

## CHAPTER 2

# Flood hazard analysis using multi-temporal SPOT-XS imagery

By:

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### Summary

In this exercise you will use multi temporal satellite images to evaluate the flood problem in the confluence area of the Ganges and Jahmuna rivers in Bangladesh, Southwest of the capital of Dhaka. In this area river dynamics are impressive. Rivers change their course for kilometers within years.

You will evaluate the areas covered by water during three periods:

- During the dry season, using a SPOT image from 9-1-1987,
- During a moderately severe flood, using a SPOT image from 7-11-1987,
- During a severe flood, using a SPOT image from 10-10-1988.

### Getting started

The data for this case study are stored on the ILWIS 2.1 CD-ROM in the directory d:\appguide\chap02. 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\chap02. 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\chap02.

## 2.1 Introduction

Bangladesh probably is the most affected country by natural catastrophes, especially floods, in the world. Approximately 40 percent of the country is subjected to regular flooding. It contains more than 250 perennial rivers, of which 56 originate outside of the country, in Tibet, India, Bhutan and Nepal. Ninety percent of the river discharge from the main rivers, the Ganges, the Brahmaputra and the Meghna originates from other countries.

The primary cause of flooding in Bangladesh is directly or indirectly related to rainfall in the catchment areas of the three major river systems. The rainfall, together with snow-melt from the Himalayas generates enormous quantities of runoff to be discharged through Bangladesh into the Bay of Bengal.

Moderately strong semidiurnal tides are prevailing in the Bay of Bengal. Due to the extreme flat topography of the country (half the country lies below the eight meter contour line), the tidal influence reaches very far into the country. During the monsoon, recession of the floodwater is delayed due to the tidal effect. Cyclonic sea flooding occurs when due to the friction of the wind on the surface of the sea a storm surge moves inland.

From 1960-81 Bangladesh has suffered 63 disasters with the loss of 655.000 lives. Of these events, 37 were tropical cyclones, which killed 386.200 people. The last major floods were in 1987 and 1988 and a cyclone in 1990, killing about 140.000 inhabitants on the Bay of Bengal coast.

The evaluation of the flooding hazard is an international effort, as rainfall and river discharge monitoring in the entire catchment of the major rivers is required, as well as monitoring of sea levels and warning systems for tropical cyclones. For flood stage mapping and river dynamics determination, digital image processing and analysis of sequential SPOT images using GIS can be of large use. The study area covers the confluence of the rivers Meghan and Ganges, south east of the capital of Dhaka.

With the images from the three dates you can evaluate two things:

- Monitoring the extend of inundations,
- Monitoring river dynamics.

First a method has to be used for discriminating water surfaces from the other land cover types present in the images.

### **Selection of a single band in which water can be differentiated**

All images are multi spectral SPOT-XS images, with a spatial resolution of 20 meters, consisting of three bands:

- Band 1: spectral resolution 0.5-0.6  $\mu\text{m}$ : green portion of the visible spectrum.
- Band 2: spectral resolution 0.6-0.7  $\mu\text{m}$ : red portion of the visible spectrum.
- Band 3: spectral resolution 0.8-0.9  $\mu\text{m}$ : near infrared portion of the spectrum.

This method can be applied when individual bands are selected in which water has a specific reflectance that does not spectrally overlap with other cover classes. In this exercise SPOT XS imagery is used and the reflectance curves for some cover types are given in figure 2.1.

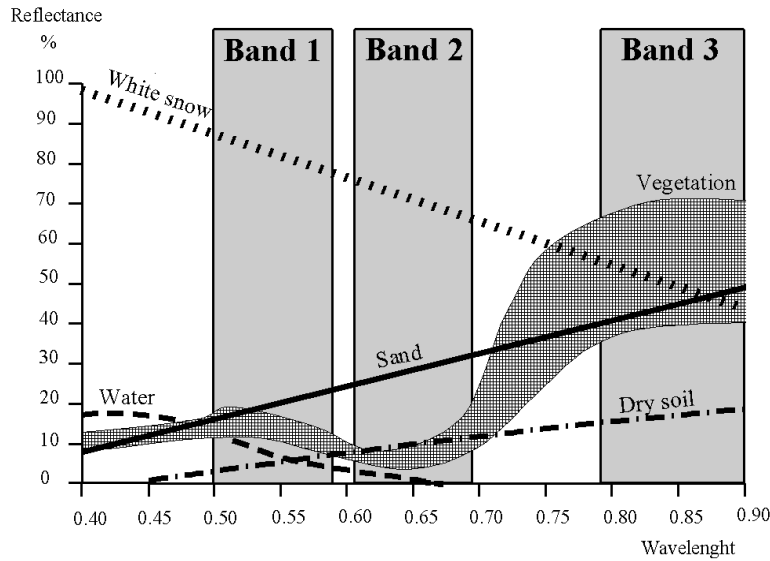


Figure 2.1: Reflectance curves for some cover types, and the spectral resolution of the three SPOT XS bands

**Band ratio's**

Another method is the use of band ratios, which are combinations of the individual bands. This method has the advantage that if spectral reflectances of cover types in one band are similar, the ratio of two bands can be used to differentiate them.

Table 2.1: Relative reflectance for different land cover types for the 3 SPOT XS bands

| Cover type | Band1    | Band3 | Band ratio 3/1 |
|------------|----------|-------|----------------|
| Water      | Moderate | Low   | Low-moderate   |
| Clouds     | High     | High  | Moderate       |
| Shadow     | Low      | Low   | Moderate       |
| Vegetation | Moderate | High  | Moderate-high  |
| Bare soil  | High     | High  | Moderate       |

The table shows that water has the same range of reflectance if compared to vegetation in band 1 and shadow in band 3. Using a band ratio water can be better separated. On the other hand clouds, shadow and bare soils are harder to distinguish. It therefore depends on the type of research which method to use.

## 2.2 Flood stage mapping

Before the band ratios are made, it is important to get a good idea of the individual images. First band 1 of the image from the moderate severe flood will be displayed.



- Display the image Mf187\_1w by double-clicking the map icon. Deselect the check box `stretch` in the `Display Options` dialog box. Click `OK`. The map will be displayed. Note the overall gray, or low contrast, throughout the whole image. You can find out the DN (digital number) value of each pixel by clicking on a pixel within the image.
- Close the map window.
- Double-click the histogram of the map Mf187\_1w. The histogram is shown in a table window. Observe the values in the table (scroll down to see the values). Display the histogram in a graph by selecting `Options` and `Show Graph`. Select `Image value` for the X-axis and `Pixel` for the Y-axis in the `Graph` dialog box. Click `OK`, and again click `OK` in the `Edit Graph` window. Now the histogram is displayed as a line.

The horizontal axis of the histogram may be interpreted as if it is a gray scale, with 256 different shades of gray. A reflectance value of zero is displayed in black, a reflectance value of 255 is displayed in white, and all values in between in various shades of gray. The vertical axis shows how many pixels in the image have that value. Notice that practically all pixels have a DN value between 20 and 50. Only the white spots in the image, which are actually clouds, may have higher DN values. That is why the image is mostly dark gray. To increase the contrast in the image, we will need to change the display so that all the colors of the palette are used, ranging from black to white.



- Close the graph window.
- Scroll down the table and write down the DN values for which the cumulative percentage (column `Npcumpct`) = 1 and to 99. Close the table window.
- Double-click the raster map Mf187\_1w again, but now select the check box `stretch` in the `Display Options` dialog box, and enter the values you have just written down, as the minimum and maximum values. Click `OK`. The image is now displayed with much more variation in gray tone.

The easiest way to improve the visibility of an image is by using the option **stretch**. When this is used, the minimum value in the image is displayed with the lowest color in the gray representation (black) and the maximum is displayed with the highest color (white). If we use the stretch option in the display of the map, the actual image values are not changed. Only the way in which they are represented changes.

If we want to actually create a map with DN values between 0 and 255 we have to use a **Stretch** operation, which will produce another image. In ILWIS two possibilities exist for stretching an image: **linear stretching**, and **histogram equalization**. The most commonly used method is the linear stretch. The principle of linear stretching is shown in the figure below. IN represents the original image values; OUT the corresponding image values after stretching.

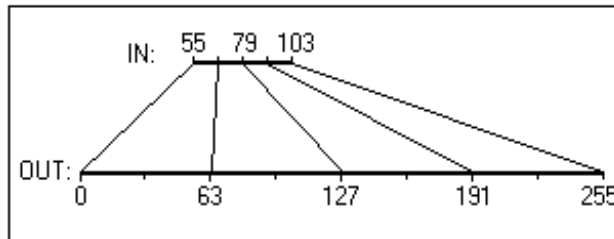


Figure 2.2: Principle of the linear stretching technique



- Close the map window.
- From the **Operations** menu in the Main window, select **Image Processing, Stretch**. The **Stretch** dialog box is opened. Select the image `Mf187_1w` as input map. Use the **Linear Stretch** option, and a percentage value of 1%. Enter `Mf187_1s` as the output image, and click on **Show** and **OK**. After calculation the **Display Options** dialog box is opened. Click **OK**. The image is shown. It will look the same as the previously displayed image, except when you now click on the values in the map, you will see that they are really in the range of 0 to 255.
- From the **File** menu of the Main window, select **Open Pixel Information**. Drag-and-drop the maps `Mf187_1w` and `Mf187_1s` into the pixel information window. Move the mouse pointer over the image and observe the different values before and after stretching.

- Compare the histograms before and after stretching.
- Close the map window and the pixel information window.

### Creating a false color composite

The first step is to evaluate the pixel values for different cover types. This will be done using a color composite from the moderate flood.



- From the Operations menu, select Visualization, Color Composite

Enter for the Name of red band: Mf187\_3w

Enter for the Name of green band: Mf187\_2w

Enter for the Name of blue band: Mf187\_1w

Name of output image: Mf187fcc.

Switch off 24 bits. Select Linear Stretching and a percentage of 1.00 for all three input bands.

- Click Show and OK. After calculating the map the Display Options dialog box is opened. Click on OK. The false color composite is displayed.

In this image you can see more clearly the different land cover units. As you can see water is shown in blue green colors, vegetation in red colors, clouds and bare soils (e.g. sand bars) in white, and shadows in black. Now you will evaluate how these classes are shown in the three individual bands.




- Open the pixel information window and add the maps Mf187\_1w, Mf187\_2w and Mf187\_3w to it. If you move the mouse pointer through the image you see the values of three input bands.
- Zoom in on certain parts of the map with water, vegetation, clouds, shadows and bare soil. Note in the table below the DN values per band of the given land cover types.
- Calculate the band ratio 3/1 using the ILWIS pocket line calculator. For example, if you want to calculate 34/45, you type ?34/45↵ on the command line of the Main window. Select at least 5 pixels per cover class.

Table 2.2: Fill in the DN values for the indicated bands and cover types. Also calculate the ratio 3/1


| Cover type | Band 1 | Band2 | Band3 | Band3/Band1 |
|------------|--------|-------|-------|-------------|
| Water      |        |       |       |             |
| Water      |        |       |       |             |
| Water      |        |       |       |             |
| Water      |        |       |       |             |
| Water      |        |       |       |             |
| Vegetation |        |       |       |             |
| Vegetation |        |       |       |             |
| Vegetation |        |       |       |             |
| Vegetation |        |       |       |             |
| Vegetation |        |       |       |             |
| Clouds     |        |       |       |             |
| Clouds     |        |       |       |             |
| Clouds     |        |       |       |             |
| Clouds     |        |       |       |             |
| Clouds     |        |       |       |             |
| Shadow     |        |       |       |             |
| Shadow     |        |       |       |             |
| Shadow     |        |       |       |             |
| Shadow     |        |       |       |             |
| Shadow     |        |       |       |             |
| Bare soils |        |       |       |             |
| Bare soils |        |       |       |             |
| Bare soils |        |       |       |             |
| Bare soils |        |       |       |             |
| Bare soils |        |       |       |             |

As you can see from the results we cannot differentiate the water from vegetation in band 1. In band 3 we can differentiate the two, but then shadows will also have a low reflectance. That is why, if we take the ratio of band 3 and band 1, we can differentiate the water.

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  - Close the map window and the pixel information window.

### 2.3 Computation of Band ratio's

Now you will calculate the ratio of bands 3 and 1.

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  - Type the following formula on the command line:  

$$B_{r3/1} = M_{f187\_3w} / M_{f187\_1w}$$

- The Raster map definition dialog box is opened. Click the Create domain button. The Create Domain dialog box is opened.  
Type `Ratio` for the domain name. Select the domain type `Value`. Click OK. The Domain Editor is opened.
- Enter 0 for `Min`, 10 for `Max` and 0.01 for the `Precision`. Click OK. You are back in the Raster Map Definition dialog box. Change also here the value range to 0 and 10. Click OK.
- Double-click the map `Brmf1`. Make sure the representation `Gray` is selected in the Display Options dialog box. Accept the defaults and click OK.
- The map `Brmf1` is shown in gray tones. Read the values in the map and see if you can now differentiate between the water and the rest. Also consult the histogram for this. Find the critical value that limits water from land.

To find out the limiting value for differentiating land and water, it is helpful to create a representation, with two colors (blue and green). All pixels with values below the limit will be displayed in blue (water), and those with higher values in green (land). When you change the limit, the display changes as well, and you can evaluate if all the water pixels are classified as water. This way you can interactively find out the best value for differentiating land and water.



- When you have an idea about the boundary value, double-click the `New Repr` item in the Operations-list. The `Create Representation` dialog box is opened. Enter `Ratio` for the Representation name, and select the domain `Ratio`. Click OK. The Representation Editor is opened.
- In the `Edit` menu of the Representation Editor, select `Insert Limit`. Enter the critical value that differentiates between land and water (for example 0.5), and select the color `blue`. Click OK.
- Activate the map window, and press the right mouse button while the mouse pointer is on the image. Select map `Brmf1` from the context-sensitive menu. The Display Options dialog box is opened.
- Select the representation `Ratio` and click OK. Now the map `Brmf1` is redisplayed, according to the representation `Ratio`.
- Activate the Representation Editor again. Change the color of the limit 10 to `Green`. Double-click on the word “stretch” between the limits until it changes to “upper”.





- Press the **Redraw** button in the map window. Now the map is shown in two colors: blue (water) or green (land). Evaluate if the limit 0.5 is correct for differentiating water and land. If not change the limit in the Representation Editor, and press the **Redraw** button again in the map window.

When you are sure about the value for differentiating land and water, you can use the **Slicing** operation, to change the ratio image into a class map. For the **Slicing** operation, a group domain is required.



- Create a domain **Mf1** (you do this by selecting the menu items **File, Create, Create Domain** from the Main window). The domain should be **class** and **group**. Press **OK**. Now you can enter the boundary values and the names of the classes. Select **Edit, Add Item** and fill in the value that you found earlier as the boundary value, and **Watermf1** as the name. Press **OK**. Add another class: **Landmf1** with as boundary value the maximum value in the map. Close the Domain Editor.
- Now use the **Slicing** operation (by selecting the menu items **Operations, Image processing, Slicing** from the Main window). Use **Brmf1** as input map, **Mf1** as domain, and **Mf1** as output map.
- Display the map **Mf1**, and compare it with the image **Brmf1**.

Now you have a class map, indicating the flooded area during the moderate flood of 1987.



- Follow the same procedure for the images of the other two dates: 9-1-1987 (dry season by making a band ratio map **Brdry**, a domain **dry**, with the classes **Waterdry**, and **Landdry** and a final map **dry**) and 10-10-1988 (severe flood: by making a band ratio map **Brfl**, a domain **fl** with the classes **Waterfl**, and **Landfl** and a final map **Fl**).
- Create a false color composite using the three bands from 10-10-1988. Name the resulting map **Fl88fcc**.



- Display the image F188f00 and the maps Dry, Mf1, F1 all together on the screen. Compare them.
- Close the map window.

## 2.4 Combining the three water level maps

You now have three maps which show the difference in land/water for three periods: the dry season of 1987, the moderately severe flood of 1987, and the severe flood of 1988. These maps will be combined into one final map, using the Crossing operation.



- Cross the maps Dry and Mf1, create a cross map and a cross table, both called Drymf1.
- Cross the maps Drymf1 and F1, create a cross map and a cross table, both with the name Final.
- Convert the domain Final from Identifier to Class, by pressing the Convert to Classes button in the Properties dialog box.
- Create a representation Final.
- Create annotations for the map Final and store the result as a map view.
- Calculate the percentage of the different classes of the output map.

## References

- Alexander, D. (1993). *Natural disasters*. UCL Press Ltd., University College London. 632 pp.
- Asaduzaman, A.T.M. (1994). *A geomorphologic approach to flood hazard assessment and zonation in Bangladesh, using Remote Sensing and a geographic information system*. MSc thesis, ITC, Department of Earth Resources Surveys. Enschede. 85 pp.
- Maathuis, B.H.P (1993). *Flooding Bangladesh: ITC Demo*. CZM Toolbox, tools and applications for Coastal Zone Management, World Coast Conference 1993, pp. 15-18 (+demo diskette).
- van Westen, C.J. (1993). Remote sensing and geographic information systems for geologic hazard mitigation. *ITC Journal* 1993-4: 393 - 399.