Chapter 7

# Operations

## 7.1 Visualization

### 7.1.1 Show Map or other object

Select a map, table, or any other object and show/open it in a new window.

This dialog box appears:

- when you choose Open from the File menu in the Main window,
- when you choose Visualization, Show Map from the Operations menu in the Main window,
- when you double-click the Show item in the Operation-list,
- when you click the Show Map button in the button bar of the Main window,
- when you choose the Open Map Window command from the File menu in an existing map window.

**Dialog box options**

| | |
|---|---|
| Select an object: | Select an object which you want to open in a new window. |
| Select object type: | Select the type of object you want to open: a map, a table, a map list, a map view, a domain, a representation, a georeference, a coordinate system, a histogram, etc. |
| Directories: | If necessary, change the current directory. |
| Drives: | If necessary, change the current drive. |

A map is displayed in a new map window. A Display Options dialog box appears to set display options for the map. To display multiple maps in one map window, use the Add Data Layer command on the Layers menu of a map window. A table is displayed in a new table window.

When the selected object is not open yet, it is opened in a new window. When the selected object is already open, this object is restored and that window becomes the active window.

☞ To open a map or table or any other object, you can also double-click it in the Catalog, or click the right mouse button on the object in the Catalog and select Open from the context-sensitive menu.

☞ To make domains, representations, georeferences, coordinate systems, or histograms, etc. visible in the Catalog, use the Catalog command on the Options menu of the Main window.

- ☞ To view the contents of system objects, change the drive and directory to the drive and directory where the system objects are located (e.g. \ILWIS21\SYSTEM).
- ☞ You can also open objects by typing the Open or Show command on the command line of the Main window. For more information, see Appendices : ILWIS commands.

## 7.1.2 Color composite

## Functionality

A color composite is created by combining 3 raster images (bands/maps). One band is displayed in shades of red, one in shades of green and one in shades of blue. Either the standard color composite representation is used or a new representation is created.

A color composite can be created in various ways:

- Standard:
  - Linear stretching: input values are linearly stretched; user-defined input intervals;
  - Histogram equalization: input values are equally divided over output colors; user-defined input intervals;
- Dynamic (Heckbert): input values are automatically distributed over a user-defined number of colors.

The different methods of creating a color composite are merely a matter of scaling the input values over the output colors. The exact methods by which this is done are described in Color Composite : algorithm.

**General information on color composites**

- A color composite gives a visual impression of 3 raster bands. Putting the three bands together in one color composite map can give a better visual impression of the reality on the ground, than by displaying one band at a time. Examples of color composites are false color (or IR) images and 'natural color' images.
- The input pixel values of each band are measures of the amount of reflection in a certain wavelength interval. The values in the output color composite map just refer to certain colors; the output values themselves have no meaning.
- Color composites can be created to be able to locate the spots where the bands should be sampled (for sampling and subsequent image classification), for visual interpretation or just for illustration purposes.
- Before creating a color composite, you might filter the bands in order to increase sharpness of features of interest.

**Input map requirements**

The three input maps should use domain Image. A georeference is not required for the input maps. If the maps do have a georeference, all input maps should use the same georeference.

**Domain of output map**
For a standard color composite: the operation always uses system Picture domain `ColorCmp` for the output color composite. This domain always uses system representation `ColorCmp`. For a dynamic color composite: the operation creates a new domain (type Picture) for the output color composite and a new representation for this domain. This output domain and representation are always stored by the output map (internal domainand internal representation).

**Georeference of output map**
The output color composite always uses the same georeference as the input maps.

☞ If the user is interested in the image as a whole, it is best to use the Dynamic option. This usually results in a composite with good contrast. The Dynamic option does not take into account the structure of the input bands. Therefore, if the user is interested in specific intervals of the input bands, it is better to use the Standard option, using linear stretching. However, if the pixels that are of less interest can be masked, the user can calculate a Heckbert composite using only the pixels that are of interest.

☞ For more information on internal domains and representations, refer to How to open internal domains/representations.

## Dialog box

A color composite is created by combining 3 raster images or maps. One map is displayed in shades of red, one in shades of green and one in shades of blue.

**Dialog box options for 24 Bit Color Composite**

24 bit: Select this check box if you want to create a map that can be displayed in 24-bit graphic mode (domain Color). Clear this check box if you want to create a domain Picture color composite.

RGB: Creates a 24 -bit color composite with Red, Green and Blue bands as input. See Standard Color Composite options below.

HSI: Creates a 24-bit color composite with Hue, Saturation and Intensity bands as input.

Only select the options above, if your graphic board is configured for 24-bit display.

**Dialog box options for Standard Color Composite**

◉ Standard: Select the Standard option button when you want to use the standard color composite representation which has six shades of red, six shades of green and six shades of blue (total 216 colors).

Linear Stretching: Select Linear Stretching if you want to obtain intervals of equal length (in terms of input values) for the output colors.

Histogram equalization: Select Histogram Equalization if you want to obtain an equal number of pixels for the different output colors.

| | |
|---|---|
| Percentage: | Select this check box to define input intervals by a percentage of pixels to be ignored on both sides of the input map's histogram. Clear this check box to specify input intervals by a minimum and maximum value of each input map. |

**Dialog box options for Dynamic (Heckbert) Color Composite**

| | |
|---|---|
| ◉ Dynamic: | Select the Dynamic option button when you want an automatic division of input values over a number of output colors. |
| Colors: | Enter a value for the number of colors of which the dynamic color composite should consist (integer value between 3 and 255). |

**General dialog box options**

| | |
|---|---|
| Red Band: | Select a raster map to be displayed in shades of red. Open the list box and select the appropriate raster map, or directly drag a raster map from the Catalog into this box. |
| Green Band: | Select a raster map to be displayed in shades of green. |
| Blue Band: | Select a raster map to be displayed in shades of blue. |
| Output raster map: | Type a map name for the output color composite. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created. When the Dynamic option is used, the output map will use an internal Picture domain which has an internal representation.

## Command line

A color composite can be directly created by typing one of the following expressions on the command line of the Main Window:

OUTMAP = `MapColorCompLinear`(MapList, range1, range2, range3)

OUTMAP = `MapColorCompHistEq`(MapList, range1, range2, range3)

OUTMAP = `MapHeckbert`(MapList, NrColors)

where:

| | |
|---|---|
| OUTMAP | is the name of your output color composite. |
| `MapColorCompLinear` | is the command start the Color composite operation using linear stretching. |
| `MapColorCompHistEq` | is the command to start the Color composite operation using histogram equalization. |
| `MapHeckbert` | is the command to start the Color composite operation using the Heckbert dynamic algorithm. |
| MapList | is the name of your input map list. |
| range1..3 | interval of input values for each input band as *min:max* or as *perc* |
| *min:max* | minimum and maximum value determining range of input values, e.g. 20:200; integer values between 0 and 255. |
| *perc* | percentage of input values to be ignored on both sides of the maps' histogram during linear stretch or histogram equalization; 0 <= real value < 50. |
| NrColors | are the number of colors present in the output map (3 - 255). |

All maps in the input map list must have the same georeference.

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated. When the Dynamic option is used, the output map will use an internal Picture domain which has an internal representation.

You may define an inline map list on the command line itself:

OUTMAP = `MapHeckbert`(`mlist`(image1, image2, image3), NrColors),etc.

where:

| | |
|---|---|
| OUTMAP | is the name of your output map. |
| `MapHeckbert` | is the command to start the Color composite operation using the Heckbert dynamic algorithm. |
| `mlist` | is the command to indicate that an inline map list is defined. |
| image1..3 | are the names of the images to be used in the map list. |
| NrColors | are the number of colors present in the output map (integer value between 3 and 255). |

## Algorithm

### Standard color composites

**Linear stretching of interval**
The specified interval range per band is linearly divided into 6 classes of equal length with numbers 0 to 5. Since this is done for three bands, the number of possible combinations is 6x6x6 = 216. This is the number of different colors that will appear in the color composite.

**Histogram equalization**
The specified interval range (lower and upper boundary) per band is divided in 6 classes with numbers 0 to 5, in which each class has an equal area under the histogram. As for linear stretching, the number of different output colors is 6x6x6 = 216.

**Output colors**
Each output color obtains an internal number of the system picture domain `ColorCmp`; this value is calculated from the following formula:

output = 36*red + 6*green + blue

This implies that the output map will contain internal values between 0 and 215 (since 215 = 5 * 36 + 5 * 6 + 5). The values of this `ColorCmp` domain are always linked to system representation `ColorCmp`.

### Dynamic color composites

A dynamic color composite is calculated using the Heckbert Quantization Algorithm. The Heckbert algorithm produces a color composite on the basis of the amount of variation in pixel values in the three input maps. This algorithm first builds a three dimensional histogram, indicating how 'popular' any given value is in the images. This is one box. This histogram is then subdivided into smaller boxes: a division occurs in the middle of the axis which has the largest variation. This process continues until it has created as many boxes as there are output colors (number defined by the user, maximum 230). This algorithm attempts to create boxes which have approximately equal popularity in the image. Then, colors are assigned to represent each box.

1. First, the input map values at 1% and 99% are determined. See also the Histogram operation.
2. The band with the largest variation in pixel values is selected, the total number of pixels for this band is calculated, and the band is divided into 2 halves, each containing half of the total number of pixels. The division leaves the other 2 bands intact. The result after one division is 2 so-called 'boxes': one band divided over both boxes, and the other 2 bands complete in both boxes.
3. The program then searches for the next (part of a) band with the largest variation in pixel values. The total number of pixels on that (part of the) band is calculated, the (part of a) band is divided into 2 halves, so that each new part of the band contains half of the total number of pixels, and the other 2 bands are left as they were. The result after 2 divisions is 3 'boxes': each with (parts of) the red, the green, and the blue band.
4. The division process is repeated until the total number of 'boxes' reaches the number of user-defined colors desired for the output map.
5. Then colors are assigned to all boxes. For each box, weighted averages are calculated of the parts of the red band, green band and blue band covered by that box; the outcome values are the Red, Green and Blue values for that box. The calculation is repeated for all boxes.

An example of the first and second division is given in Figures 1, 2 and 3 below.

**Reference**
Heckbert, P., 1982. Color image quantization for frame buffer display. SIGGRAPH '82 Proceedings, p. 297.

**Example Heckbert algorithm**
Three 1% histograms are calculated before the first division, see Figure 7.1:

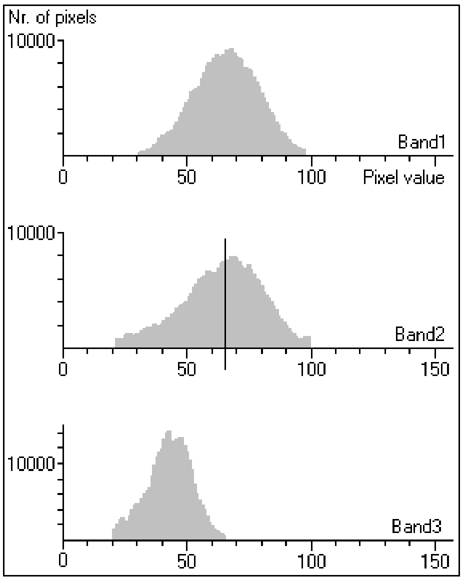


Figure 7.1

Figure 7.1 shows that the pixel values range:

- from 31 to 98 in the first input map
- from 22 to 100 in the second input map and
- from 21 to 66 in the third input map.

Thus, the largest variation is found in the second input map. The total number of pixels on this band is divided in 2 so-called 'boxes': the first division is at pixel value 65 of band 2.

The result of the first division is represented in Figures 2 and 3. Figure 2 shows the histograms of one box; Figure 3 the histograms of the other.

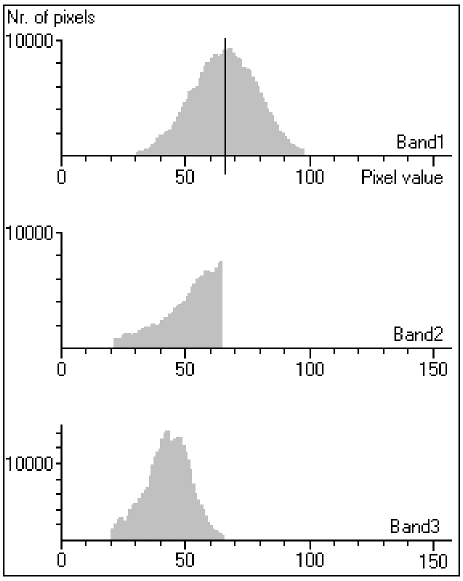


Figure 7.2

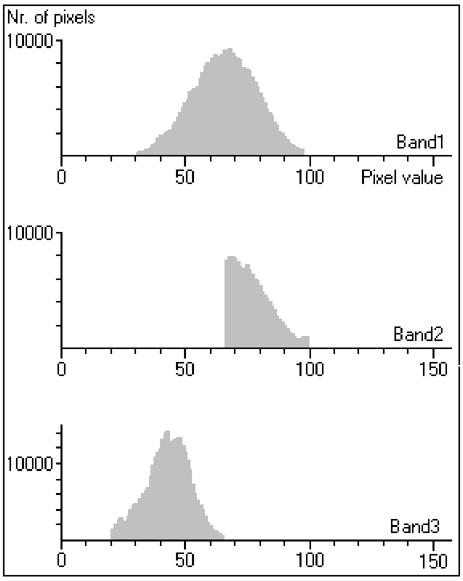


Figure 7.3

Figure 7.2 shows that the pixel values range in box 1:

- from 31 to 98 in the first input map
- from 22 to 65 in the second input map, and
- from 21 to 66 in the third input map

Figure 7.3 shows that the pixel values range in box 2:

- from 31 to 98 in the first input map
- from 66 to 100 in the second input map, and
- from 21 to 66 in the third input map.

The next largest variation is found in the first input map in box 1. The total number of pixels on this band divided into 2 parts: the next division takes place at pixel value 66.

**Output domain for dynamic composites**

The operation creates a new domain (type Picture) for the output color composite and a new representation for this domain. This output domain and representation are always stored by the output map (internal domain and internal representation).

### 7.1.3 Display 3D

With Display 3D, you can create and edit a georeference 3D in order to obtain a three dimensional view of one or more maps. A Digital Terrain Model (DTM), also called a Digital Elevation Model (DEM), is required to create a georeference 3D. For more information on creating a DEM, see How to calculate a DEM.

By relating any map with the corresponding terrain surface in a 3D model, you can discover and understand relations between spatial data sets. For example, by draping a land use map over the height values of a 3D model, you can see where your areas of interest are located: on slopes, on flat areas, in the lower areas, in the mountains, etc.

Although Display 3D was originally developed to model relief, it can of course also be used to model the continuous variation of any other value map as a surface (e.g. concentration values, land values).

1. When you start the Display 3D operation, first the Display 3D dialog box appears. Create a new georeference 3D or select an existing one.
2. Then, the Display Options - 3D Grid dialog box appears. Specify whether the DEM should displayed as 3D grid lines with or without a drape of a raster map (preferably a raster map with a class domain).
3. Subsequently, the DEM is displayed in a map window which uses the georeference 3D.
4. To edit the georeference 3D, you have to start the Georeference 3D editor: choose Georeference from the Edit menu in the map window. The large Georeference 3D editor : Edit dialog box appears.
5. When finished editing the 3D view, close the Georeference 3D editor and return to the map window.
6. In the map window, you can add point, segment and/or polygon maps and/or annotation to improve the 3D view.

## 7.1.4 Apply 3D

### Functionality

The Apply 3D operation resamples an input raster map according to a georeference 3D. This enables you to permanently and quickly display the output raster map in three dimensions, i.e. as a 3D view. To create a georeference 3D, you need a Digital Elevation Model (DEM) and you have to specify 3D view parameters in the georeference 3D editor. For more information, see Georeference 3D editor.

- In Display 3D, the georeference 3D can be used to drape a raster map over your height model, but in Apply 3D, an input raster map is resampled according to the georeference 3D. The resampled output map will then always appear in a map window as a 3D view.
- In Display 3D, the calculations to drape a raster map over your height model are performed on the fly and display may therefore be slow, but the resampled output raster map of Apply 3D can be efficiently displayed in a map window as no more complicated 3D calculations have to performed; these are handled by the Apply 3D operation.

The functionality of the Resample and the Apply 3D operations are comparable. With the Resample operation, you can resample a raster map to any georeference. The Apply 3D operation is designed to resample a raster map to a georeference 3D but the resampling process has the same result as using the Resample operation.

When the output raster map of Apply 3D is displayed in a map window, you can add extra point, segment and polygon maps to enhance the 3D view. As usual, you can save the contents of the map window a map view.

**Input map requirements**
No special requirements for the input raster map. Further, a georeference 3D is required which you can create and modify according to your wishes with Display 3D or Apply 3D and the Georeference 3D editor.

**Domain and georeference of output map**
The output raster map uses the same domain as the input raster map. The output raster map uses the georeference 3D as specified by the user.

☞ To obtain rotating 3D views in a map window:

- prepare a number of 3D views (georeferences 3D) that depict the same area but for instance from different angles,
- perform the Apply 3D operation a number of times on one input map, using the various georeferences 3D and specifying different output map names,
- combine the output maps in a map list and show the map list as a slide show.

For more information on slide shows, see How to display a map list as a slide show.

## Dialog box

The Apply 3D operation resamples an input raster map according to a georeference 3D. This enables you to permanently and quickly display the output raster map in three dimensions, i.e. as a 3D view.

You can create a georeference 3D with Display 3D or Apply 3D, a Ditigal Elevation Model is required and you have to specify 3D view parameters using the Georeference 3D editor.

**Dialog box options**

| | |
|---|---|
| Input raster map: | Select an input raster map. Open the list box and select a map, or drag a raster map directly from the Catalog into this box. |
| Output raster map: | Type a name for the output raster map that is resampled to a georeference 3D. |
| Georeference: | Select an existing georeference 3D for the output raster map or create a new georeference 3D by clicking the create button. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created.

## Command line

The Apply 3D operation can be directly executed by typing the following expression on the command line of the Main window:

OUTMAP = `MapApply3D`(InputMapName,Georef3D)

where:

| | |
|---|---|
| OUTMAP | is the name of your output raster map. |
| `MapApply3D` | is the command to start the Apply3D operation. |
| InputMapName | is the name of your input raster map. |
| Georef3D | is the name of an existing georeference 3D. |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated.

## Algorithm

The Apply 3D operation resamples an input raster map according to a georeference 3D. This enables you to permanently and quickly display the output raster map in three dimensions, i.e. as a 3D view.

You can create a georeference 3D with Display 3D; a Ditigal Elevation Model is required and you have to specify 3D view parameters using the Georeference 3D editor.

The operation is based on the display of a 3D view in a map window. For each pixel in each row of the input raster map, the position of its four corners is determined in the 3D view and the area between the four corners is filled with the class name or value of the raster drape.

The order of drawing is determined by the orientation of the 3D view:

- Rows or pixels that are farthest away from the observer are drawn first.
- Pixels that are closer to the observer are drawn later and consequently hide previously drawn pixels which are higher than previously drawn pixels.

If the coordinate system of the input map and the input georeference 3D are different but compatible, an automatic coordinate transformation is performed.

## 7.1.5 Slide Show

Select a map list in the Show Map List dialog box and show the map list as a slide show in a map window. All maps in the map list are displayed one after the other. A slide show is designed to present multi-temporal changes in maps.

Raster maps that you can include in a map list for a slide show may be:

- satellite images of the same area of for instance different months,
- derived products from satellite images, such as NDVI maps, of for instance different months,
- classified satellite images of for instance different months or years,
- thematic raster maps (e.g. land use maps) of for instance different years,
- to display a number of 3D views one after the other.

In a slide show, all maps in the map list will be displayed using one set of display options. When the maps in the map list use a class domain, a slide show always works fine. When the maps in the map list use a value domain, it is important that the range of value in the maps is approximately the same.

# 7.2 Raster Operations

## 7.2.1 Map calculation

### Functionality

For Map Calculation Functionality, see chapter 6.

### Dialog box

Map calculation can be used to perform calculations with raster maps. In the dialog box, type a MapCalc expression. For more information on the operators and functions that can be used, refer to Map Calculation. You can also type your map calculation expressions on the command line of the Main window.

**Dialog box options**

| | |
|---|---|
| Expression: | Type a MapCalc formula, for example `Map1+Map2`. |
| Output raster map: | Type a name for the output raster map. |
| Defaults: | Click this button to obtain a default domain. When the default domain is a value domain, you also obtain defaults for the value range and precision of the output map. You can also click this button to obtain defaults again after you changed the default domain, value range or precision. |
| Domain: | Accept the default domain, or select or create your own output domain. |
| Value range: | If the output map uses a value domain, accept the default value range, or specify your own range of possible values in the output map. |
| Precision: | If the output map uses a value domain, accept the default precision of output values, or specify your own precision. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created.

☞ When working with value maps, you can generally accept the default domain Value. You only need to select or create a user-defined value domain when the values have a specific meaning for which you have or want to create a meaningful representation.

## Algorithm

Your map calculation formula is processed in the following simplified way:

1. Tokenizer:
   - breaks the expression into tokens such as special characters (e.g. brackets, commas, +, *, /, <, >, =), composed tokens (e.g. <=, lt, >=, gt), strings, and values,
   - feeds the result to the parser.
2. Parser:
   - performs a simple syntax check on the tokens, for instance a check on the correct number of brackets,
   - translates the tokens into map names, tables names, column names, constants, operators (+, *), functions, variables, brackets, etc.
   - feeds the result to code generator.
3. Code generator:
   - performs an in-depth syntax check, for instance a check on the number and type of parameters for all functions and operators used,
   - determines the output domain, value range and georeference,
   - creates an instruction stack.
4. Calculator:
   - for each line of the maps carries out all instructions on the stack.

For efficiency reasons, the process is done line by line. This has the same result as when the instructions were carried out pixel by pixel.

**Example 1**

```
OUTMAP =  a+1
```

Stack contains following instructions:
load a
const 1
operator add
store

**Example 2**

```
OUTMAP =  (a+1) * (b+2)
```

Stack contains following instructions:
load a
const 1
operator add
load b
const 2
operator add
operator multiply
store

**Example 3**

```
OUTMAP =  iff(landuse="arable") and (slope<=20),
          "suitable", "not suitable")
```

load landuse
const "arable"
equal
load slope
const 20
less than or equal
and
const "suitable"
const "not suitable"
call iff
store

## 7.2.2 Attribute map of raster map

## Functionality

By creating an attribute map of a raster map, the class name or ID of each pixel in the original map is replaced by the value, class or ID found in a certain column in an attribute table.

A raster map using a Class or ID domain, can have extra attribute information on the classes or identifiers in the map. These attributes are stored in columns in an attribute table. The attribute table can be linked to the map to which it refers, or to the domain of the map. You can check whether an attribute table is linked to the raster map or to its domain through the Properties dialog box of the map or the domain.

**Example of creating an attribute map**
In the pictures below, an attribute map for pH is created for units A, B, C, and D in the input map.

Input map:

| | | | |
|---|---|---|---|
| B | B | C | D |
| A | A | C | D |
| A | A | C | C |
| B | C | D | A |

Attribute table:

| | pH |
|---|---|
| A | 6 |
| B | 3 |
| C | 4 |
| D | 5 |

Output attribute map:

| | | | |
|---|---|---|---|
| 3 | 3 | 4 | 5 |
| 6 | 6 | 4 | 5 |
| 6 | 6 | 4 | 4 |
| 3 | 4 | 5 | 6 |

**Input map requirements**

- the input map needs to be a map with a domain of the Class or ID type;
- the table, from which you want to choose a column, should use the same domain as the map;
- the attribute table can be linked to the map or to its domain;
- the attribute table should have one or more columns with attribute values, classes or IDs.

An attribute map can be created from any column with a value, class or ID domain, but not from a column using domain String.

**Domain and georeference of output map**
The output map uses the same domain as the specified attribute column. The output map uses the same georeference as the input map.

☞ This operation creates a permanent attribute map. To temporarily display an attribute map, you can select the option 'Attribute' in the Display Options dialog box when displaying a raster map.

☞ The colors in which an attribute map is displayed, depend on the domain of the specified attribute column:
- if you used a domain Class attribute column and this domain already has a user-defined representation, then this representation is automatically selected in the Display Options dialog box which appears when you display the attribute map. In the Display Options dialog box, you can also select another existing representation or create a new representation by clicking the create button.
- if you used a domain Value attribute column, you can either select one of the standard value representations or create your own representation by clicking the create button in the Display Options dialog box which appears when you display the attribute map.

☞ You can also create attribute maps of polygon maps, attribute maps of segment maps and attribute maps of point maps.

## Dialog box

By creating an attribute map of a raster map, the class name or ID of each pixel in the original map is replaced by the value, class or ID found in a certain column in an attribute table.

A raster map using a Class or ID domain, can have extra attribute information on the classes or identifiers in the map. These attributes are stored in columns in an attribute table. The attribute table can be linked to the map to which it refers, or to the domain of the map. You can check whether an attribute table is linked to the raster map or to its domain through the Properties dialog box of the map or the domain.

**Dialog box options**

| | |
|---|---|
| Input raster map: | Select an input raster map. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. The input map should be a map with a class or ID domain. |
| Table: | By default, the attribute table linked to the selected input map or to its domain is shown. In case you want to use another table, select a table with the same domain as the input map from the list box. |

| | |
|---|---|
| Attribute: | Select an attribute column from the attribute table. |
| Output raster map: | Type a name for the output raster map that will contain the attribute values. |
| Domain: | In case the output map uses a value domain, accept the default domain (the domain of the selected column), select another value domain or create a new value domain. |
| Value range: | Accept the default value range, or specify your own range of possible values in the output map. |
| Precision: | Accept the default precision of output values, or specify your own precision. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created.

## Command line

The Attribute map of raster map operation can be directly executed by typing one of the following expressions on the command line of the Main window:

OUTMAP = `MapAttribute`(InputMapName, ColumnName)

OUTMAP = `MapAttribute`(InputMapName, TableName.ColumnName)

OUTMAP = InputMapName.ColumnName

where:

| | |
|---|---|
| OUTMAP | is the name of your output raster map. |
| `MapAttribute` | is the command to start the creation of an attribute map of a raster map. |
| InputMapName | is the name of your input raster map. For the first and third expression, the attribute table needs to be linked to the input map or its domain. |
| TableName | is the name of an attribute table. The attribute table should use the same domain as the input map. |
| ColumnName | is the name of an attribute column in the attribute table. |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated.

## Algorithm

The program scans the raster map line by line, starting with the first (left) pixel in the first line until the last (right) pixel in the last line.

Each pixel is copied to the output map:

- each class name or ID in the input map is replaced with the attribute value that belongs to this class or ID as found in the attribute table.

Undefined values are assigned to an output pixel:

- if the pixel in the input map is undefined, or
- if the class name, ID, or value in the selected attribute column is undefined.

# 7.2.3 Cross

## Functionality

The Cross operation performs an overlay of two raster maps. Pixels on the same positions in both maps are compared; the occurring combinations of class names, identifiers or values of pixels in the first input map and those of pixels in the second input map are stored. These combinations give an output cross map and a cross table. The cross table includes the combinations of input values, classes or IDs, the number of pixels that occur for each combination and the area for each combination.

**Input map requirements**

- Both maps should have the same georeference.
- No restrictions on domain types.

**Domain and georeference of output map and table**

Cross creates an Identifier domain for the output map and table. This output domain obtains the same name as the output map and is filled with the combinations of class names, IDs or values of both input maps. When an input map has a class or ID domain in which the class names or IDs have codes, then these codes will appear in the output domain. The output map uses the same georeference as the input maps.

**Example**

Input map 1:

| | | | |
|---|---|---|---|
| B | B | C | D |
| A | A | C | D |
| A | A | C | C |
| B | C | D | A |

Input map 2:

| | | | |
|---|---|---|---|
| S | S | S | S |
| R | R | S | S |
| T | R | S | T |
| T | R | T | T |

Output cross map:

| | | | |
|---|---|---|---|
| BS | BS | CS | DS |
| AR | AR | CS | DS |
| AT | AR | CS | CT |
| BT | CR | DT | AT |

In the picture of the output map above, read B*S instead of BS, etc.

**Output cross table**

| Domain | Map1 | Map2 | NrPix | Area |
|---|---|---|---|---|
| A * R | A | R | 3 | ...... |
| A * T | A | T | 2 | ...... |
| B * S | B | S | 2 | ...... |
| B * T | B | T | 1 | ...... |
| C * R | C | R | 1 | ...... |
| C * S | C | S | 3 | ...... |
| C * T | C | T | 1 | ...... |
| D * S | D | S | 2 | ...... |
| D * T | D | T | 1 | ...... |

**The cross table lists**

Domain the combination of class names, identifiers, values or group names of the first map with the second map's class names, IDs or values is returned as the output domain for the cross table. If class names or IDs in an input map have codes, then these codes will appear in the output domain.

Map1 the class name, identifier, or value of pixels in the first input map.

Map2 the class name, identifier, or value of pixels in the second input map.

NrPix the number of pixels that occur as a combination.

Area the number of pixels * pixel size * pixel size.

## Dialog box

The Cross operation performs an overlay of two raster maps: pixels on the same positions in both maps are compared; the occurring combinations of class names, identifiers or values of pixels in the first input map and those of pixels in the second input map are stored. These combinations give an output cross map and a cross table. The cross table includes the combinations of input values, classes or IDs, the number of pixels that occur for each combination and the area for each combination.

**Dialog box options**

First Map: Select the first raster map. Open the drop-down list box by clicking it and select a map, or directly drag a map from the Catalog into this box.

Second Map: Select the second raster map.

Output Table: Type a name for the output cross table, containing the combinations of the two input maps. This name will also be used for the output domain.

Output Map: Select this check box if you want to obtain a cross map containing the combinations of the two input maps. Subsequently, type a name for the output raster map. Clear this check box if an output cross map is not desired.

Show: Select this check box if you want the output cross table to be directly displayed. Clear this check box if you do not want to see this table immediately: you simply define how the output table (and map) should be created.

| | |
|---|---|
| Description: | Optionally, type a description for the output cross table (and map). |

A dependent output map and a dependent table are created. Furthermore, an ID domain is created (same name as cross table) which contains the combinations of domain items of both input maps.

## Command line

Cross can be directly executed by typing one of the following expressions on the command line of the Main window:

OUTTABLE = `TableCross`(FirstInputMapName, SecondInputMapName)

OUTTABLE = `TableCross`(FirstInputMapName, SecondInputMapName, OUTMAP)

OUTMAP = `MapCross`(FirstInputMapName, SecondInputMapName, OUTTABLE)

where:

| | |
|---|---|
| OUTTABLE | is the name of your output cross table. |
| OUTMAP | is the name of your output cross map. |
| `TableCross` | is the command to start cross and produce an output cross table (optionally also an output cross map). |
| `MapCross` | is the command to start cross and produce an output cross map and an output cross table. |
| FirstInputMapName | is the name of your first input map (any domain). |
| SecondInputMapName | is the name of your second input map (any domain). |

When the definition symbol = is used, a dependent output map and a dependent table are created; when the assignment symbol := is used, dependency links are immediately broken after the output map and table have been calculated.

## Algorithm

**Cross table**
For all pixels at similar positions in both input maps, the combination of pixel 'values' in both maps is listed, and the number of pixels occurring as this combination is counted.
From the pixel size of the maps and the number of pixels encountered as a combination, the areas of the combinations are calculated.

**Domain of cross map and cross table**
Cross creates an Identifier domain for the output cross map and cross table. This output domain obtains the same name as the output table and is filled with the combinations of class names, IDs or values of both input maps. When an input map has a class or ID domain in which the class names or IDs have codes, then these codes will appear in the output domain.

## 7.2.4 Aggregate map

### Functionality

The Aggregate Map operation aggregates blocks of input pixels by applying an aggregation function: Average, Count, Maximum, Median, Minimum, Predominant, Standard Deviation or Sum. The Aggregate Map operation either creates a new georeference in which each block of input pixels corresponds to one output pixel (group) or the output raster map uses the same georeference as the input map (no group).

The Aggregate Map operation is designed for applications that require a multi-resolution approach, for instance to find densities of certain features in raster maps. You can also use this operation to generalize raster data.

First, the user has to specify a group size which determines the size of the blocks of input pixels, e.g. 3 x 3, 4 x 4, 5 x 5 pixels, etc. on which an aggregation has to be performed.

Then, you have to select an aggregation function which calculates an output value for each block of (n x n) input pixels:

| | |
|---|---|
| Average | calculates the average for each block of input pixel values; |
| Count | counts the number of pixels in each block of input pixels that are not undefined; |
| Maximum | finds the maximum for each block of input pixel values; |
| Median | finds the median for each block of input pixels; |
| Minimum | finds the minimum for each block of input pixel values; |
| Predominant | finds the most occurring (predominant) class name, ID or value for each block of input pixels; |
| Std Deviation | calculates the standard deviation for each block of input pixel values; |
| Sum | calculates the sum for each block of input pixel values. |

All aggregation functions work on value maps. The aggregation functions Count, Median and Predominant also work on maps with another domain type. For the Median function, the order of a Class or ID domain is used.

Lastly, you have to choose between Group and No Group:

- Group: the operation creates a new georeference with the same name as the output map in which the pixels are a factor larger than in the input map.
  For example, when you used a group factor of 4:
  - the aggregated value for each block of 4 x 4 input pixels is stored in 1 output pixel;
  - pixels in the output map will thus represent an area that is 16 times larger than the areas represented by pixels of the input map;
  - when an input map had 1600 rows and 1200 columns, the output map will
  - when the pixel size of pixels in an input map is 25m (pixels represent 25 x 25m), the pixel size in the output map will be 100m (pixels represent 100 x 100m).

- No Group: the output map uses the same georeference as the input map. For example, when you used a group factor of 4, the aggregated value for each block of 4 x 4 input pixels in stored in 4 x 4 output pixels which correspond to the pixels of the input map.

Figures 1, 2 and 3 below illustrate the difference between Group and No Group.

**Example using Group and No Group**
In this example, the input map has 6 x 6 pixels (Figure 1). Each block of 3 x 3 input pixels is aggregated with the Average function. With the Group option, this results in a map of 2 x 2 pixels (Figure 2); with the No Group option, this results in a map of 6 x 6 pixels (Figure 3).

Input map:

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 4 | 4 |
| 2 | 2 | 3 | 3 | 4 | 4 |
| 5 | 2 | 2 | 2 | 3 | 3 |
| 5 | 2 | 2 | 3 | 6 | 6 |
| 5 | 2 | 3 | 3 | 6 | 6 |
| 5 | 5 | 3 | 3 | 6 | 6 |

Fig. 1: Input map for an aggregation.

Output map No Group:

| | | | | | |
|---|---|---|---|---|---|
| 2 | 2 | 2 | 3 | 3 | 3 |
| 2 | 2 | 2 | 3 | 3 | 3 |
| 2 | 2 | 2 | 3 | 3 | 3 |
| 3 | 3 | 3 | 5 | 5 | 5 |
| 3 | 3 | 3 | 5 | 5 | 5 |
| 3 | 3 | 3 | 5 | 5 | 5 |

Fig. 2: Output of average aggregation when using the No Group option.

Output map Group:

| | |
|---|---|
| 2 | 3 |
| 3 | 5 |

Fig. 3: Output of average aggregation when using the Group option.

**Input map requirements**
All aggregation functions can be used on value maps. The aggregation functions Count, Median and Predominant can also be applied on raster maps with another domain type.

**Domain and georeference of output map**
The default domain depends on the selected aggregation function. When the option Group is selected, a new georeference is created for the output map. When the option No Group is selected, the output raster map uses the same georeference as the input raster map.

- ☞ To obtain smaller pixels in an output map, use the Densify operation.
- ☞ To aggregate segments, you can use the Segment Density operation.
- ☞ To aggregate points, you can use the Point Density operation.
- ☞ You can also calculate averages, maximum values, median values, minimum values, standard deviations with the Filter operation. The Aggregate Map operation considers blocks of n x n input pixels at a time; when an aggregated value is calculated for one block, the next block of n x n input pixels is considered; each time an aggregated value is either assigned to one large aggregated pixel (group) or to all pixels of the block that was considered (no group). The Filter operation considers a number of input pixels as specified by the filter size; when one filtered value is calculated, the filter moves one input pixel to right and calculates the next value; each time an output value is assigned to the center pixel of the filter.

## Dialog box

The Aggregate Map operation aggregates blocks of input pixels by applying an aggregation function: Average, Count, Maximum, Median, Minimum, Predominant, Standard Deviation or Sum. The Aggregate Map operation either creates a new georeference in which each block of input pixels corresponds to one output pixel (group) or the output raster map uses the same georeference as the input map (no group).

**Dialog box options**

| | |
|---|---|
| Input raster map: | Select an input raster map. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. Refer to Aggregate map : functionality to see which aggregation functions work on which types of input maps. |
| Group factor: | Type a value for the size of the blocks of input pixels on which an aggregation function should be applied. When you specify value 4, the aggregation is performed on each block of 4 x 4 input pixels. The Group factor should be at least 2. |
| Function: | Select an aggregation function: Average, Count, Maximum, Median, Minimum, Predominant, Standard Deviation, or Sum. For more information, refer to Aggregate map : functionality. |
| Group: | Select this check box if each block of input pixels should appear as one pixel in the output map after the aggregation. The operation will create a new georeference which will obtain the same name as the output map. Clear this check box if the georeference of the input map and the output map should be the same: each aggregated value will be stored in all pixels in the output map which correspond to the considered block of input pixels. |

| | |
|---|---|
| Offset: | Optionally, select this check box if you want to start the aggregation from specific rows and columns onward in the input map. Subsequently, specify the row and column number where the aggregation should start. Clear this check box if the aggregation should start at row 1, col 1 of the input map. |
| Output raster map: | Type a name for the output raster map that will contain the aggregated values. |
| Domain: | When the output map will contain values, accept the default domain, or select another existing value domain, or create  your own output value domain. |
| Value range: | Accept the default value range, or specify your own range of possible values in the output map. |
| Precision: | Accept the default precision for the output values, or specify your own precision. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created. Further, when the Group option is used, a new georeference is created for the output map; this georeference obtains the same name as the output map.

## Command line

The Aggregate Map operation can be directly executed by typing one of the following expressions on the command line of the Main Window.

OUTMAP = `MapAggregate`*AggFnc*(InputMapName, Groupfactor, `group`)

OUTMAP = `MapAggregate`*AggFnc*(InputMapName, Groupfactor, `nogroup`)

OUTMAP = `MapAggregate`*AggFnc*(InputMapName, Groupfactor, `group`, RowOffset, ColOffset)

OUTMAP = `MapAggregate`*AggFnc*(InputMapName, Groupfactor, `nogroup`, RowOffset, ColOffset)

OUTMAP = `MapAggregate`*AggFnc*(InputMapName, Groupfactor, `group`, NewGeoref)

OUTMAP = `MapAggregate`*AggFnc*(InputMapName, Groupfactor, `group`, RowOffset, ColOffset, NewGeoref)

where:

| | |
|---|---|
| OUTMAP | is the name of the output raster map. |
| `MapAggregate` | is the first part of the command to start the Aggregate Map operation. |
| *AggFnc* | is the second part of the command to start the Aggregate Map operation. Type an aggregation function directly after `MapAggregate` (no spaces allowed): `Avg\| Max\| Med\| Min\| Prd\| Std\| Sum`<br>If no aggregation function is specified on the command line, the operation will use the pixel in the upper left corner of each block of input pixels as output value. |
| InputMapName | is the name of the input raster map. |
| Groupfactor | is a value for the size of the blocks of input pixels to be aggregated; group factor 4 means that the aggregation is performed on each block of 4 x 4 input pixels (integer >= 2). |
| `group` | is the parameter to indicate to group the aggregated value into one output pixel. |
| `nogroup` | is the parameter to indicate to use the georeference of the input map for the output map. In this case, each output aggregation value is assigned to all output pixels that correspond to the blocks of input pixels. |
| RowOffset | is an optional parameter to start the aggregation at a specific row of the input map. |
| ColOffset | is an optional parameter to start the aggregation at a specific column of the input map. |
| NewGeoref | is an optional parameter to specify a name for the output georeference; if not specified, the output georeference will obtain the same name as the output map. |

All Aggregation functions work on input value maps; the Count, Median and Predominant aggregation functions also work on maps of other domain types.

To specify the domain and value range of the output map, you can use curly brackets after the output map name, for instance:

`OUTMAP{dom=MyDom} =` *expression*

`OUTMAP{dom=MyDom;vr=min:max:prec} =` *expression*

For more information, see Appendices : ILWIS expressions.

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated. Further, when the Group option is used, a georeference factor is created with the same name as the output map, unless you specify a new georeference name yourself.

## Algorithm

The Aggregate Map operation aggregates blocks of input pixels by applying an aggregation function: Average, Count, Maximum, Median, Minimum, Predominant, Standard Deviation or Sum. The Aggregate Map operation either creates a new georeference factor in which each block of input pixels corresponds to one output pixel (group) or the output raster map uses the same georeference as the input map (no group).

The Aggregate Map operation considers blocks of n x n input pixels at a time, as specified by the group factor. In Figure 1 below, a group factor of 3 is used. Note that the numbers 1 to 36 are pixel numbers, not pixel values.

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 |
| 31 | 32 | 33 | 34 | 35 | 36 |

Fig. 1: Principle of calculating aggregated values for blocks of 3 x 3 input pixels.

The first aggregated value is calculated for pixels 1, 2, 3, 7, 8, 9, 13, 14, and 15. Then the block is moved 3 steps to the right and the next aggregated value is calculated for pixels 4, 5, 6, 10, 11, 12, 16, 17, and 18, etc.
Mark the difference with the Filter operation in which the first filtered value is also calculated for pixels 1, 2, 3, 7, 8, 9, 13, 14, and 15. However, then the filter is moved one step to the right, and the next filtered value is calculated for pixels 2, 3, 4, 8, 9, 10, 14, 15, and 16, etc.

For each block of n x n input pixels values, the operation calculates an aggregated value. If no aggregation function is specified on the command line, the operation will use the pixel in the upper left corner of each block of input pixels as output.

An aggregated value is either assigned to 1 pixel in the output map (Group) or to all pixels in the output map which correspond to the considered block of input pixels (No Group). For more information, see Aggregate map : functionality.

When an input map cannot be completely split up in blocks (for example when using an input map of 100 lines x 100 columns and a group factor of 3) the last line(s)/column(s) are ignored. In case the option No Group is selected, these remaining lines columns are assigned the undefined value.

When a RowOffset and a ColumnOffset are specified, the aggregation starts at the specified line number and column number; the first lines and columns of the input map are skipped. In case the option No Group is selected, these skipped lines and columns are assigned the undefined value.

## 7.2.5 Distance calculation

## Functionality

The Distance operation assigns to each pixel the smallest distance in meters towards user-specified source pixels, for example distance to schools, to roads etc. The output is called a distance map.

Input for a distance calculation is a source map and optionally a weight map.

By using weight factors that are inversely proportional to the possible speed that can be obtained in different mapping units, a so-called time travel map can be calculated. Through a distance calculation, also a Thiessen map can be calculated.

**Input source map for a distance calculation**
A source map is obligatory input for a distance calculation.
A source map can be any raster map of domain type domain Class, ID or Value. All pixels in the source map that have a class name, ID or value are considered as sources. For all pixels that have the undefined value, a distance value is calculated.
As a source map, you can thus directly use any rasterized point, segment, or polygon map.
Of course, you can also use one or more MapCalc statements to prepare a source map from existing raster maps.

> For ILWIS 1.41 users: the input map for a distance calculation is no longer a map in which value 0 is used for sources and value 1 is used for accessible pixels.

**Input weight map for a distance calculation**
A weight map is optional input for a distance calculation.

- If no resistances have to be taken into account, a weight map is not necessary. All pixels are assumed to have weight 1.
- To exclude inaccessible areas from a distance calculation, prepare a weight map in which negative values or the undefined value are assigned to inaccessible areas; assign value 1 to accessible pixels.
- To work with relative accessibility, prepare a weight map in which weight values represent the relative difficulty to surpass pixels.
- To calculate a travel time map, prepare a weight map in which weight values are inversely proportional to the relative speed that can be obtained in the different mapping units.
- Pixels with value 1 in the weight map are normally accessible, pixels with value 2 are twice as difficult to access than pixels with value 1, etc.
- Pixels with a negative value or value 'undefined' in the weight map cannot be reached; such pixels have a weight that is unlimitedly large.
- Pixels with value 0 in the weight map have free accessibility: distance/time values will not increase while surpassing these areas.

**Domain and georeference of output map**
In the output distance map: value 0 is assigned to source pixels, the shortest distance value towards the nearest source is assigned to all accessible pixels, and the undefined value is assigned to inaccessible pixels. By default, the distance map obtains system domain Distance; the value range and precision of this domain can be adjusted each time you perform the Distance operation. You can also create or use a value domain of your own.

The output distance map uses the same georeference as the input map. When displaying a distance output map, by default one of the system representations graduals can be selected, for instance `Gray` or `Pseudo`. You can also create a representation of your own.

☞ If line barriers are used with a width of only one pixel (e.g. rasterized segments), these barriers should be broadened before performing a distance calculation. This is because in the distance program, pixels are regarded to be 8-connected: each pixel has access to its eight neighbours (horizontally, vertically, and diagonally). Line barriers that are 8-connected can thus still be surpassed: only 4-connected lines cannot be surpassed.
To make a raster map with line barriers 4-connected instead of 8-connected, you can use the Dilate4 filter or the Conn8to4 filter.

## Travel time map

By calculating a travel time map, each pixel is assigned the time required to reach that pixel from user-specified source pixels, for example time to reach schools, villages etc.

A travel time map is created in three steps:

- prepare a source map and a weight map. The weight (resistance) factors in the weight map reflect the relative decrease of speed in less accessible terrains compared to the best accessible terrain (see example below);
- perform a distance calculation using source and weight map;
- perform a MapCalc calculation to convert the obtained output values to time units.

**Input map requirements to create a travel time map**
Source map: All pixels in the source map that have a class name, ID or value are considered as sources. For all pixels that have the undefined value, a distance/travel time value is calculated.

Weight map: In the weight map, weight factors simulate the difficulty of crossing pixels which form barriers such as rivers and mountain ridges. Weight factors represent a 'resistance' in the distance calculation. The higher the value of accessible pixels in the weight map, the higher the resulting output distance pixel values will be.

When weight factors are used which are inversely proportional to the possible speed that can be obtained in the different mapping units, a relative time map is produced instead of a distance map. For instance, if the travel speeds in the table below are valid for crossing different Terrain Mapping Units, the displayed weight factors could define the pixel values of the different TMUs in the input weight map.

| Terrain Mapping Unit | maximum speed (km/h) | weight factors in input weight map |
|---|---|---|
| main road | 70 | 1 |
| secondary road | 35 | 2 |
| field | 5 | 14 |
| normal forest | 2.5 | 28 |
| dense forest | 1 | 70 |
| river (inaccessible) | 0 | -1 |

Note that the weight factors are inversely proportional to the speed and that the largest speed is set to weight factor 1.

**Output 'distance' map**
The values in the output 'distance' map are expressed in meters, related to weight factor 1. The output 'distance' map uses by default system domain Distance; the value range and precision of this domain can be adjusted each time you perform the Distance operation. You can also create or use a value domain of your own. The output map uses the same georeference as the input maps.

**Converting the output distance values to time units**
The values in the output distance map are expressed in meters, related to weight factor 1.
These output values should be converted to time units using a MapCalc expression. Considering the example above where the maximum speed was 70 km/h, you could apply the following:
- when the output distance values are divided by 70000 (m/h), the time in hours to reach each pixel is obtained,
- when the output distance values are multiplied by 60 and divided by 70000, the time in minutes to reach each pixel is obtained,
- when the output distance values are multiplied by 60*60 and divided by 70000, the time in seconds to reach each pixel is obtained.

## Thiessen map

By calculating a Thiessen map, each pixel is assigned the class name, ID or value of the nearest source. A Thiessen map can be created by performing a Distance calculation on any raster source map.

A Thiessen map is created in two steps:
- prepare a source map and if required a weight map;
- perform a distance calculation using the source map, and if required the weight map; indicate that you want to obtain a Thiessen map.

**Input map requirements**
As source map, it is advised to use a map with domain Identifier, but also maps with a class domain or value domain can be used. All pixels with a class name, ID or value are considered as sources. The undefined pixels in this source map obtain the ID, class name or value of the nearest source.

In the weight map, you can specify weight (resistance) factors that reflect the relative difficulty to pass the pixels.

- If no resistances have to be taken into account, a weight map is not necessary. All pixels are assumed to have weight 1.
- Pixels with value 1 are normally accessible, pixels with value 2 are twice as difficult to access than pixels with value 1, etc.
- Pixels with a negative value or value 'undefined' cannot be reached; such pixels have a weight that is unlimitedly large.
- Pixels with value 0 have free accessibility: distance/time values will not increase while passing these areas.

**Output maps**
When calculating a Thiessen map, also a distance map is calculated as a by-product. Due to the algorithm of the distance operation, the boundaries between two areas in the Thiessen map may appear not straight, but octagonal around the sources. To obtain exact shortest distances, you can use the Nearest point operation.

**Domain and georeference of output maps**
The output Thiessen map always uses the same domain as the input source Map. The output distance map obtains by default system domain `Distance`; the value range and precision of this domain can be adjusted each time you perform the Distance operation. You can also create or use a value domain of your own. The output maps use the same georeference as the input maps.

---

☞ If your sources are not too many points, and you do not want to take accessibility factors into account, the best way to create a Thiessen map is to use the Nearest point operation.

☞ If line barriers are used with a width of only one pixel (e.g. rasterized segments), these barriers should be broadened before performing a distance calculation. This is because in the distance program, pixels are regarded to be 8-connected: each pixel has access to its eight neighbours (horizontally, vertically, and diagonally). Line barriers that are 8-connected can thus still be surpassed: only 4-connected lines cannot be surpassed.
To make a raster map with line barriers 4-connected instead of 8-connected, you can use the Dilate4 filter or the Conn8to4 filter.

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## Dialog box

Create a distance map or a travel time map. For information about input map requirements, see Distance calculation : functionality.

**Dialog box options**

Source map: Select the raster map that contains the source pixels. Open the drop-down list box and select a map. Or directly drag a map from the Catalog into this box.

Weight map: Select this check box if you do not have equal accessibility in the map, subsequently select the raster map that contains weight values. Clear this check box if no weight values are to be used (equal accessibility).

Output map: Type a name for the output raster map that will contain the calculated distances (in meters) towards the source pixels.

Domain: Accept the default system domain Distance, or select or create your own output value domain. 

Value range: Accept the default value range, or specify your own range of possible values in the output map.

Precision: Accept the default precision of output values, or specify your own precision.

Show: Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created.

Description: Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed.

Thiessen map: Select this check box if you want to calculate a Thiessen map. Subsequently, type a name for the output Thiessen map.

The output distance map is a dependent output map. When calculating a Thiessen map, you obtain a distance map and a Thiessen map.

## Command line (1)

To create a distance map or a travel time map, the distance calculation can be directly executed by typing one of the following expressions on the command line of the Main window:

OUTMAP = `MapDistance`(SourceMap)

OUTMAP = `MapDistance`(SourceMap,WeightMap)

where:

| | |
|---|---|
| OUTMAP | is the name of your output raster distance map. |
| `MapDistance` | is the command to start the Distance calculation operation. |
| SourceMap | is the name of the source map. |
| WeightMap | is the name of the optional weight map. |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated.

## Command line (2)

To create a Thiessen map, one of the following expressions can be typed on the command line of the Main window:

OUTDist = `MapDistance`(SourceMap, WeightMap, OutThies)

OUTDist = `MapDistance`(SourceMap, 1, OutThies)

OUTDist = `MapDistance`(SourceMap, , OutThies)

OUTThies = `MapThiessen`(SourceMap, OutDist)

OUTThies = `MapThiessen`(SourceMap, WeightMap, OutDist)

OUTThies = `MapThiessen`(SourceMap, 1, OutDist)

OUTThies = `MapThiessen`(SourceMap, , OutDist)

where:

| | |
|---|---|
| `OUTDist` | is the name of your output raster distance map. |
| `OUTThies` | is the name of your output raster Thiessen map. |
| `MapDistance` | is the command to start the Distance calculation operation. In the expressions above, also a Thiessen map is calculated. |
| `MapThiessen` | is the command to start the calculation of a Thiessen map. When calculating a Thiessen map, also a distance map is calculated. |
| SourceMap | is the name of the source map. |
| WeightMap | is the name of the optional weight map. |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency links are immediately broken after the output maps have been calculated.

## Algorithm

The distance calculation is a process in which for each pixel the distance to its neighbouring pixels is calculated using a 3 * 3 matrix with the following values:

| | | |
|---|---|---|
| 7 | 5 | 7 |
| 5 | 0 | 5 |
| 7 | 5 | 7 |

7/5 is a good approximation of $\sqrt{2}$, and $\sqrt{2}$ is the distance between two diagonally connected pixels when the raster cell size is 1. Figure 1 presents the raw distance values as calculated by the distance program. To obtain distance values in meters, these raw values are divided by 5 and multiplied by the pixel size and a correction factor.

| | | | | | |
|---|---|---|---|---|---|
| 15 | 17 | 19 | 21 | 26 | 31 |
| 10 | 12 | 14 | 19 | 24 | 29 |
| 5 | 7 | 12 | 17 | 22 | 27 |
| 0 | 5 | 10 | 15 | 20 | 25 |
| 5 | 7 | 12 | 17 | 22 | 27 |
| 10 | 12 | 14 | 19 | 24 | 29 |

Fig 1: Raw distance values as calculated by the distance program when no weight map is used. These values are divided by 5 and multiplied by the pixel size and a correction factor.

**Initialization**
All source pixels obtain distance value 0; all other pixels obtain a value distance value that is infinitely large.

**Recursive process**
For each pixel (column by column, line by line):

- for each diagonal neighbour, the test distance of the center pixel is set to the current distance value of the neighbour plus seven;
  - if this test distance is smaller than the actual distance value of the center pixel, than the actual distance value of the center pixel is replaced by the test distance.
- for all horizontal and vertical neighbours, the test distance of the center pixel is set to the current distance value of the neighbour plus five;
  - if this test distance is smaller than the actual distance value of the center pixel, than the actual distance value of the center pixel is replaced by the test distance.

If a weight map is used, the test distances are multiplied by the weight values found in the weight map. This is a recursive process in which the output file has to be scanned forward and backward until no more changes occur. Then a final computation is performed taking into account the pixel size of the map so that the final output values are in meters; further the output values are multiplied by a correction factor to reduce overall errors, see Table 1 below.

Table 1: Table 1 presents the results of a distance calculation for a map as presented in Figure 1. This table shows the use of the correction factor which reduces the overall error in calculated distance values. Column raw distance presents raw distance values as used in Figure 1; column raw distance/5 presents the result of the distance calculation after dividing the raw distance values by 5; column Euclidian distance presents distance values as they should be; column Error before correction shows the error of the distance calculation when not performing the correction as 100*(raw distance/5)/Euclidian distance; column Corrected distance presents distance values after the correction as (raw distance/5)*0.968; column Error after correction shows the error of the distance calculation after the correction is performed as 100*Corrected distance/Euclidian distance. See that column Error before correction gives errors up to 7.5% while column Error after correction only gives errors up to 4.5%.

| raw distance | raw distance/5 | Euclidian distance | Error before correction (%) | Corrected distance | Error after correction (%) |
|---|---|---|---|---|---|
| 5.000 | 1.000000 | 1.000 | 0.000 | 0.97 | -3.200 |
| 7.000 | 1.400000 | 1.414 | -1.005 | 1.36 | -4.173 |
| 10.000 | 2.000000 | 2.000 | 0.000 | 1.94 | -3.200 |
| 12.000 | 2.400000 | 2.236 | 7.331 | 2.32 | 3.897 |
| 14.000 | 2.800000 | 2.828 | -1.005 | 2.71 | -4.173 |
| 15.000 | 3.000000 | 3.000 | 0.000 | 2.90 | -3.200 |
| 17.000 | 3.400000 | 3.162 | 7.517 | 3.29 | 4.077 |
| 19.000 | 3.800000 | 3.606 | 5.393 | 3.68 | 2.020 |
| 20.000 | 4.000000 | 4.000 | 0.000 | 3.87 | -3.200 |
| 21.000 | 4.200000 | 4.243 | -1.005 | 4.07 | -4.173 |
| 22.000 | 4.400000 | 4.123 | 6.716 | 4.26 | 3.301 |
| 24.000 | 4.800000 | 4.472 | 7.331 | 4.65 | 3.897 |
| 25.000 | 5.000000 | 5.000 | 0.000 | 4.84 | -3.200 |
| 26.000 | 5.200000 | 5.000 | 4.000 | 5.03 | 0.672 |
| 27.000 | 5.400000 | 5.099 | 5.903 | 5.23 | 2.514 |
| 29.000 | 5.800000 | 5.385 | 7.703 | 5.61 | 4.257 |
| 31.000 | 6.200000 | 5.831 | 6.329 | 6.00 | 2.927 |

Note that, due to the raster approximation, for horizontal and vertical lines of 0° or 90°, the calculated distances are around 3% too small, for diagonal lines of 45°, the calculated distances are around 4% too small, and that for lines of 22.5° and 67.5° the distances are around 4% too large. Distances along all other lines have smaller errors.

## 7.2.6 Iteration

### Functionality

Iterations are a special type of map calculations. They are a successive repetition of a mathematical operation, using the result of one calculation as input for the next. These calculations are performed line by line, pixel by pixel and take place in all directions. When a calculation in one direction is finished (for instance from top to bottom) a rotation takes place for the calculation in the next direction.

The calculation stops when the difference of the output compared to the input is negligible or if the number of steps is reached which was defined before. Iterations are often used in combination with neighbourhood operations. Such an application might be for instance the selection of an item or area which fits a certain condition, starting from one pixel. For more information, see Map Calculation : neighbourhood operations; an example is presented in topic How to calculate flooded area and water volume after constructing a dam.

In ILWIS, four iteration operations are available listed below:

`MapIter`(startmap, iterexpr)
  performs iterations on the startmap according the iteration expression until no pixel changes anymore;

`MapIter`(startmap, iterexpr, nr of iterations):
performs a specified number of iterations on the startmap according the iteration expression;

`MapIterProp`(startmap, iterexpr)
performs iterations with propagation on a startmap until no pixel changes anymore; the newly calculated value for a pixel is used in calculating the next pixel instead of in the next iteration;

`MapIterProp`(startmap, iterexpr, nr of iterations)
performs a specified number of iterations with propagation on a startmap; the newly calculated value for a pixel is used in calculating the next pixel instead of in the next iteration.

The input map for an iteration is called a start map and contains one or more pixels which act as the starting point of the calculation. The iteration expression defines a certain condition or defines a calculation to be performed.

After each iteration ILWIS shows the number of changed pixels.

**Input map requirements**
The start map should contain one or more starting pixels. The other pixels should not be undefined because then every calculation will result into another undefined, unless you use the IFUNDEF or IFF combined with ISUNDEF (see also Map calculation : calculating with undefined values).

**Domain and georeference of output map**
The output raster map will generally use the system domain Value. The output map uses the georeference of the input raster map.

## Dialog box

Iterations are a special type of map calculations. They are a successive repetition of a mathematical operation, using the result of one calculation as input for the next. The calculation stops when the difference of the output compared to the input is negligible or if the number of steps is reached which was defined before. Iterations are often used in combination with neighbourhood operations.

**Dialog box options**

| | |
|---|---|
| Start map: | Select an input raster map which contains one or more starting pixels for the iteration. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. |
| Expression: | Type the expression to be used in the calculation; for more information refer to Map calculation : neighbourhood operations. |
| Stop criterion: | Choose one of the two options: |
| ◉ Until no changes: | to stop the operation when pixel values do not change anymore; |

| | |
|---|---|
| ◉ Number of iterations: | to stop the operation after a number of iterations. Subsequently type a value for the maximum number of iterations that you want to perform. |
| Propagation: | Propagation is selected by default. Propagation means that the newly calculated value for a pixel is used in calculating the next pixel instead of in the next iteration. |
| Output raster map: | Type a name for the output raster map that will contain the result of the iteration. |
| Show box: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Domain: | When the output map will contain values, accept the default domain, or select another existing value domain, or create your own output value domain. |
| Value range: | If the output map uses a value domain, accept the default value range, or specify your own range of possible values in the output map. |
| Precision: | If the output map uses a value domain, accept the default precision of output values, or specify your own precision. |
| Description | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created.

☞ The start map should contain one or more starting pixels. The other pixels should not be undefined because then every calculation will result into another undefined.

☞ When working with value maps, you can generally accept the default domain Value. You only need to select or create a user-defined value domain when the values have a specific meaning for which you have or want to create a meaningful representation.

## Command line

Iterations can be directly performed by typing one of the following expressions on the command line of the Main window:

OUTMAP = `MapIter`(Startmap, *Iter-expression*)

OUTMAP = `MapIter`(Startmap, *Iter-expression*, *nr of iterations*)

OUTMAP = `MapIterProp`(Startmap, *Iter-expression*)

OUTMAP = `MapIterProp`(Startmap, *Iter-expression*, *nr of iterations*)

where:

| | |
|---|---|
| OUTMAP | is the name of the output raster map that will contain the result of the iteration. |
| `MapIter` | is the command to perform an iteration without propagation. |
| `MapIterProp` | is the command to perform an the iteration with propagation. |
| Startmap | is the name of the input map which contains one or more pixels acting as the starting point for the calculation. |
| *Iter-expression* | is the Iteration-expression which defines the calculation to be performed. |
| *nr of iterations* | is the number of iterations to be performed. |

## Algorithm

Any mathematical operation which is used in successive repetition using the result of one calculation as input for the next. These calculations are performed line by line, pixel by pixel and take place in all directions. When a calculation in one direction is finished (for instance from top to bottom) a rotation takes place for the calculation in the next direction.

## 7.2.7 Area numbering

## Functionality

Area numbering assigns unique pixel values in an output map for connected areas (areas consisting of pixels with the same value, class name, or ID) in an input map. Area numbering breaks down mapping units which may occur in several places in your input map (e.g. a province including some islands, all having the same pixel value), into uniquely codified connected areas (e.g. the mainland and each island separately codified.)

The output of the Area numbering operation is a map in which connected areas are codified as Area 1, Area 2, etc. Further, an attribute table is created with the map, which contains the new Area IDs and the original class names, IDs or values.

The uniquely codified areas may be useful:

- if you want to perform a cross operation with another map and you want to distinguish each connected area separately instead of mapping units, or
- if you want to add special attribute information to each connected area, instead of to the mapping units.

**4-connectivity versus 8-connectivity**

Area numbering can recognize connected areas either as:

- pixels with the same pixel value which are horizontally or vertically connected to each other (4-connected), or as
- pixels with the same pixel value which are horizontally, vertically or diagonally connected to each other (8-connected).

Below, a representation of 4 and 8-connectivity is presented; the program is looking at 4 or at 8 neighbours.

4-connectivity:

| | | |
|---|---|---|
| | 1 | |
| 2 | | 3 |
| | 4 | |

8-connectivity:

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | | 5 |
| 6 | 7 | 8 |

Using 4-connectivity results in 4-connected areas in the output map, using 8-connectivity results in 8-connected areas in the output map. Using 8-connectivity results in a smaller number of connected areas and smoother boundaries of these areas.

**Input map requirements**
In the dialog box, you can only select raster maps with a class, ID, or Bool domain. On the command line, there are no special requirements for the input map.

**Domain of output map**
The Area numbering operation creates a new Identifier domain for the output map; the IDs have names like Area 1, Area 2, etc. This output domain is either stored as a separate object or is stored by the output map (internal domain).

**Georeference of output map**
The output map uses the same georeference as the input map.

**Example area numbering 4-connected**

Input map:

| | | | | | |
|---|---|---|---|---|---|
| 8 | 4 | 5 | 6 | 6 | 6 |
| 4 | 4 | 5 | 5 | 6 | 6 |
| 8 | 4 | 4 | 4 | 5 | 5 |
| 8 | 4 | 4 | 5 | 8 | 8 |
| 8 | 4 | 5 | 5 | 8 | 8 |
| 8 | 8 | 5 | 5 | 8 | 8 |

Output map:

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 4 | 4 |
| 2 | 2 | 3 | 3 | 4 | 4 |
| 5 | 2 | 2 | 2 | 6 | 6 |
| 5 | 2 | 2 | 7 | 8 | 8 |
| 5 | 2 | 7 | 7 | 8 | 8 |
| 5 | 5 | 7 | 7 | 8 | 8 |

The order of the numbering in the output map is defined as from left to right line by line, and from top to bottom.

- Using 4-connectivity results in 4-connected areas in the output map.
- Mapping unit 5 of the input map is divided into three 4-connected areas in the output map (3, 6, 7) because only horizontal and vertical neighbours were valid to construct new areas.
- Mapping unit 8 of the input map is divided into three connected areas in the output map (1, 5, 8) because the individual parts are not neighbouring each other.

**Example area numbering 8-connected**

Input map:

| | | | | | |
|---|---|---|---|---|---|
| 8 | 4 | 5 | 6 | 6 | 6 |
| 4 | 4 | 5 | 5 | 6 | 6 |
| 8 | 4 | 4 | 4 | 5 | 5 |
| 8 | 4 | 4 | 5 | 8 | 8 |
| 8 | 4 | 5 | 5 | 8 | 8 |
| 8 | 8 | 5 | 5 | 8 | 8 |

Output map:

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 4 | 4 |
| 2 | 2 | 3 | 3 | 4 | 4 |
| 5 | 2 | 2 | 2 | 3 | 3 |
| 5 | 2 | 2 | 3 | 6 | 6 |
| 5 | 2 | 3 | 3 | 6 | 6 |
| 5 | 5 | 3 | 3 | 6 | 6 |

The order of the numbering in the output map is defined as from left to right line by line, and from top to bottom.

- Using 8-connectivity results in 8-connected areas in the output map.
- Mapping unit 5 in the input map remains one 8-connected area in the output map (3) because horizontal, vertical and diagonal neighbours were valid to construct new areas.
- Mapping unit 8 in the input map is divided into three areas in the output map (1, 5, 6) because the individual parts are not neighbouring each other .

☞ For more information on internal domains and representations, refer to How to open internal domains/representations.

## Dialog box

Each connected area of pixels with the same pixel value or meaning in the input map is uniquely codified in the output map. After area numbering, a mapping unit consisting of several rasterized polygons occurring in several places in a map is broken into its individual rasterized polygons.

For 1.4 users: The output map of Area numbering gives the same output map as rasterizing polygons using option polygons instead of mapping units.

**Dialog box options**

Input raster map: Select an input raster map. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. In the dialog box, you can only select a map with a class, ID or Bool domain; on the command line there are no special input map requirements.

Connect: Select option button 4 to retrieve 4-connected areas, i.e. areas will be constructed for pixels with the same pixel value which are horizontally or vertically connected.
Select option button 8 to retrieve 8-connected areas, i.e. areas will be constructed for pixels with the same pixel value which are horizontally, vertically or diagonally connected.

New domain: Select this check box if you want to store the output ID domain as a separate object (recommended). Subsequently, type a name

| | |
|---|---|
| | for the new domain. Clear this check box to obtain an output ID domain which is stored by the output map (internal domain). |
| Output raster map: | Type a name for the output raster map that will contain the renumbered connected areas. This name will also be used for the output attribute table. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map and an attribute table are created. Furthermore, IDs for the output map can be stored in a new ID domain or can be stored by the output map (internal domain).

## Command line

The Area numbering operation can be directly executed by typing one of the following expressions on the command line of the Main window:

OUTMAP = `MapAreaNumbering`(InputMapName, `8|4`)

OUTMAP = `MapAreaNumbering`(InputMapName, `8|4`, NewDomain)

where:

| | |
|---|---|
| `OUTMAP` | is the name of your output raster map. |
| `MapAreaNumbering` | is the command to start the Area Numbering operation. |
| InputMapName | is the name of your input raster map (any domain). |
| `8|4` | is the parameter to indicate whether to construct 8-connected or 4-connected areas (either 8 or 4). |
| NewDomain | is an optional parameter to specify a name for the output ID domain; if this parameter is not specified, the output domain will be stored by the output map (internal domain). |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated. When the NewDomain parameter is used, a new ID domain is also created.

## Algorithm

Area numbering operates as a 3 x 3 filter: the filter moves over the map and a value is assigned to the center pixel of the filter in the output map, depending on the values of the center pixel itself and its neighbouring pixels in the input map.

In case of 4-connectivity, the program compares the values of 4 neighbouring pixels with the value of the center pixel, and in case of 8-connectivity, the program compares the values of 8 neighbouring pixels with the value of the center pixel.

4-connectivity:

| | | |
|---|---|---|
| | 1 | |
| 2 | | 3 |
| | 4 | |

8-connectivity:

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | | 5 |
| 6 | 7 | 8 |

The filter runs from left to right line by line, from top to bottom over the input map.

**Rule**
If one or more of the 4 or 8 pixels neighbouring the center pixel has the same value as the center pixel itself (in the input map), then the center pixel is assigned (in the output map):

- a new value, in case the neighbour(s) with the same value as the center pixel was/were not renumbered yet, or
- the same value as was assigned to the neighbour(s) with the same value as the center pixel, in case this/these neighbour(s) already was/were renumbered.

Else, if none of the neighbouring pixels has the same value as the center pixel, a new value will be assigned to the center pixel in the output map.

Also, an attribute table is created: it lists the new IDs (Area 1, Area 2, etc.) and the original values, class names, etc. of the input map.

**Output domain**
The Area numbering operation creates a new Identifier domain for the output map; the IDs have names like Area 1, Area 2, etc. This output domain is either stored as a separate object or is stored by the output map (internal domain).

## 7.2.8 Sub-map of raster map

## Functionality

The Sub-map of raster map operation copies a rectangular part of a raster map into a new raster map. The user has to specify row and column numbers of the input map to indicate the part of the input map that should be copied into the new raster map.

This operation allows you to cut out a part of your raster map.

The Sub-map of raster map operation permanently reduces the area covered by a raster map.

☞ To temporarily reduce the area of a raster map, you can zoom in on the raster map in a map window. The result can be even be stored as a map view.

☞ To temporarily enlarge the area of a raster map, i.e. to create extra space around a raster map in a map window for annotation purposes, you can use the Extend Window command on the Options menu in the map window, or you can zoom in on the raster map and drag a rectangle partly outside the map window. Also this result can even be stored as a map view.

**Input map requirements**
No special input map requirements.

**Domain and georeference of output map**
The output map uses the same domain as the input map. The operation always creates a new georeference for the output map.

## Dialog box

The Sub-map of raster map operation copies a rectangular part of a raster map into a new raster map. The user has to specify row and column numbers of the input map to indicate the part of the input map that should be copied into the new raster map.

**Dialog box options**

| | |
|---|---|
| Input raster map: | Select an input raster map. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. No special input map requirements. |
| First line: | Type the line number in the input map where copying should start. |
| First column: | Type the column number in the input map where copying should start. |
| Number of lines: | Type the number of lines of the input map that you want to be copied starting from 'First line'. |
| Number of columns: | Type the number of columns of the input map that you want to be copied starting from 'First column'. |
| Output raster map: | Type a name for the output raster map that will contain the copied pixels. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created. Further, a new georeference is automatically created for the output map; this georeference obtains the same name as the output map.

## Command line

The sub-map of raster map operation can be directly executed by typing the following expression on the command line of the Main window:

OUTMAP = `MapSubMap`(InputRasterMap, first row, first col, nr rows, nr cols)

OUTMAP = `MapSubMap`(InputRasterMap, first row, first col, nr rows, nr cols, NewGeoref)

where:

| | |
|---|---|
| OUTMAP | is the name of your output raster map. |
| `MapSubMap` | is the command to start the sub-map of raster map operation. |
| InputRasterMap | is the name of the input raster map. |
| first row | is the line number in the input map where copying should start. |
| first col | is the column number in the input map where copying should start. |
| nr rows | are the number of rows that are to be copied from the input map starting from 'first row'. |
| nr cols | are the number of columns that are to be copied from the input map starting from 'first col'. |
| NewGeoref | is an optional parameter to specify a name for the output georeference; if not specified, the output georeference will obtain the same name as the output map. |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated. Further, a georeference submap is created with the same name as the output map, unless you specify a new georeference name yourself.

## Algorithm

The Sub-map of raster map operation simply copies a user-specified rectangular part of an input raster map into a new raster map. The user has to specify row and column numbers of the input map to indicate the part of the input map that should be copied into the new raster map.

A new georeference submap is created with the same name as the output map.

# 7.2.9 Glue raster maps

## Functionality

The Glue raster maps operation glues or merges two georeferenced input raster maps into one output raster map. The output map then comprises the total area of both input maps. The domains of the two input maps are merged when needed. With the Glue raster maps operation, you can thus merge two adjacent or partly overlapping raster maps or glue a smaller raster map onto a larger one. To produce a mosaic, you can perform this operation a number of times.

For overlapping pixels, the operation applies the following rules:

- By default, the second map appears on top of the first map: the check box Map 2 on Top in the dialog box is selected.
- Undefined pixels in the map on top are considered transparent and act as openings: when the second map is glued on top of the first one and the second map contains undefined pixels in the overlap, you will see the pixels of the first map.

Pixels in the output map that are not covered by one of the two input maps are assigned the undefined value; when combining two images, this means value 0 is assigned.

**Input map requirements**
You can always combine two raster maps of the same domain type, i.e. two Images, two Value maps, two Class maps, two ID maps, two Pictures, or two maps with the Color domain. The contents of the two input domains does not necessarily need to be the same. You can also combine a Value map with an Image. For more information, see the section Domain of output map below. Furthermore, both input raster maps must have a georeference which is not georeference None.

**Domain of output map**
- When combining two maps with the Image domain, the output map also uses the Image domain.
- When combining two maps with a Value domain, the output map always uses the system Value domain. The value range for the output map is determined by the smallest minimum and the largest maximum of both input maps; the precision is the smallest precision of the input maps.
- When merging a Value map on top of an Image, the output map always uses the system Value domain. The value range for the output map is determined by the smallest minimum and the largest maximum of both input maps; the precision is the smallest precision of the input maps.
- When combining two maps with the same Class domain, the output map also uses this Class domain.
  In case the class names in the two domains are different, both domains are merged into a new domain, and the output domain then contains all domain items, i.e. all classes, and the output map thus shows both input maps with their original class names. The new domain is either stored as a separate object, or is stored by the output map (internal domain).
- When combining two ID maps, the same procedure is followed as for Class maps but the output domain is an ID domain.
- When combining two maps with the same Picture domain, the output map also uses this Picture domain.
  In case the colors in the two Picture domains are different, both domains are merged into a new domain, and the output domain then contains all colors with a maximum of 256. When the summed number of colors of both pictures is thus 256 or less, both input pictures will keep their original colors in the output map. The new domain is always stored by the output map (internal domain) and not as a separate object.
- When combining two maps with the Color domain, the output map also uses the Color domain.

**Georeference of output map**
The operation creates a new georeference (a georeference submap) for the output map; the georeference obtains the same name as the output map. The pixel size of the first input map is used and the georeference is extended in X and Y direction so that both the first and the second input map fit into the output georeference. If needed, the second input map is resampled with the Nearest Neighbour method to this output georeference.
Usually, both input georeferences will use the same coordinate system which covers the whole area already. In case the two input georeferences use a different but compatible coordinate system (e.g. different projections), the coordinate system of the first input map is used and a coordinate transformation is performed for the second input map.

- ☞ You cannot combine an Image on top of a Value map: first convert the Image in its Edit Properties dialog box into a Value map, or use the Value map on top.
- ☞ Similarly, you cannot combine a Class map with an ID map or vice versa: first convert one of the domains into the other domain type via the Properties dialog box of one of the domains.
- ☞ When merging two Class maps or two ID maps, by default an internal domain is created for the output map to reduce the number of separately stored domains. Internal domains are stored by an output map. If you like, you can select the New Domain check box in the dialog box and specify a new name for the output domain if you want the output domain to be stored as a separate object.
- ☞ You cannot combine an Image with a Color map nor a Picture with a Color map.
- ☞ The maximum number of columns for any output map is 64000 for a 1-byte output map, 32000 for a 2-byte output map, 16000 for 4-byte output map and 8000 for a 8-byte output map.

For more information on internal domains and representations, refer to How to open internal domains/representations.

## Dialog box

The Glue raster maps operation glues or merges two georeferenced input raster maps into one output raster map. The output map then comprises the total area of both input maps. The domains of the two input maps are merged when needed. With the Glue raster maps operation, you can thus merge two adjacent or partly overlapping raster maps or glue a smaller raster map onto a larger one. To produce a mosaic, you can perform this operation a number of times.

**Dialog box options**

| | |
|---|---|
| First input map: | Select the first input raster map. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. |
| Second input map: | Select the second input raster map. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. |

| | |
|---|---|
| | You can always glue raster maps of the same domain type. For more information on mergeable domain types, see Glue raster maps : functionality. |
| Map 2 on top: | Select this check box to use for overlapping pixels the values, class names, IDs, or colors of the second map. For overlapping pixels, the second map will appear on top of the first map.<br>Clear this check box to use for overlapping pixels the pixels of the first map. |
| New domain: | When merging two Class or ID maps that do not use the same domain, select this box if you want to store the output domain as a separate object (recommended). Subsequently, type a name for the new domain. Clear this check box to obtain an output Class or ID domain which is stored by the output map (internal domain). |
| Output raster map: | Type a name for the output raster map that will contain both input maps. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created. Furthermore, a new georeference is automatically created for the output map (same name as output map), and, when needed and specified, a new domain is also created.

## Command line

The Glue raster maps operation can be directly executed by typing one of the following expressions on the command line of the Main window:

OUTMAP = `MapGlue`(FirstInputMapName, SecondInputMapName)

OUTMAP = `MapGlue`(FirstInputMapName, SecondInputMapName, `Replace`)

OUTMAP = `MapGlue`(FirstInputMapName, SecondInputMapName, NewDomain)

OUTMAP = `MapGlue`(FirstInputMapName, SecondInputMapName, NewDomain, `Replace`)

where:

| | |
|---|---|
| OUTMAP | is the name of your output raster map. |
| `MapGlue` | is the command to start the Glue raster maps operation. |
| FirstInputMapName | is the name of the first input raster map. |

| | |
|---|---|
| `SecondInputMapName` | is the name of the second input raster map. |
| `Replace` | is an optional parameter to use for overlapping pixels the values, class names, IDs or colors of the second input map. |
| NewDomain | is an optional parameter, when merging two Class or ID maps that do not have the same domain, to specify a name for the new output domain in which all input domain items will be merged. When input Class or ID domains are not the same and this parameter is not specified, the new output domain in which all input domain items are merged will be stored by the output map (internal domain). |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated. When Class or ID maps are merged that do not have the same domain, and the NewDomain parameter is used, a new output domain is also created. Furthermore, a georeference submap is created with the same name as the output map.

## Algorithm

The Glue raster maps operation glues or merges two georeferenced input raster maps into one output raster map. The output map then comprises the total area of both input maps. The domains of the two input maps are merged when needed.

First, the operation checks whether the georeferences and the domain types of the two input maps are compatible. If so, the operation can be performed. For more information on mergeable domain types, see Glue raster maps : functionality.

**Output georeference**
A new georeference submap is created with the same name as the output map.

- The pixel size of the first input map is used and the georeference is extended in X and Y direction so that both the first and the second input map fit into the output georeference.
- If needed, the second input map is resampled to this output georeference. To resample the second map, the nearest neighbour resampling method is used in the same way as when resampling the values of a single raster map to a new georeference (see Resample).
- Usually, both input georeferences will use the same coordinate system which covers the whole area already. In case the two input georeferences use a different but compatible coordinate system (e.g. different projections), the coordinate system of the first input map is used and a coordinate transformation is performed for the second input map.

**Output domain**

- When merging two maps with the same domain, the output map will also use that domain.
- When merging two Value maps, the value range for the output map is determined by the smallest minimum and the largest maximum of both input maps; the precision is the smallest precision of the input maps.
- When merging a Value map on top of an Image, the output map always uses the system Value domain. The value range for the output map is determined by the smallest minimum and the largest maximum of both input maps; the precision is the smallest precision of the input maps.
- When merging two Class maps or two ID maps that do not have the same domain, a new output domain is created which contains all domain items, i.e. all classes. The new domain is either stored as a separate object, or is stored by the output map (internal domain).
- When merging two Pictures, a new output domain and a new representation are created which are both stored by the output map (internal domain and internal representation); the representation contains all colors of the input maps with a maximum of 256.

**Overlapping pixels**

- By default, the second map appears on top of the first map.
- Undefined pixels in the map on top are considered transparent and act as openings.

## 7.2.10 Mirror/Rotate

## Functionality

The Mirror/Rotate operation allows you to reflect or mirror a raster map in a horizontal, vertical, or diagonal line, to transpose the map's rows and columns, or to rotate a raster map 90°, 180°, 270° (clock-wise).

Below, the different options are illustrated using a 3 * 3 map.

**Reflection in a horizontal line**

**Reflection in a vertical line**


**Transpose**


**Reflection in a diagonal**


**Rotate 90°**


**Rotate 180°**


**Rotate 270°**

**Input map requirements**
No special input map requirements.

**Domain and georeference of output map**
The output raster map uses the same domain as the input raster map.
The operation always creates a new georeference for the output map.

☞ When you want to rotate a raster map into another direction, create a georeference tiepoints and then use Resample.

## Dialog box

The Mirror/Rotate operation allows you to reflect or mirror a raster map in a horizontal, vertical, or diagonal line, to transpose the map's rows and columns, or to rotate a raster map 90°, 180°, 270° (clock-wise).

**Dialog box options**

| | |
|---|---|
| Input raster map: | Select an input raster map. Open the list box and select the desired input map, or drag a raster map directly from the Catalog into this box. No special input map requirements. |
| ◉ Mirror horizontal: | Reflect line numbers in a horizontal line. |
| ◉ Mirror vertical: | Reflect column numbers in a vertical line. |
| ◉ Transpose: | Transpose row and column numbers. |
| ◉ Mirror diagonal: | Reflect line and column numbers in a diagonal. |
| ◉ Rotate 90 degrees: | Rotate the map 90° clock-wise. |
| ◉ Rotate 180 degrees: | Rotate the map 180° clock-wise. |
| ◉ Rotate 270 degrees: | Rotate the map 270° clock-wise. |
| Output raster map: | Type a name for the output raster map that will contain the reflected or rotated map. |
| Show: | Select this check box if you want the output map to be displayed in a map window when the operation has finished. Clear this check box if you do not want to see this map immediately: you simply define how the output map should be created. |
| Description: | Optionally, type a description for the output map. The description appears in the title bar when the output map is displayed. |

A dependent output map is created. Further, a new georeference is automatically created for the output map; this georeference obtains the same name as the output map.

## Command line

The Mirror/Rotate operation can be directly executed by typing the following expression on the command line of the Main window:

OUTMAP = `MapMirrorRotate`(InputRasterMap, *rotatetype*)

where:

| | |
|---|---|
| OUTMAP | is the name of your output raster map. |
| `MapMirrorRotate` | is the command to start the Mirror/Rotate operation. |
| InputRasterMap | is the name of the input raster map. |
| *rotatetype* | is the type of reflection or rotation that you want to use: `mirror\| mirrvert\| mirrdiag\| transpose\| rotate90\| rotate180\| rotate270`. |

When the definition symbol = is used, a dependent output map is created; when the assignment symbol := is used, the dependency link is immediately broken after the output map has been calculated. Further, a georeference mirrorrotate is created with the same name as the output map.

## Algorithm

The Mirror/Rotate operation allows you to reflect or mirror a raster map in a horizontal, vertical, or diagonal line, to transpose the map's rows and columns, or to rotate a raster map 90°, 180°, 270° (clock-wise).

A new georeference mirrorrotate is created with the same name as the output map.

**Reflect in horizontal line**
All line numbers are switched.

- the first line (from left to right) becomes the last line (from left to right),
- the second line (from left to right) becomes the one but last line (from left to right),etc.

**Reflect in vertical line**
All column numbers are switched.

- the first column (from top to bottom) becomes the last column (from top to bottom),
- the second column (from top to bottom) becomes the one but last column (from top to bottom),etc.

**Transpose**
Row and column numbers are interchanged. All line numbers become column numbers and all column numbers become line numbers.

- the first line (from left to right) becomes the first column (from top to bottom),
- the second line (from left to right) becomes the second column (from top to bottom), etc.

**Reflect in diagonal**
- the first line (from left to right), becomes the last column (from bottom to top),
- the second line (from left to right) becomes the one but last column (from bottom to top, etc.

**Rotate 90° (clock-wise)**
- the first line (from left to right) becomes the last column (from top to bottom),
- the second line (from left to right) becomes the one but last column (from top to bottom), etc.

**Rotate 180° (clock-wise)**
- the first line (from left to right) becomes the last line (from right to left),
- the second line (from left to right) becomes the one but last line (from right to left), etc.

**Rotate 270° (clock-wise)**
- the first line (from left to right) becomes the first column (from bottom to top),
- the second line (from left to right) becomes the second column (from bottom to top), etc.