map Dem as input map.
- Select Linear in the filter type box list and select dfdx to create the x-gradient map Dx (accept the default Value domain, range and Precision).

- Repeat the same operation to create the y-gradient map `Dy` by selecting the dfdy filter.
- To create the slope map `Slope` in percentages, apply the following equation in MapCalc:

```
Slope=(hyp(Dx,Dy)/pixel size)*100↲
```

The relationship between the slope steepness in percentages (S) and slope length in metres (L) in the Cibodas Biosphere Reserve has been estimated to be about:

$$L = 0.4 * S + 40 \qquad [23.5]$$

where,

L = Slope length (m).

S = Slope steepness (%).

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- Calculate the slope length map `Slength` using the above equation in MapCalc.
- The result will be a map with the slope length in metres.

Finally calculate the slope factor map by combining the slope steepness and slope length map through applying the equations:

$$Lsfact = (L/72.6) * (65.41 * \sin(S) + 4.56 * \sin(S) + 0.065) \qquad [23.6]$$

and

$$Lsfact = (L/22.1)^{0.7} * \left(6.432 * \sin(S^{0.79}) * \cos(S)\right) \qquad [23.7]$$

where,

Lsfact = Slope factor.

L = Slope length (m).

S = Slope steepness (%).

However, for the functions SIN, COS and TAN, the input angles should be in radians! To convert degrees to radians, the angular function DEGRAD has to be used.

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- To convert the map Slope (calculated in percentage) in degrees, apply this formula:

  ```
  Slopedeg=raddeg(atan(Slope/100))↵
  ```

- Finally the LS-factor map can be calculated by changing degrees to radians by applying the equations:

  ```
  Lsfact1=(Slength/72.6)*(65.41*sin(degrad
  (Slopedeg))+4.56*sin(degrad(Slopedeg))+0.065)↵
  ```

  ```
  Lsfact2=pow((Slength/22.1),0.7)*6.432*sin
  (degrad(pow(Slopedeg,0.79)))*cos(degrad
  (Slopedeg))↵
  ```

- Combine Lsfact1 and Lsfact2 following the formula:

  ```
  Lsfactor=iff(Slope<21,Lsfact1,Lsfact2)↵
  ```

23.3.4 Potential soil loss calculation

As stated before, the rain erosivity, soil erodability and the factor slope as elements of the USLE equation can be considered as naturally occurring factors determining the sheet and rill erosion processes. Together, they can be considered as the erosion susceptibility (Rkls) or potential erosion or soil loss (tons/ha/year) for the area.

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- Calculate the potential soil loss map by multiplying the R-factor map Rfactor, the K-factor map Kfactor and the SL-factor map Lsfactor.
- Use as domain Value and select a precision of 20. Name the output map Rkls.
- The result will be an estimation of soil loss in tons/ha/year.

Classify the potential soil-loss map Rkls into suitable soil-loss classes.

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- Create a domain by clicking New Domain from the operation list and activate both Class and Group. Name the new domain Rflsclfy.
- Select Edit and Add Item and enter the upper boundaries of the decided classes of potential soil loss.

- Double click Slicing from the operation list. Classify the map `Rkls` according to the group domain `Rklsclfy`. Name the new map `Rklsclfy`.

It is also possible to classify this map directly with the use of a MapCalc expression:

```
RKLSclfy=clfy(Rkls,Rklsclfy)
```

where,

Rklsclfy =	Output raster map name.
Rkls =	Input raster map name.
Rklsclfy =	Group domain (functions as a classify table).

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- Create a histogram table, showing the area (m^2) of each potential soil loss mapping unit (class).
- Select Histogram from the operation list and select as input raster map `Rklsclfy`. Name the output table `Rklsclfy`.

The histogram table has been displayed. Analyse its content.

! Which potential soil loss class is covering the largest area?
And which class is covering the less?

Estimate the potential soil loss for each terrain unit (use map `Terrain`).

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- Use the Cross operation in the operation list. Name the 1st input map `Terrain`. Name the 2nd input map `Rkls`. Name the output table `Rktecros`.

In the cross table, the combinations of terrain units, potential soil loss classes (tons/ha/year) and affected area (m^2) are displayed.

To calculate the total potential soil loss per terrain mapping unit, the potential soil loss has to be recalculated in tons/m^2/year and multiplied with the area affected.

Yet, the total potential soil loss/ terrain mapping unit (tons/m^2/year) can be estimated by aggregation per terrain mapping unit and eventually recalculated in ton/ha/year.

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- Open cross table Rktecros.
- Recalculate the column Area (m^2) to a new column Areaha (ha) by dividing the column Area by a factor 10000.
- Calculate the potential soil loss in a new column Rklsha by multiplying the columns Rkls and Areaha.
- Select Columns and Aggregation and enter the column name Rklsha. Select the function Sum, grouped by Terrain. Type Terrain for the table output name and Rklstym for the output column.

Or recalculate the area directly from m^2 to ha.

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- Display the table Terrain and check the column Rklstym which gives the total potential soil loss (tons/year) for each terrain unit. Enlarge the maximun value in the column properties.
- Recalculate the potential soil loss (tons/ha/year) for each mapping unit.
- Select domain Value and give the proper precision to get rounded values. Name the new column Rklsthy.
- Close the table.

It is also possible to calculate in the cross table the pot. soil loss for each terrain unit directly by using the function Average and the Weight factor in the Aggregation module.

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- Open the cross table Rktecros. The input column is Rkls (tons/ha/cross combination). Select the function Average, group by Terrain. Use the weight column Area. Give Terrain as the table output name and Rklsunit (ton/ha/land unit) column for the output column.

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- Open the table Terrain and compare the two columns Rklstym and Rklsunit.
- Explain the (small) difference between the two columns.

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- Create a new attribute map with the potential soil loss per terrain unit (tons/ha/year/terrain unit). Name the map Terrkls.
- Make a representation and add some annotations layers such as legend, title, etc. Save this as view.

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- Estimate the potential soil loss for each land cover unit (use the map Landuse) following the same procedures as for the terrain unit map.
- Name the final output map Landrkls.

23.3.5 Cover and management practices (CP) calculation

The C factor necessary for the USLE equation is calculated as follows:

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- Create the cover and management factor map for the Cibodas Biosphere Reserve by applying (linking) the CP-factor column Cpfactor for each landuse type in table Cpfactor to the map Landuse as an attribute. Name the output map Cpfactor.

23.4 Expected soil loss (A) calculation

The “actual” soil loss can be estimated for each landuse type and for each administrative unit. By comparing the “potential” soil loss (estimated as RKLS) and the 'actual' soil loss (estimated as USLE) the difference can be significant and is mainly due to management practices in the Biosphere Reserve. By comparing and analysing both maps, the cause of the increased erosion might be detected and improved management should be proposed to prevent further degradation.

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- Estimate the actual soil loss for each land unit (use map Landuse). Use the USLE equation:

  USLE=R*K*SL*CP (ton/ha/year)

- Name the output map Uslecbr. Use as domain Value with a precision of 20.
- Create and display the histogram table Uslecbr.

Note: The rounded values are necessary to be able to create a histogram table. Otherwise, (when using, for instance, 3 decimals) the histogram table will become to complex for the program to handle. The same counts for using the Cross option.

! What is the highest soil loss estimated per pixel (50x50m)?

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- Use the Cross option in the operation list. Give Landuse as the first input map and Uslecbr as the second input map. The output table is Luuscros.

Note: It is not necessary to create an output map. It will not be used for the further calculation and will only occupy unnecessary disk space.

When displaying the cross table, the land units (Landuse) are displayed, the actual soil loss classes (Uslecbr) (tons/ha/year) are displayed and the area affected (m^2) for each (Area) combination is, as well, displayed.

To calculate the total soil loss per landuse mapping unit, the potential soil loss has to be recalculated in tons/m^2/year and multiplied with the area affected.

Yet, the total potential soil loss per terrain mapping unit (tons/m^2/year) can be estimated by aggregating per terrain mapping unit and eventually recalculated in tons/ha/year.

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- Open the cross table Luuscros.
- Recalculate the column Area (m^2) to a new column Areaha (ha) by dividing the column Area by a factor 10000.

- Calculate the actual soil loss in the new column Soilloss by multiplying the columns Uslecbr and Areaha. To do it, select Columns and Aggregation and enter the column name Soilloss. Use the function Sum, Grouped by Landuse. Select as the output table Landuse and enter as output column Slusle.

Recalculating the area from m^2 to ha with factor 0.0001 has the same result.

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- Display the table Landuse and check the column Slusle. This column gives the total actual soil loss (tons/year) for each land unit.
- Recalculate the actual soil loss in (tons/ha/year) for each mapping unit. Select domain Value with precision 1 to get rounded values. Name the new column Lsuslelu.

It is also possible to calculate in the cross table the actual soil loss for each land unit directly by using the function Average and the Weight factor in the Aggregation module.

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- Open the cross table Luuscros. Select the column Uslecbr (tons/ha/cross combination). Use the function Average, Group by Landuse. Enter the column Area (area/cross combination) as weight. Give Landuse as the output table name and Lsuslelw (tons/ha/land unit) as the output column.
- Open the table Landuse and compare the two columns Lsuslelu and Lsuslelu.
- Explain the (small) difference between the two columns.

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- Create a new attribute map with the actual soil loss (tons/ha/year/land unit). Name the map Usleland.
- Make a representation (including legend etc.) and save this as view.

! Which landuse types are causing the most severe erosion? Give some reasons why

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- Estimate the actual soil loss for each terrain unit (use map `Terrain`) following the same procedures as for the landuse map.
- Name the final output map `Usleterr`.

! Which terrain units are causing the most severe erosion? Give some reasons why?

Make a representation (including legend etc.) and save this as view.

☞

- Estimate the actual soil loss for each administrative unit (use map `Admin`) following the same procedures as for the landuse map
- Name the output map `Usleadmn`.

! Which administrative units are suffering from the most severe erosion? Give some reasons why?

Make a representation (including legend etc.) and save this as view

☞

- Estimate for each land unit the difference between the potential soil loss and actual soil loss and create this attribute map.
- Name the output map `Landdiff`.

! When analysing the difference between the potential and the actual soil loss estimations, what might be the most important factor in the USLE equation considering the landuse aspects? Try to find the reason why.

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- Estimate for each terrain unit the difference between the potential and actual soil loss and create this attribute map. Name the output map `Terrdiff`.

- Find a correlation between the amount of soil loss between the cover and terrain and identify the main causes of soil erosion in the Cibodas Biosphere Reserve.

! Which administrative units suffer most of soil erosion and should really do something to prevent severe degradation of their land?
Which management practice could be applied to improve the situation in those administrative units with severe erosion?

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