

An Introduction to Spatial Data Analysis

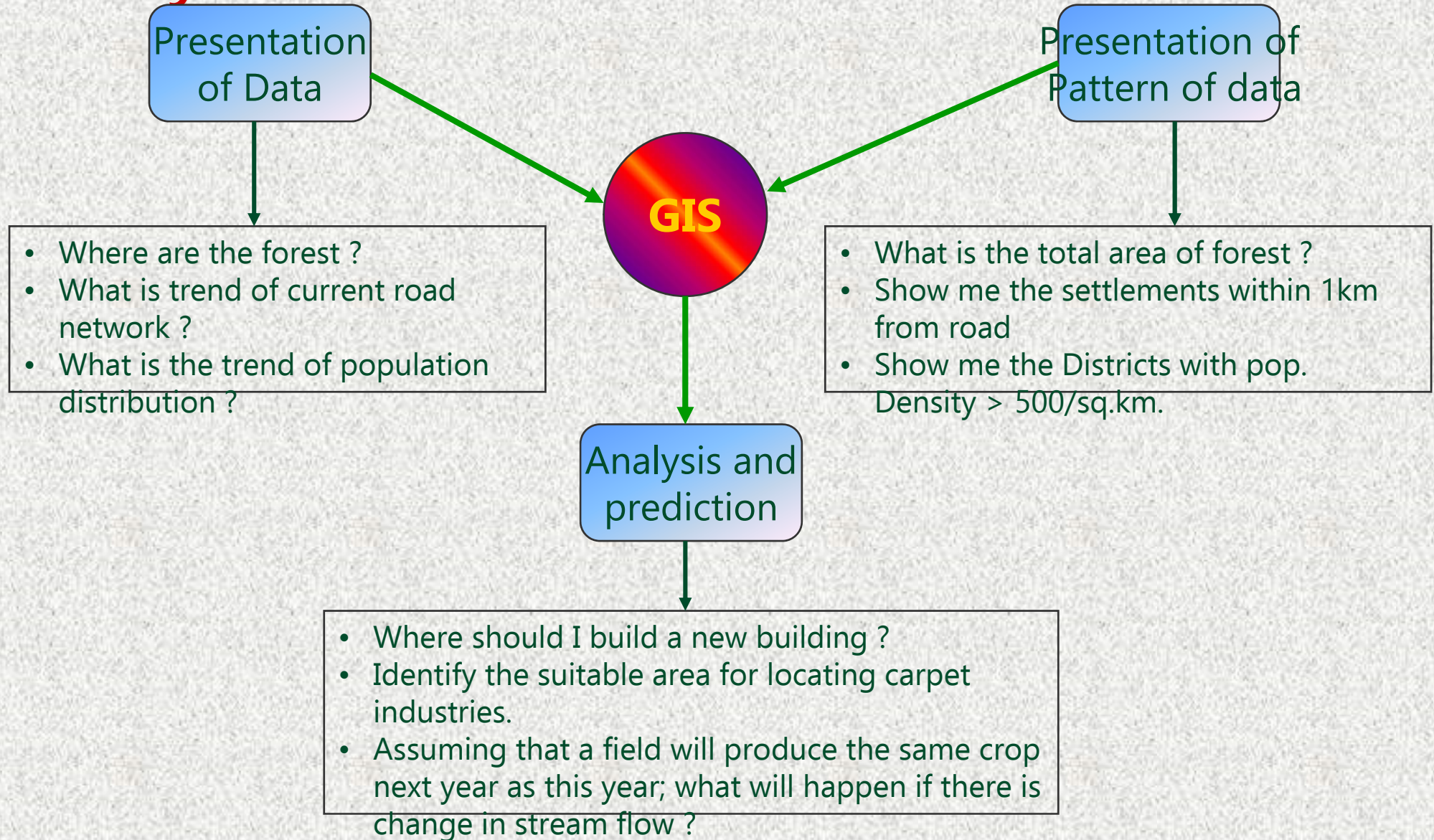


What is Spatial analysis ?

- ◆ Heart of GIS which Allows to study real-world processes
- ◆ Uses the existing geographic information and generates new information
- ◆ Important use of the analysis is predicting what will happen after certain time which provides the opportunity to select the best possible alternative

Functions of GIS

Analysis



Spatial Data analysis

- ◆ Perform database query
- ◆ Perform overlay analysis
- ◆ Create buffer distance and proximity analysis
- ◆ 3-D analysis
- ◆ Network analysis
- ◆ Tabular and statistical analysis.

Spatial Data analysis

- Retrieval, (re)classification & measurement operations
- Overlay operations
- Neighborhood operations.

Retrieval, (re)classification & measurements

- ◆ Starting point of the data analysis process and enables to explore the spatial and attribute data
- ◆ No changes are made to the location of spatial elements, and no new spatial elements are created
- ◆ Retrieval involves searching of data from the database
- ◆ Reclassification involves reassignment of thematic values to different categories
- ◆ Measurement operation involves the measuring distance between points, length of lines, and area of polygons

Retrieval Functions

- ◆ Retrieval operations involves the selective search, manipulation, and output of data

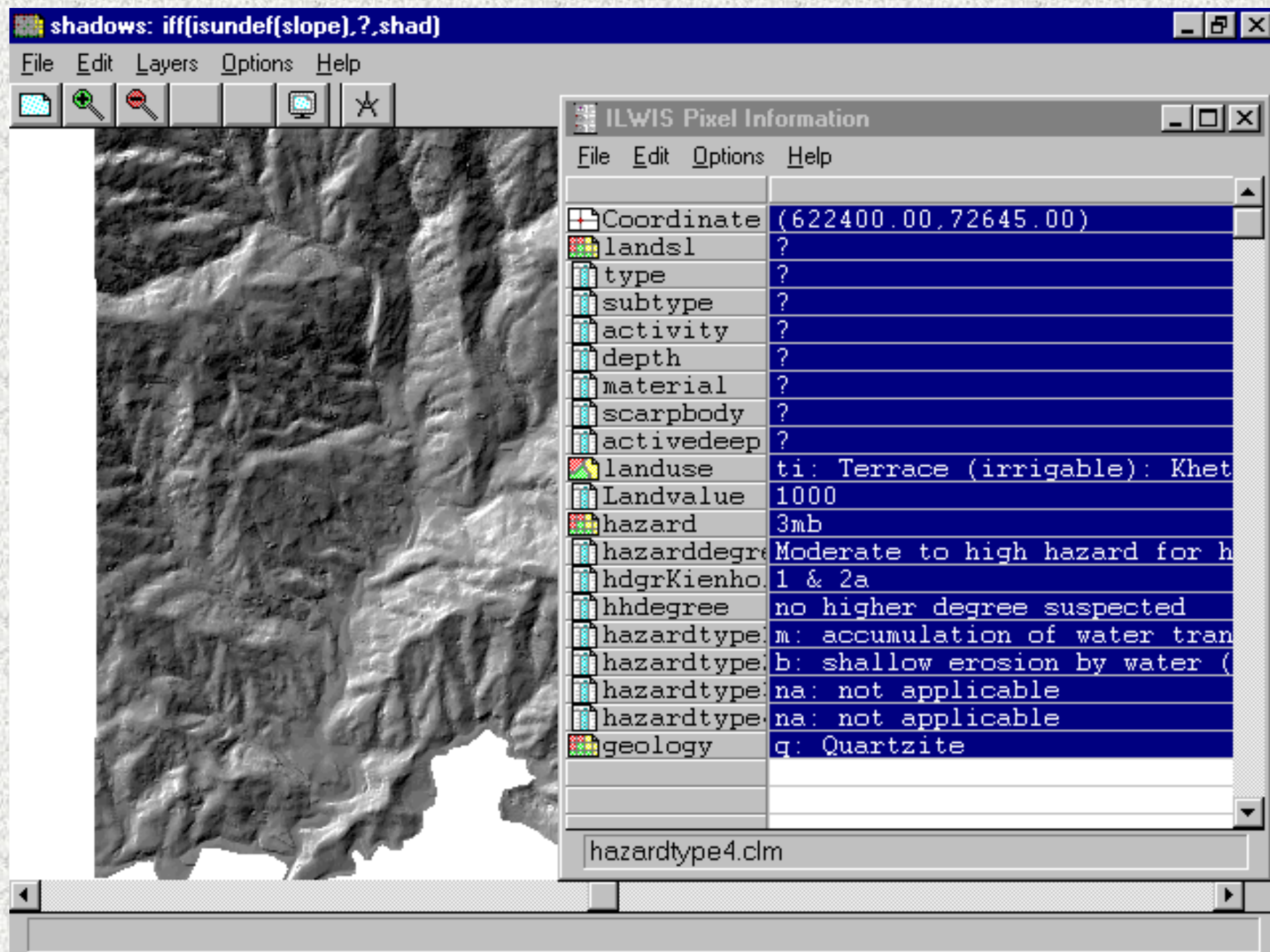
Examples:

- Where are the forests ?
- Where are the agricultural lands ?
- Where are the units with granite ?
- What is the elevation value at X,Y ?
- What is the land use type at X,Y ?
- What is the geology in location X,Y ?

Data retrieval Using Pixel Information

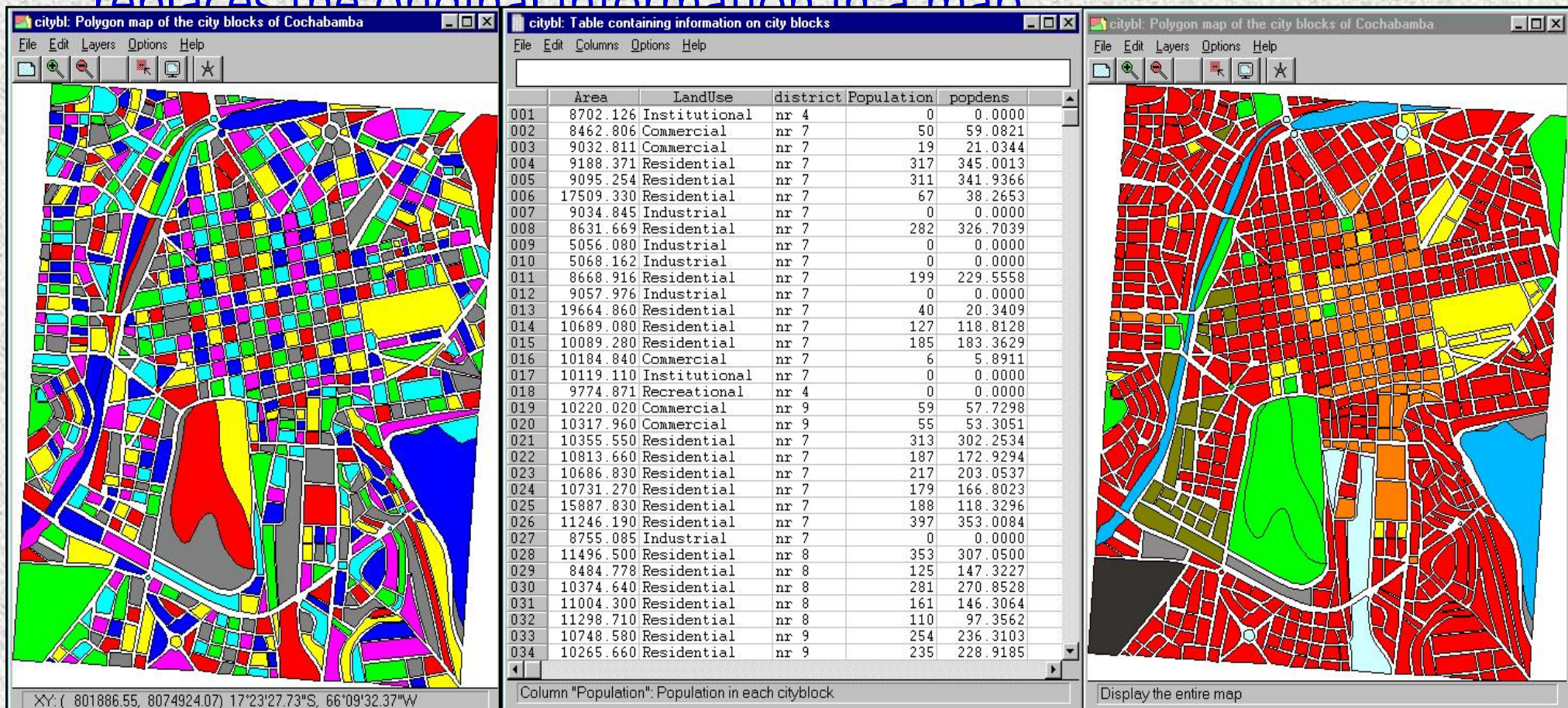
Data retrieval involves the (selective) search, manipulation and output of spatial and/or attribute data:

- ◆ To find out what exist at a particular location. What is at... ?
Use Pixel-information OR ID values
- ◆ Retrieval of spatial data (points, lines, polygons or mapping units in a raster map), which are an answer to the question Where is?
- ◆ Retrieval of information using conditional, logical and arithmetical operators



Data retrieval by Displaying Attributes

- ◆ Finds the information for entire map rather than for a particular location
- ◆ Involves in displaying map based on attribute information which replaces the original information in a map



Retrieval using a mask

- ◆ A Mask is used to selectively display data.

For example:

- mask: Forest, Pasture
- Wildcards: * and ?
- Mask: Bare* will display units Bare rocks, and Bare soils.
- Meks: 30* will display all values starting with 30: 3001, 3002, ...

Retrieval with Map Calculation

- Map calculation used for both data retrieval and reclassification which is the important tool used in GIS analysis
- Uses conditional statements: IF...THEN...ELSE

Example:

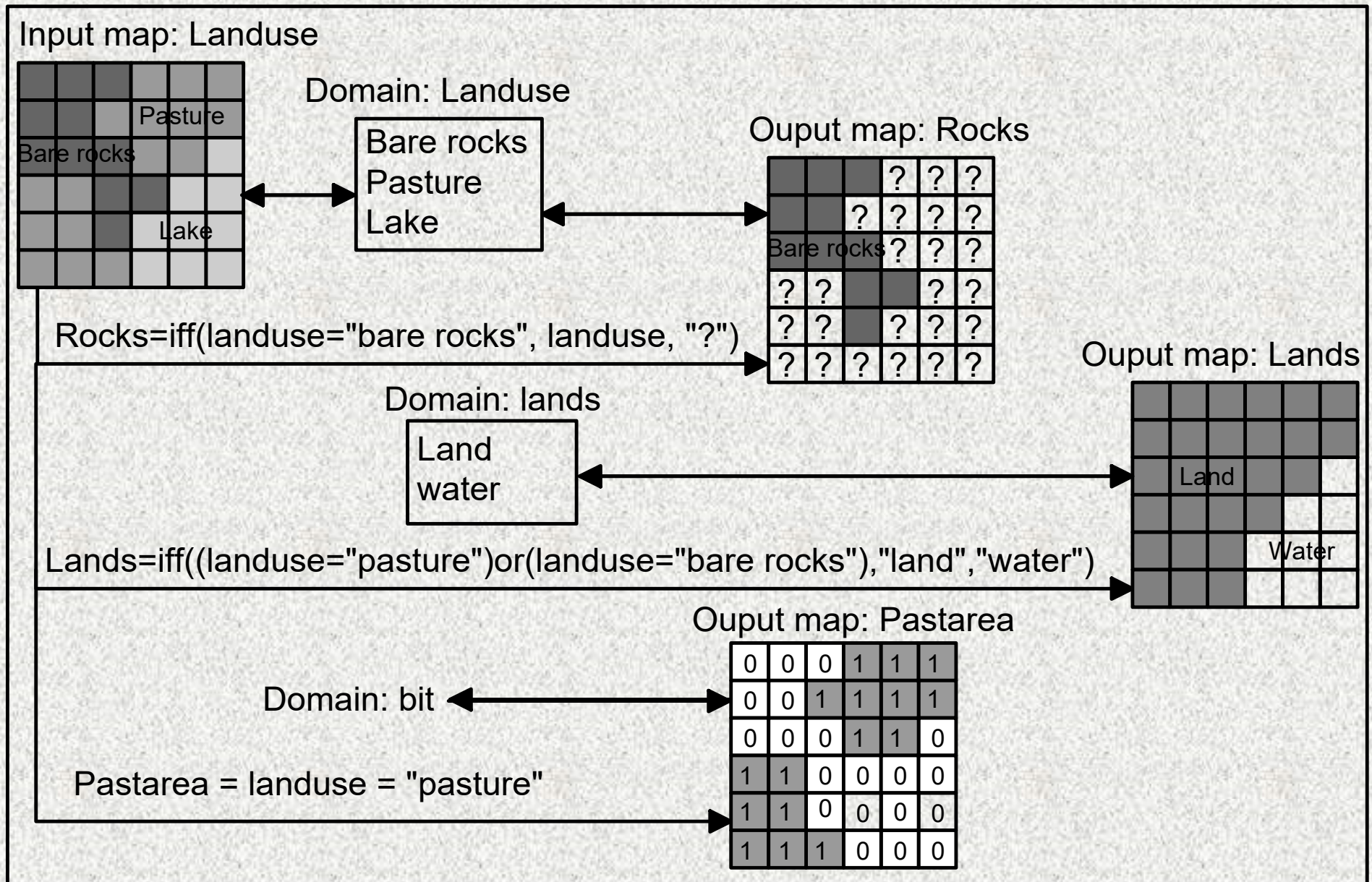
Granite:=iff(geology="granite",1,0)

- Uses Boolean statement: 1 = True, 0 = False

Example:

Grass = Landuse = "GrassLand"

Retrieval using Formulas



Classifying Value Maps with Map Calc Formula

DEM: 500, 600, 700, 6000

Ranges: 500 - 2000 = Low

2000 - 4000 = Moderate

4000 - 6000 = High

IFF (DEM < 2000, "Low", IFF (DEM > 4000, "High", "Moderate"))

Summary: retrieval operations

- ◆ Pixel information window: allows you to read data from many maps and tables simultaneously, for the X Y-coordinate.
- ◆ Displaying a map by one of its attributes is useful to investigate the spatial distribution of attribute information, without the need of generating a new map.
- ◆ You can also use a Mask to selectively display some classes, IDs or values of a map.

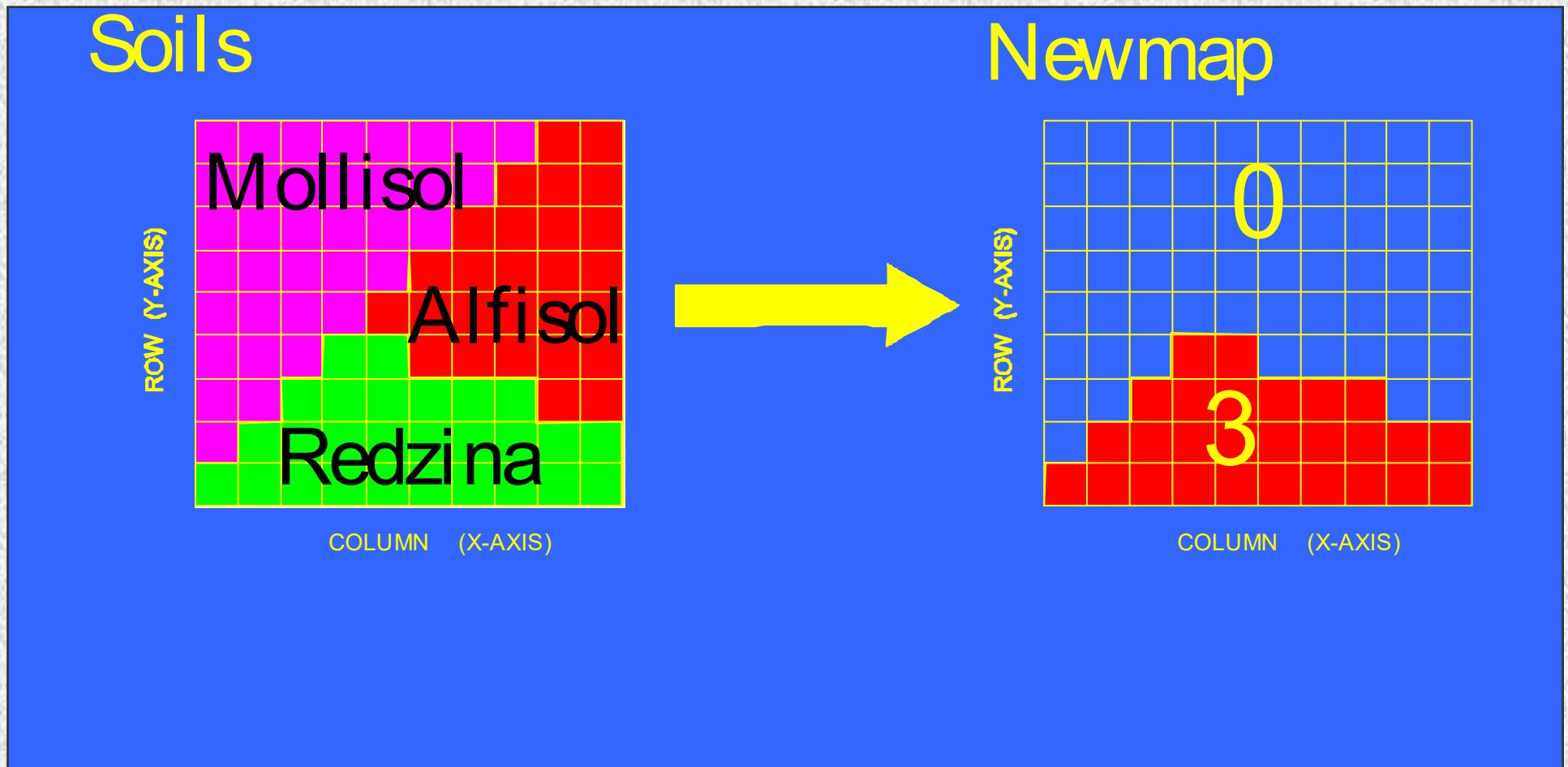
Map (re)classification

- ◆ (Re) classification operations involve the reassignment of thematic values to the categories of an existing map.

Examples:

- ◆ Reclassify a district map based on population density
- ◆ Reclassify a soil map into a PH map
- ◆ Classify an elevation map into classes with intervals of 500 m.

Reclassification with formula:
`newmap:=IFF(soils="redzina",3,0)`



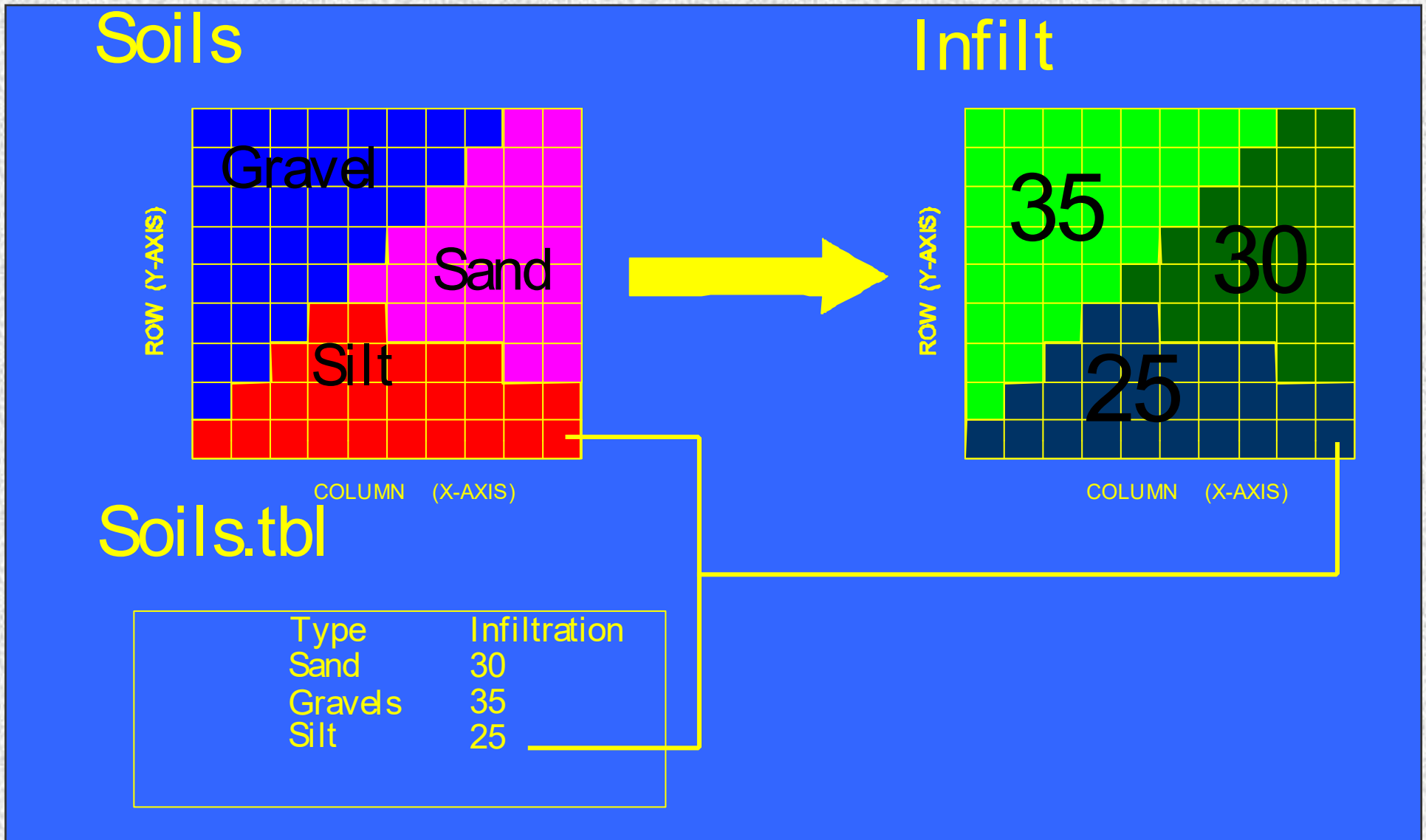
Using Map Calc formulas for retrieval and (re)classification

- Data retrieval with a Map calculation formula is required in those situations where you want to use the result map in other calculations.
- MapCalc formulas are a suitable tool for performing simple reclassifications of class maps. More complex reclassifications would require many nested IFF statements.
- Therefore, for more complex reclassifications of raster maps with a class or ID domain, it is easier to store the attributes in a table and to reclassify the map with the values from the table.
- For value maps, the problem of complex classifications can be solved by using a special operation called Slicing.

Reclassifying a map using attribute data

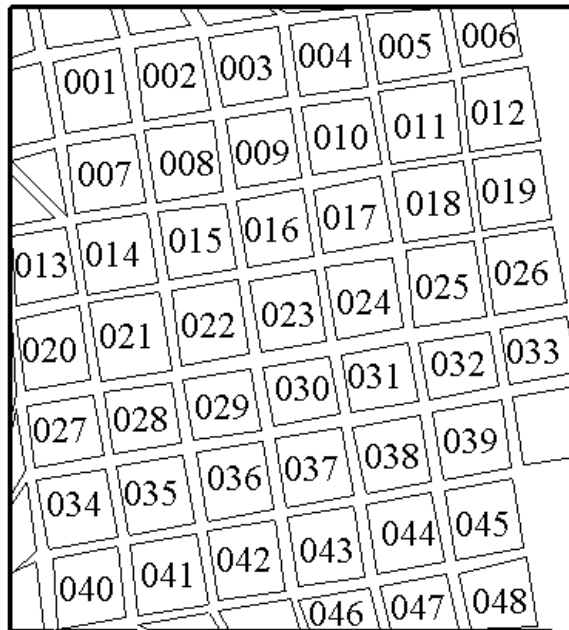
- Vector or raster maps with a class or identifier domain often have an attribute table linked to it.
- The attribute table and the map have the same domain. The table contains columns with attribute information on the units of the map.
- Each of the columns in an attribute table also has a certain domain (either another class domain, an identifier domain, or a value domain).
- You can substitute the classes of the original map by the attribute values from one of the columns in the attribute table. The new map always uses the same domain as the selected attribute column.

Renumbering using table



Reclassify from table

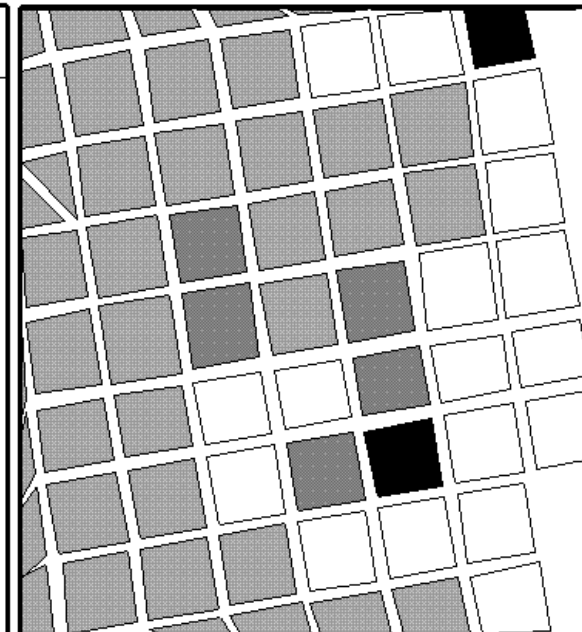
Map: city blocks



**Attribute table:
City blocks**

	Landuse
001	Residential
002	Residential
003	Residential
004	Commercial
005	Commercial
006	Recreational
007	Residential
008	Residential
009	Residential
010	Residential
011	Residential
012	Commercial
013	Residential
014	Residential
015	Institutional
016	Residential
017	Residential
018	Residential
019	Commercial
020	Residential
021	Residential
022	Institutional
etc.	

**Attribute map:
Land use**



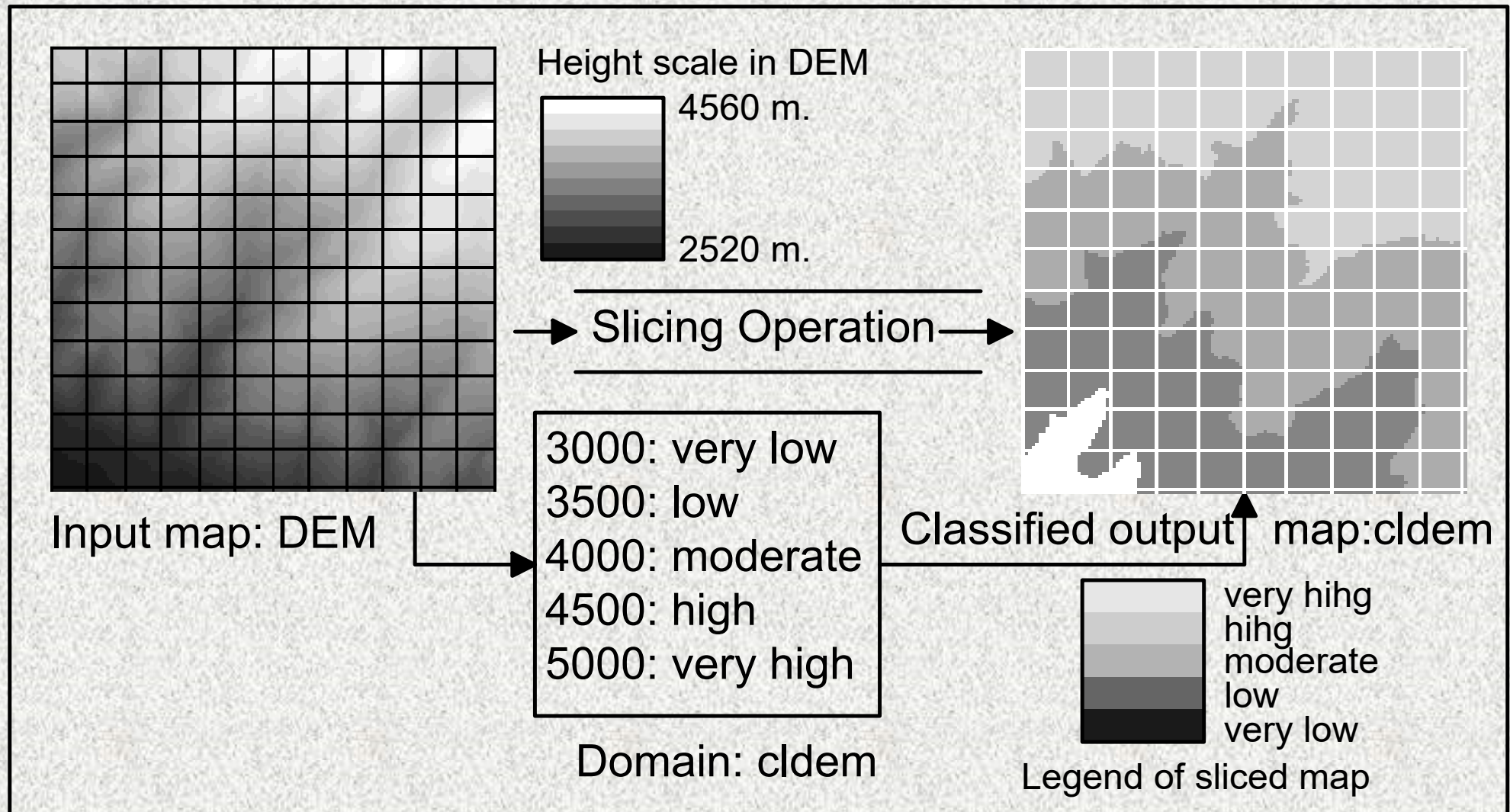
Landuse:

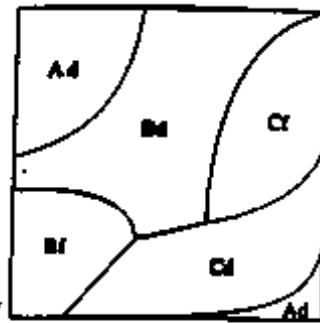
White	Commercial
Dark Gray	Institutional
Black	Recreational
Light Gray	Residential

Classifying a value map

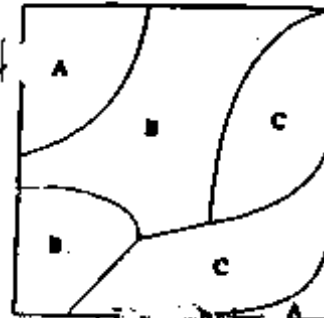
- A value map cannot be reclassified from an attribute table.
- A value map can be classified with the **Slicing operation**, which requires a group domain. A group domain is a special class domain, containing the names of the classes and the boundary values.
- A group domain can also be used for classifying values in tables .

Reclassification using group domain: Slicing





Soil Types A, B and C
with growth potential d and f



Soil Types A, B and C



Soil Types A, B and C

Steps

1. Reclassify soil Areas by Soil Type Only
2. Dissolve Boundaries between Areas of Same Soil Type
3. Merge Polygons into Large Objects

Reclassify, Dissolve and Merge

Measurement Functions

- Measurement functions involve the calculation of distances, lengths, perimeters, areas etc.
- Enables to obtain all kind of statistical information

Examples:

- the distance between two bore holes
- the area of sedimentary rocks
- the total length of the main river
- Different types of measurement operations:
Points, Segments, Polygons, Raster

Measurement Functions: Points

- Calculation of histograms for points
- Calculation of point density within pixels
- Calculation of distance between points
- Point in polygon calculation

Measurement functions: segments

- Calculation of histograms for segments
- Number of segments
- Length of segments
- Direction of segments
- Convert classes to unique segments

Measurement Functions: Polygons

- Number of polygons per class
- Area
- Perimeter
- Convert classes to unique polygons

Measurement Functions: Raster Maps

- Number of pixels per class
- Area
- Convert classes to unique groups of pixels: area numbering

Spatial Data analysis

- Retrieval, (Re)classification & Measurement operations,
- Overlay Operations,
- Neighbourhood Operations, and
- Connectivity Operations.

Overlay Operations

- Core of GIS analysis which combines several maps and give new information, i.e. new spatial elements
- Performed in both vector and raster data sets
- Combination of maps using arithmetic, relational, or conditional operators, and different functions
- Combines raster maps with Map Calculation tool
- Cross operation: Calculates possible occurrence of two maps
- Two dimensional tables: Matrix in which user can define how all classes of of two maps should be combined

Vector Overlay

During vector overlay, map features and the associated attributes are integrated to produce new composite map. Logical rules can be applied to how the maps are combined. Vector overlay can be performed on different type of map feature: viz., polygon-on-polygon overlay, line-in-polygon overlay, point-on-polygon overlay.

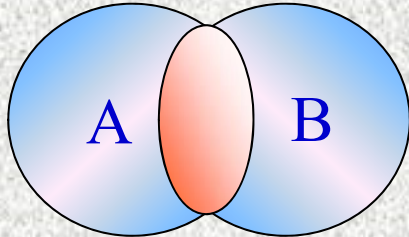
During the process of overlay, the attribute data associated with each feature type is merged. The resulting table will contain both the attribute data. The process of overlay will depend upon the modelling approach the user needs. One might need to carry out a series of overlay procedures to arrive at the conclusion, which

Vector Overlay: Logical Operators

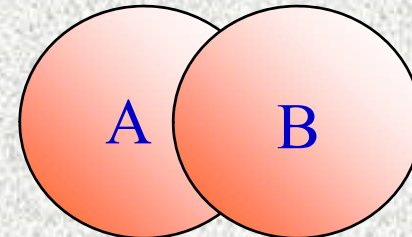
The concept of map logic can be applied during overlay. The logical operators are Boolean functions. There are basically four type of Boolean operator: OR, AND, NOT, XOR

With the use of logical, or Boolean, operators spatial elements/or attributes are selected that fulfill a certain condition, depending on two or more other spatial elements or attributes.

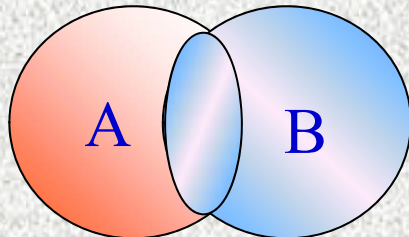
Vector Overlay: Boolean Operators



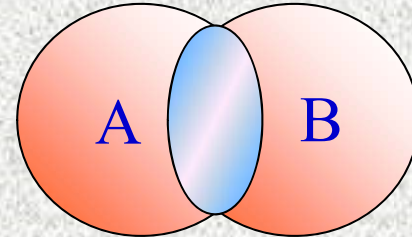
$A \text{ AND } B$



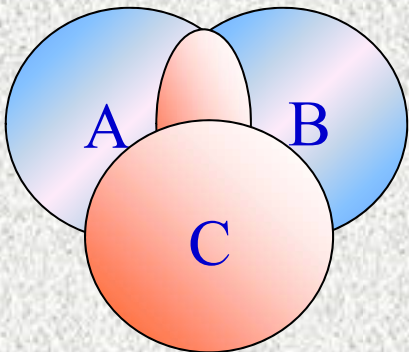
$A \text{ OR } B$



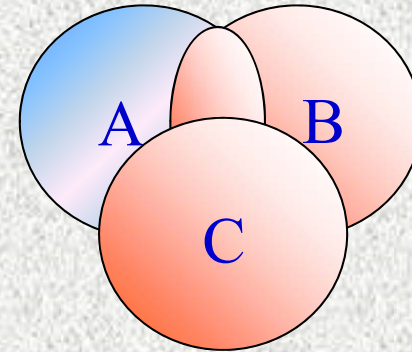
$A \text{ NOT } B$



$A \text{ XOR } B$

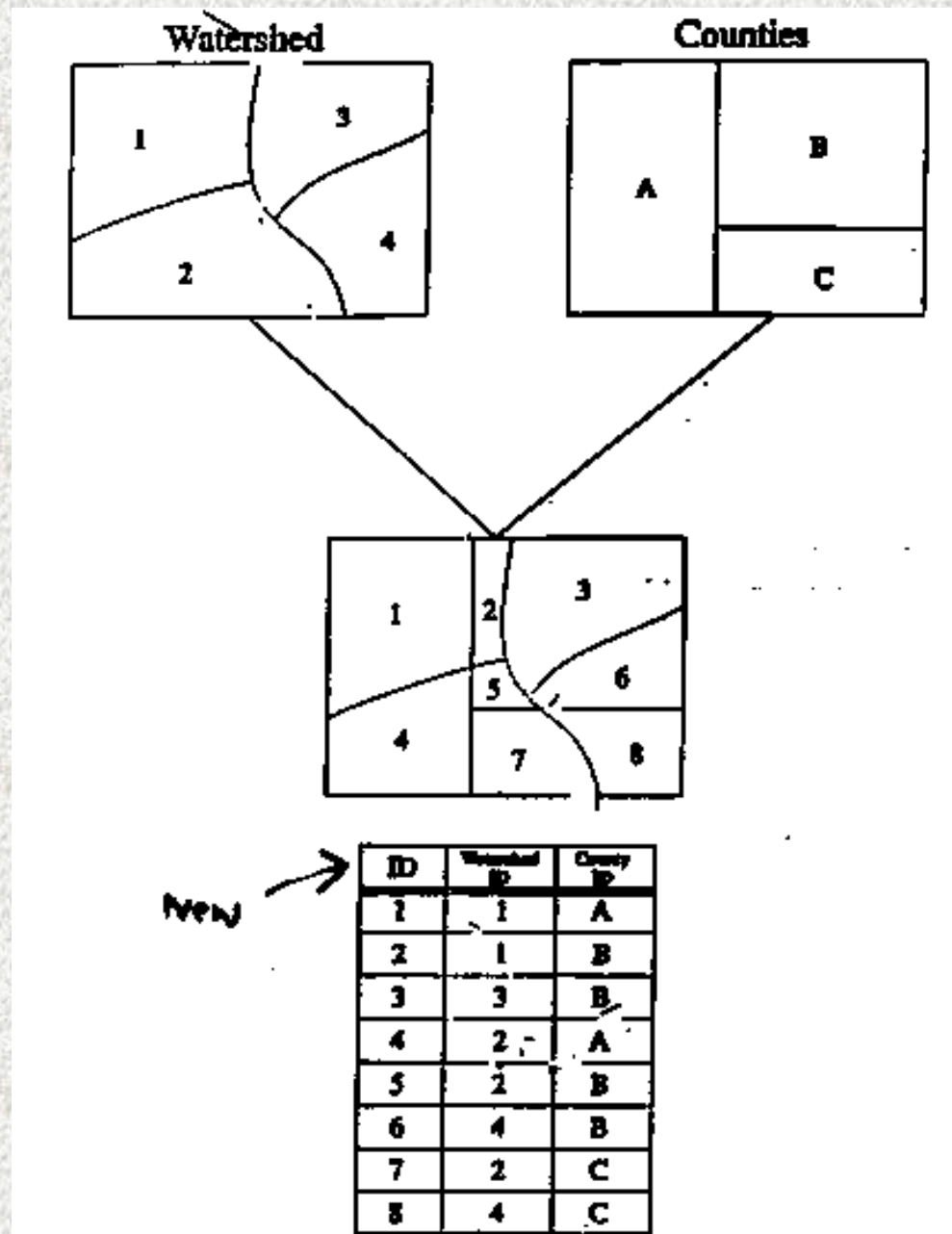


$(A \text{ AND } B) \text{ OR } C$

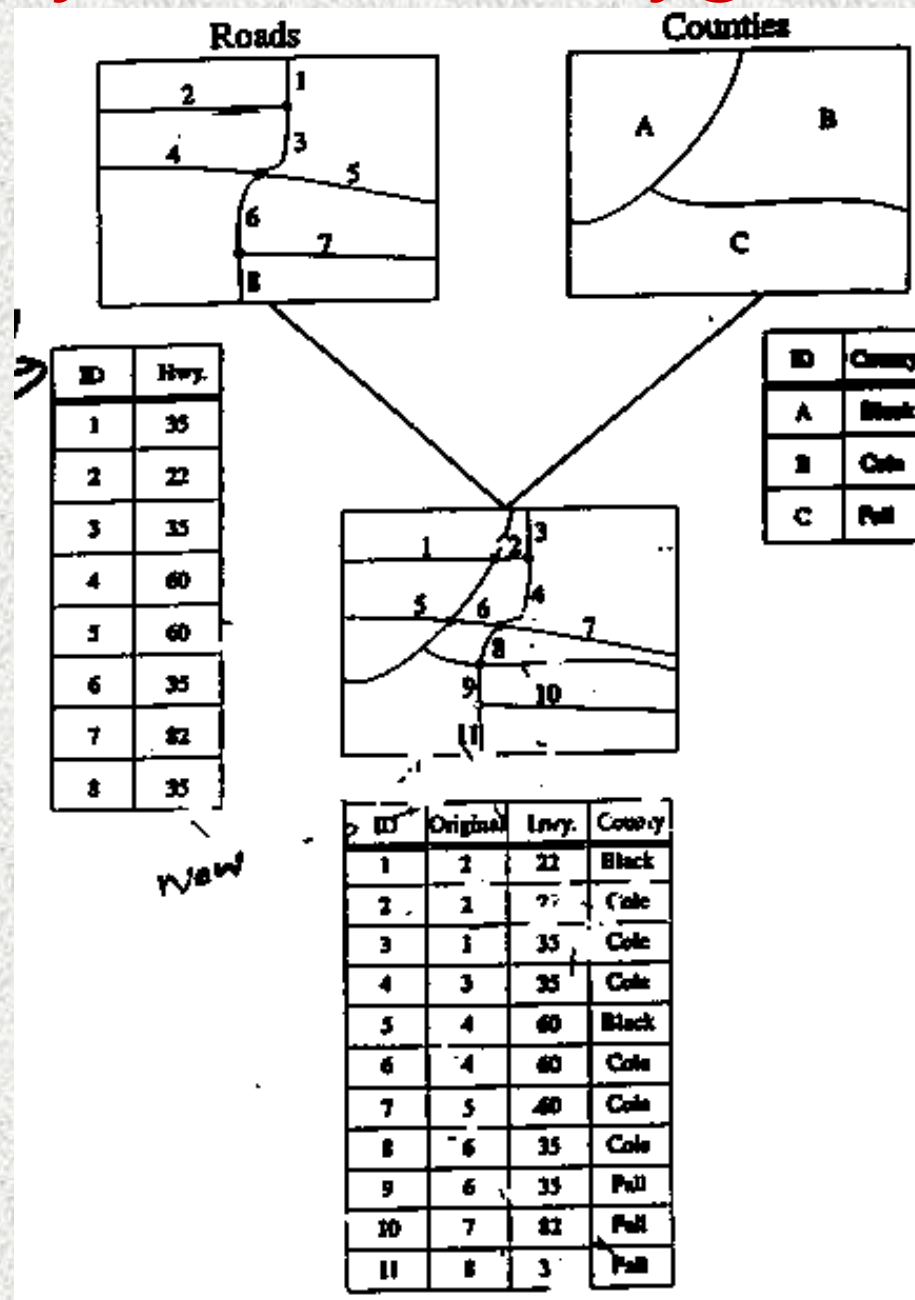


$A \text{ AND } (B \text{ OR } C)$

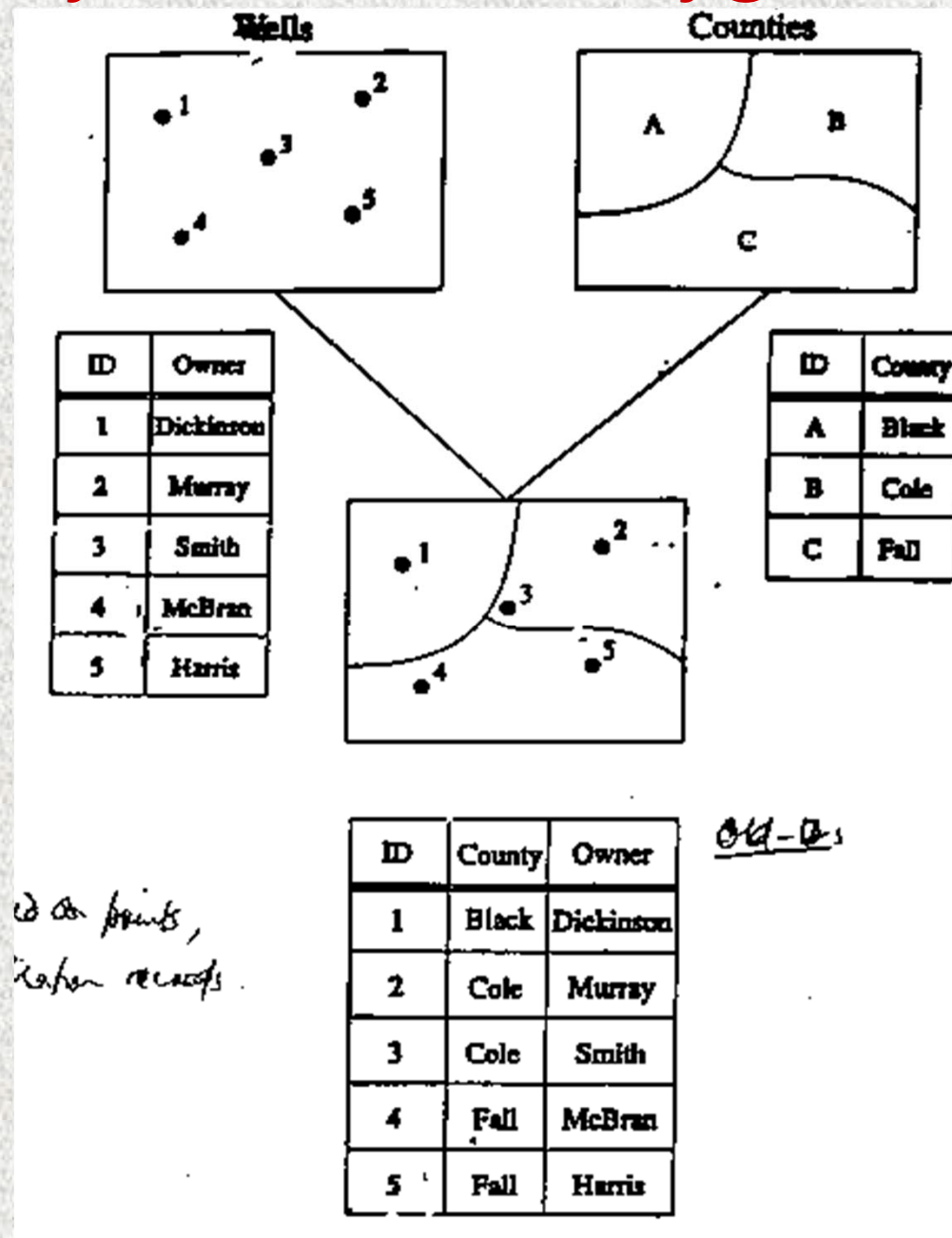
Vector Overlay: Polygon-on-Polygon



Vector Overlay: Line-on-Polygon

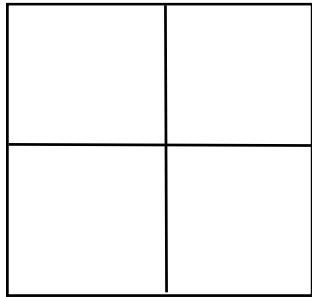


Vector Overlay: Point-on-Polygon

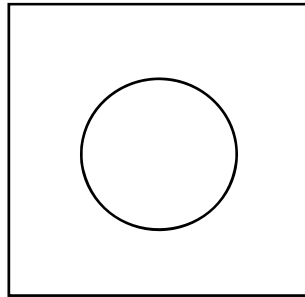


Vector Overlay: Summary

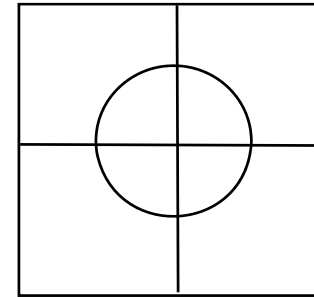
Polygon-on-polygon



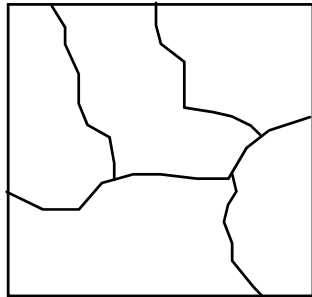
OR



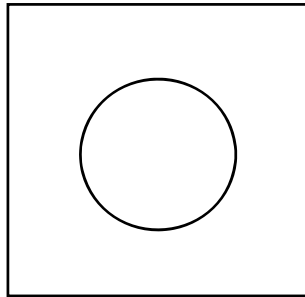
=



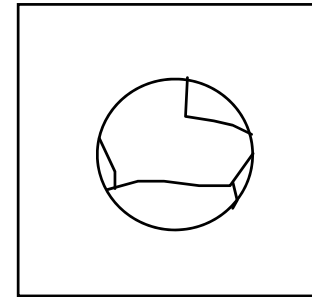
Line-on-polygon



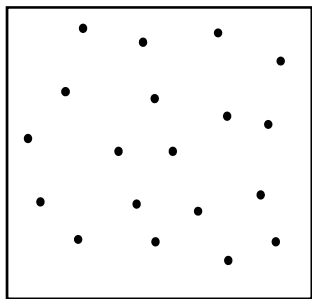
AND



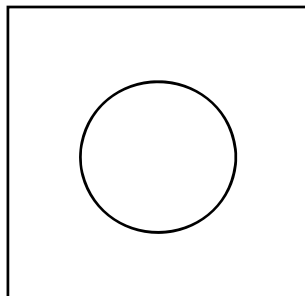
=



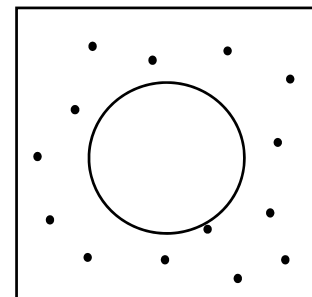
Point-on-polygon



NOT

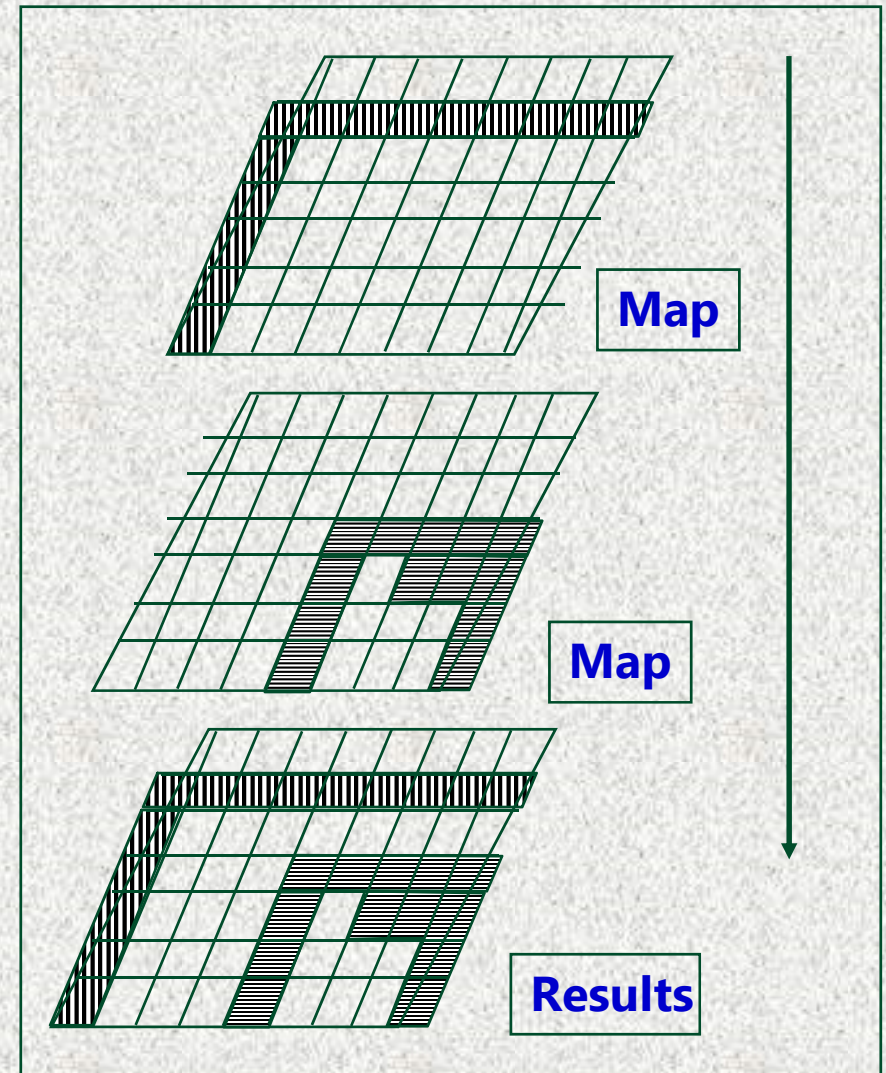


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Raster Overlay

In raster overlay, the pixel or grid cell values in each map are combined using arithmetic and Boolean operators to produce a new value in the composite map. The maps can be treated as arithmetic variables and perform complex algebraic functions. The method is often described as map algebra. The raster GIS provides the ability to perform map layers mathematically. This is particularly important, for the modelling in which various maps are combined using various mathematical functions. Conditional operators are the basic mathematical functions that are supported in GIS



Raster Overlay: Map Calculation

Mathematical operators apply a mathematical operation to the values in two or more input raster maps; mathematical functions apply a mathematical function to the values in a single raster map. There are three groups of mathematical operators in the Map Calculator: Arithmetic, Boolean, and Relational.

Arithmetic Operators - The Arithmetic operators (*, /, -, +) allow for the addition, subtraction, multiplication, and division of two raster maps, or numbers, or combination of the two.

Boolean Operators - The Boolean operators (And, Not, Or, and Xor) use Boolean logic (TRUE or FALSE) on the input values. Output values of TRUE are written as 1 and FALSE as 0.

Relational Operators - The Relational operators (<, <=, <>, =, >, and >=) evaluate specific relational conditions. If the condition is TRUE, the output is assigned 1; if the condition is FALSE, the output is assigned 0. In an avalanche study, a relational operator can be used to show the areas of highest avalanche risk by identifying all cells that are greater than 5,000 meters.

Map calculation

- Map calculation is used for the execution of most spatial analysis functions and modeling operations.
- It integrates spatial and tabular data.
- Map calculation enables the user to perform queries and overlays.

The following operations can be executed:

- manipulation of one or more raster maps by using arithmetic, relational, logical, conditional, exponential, logarithmic and other operators and functions,
- creation of attribute maps from raster maps with an attribute table,
- classification of a domain Value map according to a domain Group,
- application of user-defined functions.

General Syntax of MapCalc Formulae

A MapCalc formula or statement to be executed consists of :

- an output raster map name that will contain the result of the calculation
- a definition symbol (=), or an assignment symbol (:=),
- and an expression.

OutputMap = Expression or

OutputMap:= Expression

Example: A simple MapCalc formula reads:

Map3 = Map1 + Map2

The values of the pixels in Map3 are the sums of the values in the corresponding pixels of Map1 and Map2.

WHAT CELLS ARE BOTH A AND 7?

A	A	B
A	A	B
C	C	B

RECLASSIFY

1	1	0
1	1	0
0	0	0

MULTIPLY

1x0	1x1	0x1
1x0	1x1	0x1
0x0	0x0	0x1

6	7	7
6	7	7
8	8	7

RECLASSIFY

0	1	1
0	1	1
0	0	1

0	1	0
0	1	0
0	0	0

Logical Operations on Raster: LOGICAL AND

WHAT CELLS ARE A OR 7?

A	A	B
A	A	B
C	C	B

6	7	7
6	7	7
8	8	7

RECLASSIFY

1	1	0
1	1	0
0	0	0

RECLASSIFY

0	1	1
0	1	1
0	0	1

ADD

1+1	1+1	0+1
1+0	1+1	0+1
0+0	0+0	0+1

1	2	1
1	2	1
0	0	1

RECLASSIFY

1	1	1
1	1	1
0	0	1

Logical Operations on Raster: LOGICAL OR

Difference between "=" and ":="

- By using the definition symbol "=" on the command line, a dependent map is created in which the data depends on the data of the input data; i.e. defines how this map was created is stored.
- By using the ":=" assignment symbol on the command line, a map is created which is independent from other maps. The output values are directly assigned to output pixels, etc.

Expression

- The expression usually contains operators and/or functions to specify what calculation has to be performed.
- Operators used in an expression are for instance: + - / * ,etc.
- When using class names or IDs in an expression, "double quotes" are needed around the class names or IDs.

Operators

- Arithmetic operators, to multiply, divide, subtract or add maps and/or constant values.
- Logical operators, to compare two expressions and check if both are true (AND), at least one is true (OR), only one is true (XOR). The NOT statement checks whether an expression is not true.
- Relational operators to test whether one expression is larger, smaller, equal than another expression etc.

Arithmetic operators

5	5	2	2
5	5	5	2
6	2	2	2
6	6	6	6

MapA

4	4	8	8
4	4	4	8
1	1	1	8
1	1	8	8

MapB

$$\text{MapC} = \text{MapA} + 10$$

15	15	12	12
15	15	15	12
16	12	12	12
16	16	16	16

MapC

$$\text{MapC1} = \text{MapA} + \text{MapB}$$

9	9	10	10
9	9	9	10
7	3	3	10
7	7	14	14

MapC1

$$\text{MapC2} = ((\text{MapA} - \text{MapB}) / (\text{MapA} + \text{MapB})) * 100$$

Negative values in the map mapC2 are showed in Bold

11	11	60	60
11	11	11	60
71	33	33	60
71	71	14	14

MapC2

Logical Operators

F	F	F		
F	F			
	F	F		F
		F	F	F
			F	F

MapA

F = forest
7 = 700 m.
6 = 600 m.
4 = 400 m.

7	7	7	7	4
7	7	7	7	4
4	4	4	4	4
6	6	4	4	4
6	6	6	6	6

MapB

MapD = (MapA = "forest") and (MapB < 500)

0	0	0	0	0
0	0	0	0	0
0	1	1	0	1
0	0	1	1	1
0	0	0	0	0

MapD

MapD1 = (MapA = "forest") or (MapB < 500)

1	1	1	0	1
1	1	0	0	1
1	1	1	1	1
0	0	1	1	1
0	0	0	1	1

MapD1

MapD2 = (MapA = "forest") xor (MapB < 500)

1	1	1	0	1
1	1	0	0	1
1	0	0	1	0
0	0	0	0	0
0	0	0	1	1

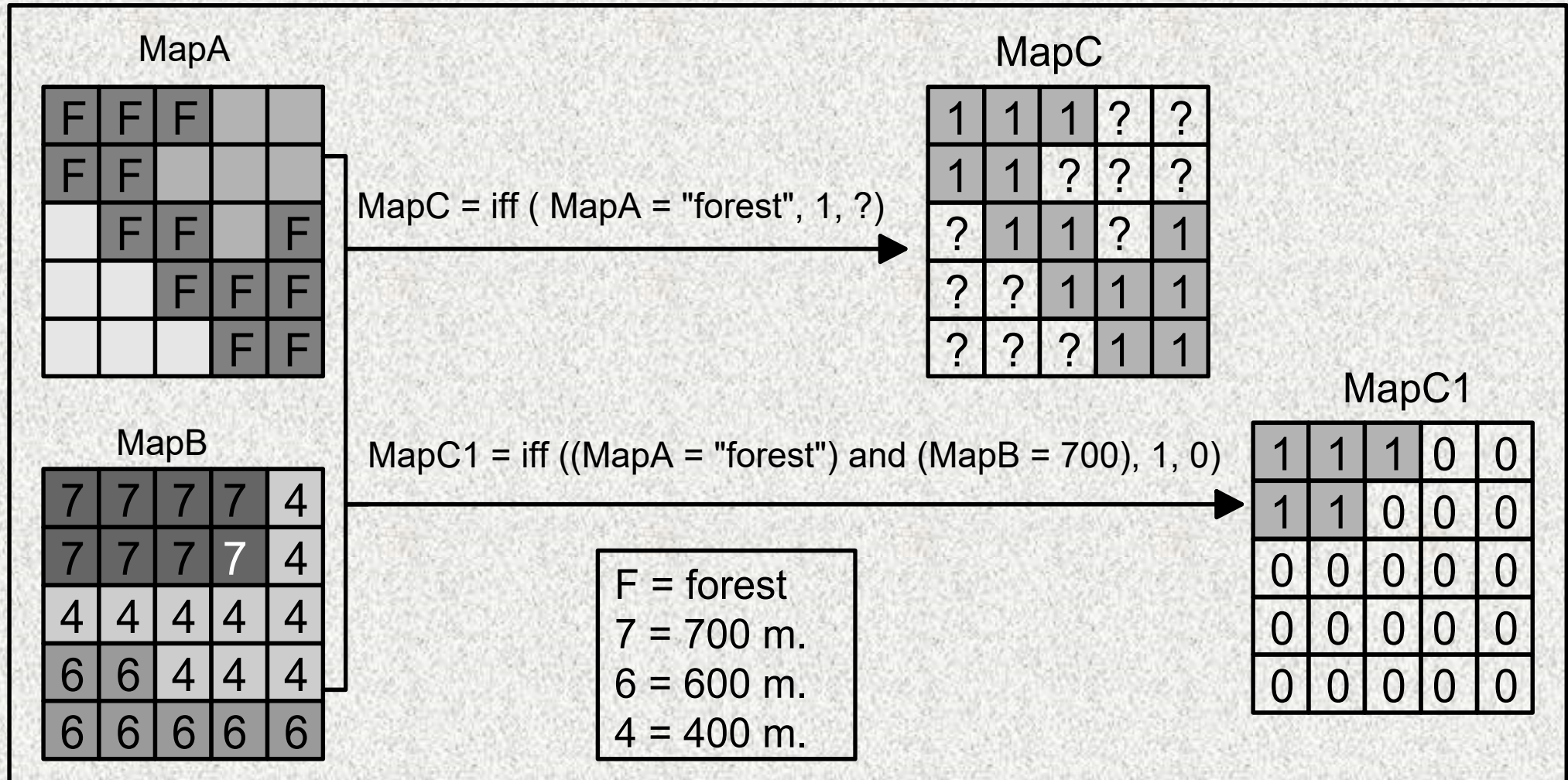
MapD2

MapD3 = (MapA = "forest") and not (MapB < 500)

1	1	1	0	0
1	1	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	1	1

MapD3

Conditional Operators: IFF Function



IFF Functions with class maps

- IFF(expression, domain1, "?").
Slide=iff((Geom = "al") or (Geom="ol"), Geom, "?")
- IFF(expression, domain1, "name").
Slide2=iff((Geom="al") or (Geom="ol"), Geom, "no Landslide")
- IFF(expression, domain1, domain2).
Slide4=iff((Geom="al") or (Geom="ol") or (Geom="he"),
Geom, Landuse)
- IFF(expression, "name", "name").
Slide5=iff((Geom="al") or (Geom="ol"), "Landslides", "No
landslides")

Undefined values: ?

- No data available for the pixel: data should still be supplied
- Pixel is outside the study area,
- The result of a calculation was wrong
`Result=iff(Landuse="Forrest",Landuse,"?")`
- Value is outside of the value range that is defined.

Undefined values and IFF functions

IFF(a, b, c):

- Statement a is true, so the result will be b ,
- Statement a is false, so the result will be c , or
- Statement a is *undefined*. If we don't know what a is, then we also can not say whether a is true or false, so the result is also undefined.

Land = Iff(Landuse = "Forest") or Iff(Landuse = "Agriculture", Landuse, "Water")

Undefined values and IF functions

a AND b	a=True	a=False	a=Undefined
b=True	True	False	Undefined
b=False	False	False	False
b=Undefined	Undefined	False	Undefined
a OR b	a=True	a=False	a=Undefined
b=True	True	True	True
b=False	True	False	Undefined
b=Undefined	True	Undefined	Undefined

Cross Operation

- Map calculation tool not useful if we are interested in many combinations of two maps, e.g. 10 classes from Map A and 5 classes from Map B.
- The Cross operation performs an overlay of two raster maps by comparing pixels at the same positions in both maps and keeping track of all the combinations of values or classes that occur in both maps.
- The input maps should have same georeference.
- The results are stored in an output cross-map and a cross-table. These obtain an Identifier domain. This domain contains items which are combinations of the class names, IDs, group names or values, of the first input map and those of the second input map.

Cross Operation: An Example

Input map: Landuse

G	G	F	F	F	F
G	G	G	G	F	F
G	G	G	G	F	F
G	L	L	F	F	F
L	L	L	F	F	F
L	L	L	F	F	F

Crosstable

	Landuse	Geology	Npix
Forest*Alluvial	Forest	Alluvial	9
Forest*Shale	Forest	Shale	8
Grass*Alluvial	Grass	Alluvial	1
Grass*Shale	Grass	Shale	10
Lake*Alluvial	Lake	Alluvial	8

Input map: Geology

S	S	S	S	S	S
S	S	S	S	S	S
S	S	S	S	S	S
A	A	A	A	A	A
A	A	A	A	A	A
A	A	A	A	A	A

Cross map

G*S	G*S	F*S	F*S	F*S	F*S
G*S	G*S	G*S	G*S	F*S	F*S
G*S	G*S	G*S	G*S	F*S	F*S
G*AL	A	L*A	F*A	F*A	F*A
L*A	L*A	L*A	F*A	F*A	F*A
L*A	L*A	L*A	F*A	F*A	F*A

Legend: Landuse

F	Forest
G	Grass
L	Lake

Legend: Geology

A	Alluvial
S	Shale

Two Dimensional Tables

- In some cases it is better to select the output results yourself, so that you can decide for each combination of classes or Ids in the input maps.
- A matrix, with user defined output class names, IDs or values, for each combination of classes/IDs of two input maps.

Two Dimensional Tables

Input map: Landuse

G	G	F	F	F	F
G	G	G	G	F	F
G	G	G	G	F	F
G	L	L	F	F	F
L	L	L	F	F	F
L	L	L	F	F	F

Two-dimensional table

	Alluvial	Shale
Forest	Suitable	Unsuitable
Grass	Unsuitable	Suitable
Lake	Unsuitable	Unsuitable

Input map: Geology

S	S	S	S	S	S
S	S	S	S	S	S
S	S	S	S	S	S
A	A	A	A	A	A
A	A	A	A	A	A
A	A	A	A	A	A

Output map

S	S	U	U	U	U
S	S	S	S	U	U
S	S	S	S	U	U
U	U	U	S	S	S
U	U	U	S	S	S
U	U	U	S	S	S

Legend: Landuse

F	Forest
G	Grass
L	Lake

Legend: Geology

A	Alluvial
S	Shale

Legend: output map

S	Suitable
U	Unsuitable

Raster description

- resolution is 500 m
- entire array is 2.5 km by 2.5 km
- columns are aligned North-South

LAYER 1: LAKE

1 = lake, 0 = not lake

1	1	0	0	0
1	1	0	0	0
1	0	0	0	0
0	0	0	0	0
0	0	0	0	0

LAYER 2: FOREST SPECIES

0 = Black Spruce, 2 = Jackpine, 0 = no forest

0	0	2	2	2
0	0	2	2	2
0	1	1	1	2
1	1	1	1	1
1	1	1	1	1

LAYER 3: SOIL DRAINAGE

0 = waterlogged, 1 = poor, 2 = good

0	0	2	2	2
0	0	1	1	2
0	0	1	1	2
0	1	1	1	2
1	1	1	2	2

OBJECTIVE: Identify areas suitable for logging

An area is suitable if it satisfies the following criteria:

- is Jackpine
 - Black Spruce are not valuable
- is well drained
 - poorly drained and waterlogged terrain cannot support equipment, logging causes unacceptable environmental damage
- is not within 500 m of a lake or watercourse
 - erosion hazard

PROCEDURE:

Recode layer 2 - y if value 2 (Jackpine), n if other value

LAYER 2: FOREST SPECIES

0	0	2	2	2
0	0	2	2	2
0	1	1	1	2
1	1	1	1	1
1	1	1	1	1

LAYER 4: LOGGABLE SPECIES

n	n	y	y	y
n	n	y	y	y
n	n	n	y	y
n	n	n	n	n
n	n	n	n	n

Recode layer 3 - y if value 2 (good), n if other value

LAYER 3: SOIL DRAINAGE

0	0	2	2	2
0	0	1	1	2
0	0	1	1	2
0	1	1	1	2
1	1	1	2	2

LAYER 5: DRAINED SOIL

n	n	y	y	y
n	n	n	n	y
n	n	n	n	y
n	n	n	n	y
n	n	n	y	y

Example Project Details

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Spread the lake on layer 1 by one cell (300 m)

LAYER 1: LAKE

```

1 1 0 0 0
1 1 0 0 0
1 0 0 0 0
0 0 0 0 0
0 0 0 0 0

```

LAYER 6: NEAR LAKE

```

1 1 1 0 0
1 1 1 0 0
1 1 0 0 0
1 0 0 0 0
0 0 0 0 0

```

Recode layer 6 - if in spread lake, y if not

LAYER 6: NEAR LAKE

```

1 1 1 0 0
1 1 1 0 0
1 1 0 0 0
1 0 0 0 0
0 0 0 0 0

```

LAYER 7: AWAY FROM LAKE

```

n n n y y
n n n y y
n n y y y
n y y y y
y y y y y

```

Overlay layers 4 and 5 - if both 4 and 5 are y, n otherwise

LAYER 4: LOGGABLE SPECIES

```

n n v y y
n n y y y
n n n n y
n n n n n
n n n n n

```

LAYER 5: DRAINED SOIL

```

n n y y y
n n n n y
n n n n y
n n n n y
n n n y y

```

LAYER 8: SPECIES AND SOILS

```

n n y y y
n n n n y
n n n n y
n n n n n
n n n n n

```

Example Project Details
(Page 2 of 3)

Overlay layers 7 and 8 - if both 7 and 8 are y, n otherwise

LAYER 7: AWAY FROM LAKE

```

n n n y y
n n n y y
n n y y y
n y y y y
y y y y y

```

LAYER 8: SPECIES & SOILS

```

n n y y y
n n n n y
n n n n y
n n n n n
n n n n n

```

LAYER 9: LOGGABLE SITES

```

n n n y y
n n n n y
n n n n y
n n n n n
n n n n n

```

RESULT: The loggable cells are y on layer 9

Example Project Details
(Page 3 of 3)

Spatial Data Analysis

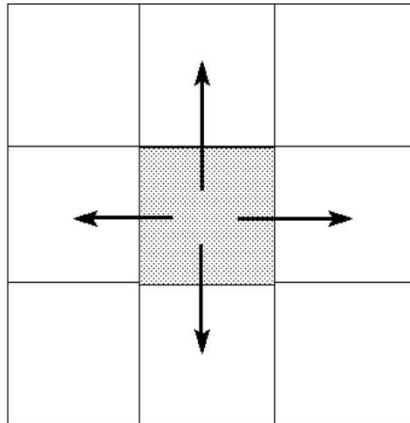
- Retrieval, (re)classification & Measurement operations,
- Overlay Operations,
- Neighbourhood Operations, and
- Connectivity Operations.

Neighbourhood Operations

- Neighbourhood operations evaluate the characteristics of an area **surrounding** a specified location

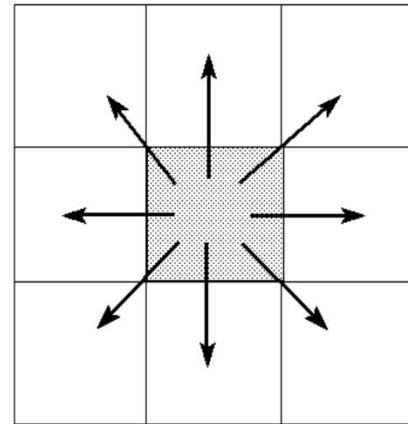
4-connected

Only the horizontal and Vertical neighbours of the Central pixel are used



8-connected

All 8 neighbours of the Central pixel are used



Neighbourhood operations

Can be sub-divided into:

- **Retrieval functions:** calculate values based for a certain pixel, based on the values of its neighbours.
- **Interpolation functions:** estimates unknown values at unsampled sites using known values of existing observations at neighbouring locations.
- **Topographic functions:** calculates values that describe the topography at a specific location using local terrain information (= neighbourhood).

Neighbourhood Retrieval Operations

This is done by moving a small calculation window, of 3 by 3 cells, or 5 by 5 cells, over the whole map, and store the calculation result in the central pixel. The process is quite similar to Filtering procedure.

This operation can be executed on both scalar (e.g. water depth, elevation), or on ordinal (class1, class2, class3) or nominal (e.g. lithological types) data. On scalar data we can calculate properties, such as average, standard deviation, total, and ,maximum/minimum. For nominal and ordinal data, we can calculate the same, with exception of average, standard deviation, and total, which have no meaning when the pixels represent geological units.

Topographic Functions

Topographic functions are used to calculate values that describe the topography at a specific geographic location. A neighbourhood is used to characterize local terrain.

Many of the applications of DEM, such as slope angle, slope direction, slope convexity, hillshading, automatic catchment delineation and drainage pattern, and slope length calculation can be done using neighbourhood operations. Also, such as calculation of groundwater flow, runout distance of debris flow, etc.

Interpolation

- Interpolation is the procedure of estimating **unknown** values at unsampled sites using the known values of **existing** observations at **neighbouring** locations

Examples:

- Point interpolation (rainfall, spot heights)
- Line interpolation (contours)

Interpolation

10		30	60		40
	20				
	40		70	80	
20		80			90
			80		

10	20	30	60	50	40
15	20	25	65	72	57
30	40	55	70	80	67
28	32	63	74	84	86
20	50	80	77	86	90
38	50	62	80	84	87

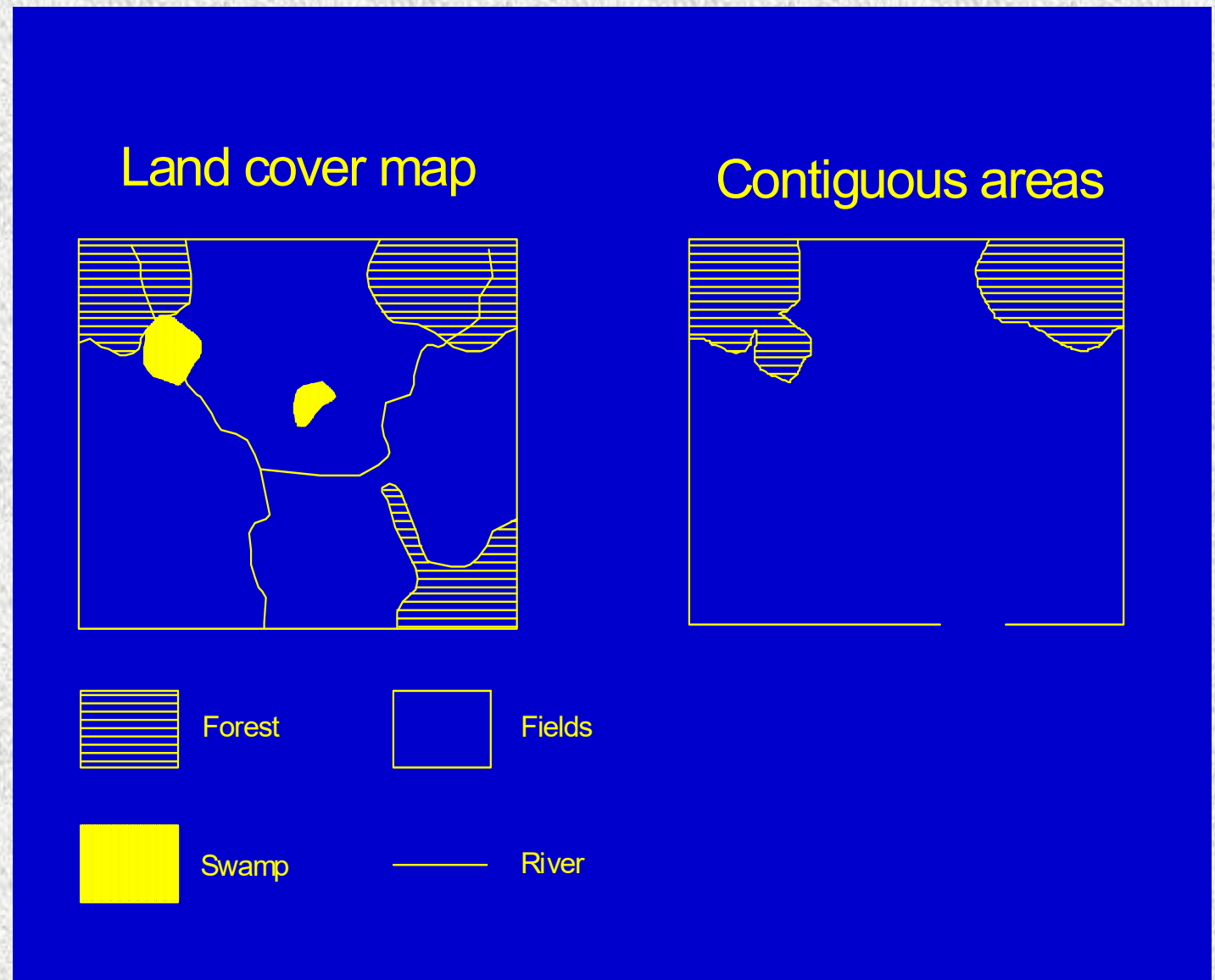
Connectivity operations

- **contiguity functions:** connected areas that share (a) common characteristic(s),
- **proximity functions:** connected areas having the same distance (in time, distance, costs, etc) to a given point, line or area,
- **network functions:** areas (usually lines) that form a set of interconnected features through which resources from one location to another are moved.
- **spread functions:** connected areas that result for spreading, dilution or accumulation of phenomena from a given point, line or area, and
- **seek functions:** connected areas (usually lines) that form an optimum pathway according (a) specified decision rule(s),

Connectivity operations

Contiguity Functions

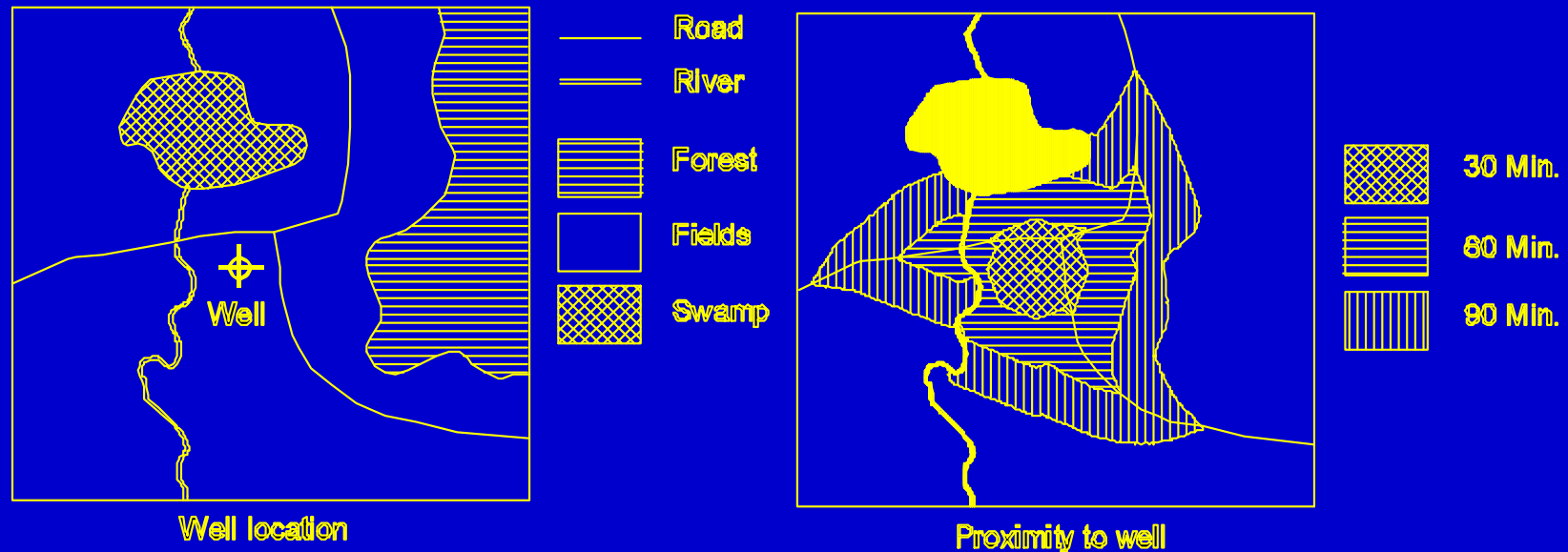
- Evaluates the characteristics of spatial units that are connected. Consists of spatial units that share one or more specified characteristics.
- Unbroken adjacency, I.e. no gaps are permitted.



Determine land units to be used as nature reserves. Include forests, rivers, and swamps under the condition that the minimum area is 400 km² with no section narrower than 10

Proximity Functions

- Proximity is a measure of distance between features
- Evaluates the characteristics of connected areas having the same distance (in time, distance, costs, etc) to a given point, line or area,



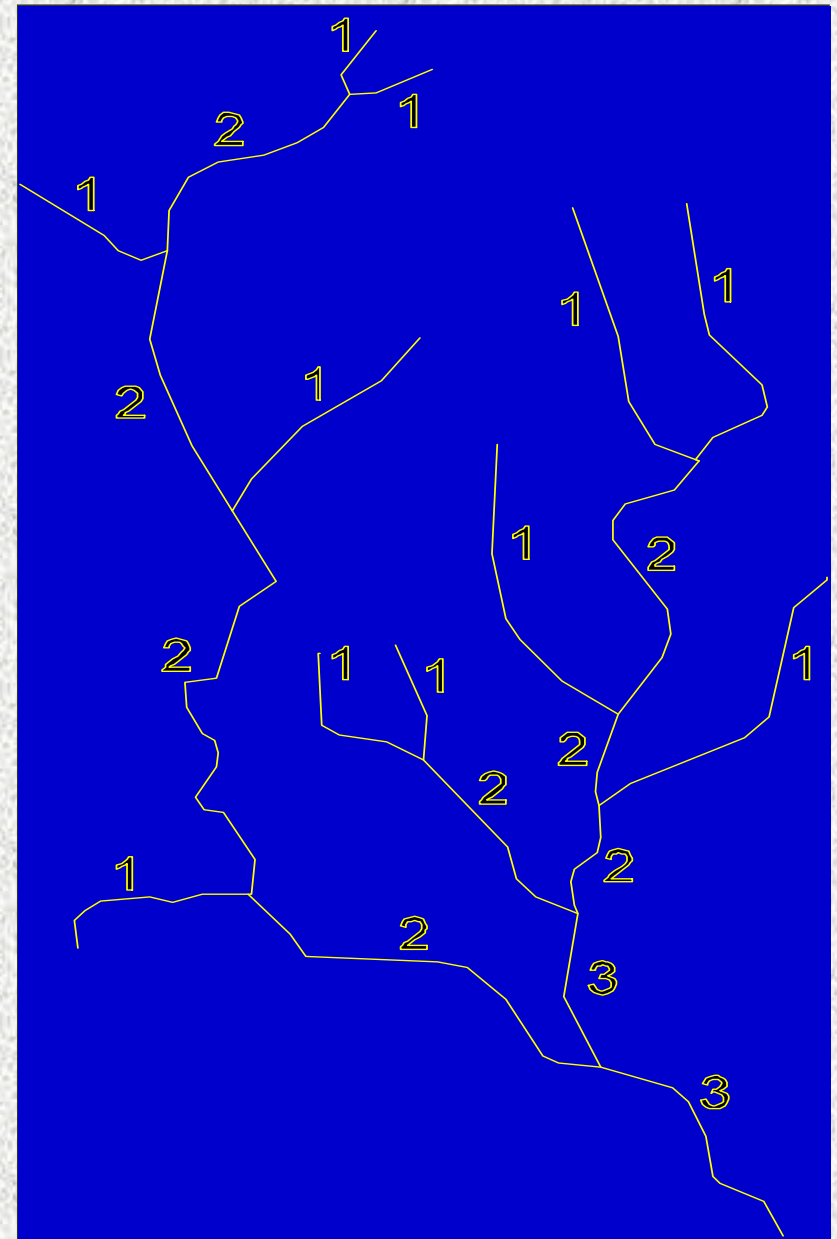
Determination of a travel time map to drinkwater wells, using different speeds through different terrain. On the road: 2 km/hour, in the fields: 1 km/hour, through the bush: 0.7 km/hour. Swamp and river: inaccessible

Network Functions

- A network is a set of interconnected linear features that form a pattern or framework.
- Network functions are commonly used for the analysis of moving resources from one location to another through a set of interconnected features.

Typical examples:

- stream ordering
- urban transportation service (fastest ambulance route)



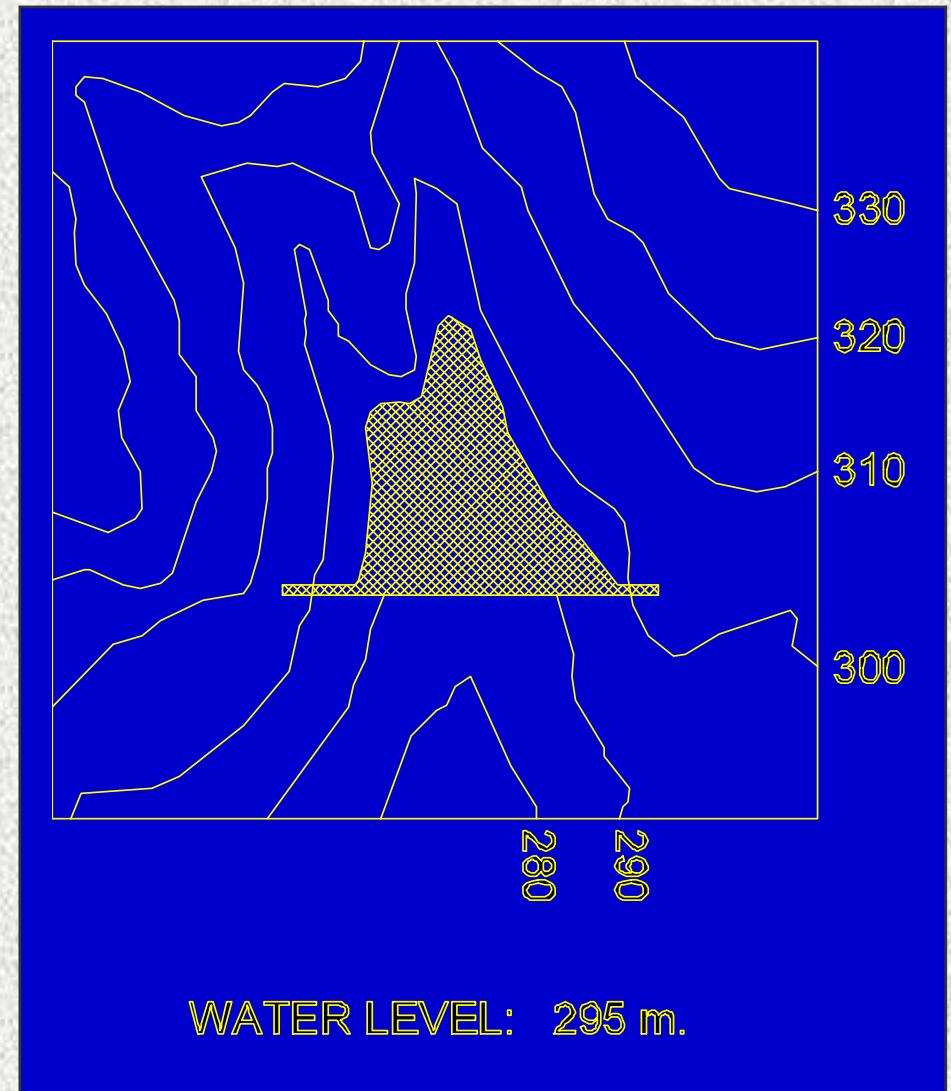
Strahler orders

Spreading Functions

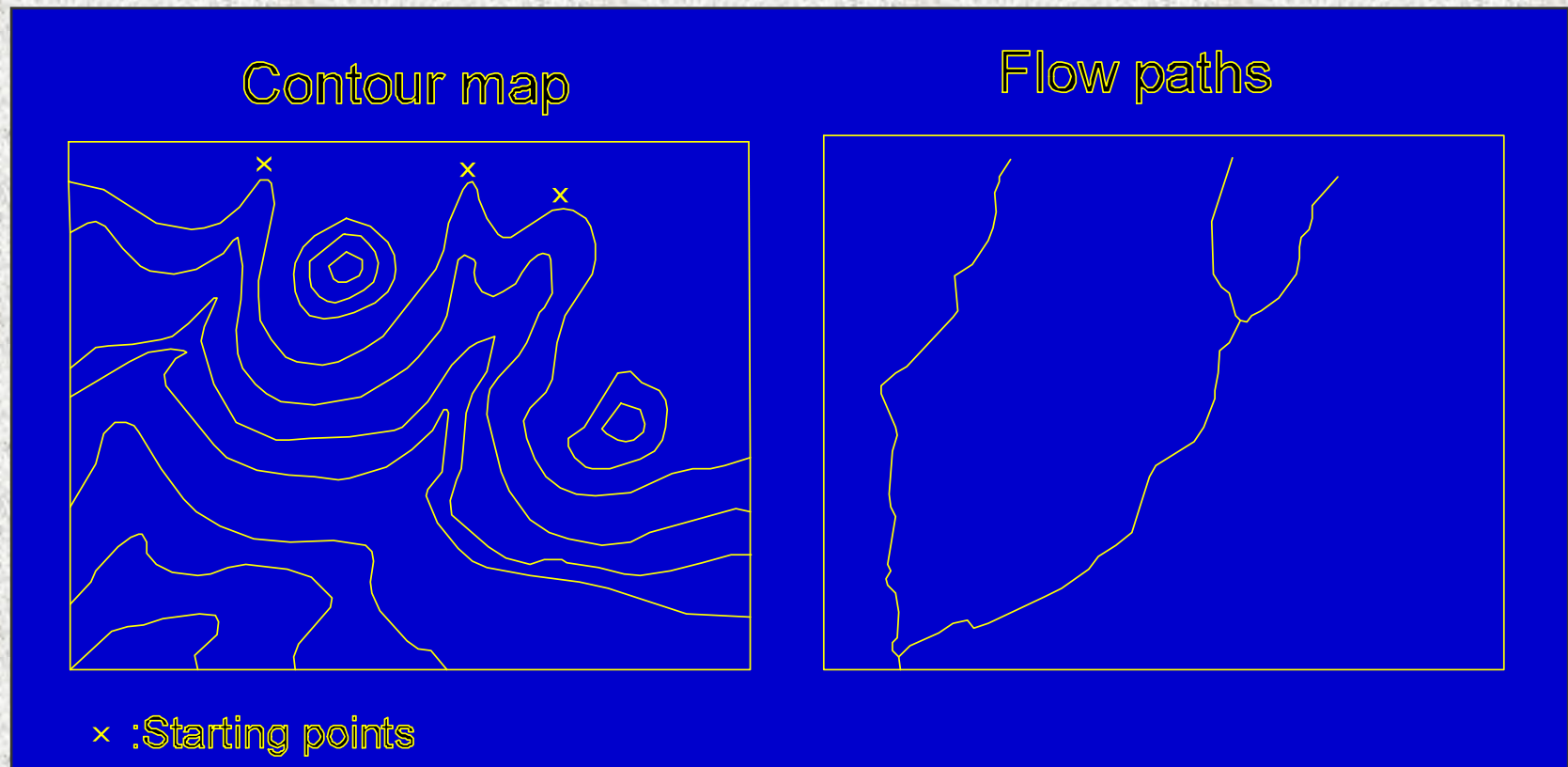
- Powerful tool to analyze a wide range of phenomena.
- Mix of proximity and network functions.
- Spread functions evaluate phenomena that spread, dilute or accumulate with distance.

Examples:

- To define drainage basins by spreading out from a point and allowing movement only to adjacent cells with the same or higher elevation.
- Ground water pollution from a pollution source



Seek or Stream Functions



Seek functions determine optimum pathways using specified decision rules
Example: determination of the path of water flow.

Calculating distances

- Source map is required: points, lines, or areas. It is a raster map, in which the distance is calculated for the undefined values.
- Euclidian distance calculation: straight line between two points, based on rule of Pythagoras

Distance calculation

- Distance of each pixel to the central pixel is calculated.
- Distance is in meters, but can be changed in time units.
- Program calculates in a 3*3 window, in several passes.

2.8	2.4	2	2.4	2.8
2.4	1.4	1	1.4	2.4
2	1		1	2
2.4	1.4	1	1.4	2.4
2.8	2.4	2	2.4	2.8

Example of proximity function

