CHAPTER 5

Statistical landslide hazard analysis

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Summary

This exercise will show a method to make a hazard map based on quantitatively defined weight-values. Many different methods exist for the calculation of weight-values. The method used here is called the *landslide index method*. A weight-value for a parameter class, such as a certain lithological unit or a certain slope class, is defined as the natural logarithm of the landslide density in the class divided by the landslide density in the entire map.

Getting started

The data for this case study are stored on the ILWIS 2.1 CD-ROM in the directory d:\appguide\chap05. 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\chap05. 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\chap05.

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

5.1 Introduction

This method is based upon the following formula:

$$\ln W_i = \ln\left(\frac{\text{Densclas}}{\text{Densmap}}\right) = \ln\left(\frac{\frac{\text{Npix(Si)}}{\text{Npix(Ni)}}}{\frac{\sum \text{Npix(Si)}}{\sum \text{Npix(Ni)}}}\right) \qquad [5.1]$$

where,

Wi =	the weight given to a certain parameter class (e.g. a rock type, or a slope class).
Densclas =	the landslide density within the parameter class.
Densmap =	the landslide density within the entire map.
Npix(S_i) =	number of pixels, which contain landslides, in a certain parameter class.
Npix(N_i) =	total number of pixels in a certain parameter class.

The method is based on map crossing of a landslide map with a certain parameter map. The map crossing results in a cross table, which can be used to calculate the density of landslides per parameter class. A standardization of these density values can be obtained by relating them to the overall density in the entire area. The relation can be done by division or by subtraction. In this exercise the landslide density per class is divided by the landslide density in the entire map. The natural logarithm is used to give negative weights when the landslide density is lower than normal, and positive when it is higher than normal. By combining two or more maps of weight-values a hazard map can be created. The hazard map value is obtained by simply adding the separate weight-values. An overview of the method is shown in figure 5.1.

5.2 Visualization of the input data

In this exercise the landslide hazard map is made by using only two parameter maps: `Geol` (geology) and `Slope` (slope classes in classes of 10 degrees). The landslides are stored in the map `Slide`, which is linked to a table, containing detailed information for each landslide. The maps are from the Chinchina area in the Caldas department in Central Colombia.

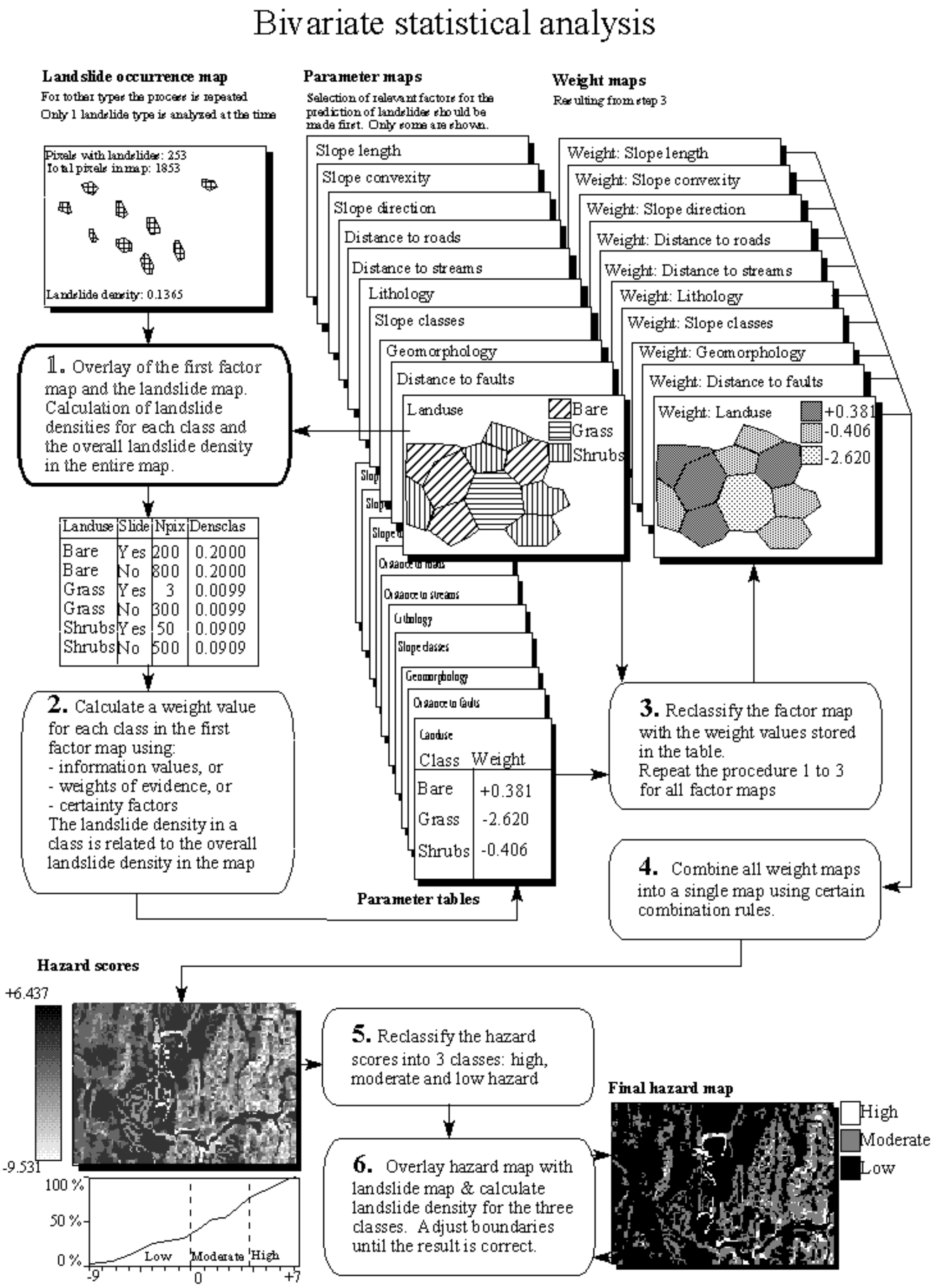

Figure 5.1: Simplified flowchart for bivariate statistical analysis. In this exercise only 2 input maps are used

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- Double-click the map `Slide`. Click OK in the Display Options dialog box. The map is displayed.
- Move through the map and press the left mouse button for information on the various units. As you can see the area outside of the landslides reveals a ? when you press the left mouse button. These areas are called *undefined*. This means that no information is stored for the non-landslide areas. The landslides themselves all have a unique code.
- Move your mouse pointer to one of the landslides and double click on it. Now the information from the table connected to the map `Slide` is displayed.

The map `Slide` has a so-called identifier domain. This means that each unit (land-slide) from this map has a unique code.

When you move the mouse pointer to one of the landslides, you will see that the attribute code is composed of two parts: first the landslide ID number is given, followed by a `-` and after that a six-digit code for `Type`, `Subtype`, `Activity`, `Depth`, `Vegetation` and `Scarp`.

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- Each time you double click on a part of the map, the information from the table for that unit will be displayed. Try this out for several different units. Close the Edit Attribute window.
- Open the pixel information window and drag-and-drop the map `Slide` into it. Now if you move with the mouse pointer the information is shown without the need to double-click.
- To see what the table looks like, go to the main ILWIS window and open the table `Slide` by double-clicking it. Have a look at the different columns. If you double-click the name of a column you get information on the column type.
- Close the table window.

The columns `Type`, `Subtype`, `Activity`, `Depth`, `Vegetation`, `Scarp` are so-called class domain columns, in which each unit has a name. These names are defined in the domain files. The various domain items of these columns are shown in table 5.1.

Table 5.1: List of domain items for mass movement characteristics

	Type	Subtype	Activity	Depth	Vegetation	Scarp
0	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
1	Slide	Rotational	Stable	Shallow	Bare	Scarp
2	Flowslide	Translational	Dormant	Deep	Low vegetation	Body
3	Flow	Complex	Active		High vegetation	
4	Derrumbe					
5	Creep					

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- Open the domain `Activity` by double-clicking it. As you can see each class has a *code*, which corresponds to the values in the left column of table 5.1. Each class domain also contains a representation, in which the colors for each class are defined.
- Open the representation `Activity` and have a look at the content. After that close the representation and the domain.

You can also display the map `Slide` with an attribute from its table.

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- Make the landslide map `Slide` active, by clicking on a visible part of the map, or by selecting the upper left box of a window, and then switch to...
- Press the right mouse button while in the map, and select: 1.map Slide. In the following Display Options dialog box click on Attribute and select the column `Activity`. Press OK. Now the map is redisplayed, with the colors from the representation `Activity`. If you click on a landslide you will see the activity information displayed.
- Also try this with some other columns (`Type`, `Subtype`, `Activity`, `Depth`, `Vegetation` and `Scarp`).
- Close the map.

Along side the landslide map you also have two parameter maps: `Geol` (geological units) and `Slope` (slope classes). Both maps have the class domain.

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- Open the map Geol and consult the information from the map and the accompanying table.
- Add the maps Geol and Slope to the pixel information window. When you move through the map you can simultaneously read the information from all three maps and their tables.
- Also open the map Slope and look at the content.
- Close the map windows and the pixel information window.

So far you have only been looking at the content of the maps. You will now start with the actual analysis.

5.3 Creating a landslide distribution map

Previously you displayed the activities of the landslides in the study area. However, you did not actually make a new map showing these activities. This is what you will do now, by renumbering the map Slide with the attribute Activity.

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- Select the following items from the main ILWIS menu: Operations, Raster operations, Attribute.
- Select the raster map: Slide.
- Select the attribute: Activity.
- Type the output map name: Activit.
- Press Show and OK. After calculation you will see the Display Options dialog box. Press OK.
- Move your mouse pointer through the map, and consult the values. The areas outside the landslides are still undefined, because the map Slide also has undefined values for this areas. In the analysis you do not want to have undefined values, as you want to calculate the density of active landslides in each geological unit and each slope class.
- To remove the undefined values from the map Activit type the following formula in the command line:

```
Activity=iff(isundef(Activit),"unknown",
Activit)↵
```

This means: if there is an undefined value in the map Activit, you replace it by the name "unknown", otherwise you keep the name from map Activit.

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- Display the map Activity and read the values from this map. Now you have the classes Active, Dormant, Stable, and Unknown.

5.4 Crossing the parameter maps with the landslide map

The landslide occurrence map, showing only the activity of the landslides (Activity) can be crossed with the parameter maps. In this case the two maps Slope and Geol are selected as examples. Of course in real applications many more parameter maps should be evaluated. First the map crossings between the occurrence map and the two parameter maps have to be carried out.

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- Select from the main ILWIS menu the options: Operations, Raster operations, Cross.
- Select the map Slope as the first map, the map Activity as the second map, and call the output table Actslope. Click Show and OK. Now the crossing of the two maps takes place.
- Have a look at the resulting cross table. As you can see this table contains the combinations of the classes from the map Slope and the types from the map Activity.
- Repeat the procedure for the crossing of the maps Geol and Activity. Name the output cross-table Actgeol.

Now the amount of pixels with different landslide activities in each slope class and each geological unit, has been calculated, the landslide densities can be calculated.

5.5 Calculating landslide densities

After crossing the maps, the next step is to calculate density values. You will do this only for active landslides.

The cross-table is given below (table 5.2). It includes the columns that will be calculated during this exercise. Each of the calculation steps is indicated below.

Table 5.2: The cross table resulting from the combination of the map Slope and Activity. The resulting columns of the different steps in the exercise are also shown

			Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
slope	activity	npix	npixact	npslopetot	npslopact	npmaptot	npmapact	densclas	densmap
0 - 10 degrees	Unknown	160964	0	168691	1659	437019	6887	0.009728	0.0158
0 - 10 degrees	Stable	4006	0	168691	1659	437019	6887	0.009728	0.0158
0 - 10 degrees	Dormant	2062	0	168691	1659	437019	6887	0.009728	0.0158
0 - 10 degrees	Active	1659	1659	168691	1659	437019	6887	0.009728	0.0158
10 - 20 degrees	Unknown	104195	0	110363	1283	437019	6887	0.011489	0.0158
10 - 20 degrees	Stable	2524	0	110363	1283	437019	6887	0.011489	0.0158
10 - 20 degrees	Dormant	2361	0	110363	1283	437019	6887	0.011489	0.0158
10 - 20 degrees	Active	1283	1283	110363	1283	437019	6887	0.011489	0.0158
20 - 30 degrees	Unknown	84406	0	90429	2028	437019	6887	0.021730	0.0158
20 - 30 degrees	Stable	1242	0	90429	2028	437019	6887	0.021730	0.0158
20 - 30 degrees	Dormant	2753	0	90429	2028	437019	6887	0.021730	0.0158
20 - 30 degrees	Active	2028	2028	90429	2028	437019	6887	0.021730	0.0158
30 - 40 degrees	Unknown	41490	0	44987	1320	437019	6887	0.029875	0.0158
30 - 40 degrees	Stable	1030	0	44987	1320	437019	6887	0.029875	0.0158
30 - 40 degrees	Dormant	1147	0	44987	1320	437019	6887	0.029875	0.0158
30 - 40 degrees	Active	1320	1320	44987	1320	437019	6887	0.029875	0.0158
40 - 50 degrees	Unknown	15085	0	16122	407	437019	6887	0.025245	0.0158
40 - 50 degrees	Stable	252	0	16122	407	437019	6887	0.025245	0.0158
40 - 50 degrees	Dormant	378	0	16122	407	437019	6887	0.025245	0.0158
40 - 50 degrees	Active	407	407	16122	407	437019	6887	0.025245	0.0158
50 - 60 degrees	Unknown	3791	0	4424	172	437019	6887	0.038879	0.0158
50 - 60 degrees	Stable	336	0	4424	172	437019	6887	0.038879	0.0158
50 - 60 degrees	Dormant	125	0	4424	172	437019	6887	0.038879	0.0158
50 - 60 degrees	Active	172	172	4424	172	437019	6887	0.038879	0.0158
60 - 70 degrees	Unknown	832	0	857	18	437019	6887	0.021004	0.0158
60 - 70 degrees	Dormant	7	0	857	18	437019	6887	0.021004	0.0158
60 - 70 degrees	Active	18	18	857	18	437019	6887	0.021004	0.0158
70 - 80 degrees	Unknown	593	0	594	0	437019	6887	0.000000	0.0158
70 - 80 degrees	Dormant	1	0	594	0	437019	6887	0.000000	0.0158
80 - 90 degrees	Unknown	552	0	552	0	437019	6887	0.000000	0.0158

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- Make sure that the cross-table `Actslope` is active.

  Step 1: Create a column in which only the active landslide are indicated by typing the following formula on the command line of the table window:

  `Npixact=iff(Activity="Active",npix,0)↵`

  You do this in order to calculate for each slope class the number of pixels with only active landslides.

- **Step 2:** Calculate the total number of pixels in each slope class. Select from the table menu: Columns, Aggregation.
  Select the column: `Npix`. Select the function Sum. Select group by column `Slope`. Deselect the box Output Table, and enter the output column `Npsloptot`. Press OK. Select a precision of 1.0.

- Step 3: Calculate the number of pixels with active landslides in each slope class.
  Again select from the table menu: Column, Aggregation.
  Select the column: `Npixact`, Select the function Sum, select Group by column `Slope`. Deselect the box Output Table, and enter the output column: `Npslopeact`. Press OK. Select a precision of 1.0.

- **Step 4:** calculate the total number of pixels in the map.
  Again select from the table menu: Columns, Aggregation.
  Select the column: `Npix`. Select the function Sum. Deselect the box group by. Deselect the box Output table, and enter the output column: `Npmaptot`. Press OK. Select a precision of `1.0`.

- **Step 5:** The next step is to calculate the total number of pixels with landslides in the map. Again select from the table menu: Columns, Aggregation.
  Select the column: `Npixact`. Select the function Sum. Deselect the box group by. Deselect the box Output Table, and enter the output column: `Npmapact`. Press OK. Select a step size of `1.0`.

- **Step 6:** Calculate the landslide density per slope class
  Type:

  `Densclas=Npslopeact/Npsloptot↵`

  Select a precision of `0.0001`.

- **Step 7:** Calculate the landslide density for the entire map.
  Type:

  `Densmap=Npmapact/Npmaptot↵`

  Select a precision of `0.0001`.

Now you have calculated all the required densities for the map `slope`.

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- Repeat the procedure for the cross-table `Actgeol`. You don't have to calculate the density in the map anymore, since it is the same for both maps.

5.6 Calculating weight values

The final weight-values are calculated by taking the natural logarithm of the density in the class, divided by the density in the map. With this calculation we find that the density in the entire map = 6887/437019 = 0.01576.

Previously the calculation was done on the cross-table for the maps `Slope` and `Active`. As you could see from table 5.2, this results in many redundant values, since you only want to calculate the densities and the weights for each slope class. The result should look like table 5.3 instead, where each slope class occupies only one record. That is why you will work now with the attribute table connected to the map `Slope` and use table joining combined with aggregation to obtain the data from the cross table.

Table 5.3: The calculation of densities directly in the table Slope. Data is obtained from the cross table through table joining and aggregation

			STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7
slope	activity	npix	npixact	npslopetot	npslopact	npmaptot	npmapact	densclas	densmap
0 - 10 degrees	Unknown	160964	1659	168691	1659	437019	6887	0.009728	0.0158
10 - 20 degrees	Unknown	104195	1283	110363	1283	437019	6887	0.011489	0.0158
20 - 30 degrees	Unknown	84406	2028	90429	2028	437019	6887	0.021730	0.0158
30 - 40 degrees	Unknown	41490	1320	44987	1320	437019	6887	0.029875	0.0158
40 - 50 degrees	Unknown	15085	407	16122	407	437019	6887	0.025245	0.0158
50 - 60 degrees	Unknown	3791	172	4424	172	437019	6887	0.038879	0.0158
60 - 70 degrees	Unknown	832	18	857	18	437019	6887	0.021004	0.0158
70 - 80 degrees	Unknown	593	0	594	0	437019	6887	0.000000	0.0158
80 - 90 degrees	Unknown	552	0	552	0	437019	6887	0.000000	0.0158

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- Open the table `Slope`. This table contains no additional columns, except the column with the domain. Repeat the procedure from above, but now with table joining.
- **Step 2:** Calculate the total number of pixels in each slope class. Select Columns, Join. Select table `Actslope`. Select column: `Npix`. Deselect key column. Select function Sum. Select group by column `Slope`. Select output column `Npsloptot`. Press OK.
- **Step 3:** Calculate the number of pixels with active landslides in each slope class. Select Columns, Join. Select table: `Actslope`. Select column `Npixact`. Deselect key column. Select function Sum. Select group by column `Slope`. Select output column `Npslopact`. Press OK.
- **Step 6:** With both columns, you can calculate the landslide density in each slope class with the formula:

  `Densclas:=Npslopact/Npsloptot`↵

  Select a precision of `0.0001`.
- If you look at the result, some classes have a density of 0. This should be adjusted, since the calculation of the weights is not possible. To adjust type the following formula:

  `Dclas:=iff(Densclas=0,0.00001,Densclas)`↵

- The final weight can now be calculated with the formula:

  `Weight:=ln(Dclas/0.01576)↵`

- Close the table.

Now you have calculated the weights for the map `Slope`.

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- Repeat the procedure for the table of the map `Geol`.

5.7 Creating the weight maps

The weights from the table can now be used to renumber the maps.

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- Select from the main ILWIS menu: Operations, Raster operations, Attribute map. Select raster map `Slope`. Select attribute `Weight`. Select output raster map `Wslope`. Press OK.
- Display the resulting map `Wslope`. Stretch between -0.5 and +6.5
- Use the same procedure the other parameter map `Geol`. The resulting map should be called: `Wgeol`.
- The weights for the two maps can be added with the formula:

  `Weight=Wslope+Wgeol↵`

- Display the map `Weight` and use the pixel information window in order to read the information from the maps `Slope`, `Wslope`, `Geol`, `Wgeol` and `Weight`.

5.8 Classifying the Weight map into the final hazard map

The map `Weight` has many values, and cannot be presented as it is as a hazard map. In order to do so we first need to classify this map in a small number of units.

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- Calculate the histogram of the map Weight and select the boundary values for three classes: Low hazard, Moderate hazard, and High hazard.
- Create a new domain: Hazard. By selecting: File, Create, Create domain. The domain should be a Class and tick on Group. Now enter the names and the boundary values of the different classes in the domain. When you are ready, close the domain.
- The last step is using the program slicing. Select: Operations, Image processing, slicing. Select raster map: Weight. Select output raster map: final. Select domain: hazard. Press show and OK.
- Evaluate the output map with Pixel information. If necessary adjust the boundary values of the domain hazard and run slicing again, until you are satisfied with the result.

5.9 Additional exercise

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- Create a script for the calculation of weight values (see ILWIS User's Guide for more information on scripts).

References

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