

# Layer tinting and shading

By:

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## Summary

Landforms are usually shown on maps by means of contour lines, spot heights, layer tints and/or hillshadings or a combination of these representation methods. This application shows the steps for the production of a layer-tinted map, portraying the volcanic range of SE Luzon Island, the Philippines. The layer-tints (coloured height zones) show the major elevation structures. The map is combined with a hill shading, to show the detailed land forms. All the maps, including two 3-dimensional perspective views, are derived from a digital elevation model.

## Getting started

The data for this case study are stored on the ILWIS 2.1 CD-ROM in the directory `d:\appguide\chap25`. 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\chap25`. 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\chap25`.

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

## 25.1 Visualization of the input data

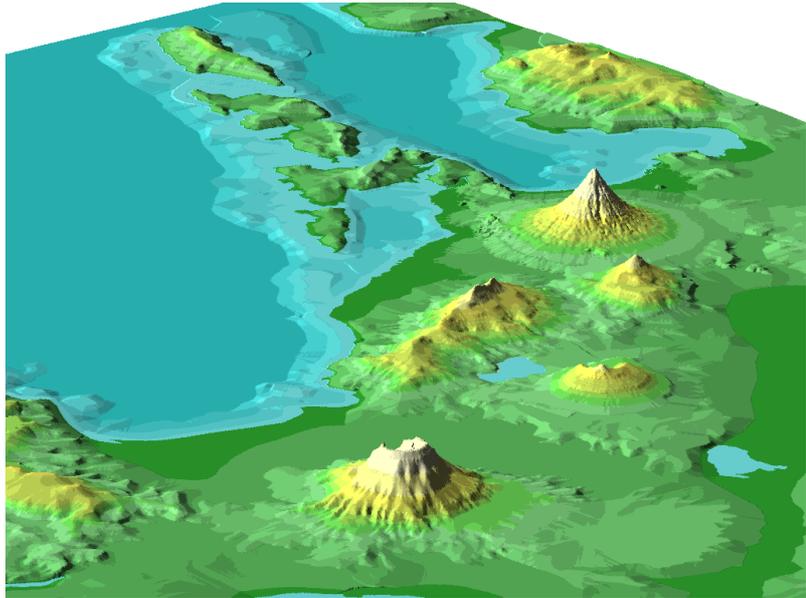


Figure 25.1: Three-dimensional view of the study area in SW Luzon island, Philippines. The upper right volcano is the Mayon volcano, near Legazpi city

The Digital Elevation Model of the area is the starting point for the production of the maps. The DEM is derived from contours at an interval of 50 m. The contours were digitised from topographic maps at a scale 1:50,000.



- Display the map DemLuzon, the digital elevation model.

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! Examine the digital elevation model and answer the following questions:  
What is the Domain of the map?  
What is the minimum and maximum height value?  
What is the resolution (pixel size) of the DemLuzon?  
Is the resolution adequate, considering the source and the products to be generated?  
Note that the output scale of the final map will be 1:250,000.

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The following steps are required to produce the layer-tinted map with shading

1. Create a height zone map (classify the digital elevation model) and an appropriate colour representation to portray the height-zones.

2. Calculate a relief shaded image from the digital elevation model.
3. Combine the height zone map (a class map) with the relief-shaded image (a value map) by means of a Red, Green and Blue transformation.

The following steps are required to produce the colour-coded 3-dimensional perspective views:

1. Create the 3d-views by means of the digital elevation model.
2. Assign the colour representation table for the layer tints to the 3d-views.

## 25.2 Create a height zone map (layer-tinting)

A frequently used method of presenting land-surface information on wall maps, in atlases, and on 'physical' maps is layer-tinting. Layer-tinting is actually applying area symbols to the zones between contours. The map of Luzon Island portrays height and sea-depth zones by means of tinted colours (layer-tints). The choice of the number and range of the height-zones depends very much on the relief and the scale of representation. In this case study 3 height zone classes below sea-level and 9 classes above sea-level have been selected.



- Create a domain Zone (type Class Group) by selecting **File, Create, Create Domain** in the ILWIS main menu. A dialog box will be opened.
- Select **Edit, Add Item** and add the upper-value boundaries and output group names as indicated in table 25.1.
- Classify the value map DemLuzon (the digital elevation model) with the domain Zone by typing the following statement on the command line of the main window:  

```
Zone=CLFY(DemLuzon, Zone)↵
```
- Open the representation Zone As table and change the colors according to the values of table 25.1.
- Display the height map Zone.



Note that the standard colour representation table does not give appropriate colour ranges for the representation of the layer tints. You can edit the colour representation for each class.

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Table 25.1: The boundaries, class names and Red, Green, Blue values of the domain Zone

Bound	Name	Red	Green	Blue
-100	lower than -100 m.	0	255	230
-50	from -100 to -50 m.	96	243	235
-10	from -50 to -10 m.	155	255	223
0	from -10 to 0 m.	205	255	255
20	from 0 to 20 m.	0	255	164
100	from 20 to 100 m.	66	255	134
200	from 100 to 200 m.	128	255	120
300	from 200 to 300 m.	166	255	88
400	from 300 to 400 m.	146	255	0
500	from 400 to 500 m.	255	255	80
750	from 500 to 750 m.	255	215	121
1000	from 750 to 1000 m.	255	167	101
1500	from 1000 to 1500 m.	255	197	154
3000	from 1500 to 3000 m.	255	255	255

It is also possible to change the colour representation without classifying the map by creating a **Value** representation, linked to the map DemLuzon.



- Create a representation `Zonecol1` for the domain `DemLuzon`.
- Enter the limits in this representation as shown in table 25.2:  
Change the number of stretch steps: 20.
- Display the map `DemLuzon`, using the representation `Zonecol1`.

Table 25.2: Representation Zonecol1

Limit	Color
-200	Blue
-10	Royal Blue
0	Turquoise
20	SeaGreen
200	Green
1000	Yellow
2000	Orange
2500	White

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! This colour scale, ranging from blue via light green to an orange-brown tint, is a rather traditional colour scale to represent relief. The differences between the colour zones are clear, but the highly saturated colours makes it not very suitable for use on printed maps (notice also that saturated colours printed on an ink-jet printer appear very dark).

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A more appropriate colour scale to portray height-zones on maps is ranging from a light colour tone, for the lower altitudes, to a dark colour tone, for the higher altitudes (Wang and Brown, 1991). The colours are less saturated and the hue differences are smaller. These colour scales are intended for use on a map. The colour scales shown below are examples.

Examples of colour scales for layer tints (from a light colour tone, i.e. light green to a dark colour tone, i.e. brown) are shown in tables 25.3, 25.4 and 25.5.

- Create three value representations: Zonecol2 (table 25.3), Zonecol3 (table 25.4) and Zonecol4 (table 25.5). You can define colors in red, green, blue by clicking the **Create** button next to the color list box in the **Edit Limit** dialog box. Display the map Demluzon with these three representations and compare them.

Table 25.3: Representation Zonecol2

limit	Red	Green	Blue
-200	230	255	230
0	230	255	128
20	230	204	77
300	166	77	0
3000	77	0	0

Table 25.4: Representation Zonecol3

limit	Red	Green	Blue
-200	230	255	230
0	230	230	166
20	230	166	128
300	204	77	0
3000	77	0	0

Table 25.5: Representation Zonecol4

limit	Red	Green	Blue
-200	230	255	230
0	166	225	166
20	166	204	77
300	166	128	0
3000	77	0	0

Notice that all these colour scales start and end with the same colour.

## 25.3 Calculating a relief-shaded map

Contours accurately portray elevations, but a contour map does not look very realistic.

A more realistic way of landform portrayal is a pictorial method, by varying dark and light. Smooth tonal variations from light to dark are easier to read by the map user and details in land-surface form can be shown. This method of portraying the land-surface form is called *hill-shading*. It is also known as relief-shading, or simply shading.

Spatial filters are commonly used to calculate relief shading maps from a digital elevation model. ILWIS has a standard spatial filter, the filter **Shadow**, that calculates a hillshading with the illumination coming from the upper left (that is, north-west if the map is oriented with north at the top). On most maps, hillshadings are shown with illumination coming from the upper left.



- Apply the linear filter **Shadow** to the map DemLuzon (the digital elevation model). The output map Shad should have a precision 1.0.
- Stretch the raster map Shad and call the output map Shads. Make an output domain Shad (type **Value**, with value range between 0 and 1, and precision 0.01).
- Display the relief-shaded map (Shads) using the representation **Gray**.

In oblique illuminations, light coming from any direction other than the zenith, the shading depends on its orientation relative to the direction of the incoming light.

Oblique illuminations are calculated by taking the inner product between the unit surface normal vector and the light source vector with a given elevation and direction (Pickering, 1990).

1. Unit Surface normal vector:

$$N' = \frac{1}{\sqrt{\Delta Z_x^2 + \Delta Z_y^2 + d^2}} * \begin{bmatrix} -\Delta Z_x \\ -\Delta Z_y \\ d \end{bmatrix} = \begin{matrix} n_1 \\ n_2 \\ n_3 \end{matrix} \quad [25.1]$$

2. Unit Light source (sun) vector:

$$S' = \begin{bmatrix} \sin\gamma & \sin\delta \\ \sin\gamma & \sin\delta \\ \cos\delta \end{bmatrix} = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix} \quad [25.2]$$

$$\gamma = (90^\circ - \alpha) \quad \gamma = \text{sunazimuth}$$

$$\delta = (90^\circ - \beta) \quad \delta = \text{sunelevation}$$

3. Inner product:

$$\cos\theta_{n,s} = n_1s_1 + n_2s_2 + n_3s_3 \quad [25.3]$$

$$\cos\theta_{N,S} = \frac{(-s_1\Delta Z_x - s_2\Delta Z_y + s_3d)}{\sqrt{\Delta Z_x^2 + \Delta Z_y^2 + d^2}} \quad [25.4]$$

where,

$\Delta Z_x$  = height difference in X - direction

$\Delta Z_y$  = height difference in Y - direction

$d = 2 * \text{grid cell}$

A shading with the illumination coming from the lower right (that is, south-east if the map is oriented with north at the top) is calculated below. The sun azimuth angle equals to 135 degrees and the elevation angle equals to 20 degrees



- Apply the linear filters Dfdx and Dfdy to calculate the height difference in X and Y directions from the digital elevation model (DemLuzon). Call the output maps Dhx and Dhy.
- Stretch the maps Dhx and Dhy between 0 and 255. Call the result Dhxs and Dhys.
- Type the following formula to calculate the shading with the light source coming from the south-east:

$$\text{Shadse} := ( (-0.66 * \text{Dhxs}) + (0.66 * \text{Dhys}) ) / \sqrt{(\text{Dhxs} * \text{Dhxs} + \text{Dhys} * \text{Dhys})}$$

Notice that the lower the elevation of the light source, the more you emphasise the low relief forms, but it decreases the visibility of detail in the darkened areas.

## 25.4 Combine height zone and relief-shaded map

The height-zones (layer-tints) can be made more meaningful if we combine them with shading. The height zones present major structures, while the shading shows some details of the land forms

To combine the height zone map and the relief-shaded map you separate the height zone map into Red, Green and Blue maps. Then the Red, Green and Blue maps are multiplied by the shading. After stretching a colour composite can be generated from the new Red, Green and Blue maps.



- Create a map `Zonocol` using this formula:  
`Zonocol := Mapcolor ( Zone ) ↵`
- Select Operations, Image Processing, Color Separation from the menu in the Main window. Use `Zonocol` as the input map and mark the red box; the output map is called `Zonered`.
- Repeat the same procedure but marking the green and the blue boxes and call the output maps `Zonegree` and `Zoneblue`, respectively.

The red, green and blue maps separated are then combined with the shading.



- Type the following formulas on the command line to combine the separates with the shading (make sure to select the output domain image for the three maps):  
`Shadred := Zonered * Shads ↵`  
`Shadgree := Zonegree * Shads ↵`  
`Shadblue := Zoneblue * Shads ↵`

The new red, green and blue separations now have varying values, depending on the hillshading, between 0 and 255. You can now combine the three again by creating a color composite.



- Select Operations, Visualisation, Color Composite from the menu bar. Clear the option 24 bit, select Standard, Linear Stretching, and clear the check box Percentage:

Red Band: Shadred

Green Band: Shadgree

Blue Band: Shadblue

The output map is Shadzone (mark the Show box).

- Display the result Shadzone.

As you can see the colors are a bit dark. This is caused by the fact that the individual red, green and blue components are multiplied by the hillshading (Shads), which has a value between 0 and 1. So flat areas will have a value of 0.5, resulting in colors with lower intensities.



- To improve the result you could stretch the map Shad again, but now to a map Shadsn, with a value domain between 0.5 and 1 (precision of 0.01).
- Multiply the map Shadsn with the maps Zonerred, Zonegree and Zoneblue, and create the maps Shadnred, Shadngre, and Shadnblu (all with image domain).
- Combine these as a color composite, as explained before, and create the map Shadzon2.
- Display the result Shadzon2.
- You can also get better results by improving the colours of the map Zone.

## 25.6 Map compilation

After generating the layer tinted map (Shadzon2) you can combine it with contour information and the road and drainage network in order to make a result map.



- Screen-digitise spot heights for the volcanos from the Digital Elevation Model and save the spot heights in a point map called `Spotheig`.
- Display the map `Shadzon2`.
- Display the segment map `Topo` (topographic features such as roads and streams), edit the representation, and add the map to the map window of the map `Shadzon2`.
- Display the segment map `Contours` (assign a brown colour to the contours) and add it also to the map window. You could also first copy the 100 meter contour lines in separate file, and use that instead.
- Create a representation for the point map `Spotheig` and add it to the map window.
- Add annotation items (scale bar, title, grid lines, etc.) and zoom into a scale 1:250,000 (the output scale of the printed map). Save it as a view.

Note: Contours present a less strong visualisation of the landform surface than hill shading, but they provide more information to the skilled map reader than a hill shading.

The contours on the resulting map show too much detail and complexity. They do need some simplification (generalisation).



- Create two 3-dimensional views for the map `Shadzon2`. One view, `ViewSE`, is viewing from the South-East and the other, `ViewNW`, is viewing from the North-West.

## References

- Wang, Z.S. and Brown, A. (1991). A knowledge based system for selection of area colours for maps from a Colour Chart. *Proceedings 15<sup>th</sup> ICC*, Bournemouth.
- Pickering, R.P. (1990). *Digital image analysis of SPOT Multi-spectral data for topographic mapping*, Msc. Thesis ITC-Enschede, The Netherlands.
- Robinson, A.H., Morrison, J.L., Muehrcke, P.C., Kimerling, A.J. and Guptill, S.C. (1995). *Elements of cartography*, 6<sup>th</sup> edition, Wiley.