"Knowing where things are and why is essential to rational decision-making."
Jack Dangermond

Chapter 7 Spatial Analysis

Playing with places

When you think of a name and address database, you probably visualise a table of data in rows and columns. What you might miss is that each of these records represents a person or family that lives in a particular place (location). Furthermore, that particular place (location) can tell us something about a person's standard of living, neighbourhood, access to schools, access to hospital, distance to the main market, vulnerability to local crime, exposure to pollution levels and so on. Through GIS analysis, it allows us to visualise the 'bigger picture' by allowing us to see patterns and relationships within the geographic data. The results of analysis give insight into a place, help focus actions or select an appropriate option. The beauty of GIS is its ability to perform spatial analysis.

What is spatial analysis?

Spatial analysis is a process for looking at geographic patterns in data and relationships between features. The actual methods used can be simple—just a map of the theme being analysed—or more complex involving models that mimic the world by combining many data layers.

Spatial analysis allows us to study real-world processes. It gives information about the real world that may be the present situation of specific areas and features or the changes or trends in a situation. For instance, it may be able to answer 'where and by how much are forest areas decreasing or increasing?' or 'where are urban areas growing in the Kathmandu valley?' and so on.

Spatial analysis functions

Spatial analysis functions range from simple database query to arithmetic and logical operation to complicated model analysis. Each of these functions is briefly described below.

Database query

Database query is used to retrieve attribute data without altering the existing data. The function can be performed by simply clicking on the feature or by means of a conditional statement for complex queries. The conditional statement can involved Boolean (logical) operators—and, or, not, xor (exclusive of or)—or relational (conditional) operators—=, >, <, <> (not equal to). An example of Boolean operators that combine more than two conditions is shown in Figure 7.1.

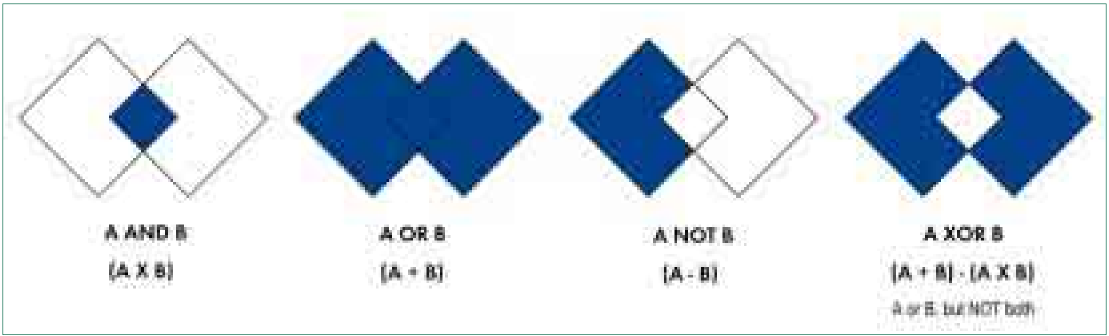


Figure 7.1
Boolean operations

For example, in Figure 7.2, the Boolean operator used is ([LandUse] = 'Agriculture') OR ([LandUse] = 'Shrub').

Reclassification

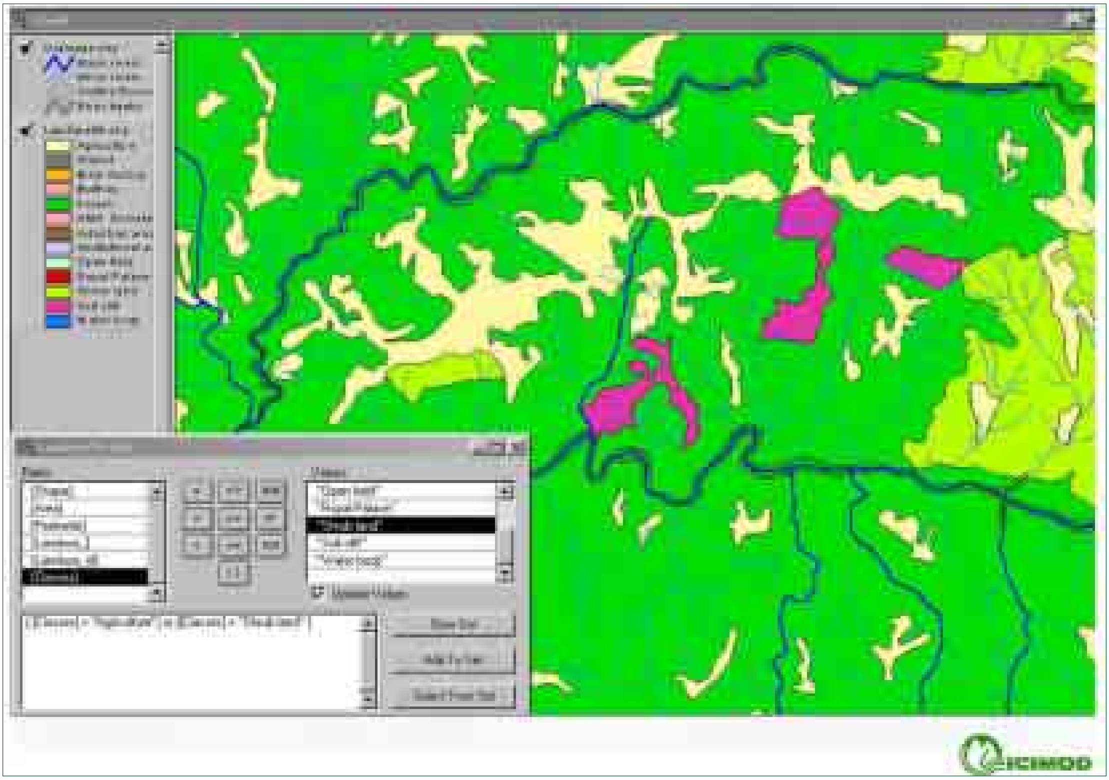
(Re)classification operations involve the reassignment of thematic values to categories of an existing map. The following are examples.

- Classify an elevation map into classes with intervals of 500 m (Figure 7.3).
- Reclassify a VDC (village development committee) map based on population density (Figure 7.4).

Overlay

Overlay is at the core of GIS analysis operations. It combines several spatial features to generate new spatial elements. Overlay can be defined as a spatial

Figure 7.2
Selection using Boolean operators



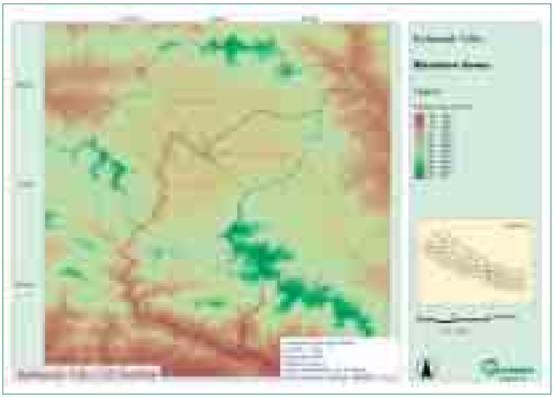


Figure 7.3
Classification of an elevation map of Kathmandu valley into different intervals

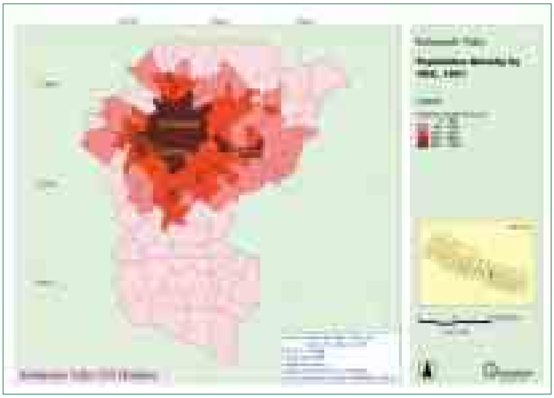


Figure 7.4
Classification of a VDC map of Kathmandu valley based on population density, 1991

operation that combines various geographic layers to generate new information. Overlay is done using arithmetic, Boolean and relational operators, and is performed in both vector and raster domains.

Vector overlay

During vector overlay, map features and their associated attributes are integrated to produce a new composite map. Logical rules can be applied to determine how the maps are combined. Vector overlay can be performed on various types of map feature: polygon-on-polygon, line-on-polygon, point-on-polygon (Figure 7.5). During the process of overlay, the attribute data associated with each feature type are merged. The resulting table will contain all the attribute data.

Figure 7.5
Vector overlay

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 (Figure 7.6). The raster GIS provides the ability to perform map layers mathematically. The map algebraic function uses mathematical expressions to create new raster layers by comparing them.

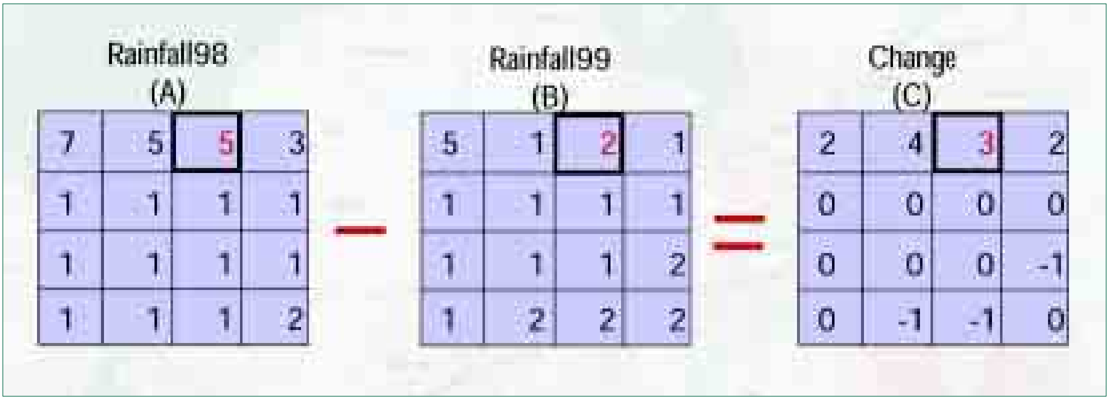


Figure 7.6
Map algebra

There are three groups of mathematical operators in the map calculator: arithmetic, Boolean, and relational.

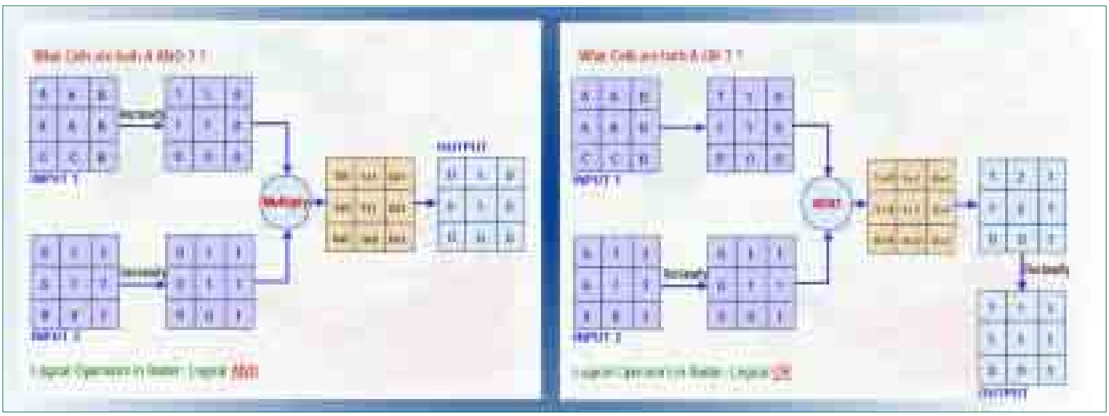
- **Arithmetic operators** (+, -, *, /) allow for the addition, subtraction, multiplication and division of two raster maps or numbers or a combination of the two.
- **Boolean operators** (and, not, or, xor) use Boolean logic (true or false) on the input values. Output values of true are written as 1 and false as 0.
- **Relational operators** (<=, <>, =, >, >=) evaluate specific relational conditions. If the condition is true, the output is assigned 1; if the condition is false, the output is assigned 0.

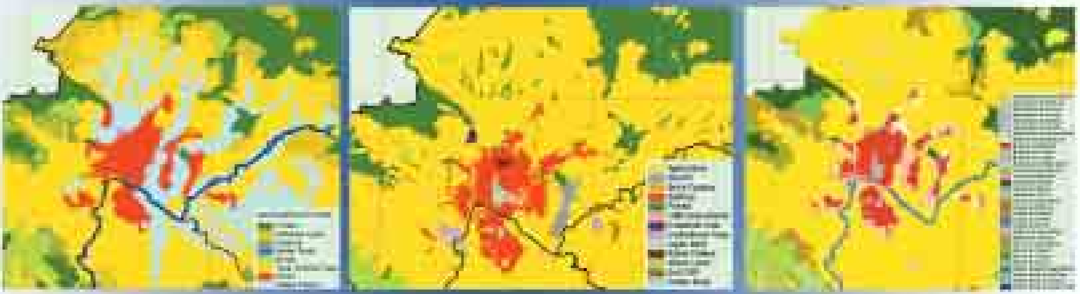
Figure 7.7 shows examples of simple raster overlay using different logical operators.

The following GIS application illustrates land-use and land-cover changes over time in the Kathmandu Valley (Figure 7.8). The analysis is done by overlaying land-use/land-cover data from different dates. The figure shows the land-use/land-cover data for 1978 and 1995, and the changes between 1978 and 1995 derived from these data.

This is the analysis of connectivity between points, lines and polygons in terms of distance, area, travel time, optimum paths, etc. Connectivity analysis consists of the following analyses.

Figure 7.7
Raster overlay using 'and' and 'or' logical operators





Land use/cover of Kathmandu Valley, 1978

Land use/cover of Kathmandu Valley, 1995

Land use/cover of Kathmandu Valley, 1978-1995

Figure 7.8
Land-cover change in the Kathmandu valley between 1978 and 1995

Proximity analysis

Proximity analysis is the measurement of distances from points, lines and boundaries of polygons. One of the most popular types of proximity analysis is 'buffering' by which a buffer zone with a given distance is generated around a point, line or area as shown in Figure 7.9. Buffering is easier to generate for raster data than for vector data.

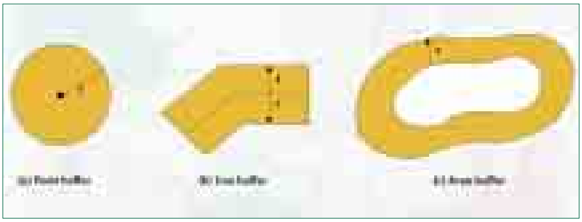
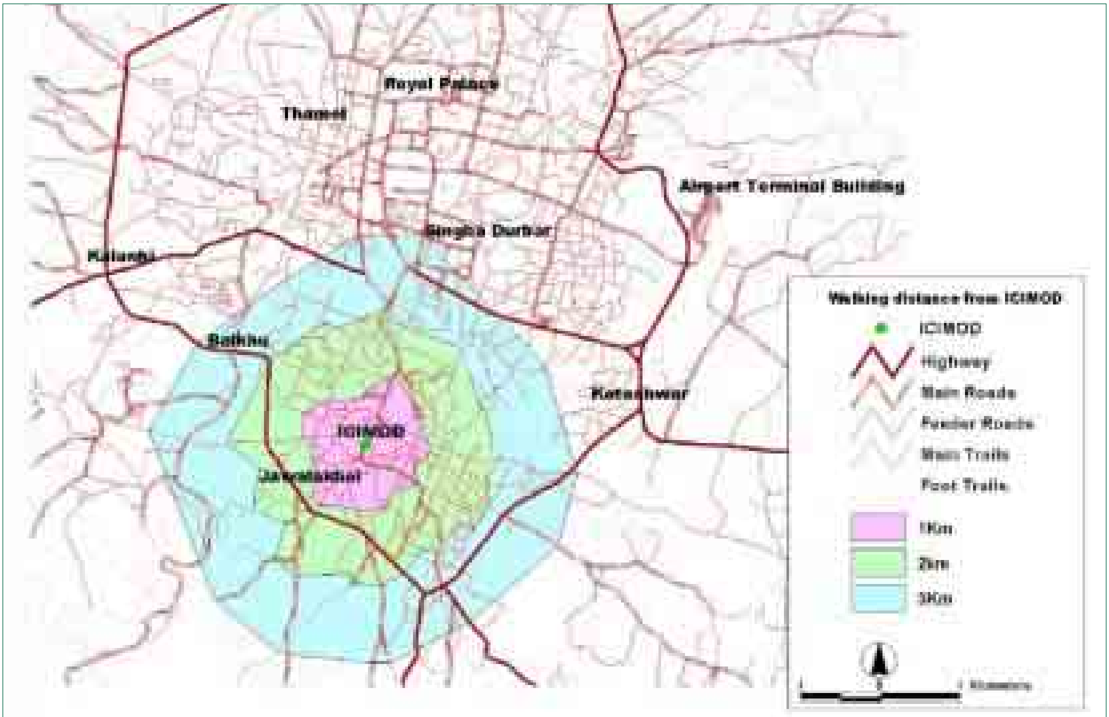


Figure 7.9
Buffer operations

Figure 7.10 shows walking distance from the ICIMOD building.

Figure 7.10
Walking distances from ICIMOD



Network analysis

Network analysis is commonly used for analysing the movement of resources from one location to another through a set of interconnected features. It includes determination of optimum paths using specified decision rules. The decision rules are likely to be based on minimum time or distance, and so on. Figure 7.11 demonstrates an example of optimum paths based on minimum distance. The figure shows the locations of a number of hospitals within the ring road of Kathmandu. If there has been an accident outside the ring road (e.g. at Bhaktapur) it may be important to know which is the closest hospital and what is the shortest route to that hospital for an ambulance. Network analysis identifies the closest hospital as Bir Hospital and indicates how to go there.

Figure 7.11
Network analysis