8 Map Visualisation and Output

Abstract

The proper visualisation of a map is most important to provide information to the user community which is governed by the objective of mapping and accordingly the kind of cartographic techniques that should be applied to fulfil the requirement. This information should be recorded in various types of output in the form of maps and reports. After reading this chapter you should be able to understand the following:

- Meaning and process of visualisation
- Factors of geo-visualisation
- Geo-visualisation techniques
- GIS output by cartographic and non-cartographic methods

Keywords

Geo-visualization · Cartogram · Symbology · Map design · Non-cartographic output

8.1 Introduction

The literal meaning of visualisation is 'visual representation'. Data visualisation is a conversion of any data into visual form, e.g. tabular data into graphical representation. Similarly, map visualisation refers to a set of tools and techniques supporting spatial data analysis through the use of a visualisation process. It is also referred to as 'geographic visualisation', or 'geo-visualisation', which focuses on visualisation as it relates to spatial data that can be applied to all the stages of problem-solving in geographical analysis, from development of initial hypotheses through knowledge discovery, analysis, presentation and evaluation. Map visualisation includes not only the development of theories, tools and methods for the visualisation of spatial data but also involves understanding the usage of tools and methods for hypothesis formulation, pattern identification, knowledge construction and the facilitation of decision-making. Most of the digital data are generated today through spatial referencing. This referencing enables us to integrate enormous spatial databases of diverse information (Singh et al. 2001). At the same time, the magnitude and complexity of data sets can be brought together through their common geospatial links, and `this presents an extraordinary challenge for information science to transform these data into information and subsequently into knowledge (MacEachren and Kraak 1997).

8.2 Visualisation Process

The visualisation process can vary depending on the purpose and place of spatial data. During the visualisation process, cartographic methods and

D. Kumar et al., *Spatial Information Technology for Sustainable Development Goals*, Sustainable Development Goals Series, https://doi.org/10.1007/978-3-319-58039-5_8

techniques are applied for the optimal design, production and use of maps. Visualisation can be created during any phase of the spatial-data handling process. It can be simple or complex while the production time can be short or long. The visualisation environment can also vary in nature; it can be on a stand-alone personal computer, network or on the worldwide web. The visualisation process is guided by the question *How do I say what to whom? How* refers to cartographic methods and techniques. *I* represents the cartographer or map-maker. *Say* deals with communicating in graphics the semantics of spatial data. *What* refers to the spatial data and its characteristics. *Whom* refers to the map audience and the purpose of the map. The audience may be scientists or laypeople. Map-making is not only the purpose of cartography but also should be tested on its effectiveness. The question *How do I say what to whom and is it effective?* guides the cartographic visualisation process and summarises the cartographic communication principle (Fig. 8.1).

8.2.1 Goals of Map-Visualisation

In general, map-visualisation goals can be broken down into four categories: data exploration, analysis, synthesis and presentation. These goals can be achieved through a series of tasks, subtasks, decisions and constraints. The *map-use cube* (Fig. 8.2) by MacEachren and Kraak (1997) modelled the space of visualisation goals with respect to three dimensions:

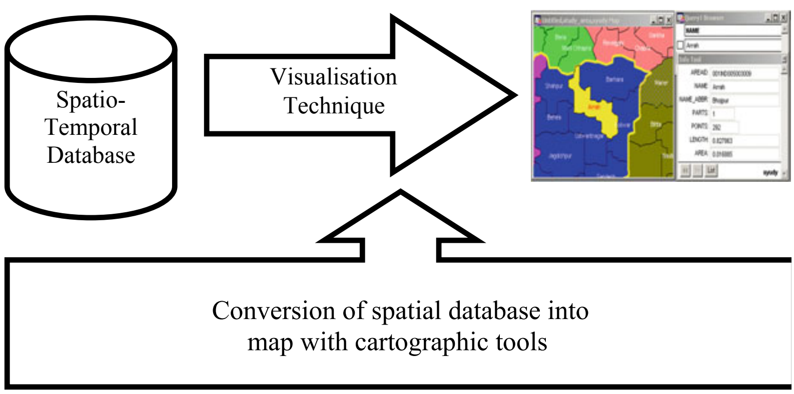
1. The *task* can range from revealing unknowns and constructing new knowledge to sharing existing knowledge.
2. The *interaction with the visualisation interface* can range from a rather passive low level to a high level where users actively influence what they see.
3. Finally, the *visualisation use* ranges from a single, private user to a large, public audience.

Exploration is an act of searching an unfamiliar or unknown area. Exploration can be seen as a private, highly interactive task to prompt thinking and to generate hypotheses and ultimately new scientific insight. The other extreme is formed by presenting knowledge in low-interaction visualisations to a wide audience. These two extremes can be described as *visual thinking* which creates and interprets graphic representations, and *visual communication* which aims at distributing knowledge in an easy-to-read graphic form. The former task is exploratory while the latter is explanatory. Presentation is via visual communication to a wide audience. As for maps, from exploration to presentation, systematic examination, analysis, evaluation and synthesis of data are required (Fig. 8.3).

8.2.2 Factors of Geo-Visualisation

There are basically three important factors for geo-visualisation: graphics and display technologies; increasing amount of geospatial data; and the rise of internet technology

Fig. 8.1 Conversion of spatio-temporal database into cartographic visualisation



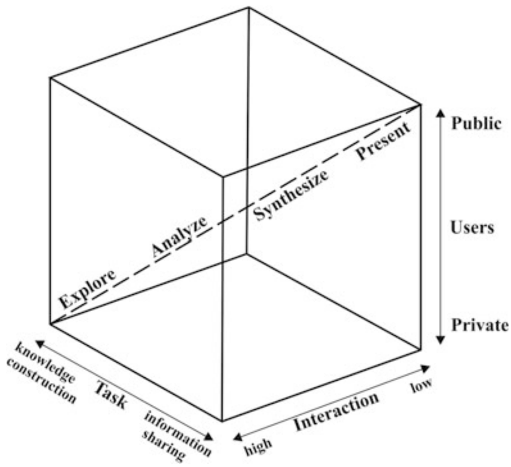


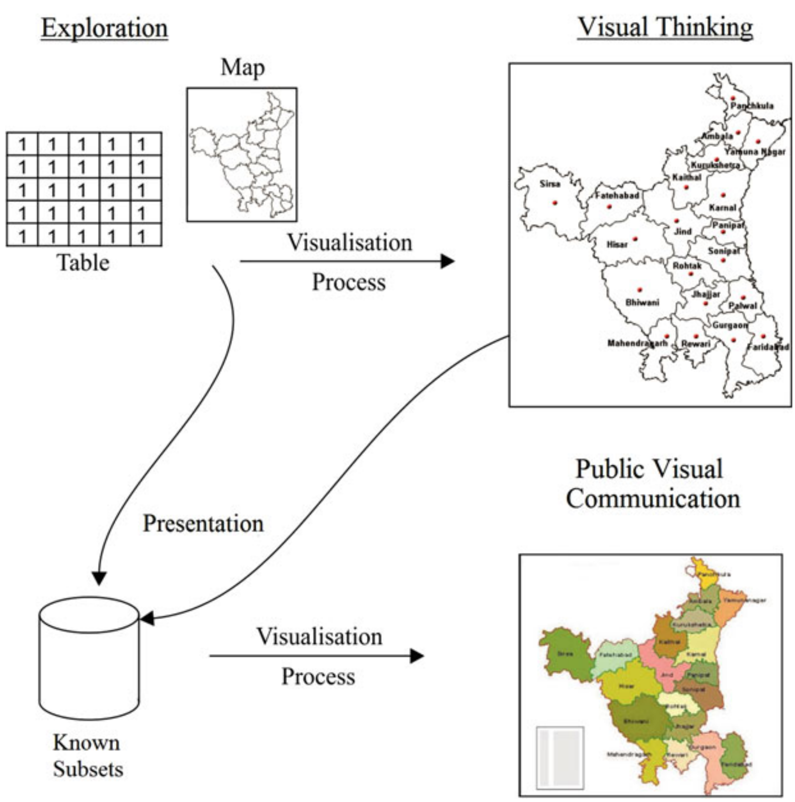
Fig. 8.2 Map-use cube (modified after MacEachren and Kraak 1997)

(Martin Nollengury 2006). The development of 3-dimensional graphics hardware in personal computing has increased the potential to visualise spatial data. Today, a huge amount of spatial data are available and day to day its availability is also increasing through various government and private institutions. The spatial data are also increasing by the development of remote-sensing and GPS technology. Increasing availability and the decreasing cost of acquiring technology, storing and processing of geospatial data have led to an increase geo-visualisation processes. The rise of the internet is a major factor in the dissemination of processes as well as open-source GIS environments such as GRASS, QGIS etc. to facilitate the geo-visualisation process.

8.2.3 Geo-Visualisation Techniques

Basically, visualisation of geospatial data consists of longitude, latitude and altitude that enable us to display 2-dimensional and 3-dimensional data. Once we add the time series data, it becomes 4-dimensional visualisation of spatial

Fig. 8.3 Relationship between exploration and presentation



data. The most common visualisation of spatial data is 2-dimensional, such as a traditionally drawn map, cartogram, choropleth map, thematic map etc. The 3-dimensional display depends on the capability of a computer's 3-dimensional graphic card. The 3-dimensional view is an effective tool to perceive the environment and display while modelling the urban environment and it is widely used by architects and town planners. *Animation* is another technique of geo-visualisation which creates motion by showing still images in sequences. This provides dynamic and interactive display of the geospatial data such as animation of continental drift, movement of plates and animation of flights over terrain. Animated maps use time to add another visual dimension to the display. The successive time data can be mapped and each frame of the animation shows the single time data. Thus, the temporal changes of the attributes become visible. For smoothing the animation, the intermediate frame is interpolated on the basis of attribute data. The *interactive user interface* encompasses the most important geo-visualisation technique. This allows the authentication protocol to obtain additional information from the user as needed during the course of the authentication session. For example, the user who is learning by interaction from Google Earth data may rediscover the appropriate route from one place to another by drawing the route on a map or find other relationships in the data. This concept was also used in traditional cartographic maps by using the colour pencil or ribbon to analyse the data but it was not so effective while using more data sets at a time. Here, GIS has the capability to analyse more maps from different sources on one platform and analyse with multi-criteria techniques (Singh and Kumar 2013). For example, we can close or open new layers for our analysis such as buildings, roads, boundaries, market layers etc. So geo-visualisation is an active process in which an individual engages in sorting, highlighting, filtering and transforming data in a search for patterns and relationships.

8.3 GIS Output

The GIS output can be in the form of maps, charts, reports or a combination of all. Mapping is the best tool to display geographic relationships whereas others are more appropriate for summarising the tabular data and documenting any calculated value by geographical analysis. Cartographic and non-cartographic are the two basic types of output of GIS.

8.3.1 Cartographic Output

The most common output of GIS is the cartographic map. Cartography aims for elimination of errors and provision of correct transfer of data by the means of a graphical representation from which the user can draw the correct conclusion. A map can act both as an input as well as an output in the GIS environment. Maps are very useful to answer the questions *where?*, *what?* and *when?* Maps are the most suitable tools to answer the question *where*. If the query arises, *Where is Delhi?* and the non-map answer is *in India*, the answer is correct and may satisfy the query but this answer does not provide a geographical perspective. The administrative map of India would provide the geographical perspective. A map can answer the second question, *what?*, in a spatial context, for example, *What is the major land-use category in Delhi?* The verbal answer could be *urban land use* but it cannot reveal the spatial distribution pattern and shape of the urban land use of Delhi. The map can also answer the third question, *when?*, in a spatial context, for example, *When does Delhi have a population of more than 1.5 million?*, and the answer is *in Census 2011*, which could satisfy people, but the decadal census map can provide complete information about decadal changes. So, maps show the locations, arrangements, distribution patterns and relations with each other of the spatial features of the Earth. These can be available in the form of thematic maps such as forest maps, soil maps, population density maps, climatic maps, or in the form of a topographic map which shows the physical as well as cultural features such as contour, forests, rivers, roads, settlements etc. in a single topographical map sheet.

A map is one of the best ways to represent while communicating geographical information by using text and symbology of point (0-D), line (1-D) and polygon (2-D) features. For example, the location of villages, towns and cities are graphically represented by dots, circles, stars, squares and their combinations; linear features such as roads, railway networks and streams can be represented by various line styles like dotted-line, dash-line, solid-line-with-different-colour and line-width. The polygon features can be represented by various patterns, colours and tones. Bertin (1967/1983) identified six categories of visual variables to symbolise point, line and polygon features. These visual variables are size, value (grey-scale), texture, colour, orientation and shape (Fig. 8.4). These symbols were conceived for the purpose of storing, understanding and communicating essential geographical information. For example, blue colour depicts a waterbody. The 3-dimensional symbology of point, line and polygon features is also available in recent GIS software, especially in ArcGIS. This 3-dimensional symbology allows us to provide a sense of real-world scenarios for geographical features. So, the different types of data can be represented in different ways. Variation in quantity can be represented by the variable size of symbols. For example, a circle diagram shows the different sizes of circle representing variable sizes of population (Fig. 8.5), and the different width of roads shows the major and minor road categories. Size is represented in only point and line features. It is not used in polygon features because the size of a polygon itself represents the size. The value denotes the density or rank in the data that can be represented by colour-scale ranges between lighter to darker and should be within five to seven levels of colour scale. Otherwise, it would be difficult to discriminate between levels where lighter shade means low value and darker means large value—e.g. distribution of population density. Representation of features in different colours can increase the distinction between the spatial features in qualitative and quantitative data – e.g. a map showing different states in India by different colours in nominal order. Generally, large areas used to be shown in light colour and small areas in darker colour.

Various geometric shapes (Fig. 8.6) are also very important visual variables in showing qualitative differences in attributes, particularly in point and line features. The shape of the line can be solid, dashed or dotted and can be easily distinguished on the map. The shape of point features can be circular, rectangular, triangular

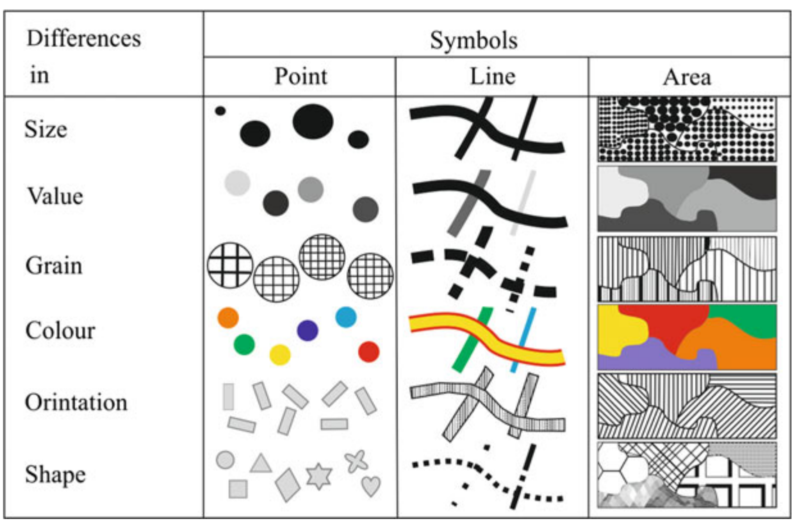


Fig. 8.4 Visual variables

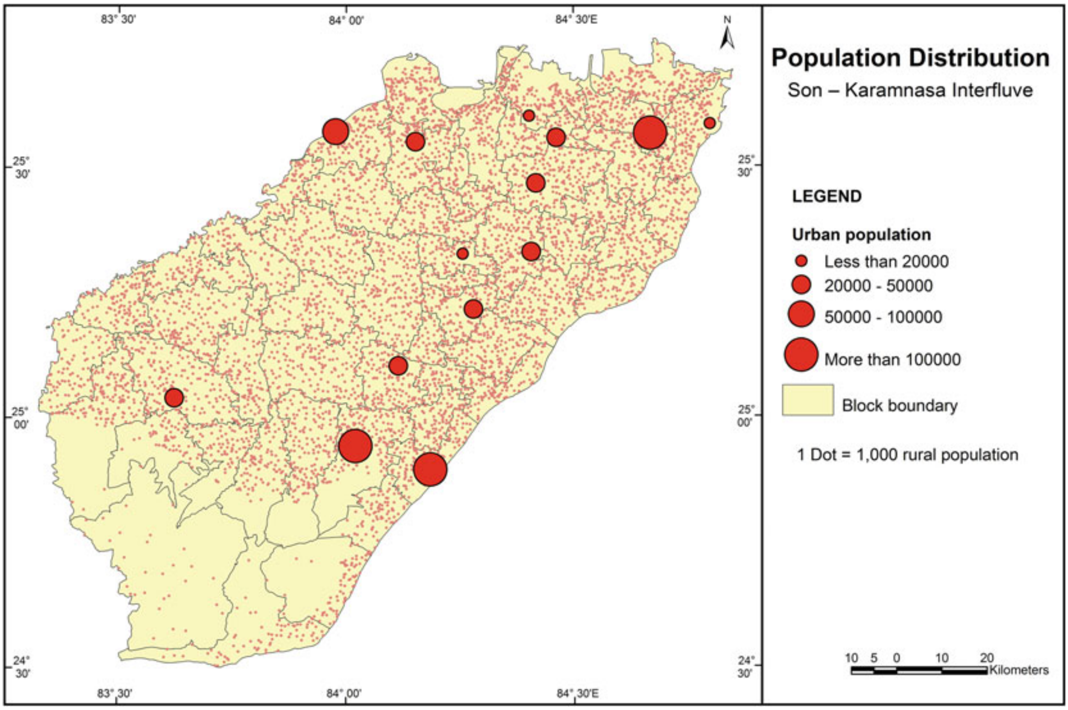


Fig. 8.5 Population distribution

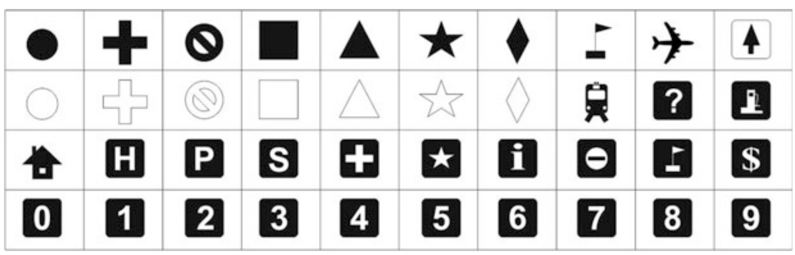


Fig. 8.6 Various geometric shapes for point symbols

etc. For example, distribution of minerals can be shown by different shapes of point features. There are various symbols available in GIS to represent various religious elements, infrastructure and facilities such as temple, church, hospital, post-office, light-house etc. (Fig. 8.6).

Orientation refers to the pattern of line direction and oriented symbols to point and line features, such as road networks, north arrow etc. Texture is also one of the important visual variables that shows density in the polygon feature. It can be shown by pattern and density of line, point and by picture. The texture may be fine to coarse, fine texture showing high value and coarse texture showing low values.

The attribute data can be quantitative and qualitative, represented by different symbology according to the level of measurements such as nominal, ordinal, ratio and interval to describe real-world phenomena. Qualitative data are represented by nominal features like the name of a road, river, worship place or town (Figs. 8.7 and 8.8).

Qualitative data can be represented by three levels of measurement: ordinal, ratio and

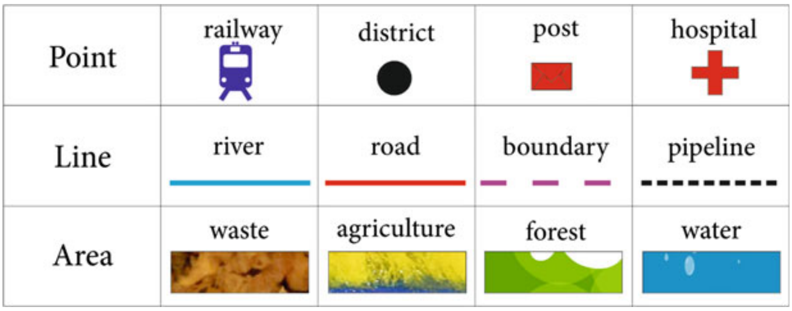


Fig. 8.7 Symbology of nominal data

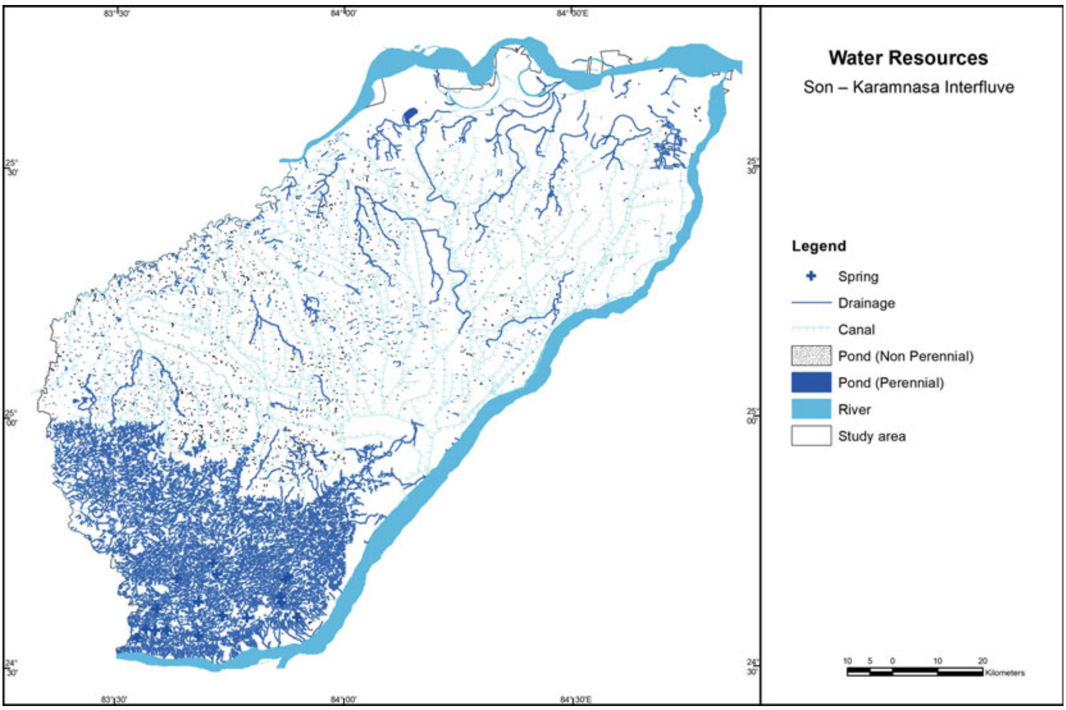


Fig. 8.8 Nominal data representation

interval. Ordinal data are arranged in hierarchical order to represent data in various categories such as high, medium or low quantity (Figs. 8.9 and 8.10), as in a population density map (Fig. 8.13).

Interval data can be placed in differently defined groups or classes and ranked in a standard unit such as the number of population (Figs. 8.11 and 8.12). For example, 50,000–100,000 people. This has a randomly selected starting point and arbitrary intervals but ratio data are indicated with exact numerical values measured on a scale in relation to a particular zero point or measured in respect to the fixed origin with a fixed interval, such as scale.

The map features presented in different symbology in a map's design and layout can enhance communication to the user community. Map design is an integration of several map elements while map layout is an arrangement of map elements on a desired paper or other medium to

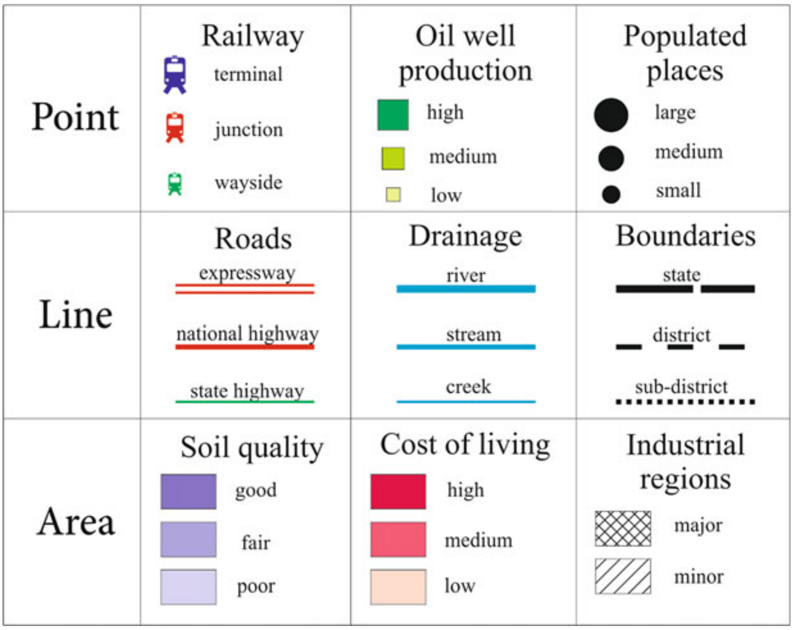


Fig. 8.9 Symbology of ordinal data

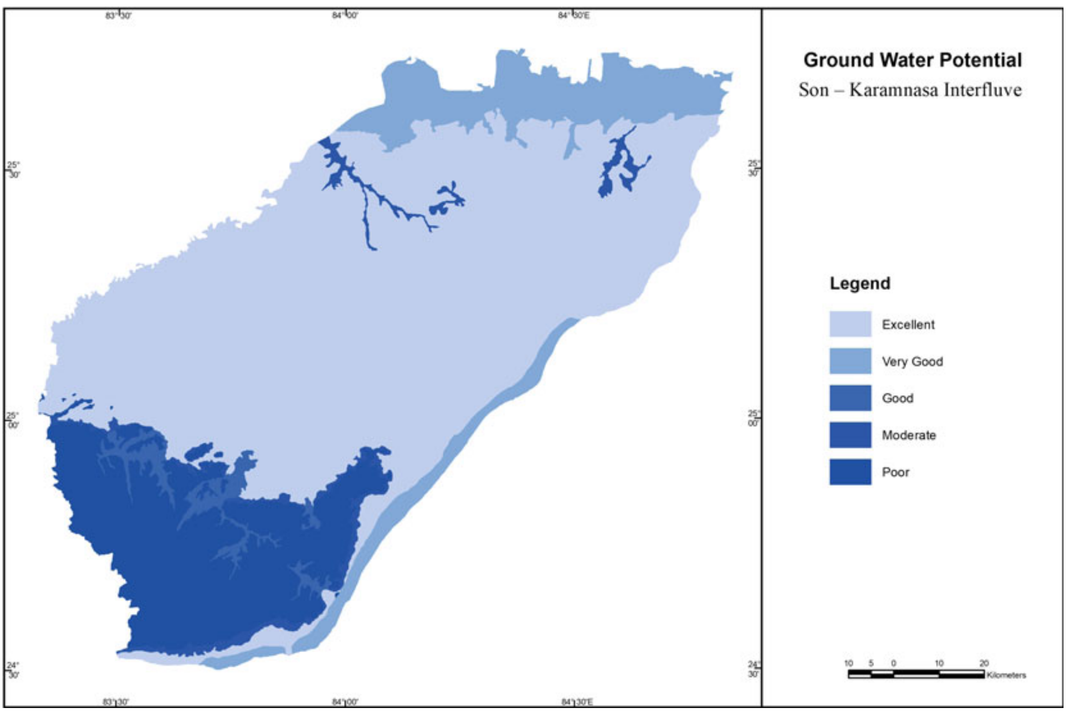


Fig. 8.10 Map representing ordinal data

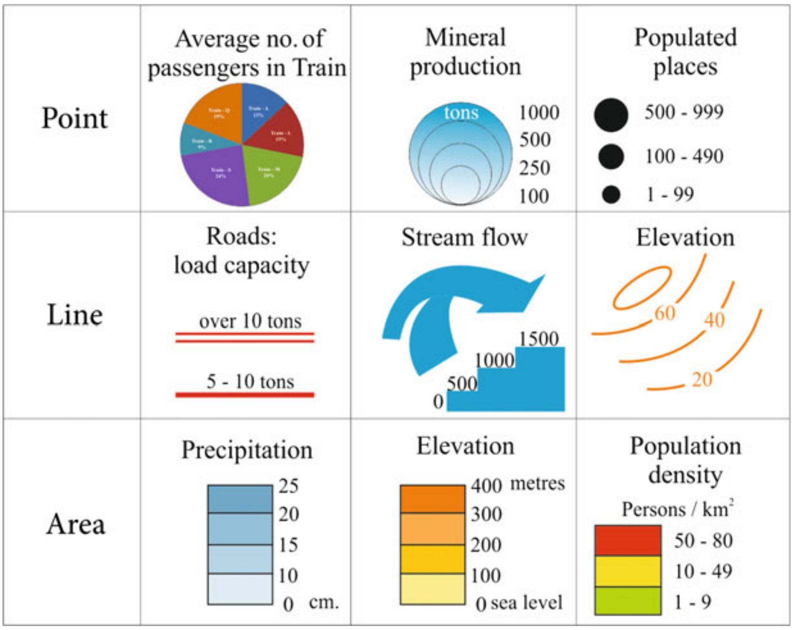


Fig. 8.11 Symbology in interval and ratio data

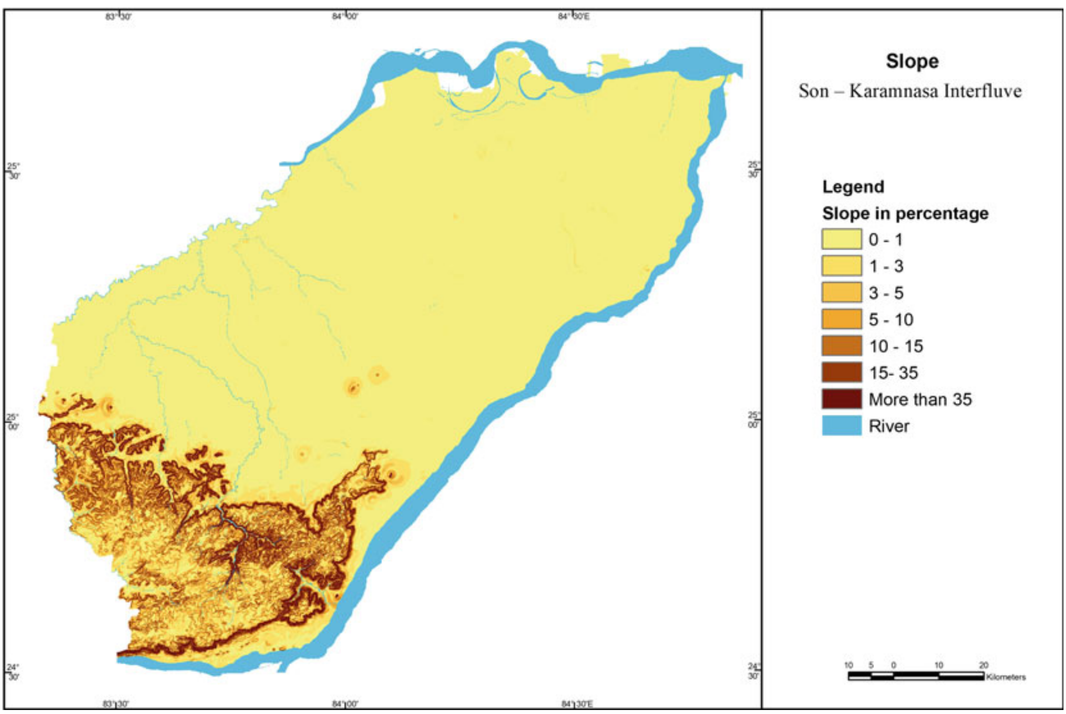


Fig. 8.12 Map showing ratio/interval data

publish. There are several map elements that are found on most maps: scale orientation, legend and data source; elements that are sensitive to context such as title, subtitle, map area, projection, cartographer name, date of production, source of data; elements that are used selectively such as neat-line, locator maps, inset maps and index maps. These map elements are most important to describe the map. The title of the map needs to be short and pronounceable and the subtitle understandable. For example, if the title is 'LAND USE/COVER' then the subtitle may contain the area name like 'Son-Karamnasa Interfluve'. The subtitle should be centrally aligned and placed below the title.

The map area is the most covered part of the map layout, also known as the map body. The map area can be single frame or multi-frame, depending upon the type of data representation. For example, if there is a single frame to show population density for one year then it should be in the centre or on any side of the page, depending on the page orientation and map extent. The temporal variation of the population density can be shown in multiple frames of the map. In the map layout, map area is more important than other elements. The legend is the most important map element of map layout. It comprises the symbology of point, line and polygon features along with their labels that describe the particular feature. Legend placement should be near the body of the particular map. If there are many map frames in a single map and a common legend is prepared, then it should be below the map frame. The orientation of the map should be depicted by the North arrow in a small size and well placed in the upper-right or -left corner of the map area. The scale-bar can be shown by the graphical and ratio methods to understand the relationship between map units and real-world units. There are different styles of scale available in GIS software. The data source should be mentioned in the lower-left or -right of the map layout. The neat-line around the entire layout should be drawn to group all the map elements in the layout. Different line styles are also available such as combinations of thick and thin lines. The latitude and longitude coordinates in lines or marks should be added according to the projection system used and should be mentioned by text in the map layout. The inset map is an important element of map layout and acts as a locater in relatively small size. The font size of different text should be according to the map layout. It should not be very large to suppress the map nor very small for visibility issues.

Designing the map layout is known as map design, and acts as a showcase of geographical data to the user and layperson (Fig. 8.13). Map layout depends upon the extent of the map. Suppose the longitudinal extent of the map is larger than the latitudinal extent, then orientation of the page should be landscape to arrange the map element accordingly, as in, for example, a map of the USA or Australia. If the latitudinal extent of the map is more than the longitudinal extent, then page orientation should be portrait, as in, for example, a map of South America or Japan.

8.3.2 Non-cartographic Output

Sometimes users need some type of representation of the spatial analysis, so there are many non-cartographic outputs from the GIS environment, such as reports, tables and charts. Tables and charts contain spatial and non-spatial information associated with the features which are sometimes necessary to explain the maps. Non-cartographic output can also be classified into graphical and statistical output. Charts are complementary to maps (Fig. 8.14) and visually summarise the information from the tables. It is helpful to understand the distribution, trend, pattern and relationship in-between the statistical data with line graphs, bar graphs, pie charts, area charts, scatter plots etc.

The output of the GIS can be a hard-copy or soft-copy map. It also serves as input for other GIS software, formats of which can easily be exported from one to another for compatibility of GIS software, such as *.kml, *.kmz, *.dxf, *.E00, *.shp, *.mdb, *.lyr etc.

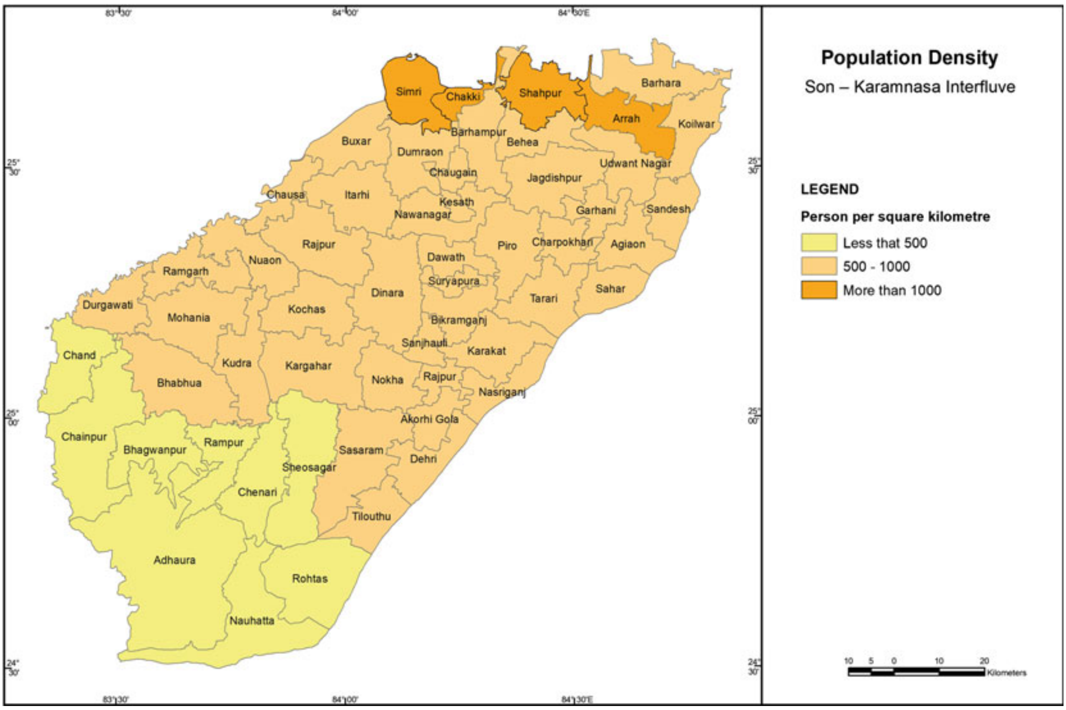


Fig. 8.13 Layout map in a landscape page

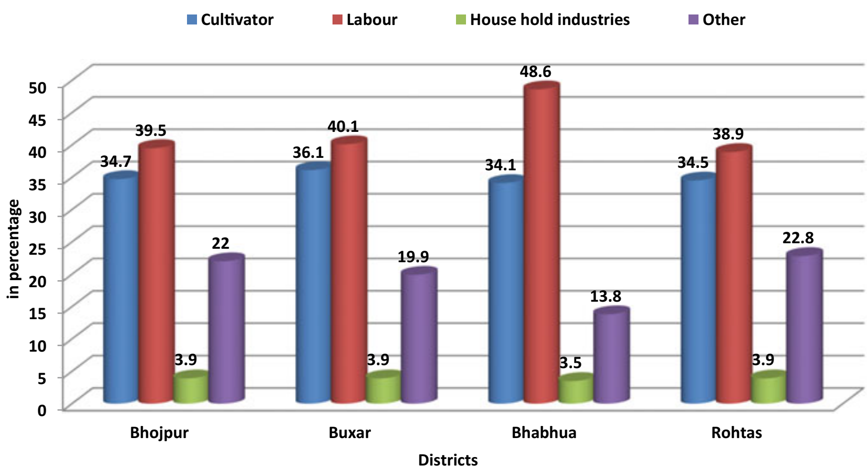


Fig. 8.14 Bar chart

8.4 Conclusion

Map visualisation is a process of visualising all the steps for decision-making for Earth's resources and phenomena. It includes all activities from thinking of the problems, hypothesis generation to final analysis of results and their presentations by exploring, analysing, synthesising and presenting the facts. Previous chapters explain the development, analysis and synthesis of spatial data. Spatial data can be presented through 2-dimensional and 3-dimensional graphics. These graphical representations can be achieved by cartographic and non-cartographic outputs. Cartographic representations need various map elements such as scale, title, subtitle, legend, sources of data and map layout. Non-cartographic representation is also done by charts, tables and reports. In this way, GIS can prove helpful in map-making and decision-making processes.

Questions

1. What is meant by map-visualisation?
2. Discuss the process of map-visualisation.
3. Discuss the types of map output in GIS.
4. Discuss the role of map elements in map layout.
5. How is the measurement of data in a GIS environment represented?

References

Bertin J (1983) Semiology of graphics: diagrams, networks, maps. Madison: University of Wisconsin Press (French edition, 1967)

MacEachren AM, Kraak MJ (1997) Exploratory cartographic visualization: advancing the agenda. Comput Geosci 23(4):335–344

Martin N (2006) Geographic visualization conference: Human-centered visualization environments, GI-Dagstuhl research seminar, Dagstuhl Castle, Germany, March 5–8, https://doi.org/10.1007/978-3-540-71949-6_6

Singh RB, Kumar D (2013) Land-use planning for sustainable development using geoinformatics: policy implications for drylands. In: Shahid SA et al (eds) Developments in soil classification, land use planning and policy implications: innovative thinking of soil inventory for land use planning and management of land resources. Springer Science+Business Media Dordrecht, pp 563–575

Singh RB, Fox J, Himiyama Y (eds) (2001) Land use and cover change. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta