Geographic Information Technology Training Alliance (GITTA) presents:

Thematic Cartography

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1. Thematic Cartography

Thematic maps are very important in the representation of space-oriented sciences. Geography or Spatial planning can not do without thematic maps. A big deal of presently published or printed maps deal with thematic content. Among others, media maps make a relevant part. The actual lesson deals with the theoretic basics of thematic cartography and introduces the most important thematic map types.

Learning Objectives

- You will get an introduction in theory of thematic cartography.
- You will learn the most important aspects of designing a thematic map.
- You will get to know the procedure of creating a thematic map.
- You will receive informations about how to get the needed data and how to make it usable for map representation.
- You will get to know the most relevant thematic map types.

1.1. Introduction to thematic cartography

As a first step to thematic cartography, this chapter will define a few important terms. In addition, different basic types of thematic maps and their relation to their application area and expressiveness are presented.

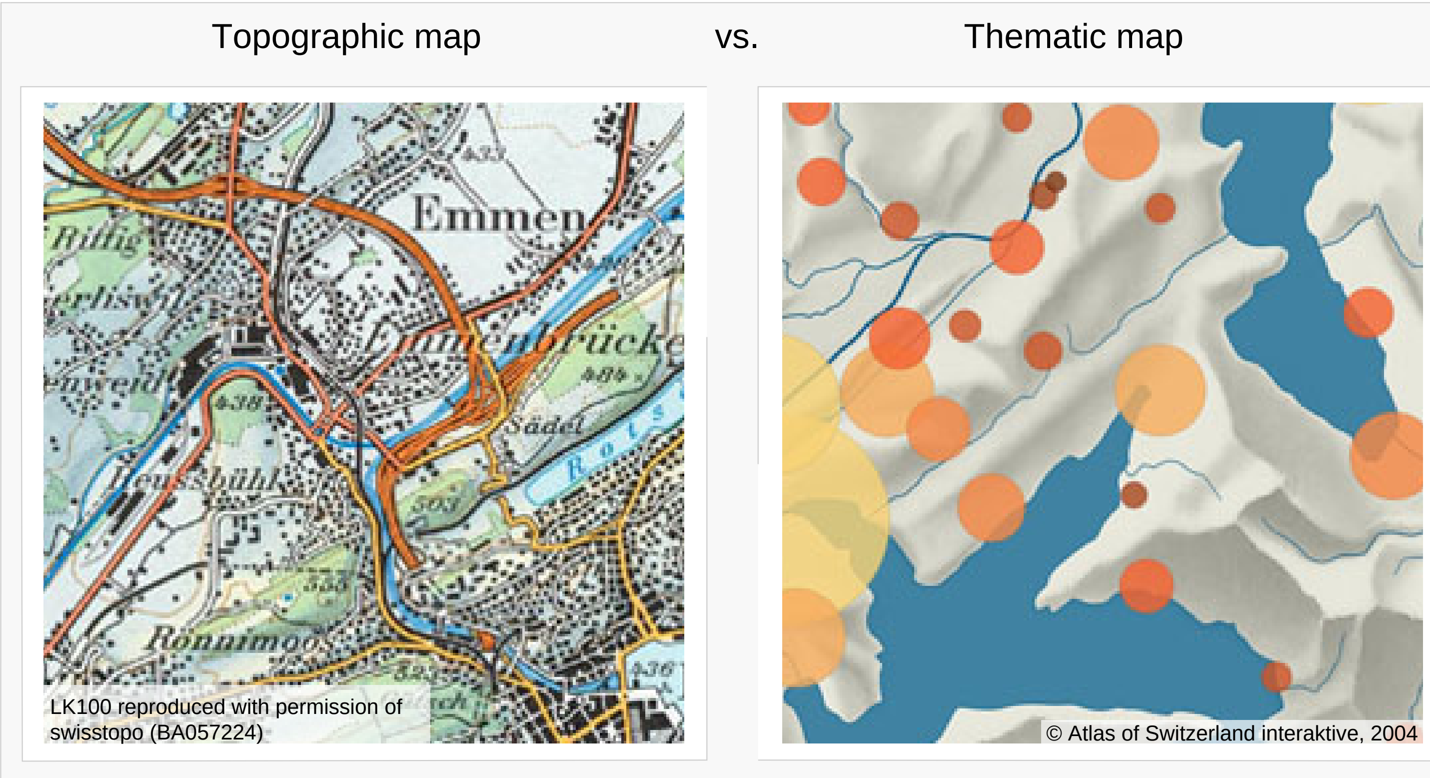
1.1.1. Definition

In Cartography, topographic maps and thematic maps are distinguished.

In the case of **topographic maps**, the situation, water bodies, landforms, landcover and a set of other elements for general orientation as well as labels form the main content of the map. [International Association of Cartography, 1972]

Thematic maps mainly consist of phenomena and occurrences of non-topographic type, which however, are related to the earth's surface. These are things which have a geospatial location, extent or motion. These can either be real things as well as relationships, functions, hypotheses, mental imaginations, possibilities and projects.

The borders between topographic and thematic maps can not always be clearly drawn. In the following illustration, one example for a topographic map and one example for a thematic map are given. Click on either map to enlarge it.



1.1.2. Map vs. cartogram vs. diacartogram

In thematic cartography, map, cartogram and diacartogram are distinguished.
The **map** is a planarized, proportionally downscaled, simplified and described depiction of the geospace or of one of its components at a specific point in time.
Cartogram is a term for maps, which basically communicate results of statistical countings and measurements within a geospatial context.
A **diacartogram** is a cartogram for which the graphical depiction is realized by using charts of amounts and numbers or groups, intervals and relations, respectively.
The cartographer decides depending on the intended statement if a map or a cartogram is more suitable. The following interaction shows this difference with two examples in a graphical way.

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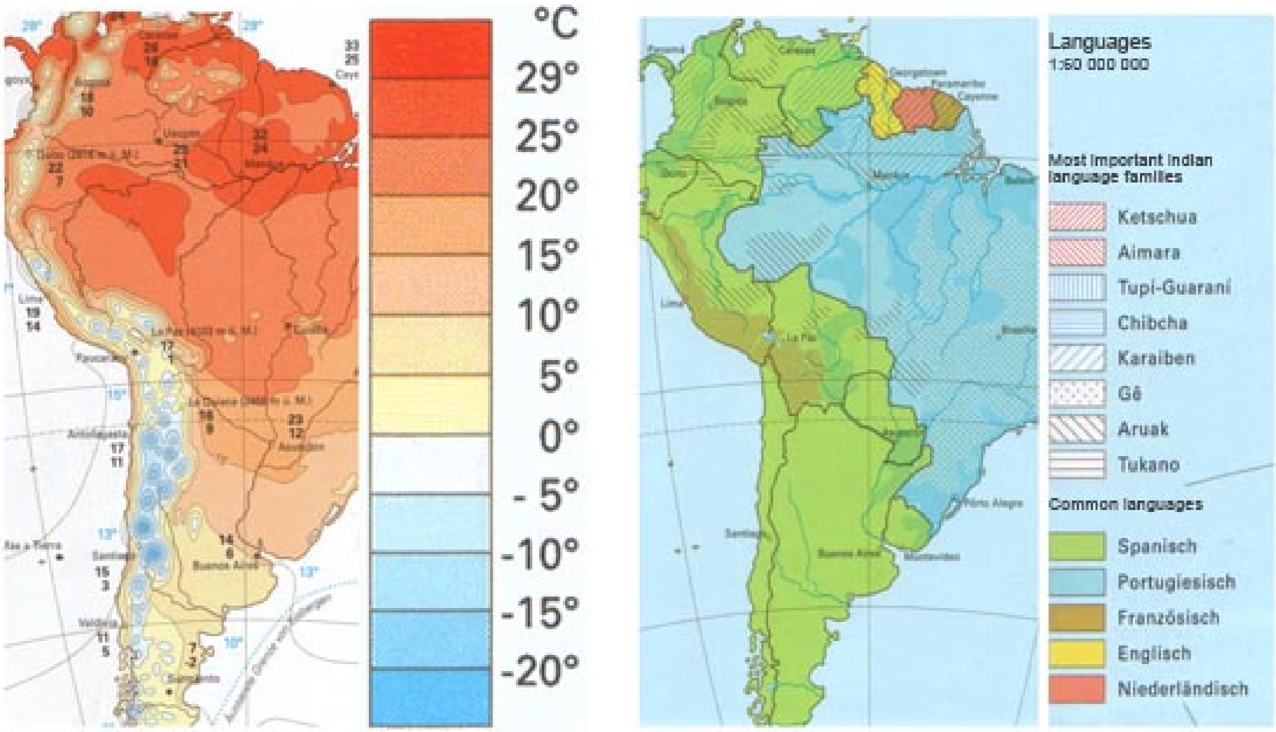
1.1.3. Statements of thematic maps

Thematic maps give explanations on type and attribute, location, extent and distribution of a phenomenon. They can depict completely qualitative as well as quantitative information in the shape of diagrams or mosaic depictions. In addition, it is possible to visualise frequencies, durations, motions, directions or relations on the map.
On a thematic level several differentiations can be employed. On the one hand, single-layered and multi-layered maps are distinguished and on the other hand thematic maps can be divided into analytical, complex and synthetic maps. These map types are described below.

Single-layered and multi-layered maps
Single-layered maps or cartograms only depict neighbouring elements based on location- or area-based signatures. No superposition of signature layers exists. Therefore, single-layered maps are constrained to one statement layer. This has the advantage of a better readability and comprehensibility.
When different signature layers as well as quantitative and qualitative statements are superimposed one speaks of a **multi-layered map**. This kind of maps can contain a high density of information. Rises the amount of data generally the maps complexity rises as well, which requires more attention from the cartographer and the map reader.
The example below shows a single-layered map on the left and a multi-layered map on the right.



(Spiess 2004)

Analytical, complex und synthetic maps
Maps can also be classified in a thematical and content related way. Depending on the amount and kind of information it can be differentiated between analytic, complex (or complex-analytic) and synthetic maps. The following interaction introduces the mentioned types.

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1.1.4. Data value types

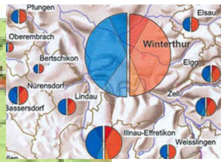
Statistical data, which are ordered in tabular form, can contain different types of numbers, which are to be explained using the categorization by Schröder (1985). These categories are: Frequency number, measure and ratio.

- **Frequency number** describes the frequency that a certain event is happening, the incidence of a certain occurrence, such as the number of traffic fatalities per year.
- **Measures** in conjunction with a unit specify a dimension such as 28°Celsius or 10,5kg or 1000m.
- **Ratio** numbers specify a relation, also called relative values. An example is population density, which is defined as the ratio between the population number and the area. Ratio numbers can be divided into four further types of numbers, depending on the values that are related to it. These are:
  Here (http://www.gitta.info/ThematicCart/en/image/verhaeltniszahlen_en.pdf) you can find detailed information.
  - Proportion numbers
  - Measurement numbers
  - Index numbers
  - Relation numbers

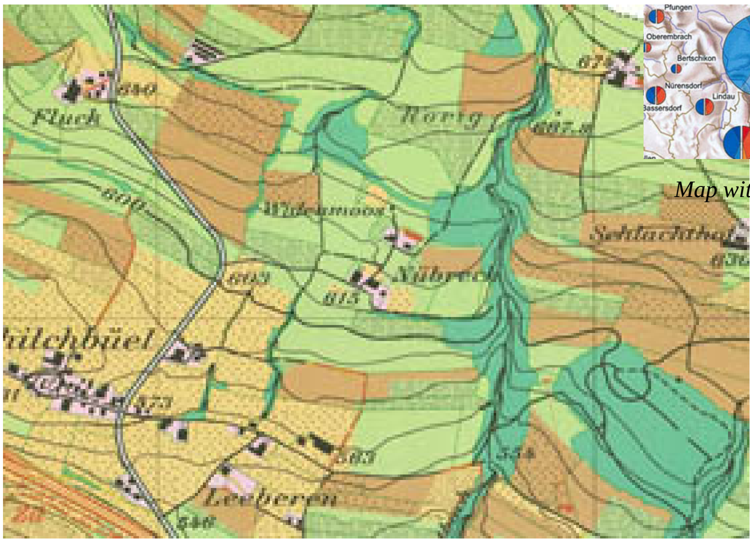
1.1.5. Quantitative and qualitative data

Data to be used in thematic maps can have different shapes. They can be fundamentally distinguished by different characteristics, which can be either of quantitative or qualitative nature. They should be arranged metrically by their value and by their category.

Population numbers of different municipalities are an example for quantitative data. An example for qualitative data would be if the municipalities are divided by land use.



Map with qualitative data (Source: student work IKA, ETH)



Map with quantitative data (Source: student work IKA, ETH)

1.1.6. Data structure

Thematic data can consist of **metric**, **ordinal** or **nominal** components, depending on the topic and data source. The definition and differences of different data structures are shown in the following animation.

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1.1.7. Summary

Topographic maps depict the landscape and their elements with high precision and true to scale. Thematic maps have the aim to communicate a certain topic using a specific map type. Possibilities to display thematic information are map, cartogram and diacartogram. In addition, the following map types can be distinguished:

- Distinction between number of layers: single-layered and multi-layered maps
- Distinction between type and complexity of the depicted data: analytical maps, complex maps, synthetic maps

1.1.8. Self Assessment

Conduct the test to see if you have understood correctly the chapter and if you are familiar with the basics of thematic cartography.

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1.2. Design of thematic maps

This chapter deals with four basic principles for the design of thematic maps. In addition, the two building blocks of thematic maps, base map and thematic content, are introduced.

1.2.1. Basic principles

The design possibilities for thematic maps can be traced back to four basic principles, cf. Arnberger (1993, p. 32):

- location principle
- chart principle
- image-static principle
- pictorial principle

The application of these four basic principles can be familiarized by the following interaction.

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1.2.2. Building blocks of a thematic map

A thematic map fundamentally consists of the topographic base map to provide background information and the superimposing thematic content. The following interaction provides an overview on the possible origin of thematic information and different designs of the base map.

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1.2.3. Thematic content

As was already shown in the interaction, the thematic content of the map can either be taken from existing sources or it is being newly generated from own acquisitions or samples. The many data sources of thematic data and the detailed explanation of acquisition and sampling methods are described **here** (http://www.gitta.info/ThematicCart/en/image/themdaten.pdf) (German version only).
Data quality is an important aspect, independently of the data source and mode of acquisition. Before these data are further used, the following criteria have to be evaluated:

- Accuracy
- Coverage
- Completeness
- Actuality
- Correctness
- Reliability & plausibility
- Validity
- Readability, data format
- Maintenance
- Provenance

Based on these criteria it is to be decided if the data are in fact suitable to present a topic in sufficient accuracy and in adequate form.

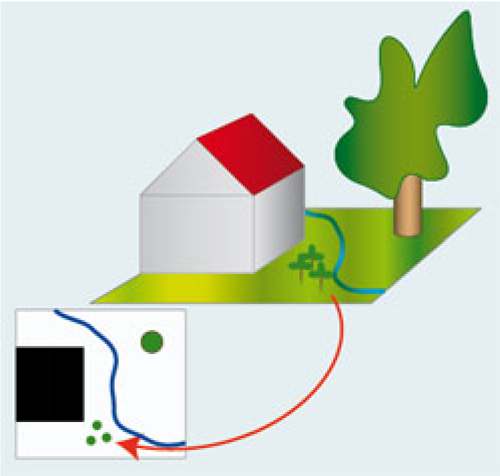
1.2.4. Base map

The base map establishes the geometrical and orientational reference for the viewer of a thematic map. This way, familiar features such as lakes and rivers, place names, localities and mountains, administrative boundaries, terrain shape, transportation routes, forests and land cover help the map viewer for orientation.
When designing a base map, the following aspects should be considered.
The basemap

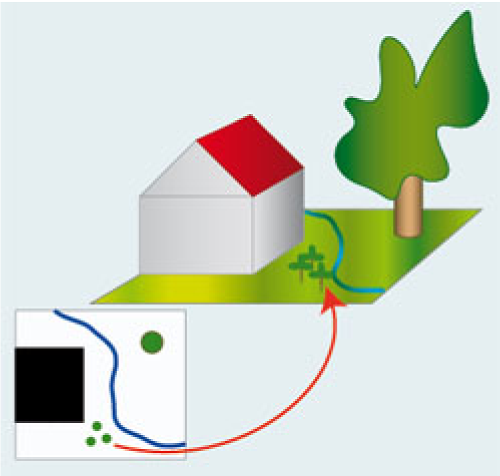
- should be tailored to the thematic content, however, a complete matching with the topic should be avoided
- should complement the included topic in the most reasonable way, while distracting as little as possible
- must correspond to the current state
- must match the scale and the degree of generalisation of the thematic content to be included
- should not exceed twice the scale and a miniaturization should be avoided completely

Functions
According to Spiess (1995), the base map serves five purposes. These are explained in the following sections. Elaborated information on the intended use of base maps can be found **here** (http://www.gitta.info/ThematicCart/en/image/basiskarten.pdf) (German version only).

Mapping thematic content
A topographic base map serves as the basis when mapping elements in their geospatial context. Depending on the topic and method of acquisition, the topographic map can either be rich in detail (e.g. in the case of a topographic map or an aerial image) or a reduced map is sufficient, which comprises only the most rudimentary elements for orientation.



Relocating map contents to the field
A basemap is also necessary when relocating thematic contents of a map to the field. It allows to relocate the exact position of objects in the field. A prerequisite for such a faultless relocalisation is that the complete thematic information of a map is available and can be read easily. All inventory maps are examples for such maps.



Comparing thematic contents of different maps of the same region

Maps with different thematic and temporal contents, which relate to the same area, can be easily compared if topographic base elements are present. This is also true for complex contents. By comparing different maps, new thematic relationships and perspectives can be generated.

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Localising thematic contents in the existing geographic field of perception

It is one of the most important tasks of a map to place a subject in a geospatial context for the map viewer, for example using objects that can be easily recognized, such as coast sections, lakes, river networks, landforms, transportation networks. The selection of these elements depends on topic and the target audience of the map.

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Comparing the thematic content with the components of the base map

The comparison of thematic information with the topographic background allows for a deeper interpretation of the topic in relation to the geographic environment. For this purpose, the emphasis lies on the relationship between topic and topography. This means that for the base map a tight correlation of the topographic elements and the topic should exist.

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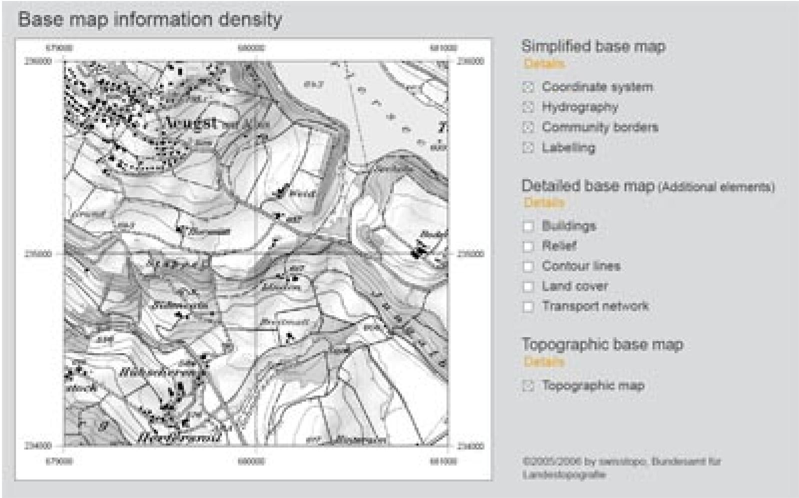
Information density

The information density of the base map depends on the topic to be depicted. It is distinguished between a base map that is rich in detail and one that is simplified. In addition, orthophotos and topographic maps can be used as base maps. The following interaction shows the different kinds of base maps.



Click on the map to start the interaction

Graphical requirements

When designing a base map, it is important to make sure that the thematic map is not being dominated by the topographic information. The base map should stay in the background. To achieve this, Spiess (1995) proposes several means to reduce contrast. These are introduced in the following interaction.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

In addition to the mentioned measures, the basemap should be generalised according to the topic. It should be paid attention that the characteristic structure is preserved.

1.2.5. Summary

The design of thematic maps follows four basic principles: location principle, chart principle, image-static principle and the pictorial principle. The most important elements of the map form the thematic information. This originates depending on the topic from different sources. If necessary, the data have to be collected. In addition, the topic is supported by a base map, which has, among others, the task to place the thematic information in a geospatial context. The information density of the base map depends on the topic of the map.

1.3. Preliminary decisions and questions for the creation of a thematic map

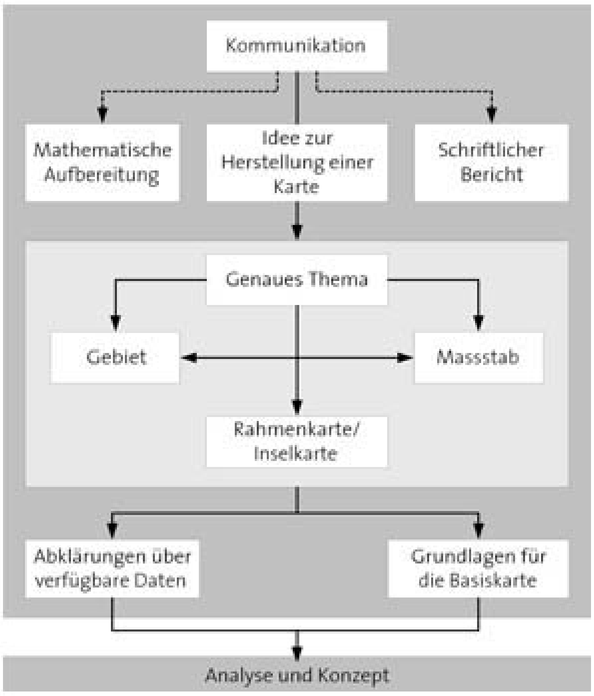
Before starting with the creation of a thematic map, some important questions have to be asked and decisions have to be made. First, it is to be determined if it is actually possible to create the desired map. Second, good preparation will facilitate an efficient map construction process. The following list shows a compilation of questions that have to be asked and decisions that have to be made:

- Which topic should be mapped?
- Conduction of an analysis and creation of a concept
- Data acquisition
- Choice of scale, format, content and area
- Which map projection should be used?
- How should basemap and topic act together?
- Should the map be displayed as a map on which only a selected area is mapped in full or as a map on which the detail extends over the whole area enclosed by the Neat Line or to the Bleeding Edge
- Should the map be single-coloured or multi-coloured?
- Considerations on map labeling
- Considerations on the design of the map contents and the legend respectively

In the following sections, some of these aspects will be discussed in more detail.

1.3.1. Choice of the topic

The decision to depict a topic as a map is tightly coupled to the chosen topic. Not every topic can be incorporated into a map in a meaningful way. A tabular depiction or a simple description in the shape of a text can be a sensible choice. However, once the decision is set the topic has to be specified precisely. In addition, first considerations have to be made concerning the data and the design of the map. Where do I get necessary data from, which data do I need for this purpose and how should the map look like in general?



Source: (Hochrein 1986)

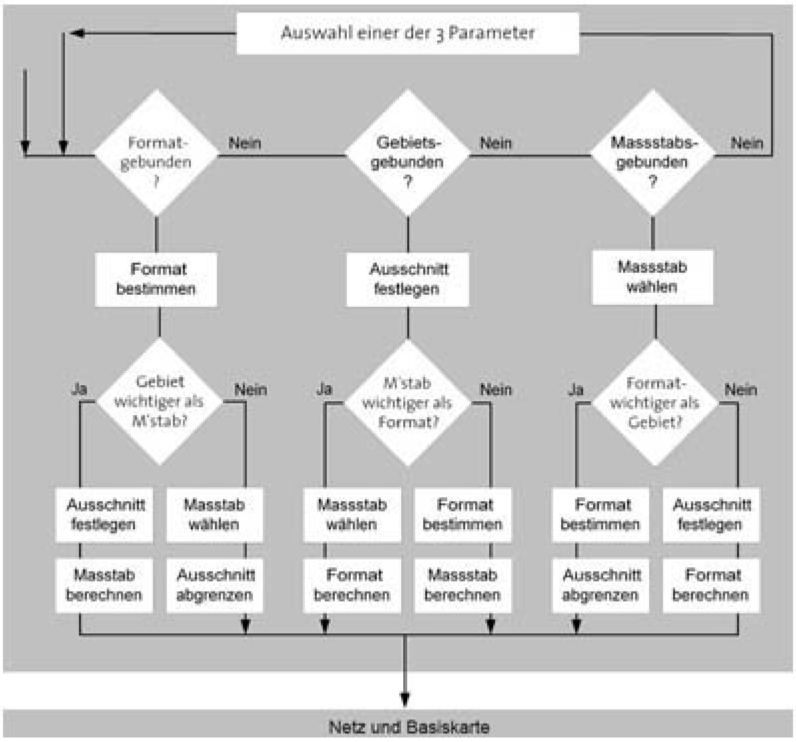
1.3.2. Analysis and concept

Afterwards, within the analysis and concept phase, the foundations for the next steps, the design of the map and the map content are determined. The analysis of the topic and the elaboration of the theme structure form the mental basis, which is followed by thoughts such as:

1. Familiarization of the topic, researching and determining which sources to use (e.g. reports, literature, atlases, magazines, but also newspaper articles and possibly domain experts to address specific questions).
2. Which questions should be answered by the map later-on? Which geometric reference does the attribute data have? Do they reference points, lines or areas? Are the data of nominal, ordinal or numerical scale? On which level should these information be made available to the user, depending on the user group?
3. According to Imhof (1972) ordering, classifying and summarizing provides the structure of the content, which has to be set to the beginning of each mapping project, because it is part of the mental preparation. The graphical construction is undertaken at a later point in time.

1.3.3. Scale, format and location

Scale, format and location depend on each other. Even if the scale and the location are determined by the decision of the topic, further corrections of these three parameters may make sense after the analysis and the map concept phases. Which parameter should possibly be changed or is of priority depends on the purpose the map should have later-on. However, at most only two of the three parameters can be changed (Hochrein 1986). If the decisions are also set, the basemap can be equipped and the map projection can be chosen.



Source: (Hochrein 1986)

1.3.4. Choice of the map projection

Often, the map projection is predetermined. If it is not predetermined, a lot depends on the map size, the scale, shape and location of the region of interest on the globe. Depending on the purpose, equivalent, conformal and compromising projections are used. However, a high degree in equivalence results in a high degree of angle distortion and a high degree of conformance results in a high degree of areal distortion. Therefore, a projection between these extremes is sought, which ideally possesses small distortions. Possibly, compromising projections can be of interest, which for example possess equidistant circles of latitude or which preserve proportional distances. If comparisons of areas are important for small scales, equivalent projections are preferred.

Choice of the projection depending on scale and map size

The following table provides an overview over the choice of the projection depending on scale and size of the area.

Scale interval	Area size	Graticules	Axis position	Examples
up to ca. 1:250 000	Sheets of official topographic maps; parts of landscapes	National geodesic projections		
1:500 000 to 1:2.5 mio	Small countries	Azimuthal projections	Often oblique aspect	France
	Sheets of regional and world maps	Conic projections	Normal aspect	IWK, Karta Mira
1:2.5 mio to 1:15 mio	Large countries and small continents	Azimuthal projections Conic projections Cylindrical projections	Normally oblique aspect Normal aspect Normal aspect Transverse aspect	Australia USA Indonesia Chili
1:20 mio to 1:40 mio	Large continents and oceans	Azimuthalprojections Cylindrical projections	Normal aspect Transverse aspect Oblique aspect Transverse aspect Oblique aspect	Arctic, Antarctica Africa, Pacific Asia, Indian Ocean Atlantic America (North+South)
1:50 mio and smaller	World, planisphere	Pseudocylindrical and polyconic projections Cylindrical projections	predominantly normal aspect, exeptionally oblique aspect	Cohesive presentation of the world
	World, planisphere	Two azimuthal projections	Normally transverse aspect	Presentation of the continents
	World	pseudocylindrical projections with different center meridians	normal aspect	

Source: according to Hufnagel 1998 in (Klauer 2000)

Choice of the projection depending on shape and location of the area

To achieve minimal distortions on the map, different map projections are preferred depending on the shape and location of the area. The following table shows the categorization into the three main design types. These are valid in particular for small to medium sized areas. It becomes more difficult when depicting greater areas, where usually compromise projections are used.

Form	Graticules	Examples
Uniform expansion to all directions	Azimuthal graticules with adjusted axis	France, Antarctis, Australia
Predominant longituginal aspect ratio in great circle direction	Cylinder graticules with adjusted axis	Indonesia, Chili, Atlantic
Predominant longituginal aspect ratio in small circle direction	Cone graticules, almost exclusively terrestrial axial	Turkey, USA

Source: according to Hufnagel 1998 in (Klauer 2000)

Choice of the projection depending on topic

Depending on the topic of the map, conformal (for nautical and navigational maps) or equal-area (for distribution maps) projections are preferred or are even inevitable for the map to serve its purpose. However, to avoid distortions compromising maps are suited best.

Purpose	Mathematic properties
Arbitrary	There is almost no difference between equidistant, equivalent and conformal projections on large scale maps (up to 1:1 mio)
Physical-geographic maps	arbitrary(equidistant) or equivalent projections
Nautical charts	Loxodromes are displayed as straight lines: conformal projections (Mercators's Projection)
Aeronautical Charts	Orthodromes are almost displayed as straight lines: conformal projections (conic projections)
Maps for spatial comparision e.g. population maps, climate and vegetation maps	Equivalent projections
Maps for angle comparision e.g. sea currents, wind directions and star charts	Conformal projections
Other thematic maps	Predominantly arbitrary projections

Source: according to Hufnagel 1998 in (Klauer 2000)

1.3.5. Frame maps or island maps?

Maps are being distinguished into frame maps and island maps based on how they are delimited.

Frame maps are typically delimited by a rectangular frame and contain the thematic and topographic information for the whole area that lies within the frame. Nature-related geographic topics as well as historical-territorial topics are frequently depicted using frame maps.

Island maps are limited to the depiction of a political or geographical region. The border of the map is aligned along the border of that region. This type is used if information of only one region is of interest or if the database does not provide any cross-border information.

1.3.6. Single-colour or multi-colour maps

Before one can begin with the creation of a map, it has to be decided if a single-colour map or a multi-colour map is more suitable.

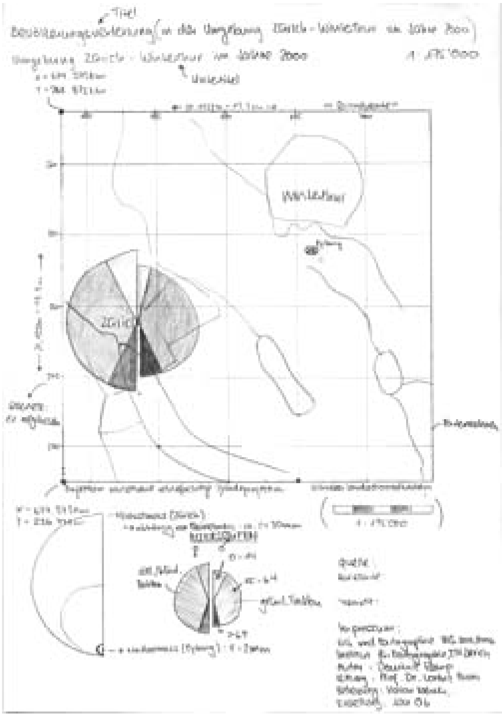
Single-colour maps have the advantage that they cost much less money to produce, because the printing-process is less laborious. The map design, however, makes great demands on the cartographer if the map should show the information density as a comparable colourful map. The design possibilities for different grey scales is somewhat limited. Single-colour maps are usually used for simple, small map displays in journals and books (Imhof 1972).

The production process for **multi-colour maps** is much more expensive. However, they allow for a wider range of design possibilities.

1.3.7. Labeling

The general rules for labeling topographic maps can be applied when choosing the font, colour and size of the text. More information on this topic can be found in the GITTA module **Layout Design Settings / Graphical Semiology** (http://www.gitta.info/LayoutDesign/en/html/index.html) in the chapter **Typography** (http://www.gitta.info/LayoutDesign/en/html/unit_TypogrDesign.html) For thematic maps, the following rules can be applied in addition to the already mentioned guidelines:
Names, that are used for orientation, such as those for landscapes or mountain ranges, waterbodies and countries, should be placed according to the actual need in textual explanation. Names are used far more sparsely. They are partly only indicated with their initial letters and sometimes even omitted completely to avoid noise. This, however, should only be done if the message of the map remains clear. Explanations describing thematic information can be omitted completely, if all necessary hues and signatures are explained in the legend. In the case where all diagrams have to be explained without having enough space to do so, only initial letters or small indices can be used, which are then explained at the map frame (Imhof 1972, p. 244f).

1.3.8. Design and structure of a map



Card sketch (student work, IKA, ETH)

An important part during preparatory work of map production is the structuring of the thematic content and as such also in the creation of the legend. After looking into the subject of the map in detail, the cartographer has to decide how the single thematic elements should be grouped, arranged and named.

Prior to map construction, he also has to have a clear vision of the layout of the map. Content, structure and placement of titles, and marginal data as well as of the legend have to be determined. To visualise these ideas, it is recommended to draft a map sketch manually.

1.3.9. Summary

A great deal of thematic map creation has to be performed prior to the actual map production process. Clarifications and decisions have to be made concerning the source data, scale, content and design of the map, regarding the map projection and the arrangement of the map itself and its elements. The results of such preliminary works typically are one or more map and layout sketches which can support the actual map production process. If these preliminary works are conducted completely and thoroughly, many surprises during production can be avoided and the efficiency of the work can be increased.

1.3.10. Recommended Reading

- **Imhof, E.**, 1972. *Thematische Kartographie*. Berlin - New York: Walter de Gruyter.
  Kapitel 4

1.4. Transformation of statistical data into thematic maps

This chapter deals with the processes that have to be followed when visualising raw thematic data in the form of a map. Before these data can be presented graphically, they have to be preprocessed and analyzed. The following interaction depicts this process graphically. Click on data processing and data analysis to see the contents of these processes.

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1.4.1. Data processing

The raw data have to be processed before they can be analyzed. Data processing includes the inspection of the datasets and the way how they were generated. It is to be checked if the datasets were assembled in a technically correct way. In addition, a plausibility check has to be performed in order to validate that the datasets are credible. Furthermore, the completeness of the datasets has to be verified. Found errors are to be corrected. Another important issue is data quality. Do the datasets provide the desired or required accuracy?
Apart from these checks, this step also includes the preparation of the data for further processing. Existing tables are assembled in such a way so that they can be used for data analysis. For example, some features may be combined or reclassified to ease their evaluation. The different aspects of data processing can be showed by using the example of a questionnaire.

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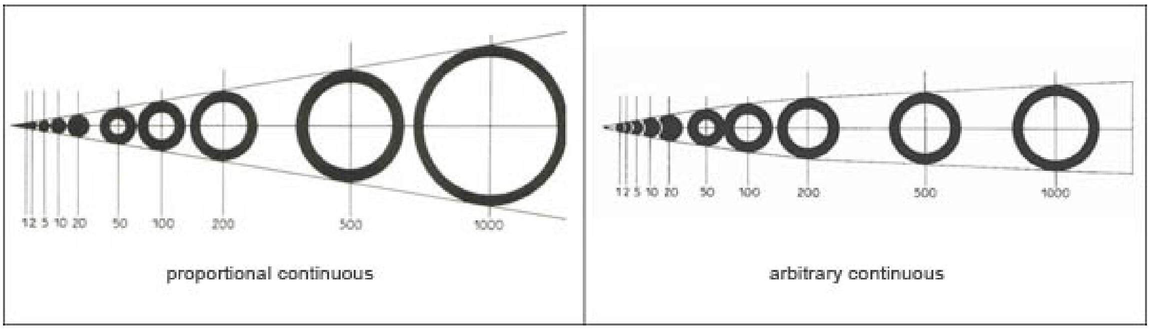
1.4.2. Data analysis

Depending on the author and viewpoint, the contents of thematic cartography may be looked at from different angles. At this point, the number of attributes to be depicted is of relevance. It is to be distinguished between one or multiple attributes. One example for a attribute may be the population number per municipality. If this number is additionally subdivided by mother tongue of its inhabitants, multiple attributes are gained. For the visualisation of one attribute the continuous depiction of quantities or the depiction of intervals can be used. If multiple attributes should be visualised within a map, diagrams are used. In the following chapters, first the methods for the depiction of one attribute are described. Afterwards, methods for the depiction of multiple attributes are described.

1.4.3. Continuous depiction of quantities

If an attribute is given as attribute values, a continuous (or steady) depiction of values can be used. This method can be either strictly proportional to the area of the signature or can be designed continuously in a more arbitrary way.



Source: (Arnberger 1993)

In general, a proportional continuous depiction should be aimed for. This may, however, lead to cluttered maps. This is particularly the case if the values are diverging heavily, which cause extreme values to be represented as symbols whose size would occlude the map too much or which would not be visible anymore. In such cases, the arbitrary continuous depiction should be chosen. It has to be taken care of, however, that extreme values can still be identified as such. For very small values, non-proportional minimal signatures can be used.

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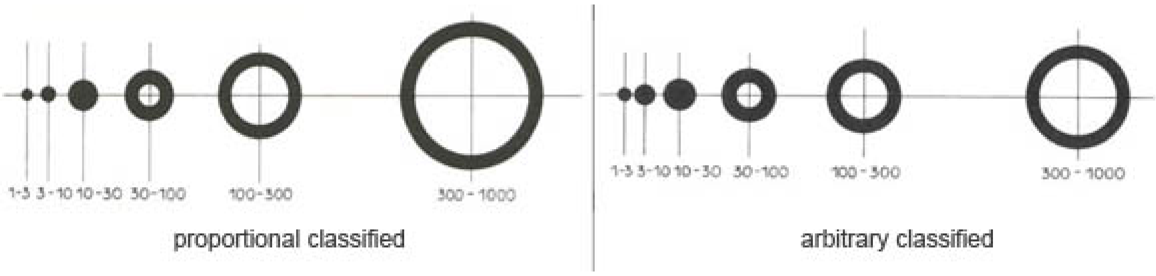
1.4.4. Depiction of intervals

In contrast to the continuous depiction of quantities, the depiction of intervals requires the separation of the underlying values into data classes. This classification, however, results in information loss. For this reason, the depiction of intervals should be only used as a secondary option after the continuous depiction of quantities. According to Spiess (1995), the depiction of intervals can make sense in the following cases:

- If the quantities are only approximately known
- If huge disparities between extreme values exist, which would make it difficult to depict all values continuously
- If very small differences of the values exist, which nonetheless should be highlighted clearly
- If the depiction of classes is desired in order to visualise the natural intervals
- If the magnitude of values is greater than the exact values
- If the values should be depicted in a simplified manner

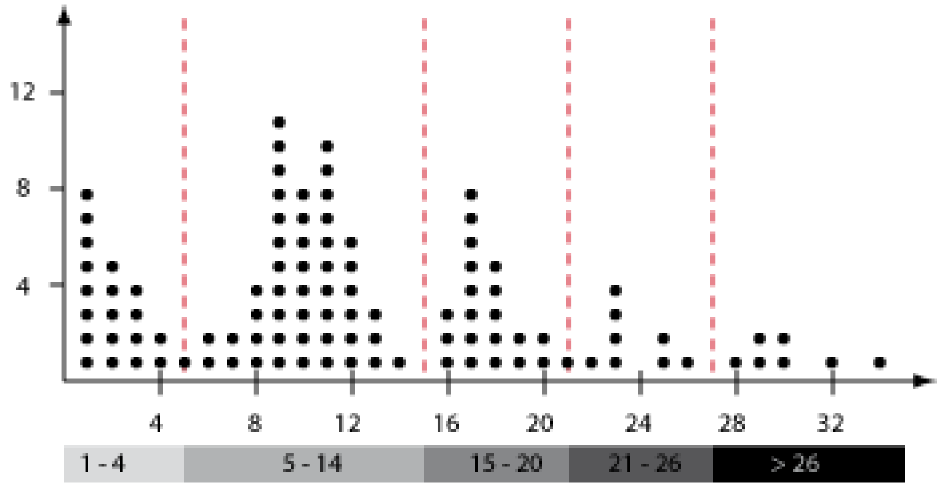
Similar to the case of the continuous depiction of quantities, the depiction of intervals can likewise be subdivided into a proportionally graduated variant and an arbitrarily graduated variant.



The data to be depicted and their spreading form the basis for the choice of which variant is to be used.
The following chapter deals with the intense and the graduated depiction of quantities. Afterwards, the classification steps are discussed.

Data analysis for the depiction of intervals

The simplest method to analyse statistical data is called line lists. These can then be visualised using a frequency diagram. Frequency diagrams form a good basis to classify the data in a next step. The following visualisation depicts a frequency diagram included possible class boundaries (red).



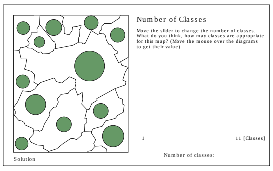
General information on classification

The number of classes, the class boundaries as well as the width of the interval play an important role in classification. The map image and the statement of the map depend on the choice of these parameters. Therefore, care has to be taken during classification. The following rules should then be followed:

- The classes among each other should preferably be different.
- The data within each class should be as similar as possible.
- Clusters and extreme values should become visible or remain visible.
- If it is sensible to do so, uniform class sizes should be aimed for.
- Class widths should preferably be chosen in such a way so that each class should be occupied more than once. Exceptions are the boundary classes.
- The whole value range of the attribute has to be represented and depicted.
- Natural boundaries should be preferably taken into account and should be considered as class boundaries.

Number of classes

The number of classes depends on the size of the dataset as well as on the signature which should represent the attribute. A too big number of classes, therefore, does not yield the necessary generalisation of the data. If the number of classes is too low, many information vanish due to generalisation. The exact number of recommended classes varies depending on the point of view. From the viewpoint of a statistician, 6 to 8 and 10 to 12 classes for single-coloured and multicoloured visualisations are recommended (Quitt 1997). From a cartographer's viewpoint, 3 to 7 classes are recommended according to Imhof (1972).



Click **here** (http://www.gitta.info/ThematicCart/en/multimedia/anzahlKlassen.svg) to enlarge the animation.

Class boundaries and interval widths

The most important criterion, which is to be considered during classification are the original data. Depending on their distribution different class sizes and interval widths are suitable. In general, classification can be performed according to the following principles:

- Classification according to groups with a common meaning
- Classification according to groups of frequencies
- Classification according to mathematical rules

The following interaction shows the three principles.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Further information on classification in general and the methods for classification according to mathematical rules in particular can be found in the GITTA lecture **Statistics for Thematic Cartography** (http://www.gitta.info/Statistics/en/html/index.html) in Chapter 1.2. and 1.3. The pdf version can be found **here** (http://www.gitta.info/ThematicCart/en/multimedia/Statistics.pdf) .

Examples for graduated depiction of quantities

Graduated depictions of quantities can be used for data of nominal, ordinal and metric scales. In addition, absolute and relative values can be depicted. In the following interaction, three examples are shown of how different data can be mapped after classification.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

1.4.5. Depiction of datasets

For the depiction of datasets with multiple attributes diagrams are used. Usually, these attributes make up a superordinate attribute which is divided into multiple subordinate attributes. These attributes can contain either relative or absolute values. One example of such a dataset would be the absolute number of employees, divided into the three economic sectors.
In general, diagram maps can be subdivided into diagram maps where the diagrams refer to single points and those where the diagrams refer to areas. Sound information concerning these map types can be found in the respective chapters. In the following text, first the most important diagram types are discussed and afterwards the choice of the design of the diagrams independently of the type of the diagram map is described.

Types of diagrams
There are uncountable forms of diagrams which can be used for their depiction in thematic maps. Many of these forms can be derived from the following four types:

- Pie charts
- Wing chart
- Bar chart
- Area chart (e.g. squares)

The following visualisation shows examples of these four forms of diagrams.

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Choice of the diagram type
The decision for a diagram type depends to great extent on the type and characteristics of the data to be depicted. During a first selection, those diagrams are determined which are in principle suitable to represent the given shape of the data. In a second step, the focus lies on the characteristics of the data.
Raw selection
Depending on the dataset, diagrams have to fulfill certain requirements such as the possibility to (Spiess 1995).

- Compare total quantities
- Compare subsets of different diagrams
- Depict zero sets
- Compare subsets with the total quantity
- Potentially depict negative values

The following table gives an overview over the properties of the four most important diagram types. It allows to determine which diagrams can generally be used to depict a dataset.

	Pie chart	Bar chart	Wing chart	Area chart
Compare total quantities	++	--	--	+
Compare subsets of different diagramms	-	++	-	0
Display zero values	--	++	++	--
Compare the proportion of subsets with the total quantity	++	--	--	++
Display negative values	--	++	--	++

most suitable ++ particularly suitable + suitable 0 moderately suitable 0- inpossible --

Detail selection

After this first overview on diagrams it is now to be determined which of the remaining diagrams is most suitable to depict the dataset. It has to be investigated if the variation of the data allows for a suitable representation. This means that the smallest diagrams should not fall below the typical minimal values and the biggest diagrams should not occlude the map disproportionately. To estimate if these criteria can be met with the chosen diagrams, the data spread has to be calculated and the diagram scale has to be selected. These values can then be used to compute the area spread.

$$\text{Variation} = \frac{\text{maximum value}}{\text{minimum value}}$$

Diagram scale = Define the dimension of the largest and the smallest diagram:
- Circle: define radius
- Wing: define radius
- Bar: define bar length
- Quadrat: Seitenlänge bestimmen

$$\text{Diagram area variation} = \frac{\text{area maximum diagram}}{\text{area minimum diagram}}$$

The comparison of the data spread with the following limits allows to determine if the chosen diagram is suitable.

Greatest possible variation

Pie charts	~< 2000 (referring to the sum)
Wing charts	~< 1000 (referring to single values)
bar charts	~< 80 (referring to the sum)

Source: experience values, E. Spiess, E. Hutzler

If these limits are exceeded, the diagram is not considered to be optimal for the depiction of the dataset. If these data only contain few outliers for the extreme values and the diagram type would actually be suitable, it is possible to treat extreme value diagrams separately. Detailed information on this topic can be found in the chapters on diagram maps.
In a next step, the data spread and the area spread are to be compared. If these values are very different, another diagram type should be used.

Diagram design and diagram placement

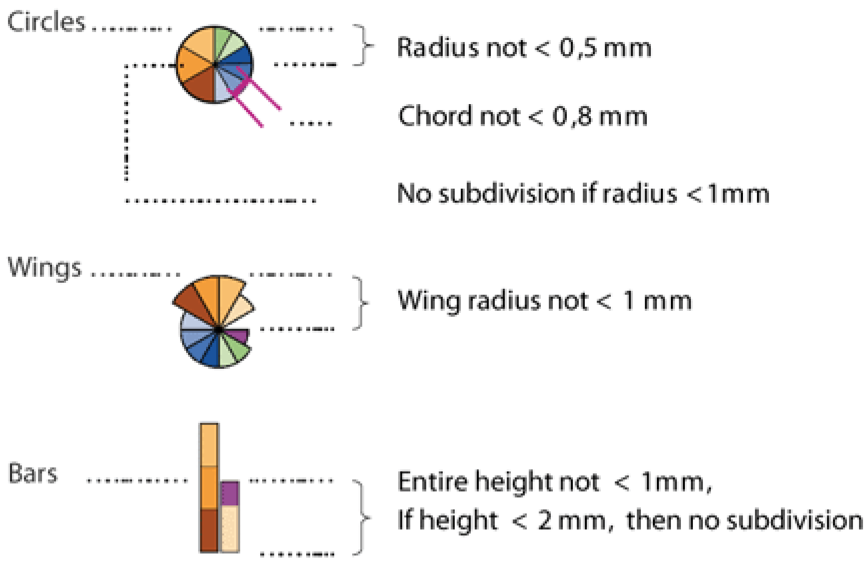
After the decision for a diagram type has been made, it has to be decided how to represent the data in the diagram and how to place the diagrams in the map. The following sections deal with the function of representation, minimum dimensions for diagrams, reference points and placement of diagrams.

Function of representation

The function of representation defines how the data are represented in the diagrams. Analogous to the representation of single attributes it has to be decided if the data is represented continuously or stepwise and if proportional or not. The aim should be a continuous proportional representation which allows a high density of information. If the spread of the data does not allow this one can refrain from the recommendation. One has to be aware that the map reader may misinterpret the map in this case.

Minimum dimensions of diagrams

To enable the map reader to easily read the presented information and to guarantee a good map readability, there are also minimal dimensions for diagrams. The following image shows reference values which have been determined empirically over time.



Reference points of diagrams and placement

Each diagram has at minimum one reference point. The diagram can be aligned to this point. Depending on the map type the diagrams are placed at a certain point or within a certain area.
The following interaction shows possible reference points for square-, pie- and bar charts.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

If the placement is done automatically, the diagrams are usually placed regarding the same reference point. The result has normally to be modified manually to gain a high cartographic representation quality.
The following interaction shows three typical problems which occur after an automatic placement. Think about how the placement could be improved.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

1.4.6. Summary

To represent statistical and other datasets in a map the data has to be processed and analysed. Data processing deals with the verification of the data quality and integrity. Furthermore, the data has to be processed for data analysis. Data analysis deals with the specific characteristics of the data. If there is only one attribute in the data it can either be visualised by continuous depiction of quantities or depiction of intervals. If there is more than one attribute relevant diagrams have to be used to visualized the data.

1.4.7. Self Assessment

With the following test you can perform a self-test to check whether you understand the content of this chapter.

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1.5. Mapping techniques for thematic maps

There are several different methods to map spatial-thematic information. Depending on the characteristics of the data a more local, linear or areal representation is suitable. Imhof (1972) subdivides thematic maps by structure types. Examples of cartographic structures are point distributions, area classes, isolines, networks and others. The following table shows structure types of thematic maps (Hufnagel) according to Imhof (1972).

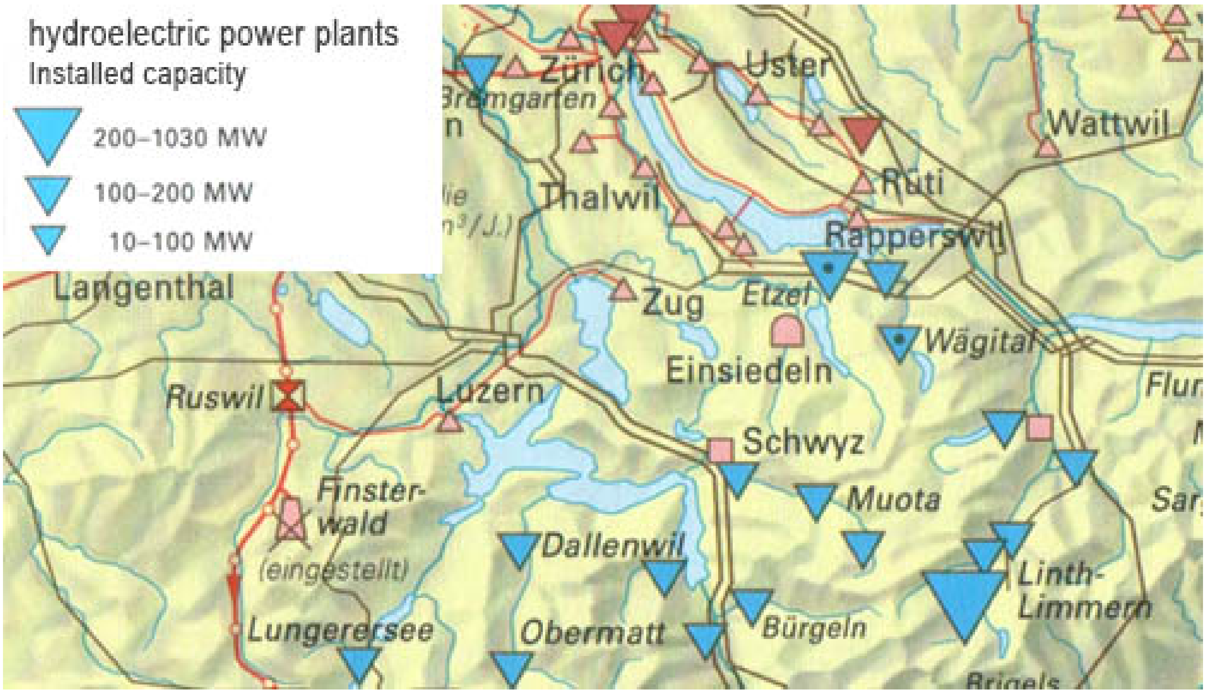
ID	Description	Elements of thematic presentation	Related to	Possibility of type differentiation	Value information	Combination possible with number	Base map	
							Ground plan	Terrain
1	Symbol map	Local symbols	Sites	yes	no	2, 3	Comprehensive	Relief
2	Network map	Line signatures	Lines	yes	no	1, 3	More or less comprehensive	Relief
3	Qualitative choropleth map	Area signatures	Areas	yes	no	1, 2, 9	More or less comprehensive	Relief
4	Isoline map	Lines (often combined with area signatures)	Areas	no	mostly absolute	1, 5, 9	More or less comprehensive	Relief (contour lines)
5	Vector map	line signatures + arrows	Lines	yes	possible	3, 4	More or less comprehensive	Relief
6	Dot map	Local symbols, local diagrams	Sites	yes	absolute	3	Hydrography	Relief
7	Quantitative choropleth map	Area signatures	Areas	no	mostly relative	-	Political or other borders	Relief
8	Other kinds of choropleth map	Area diagrams	Areas	yes	mostly relative	1	Different kinds of borders	-
9.1	Point related diagram map	local diagrams	Sites	yes	absolute and/or relative	2, 3, 4, 10	Hydrography	Relief
9.2	Area related diagram map		Areas			3, 7	Political or other borders	-
10	Band diagram map	line diagrams	Lines	yes	mostly absolute	3, 9, 1	Settlements (Hydrography)	Relief

In the following sections specific types of thematic maps are presented.

1.5.1. Thematic map using point symbols

Definition

In this type of maps, phenomena are represented by point symbols which are located as accurate as possible regarding their topographic position. Strictly designed maps of this type only show qualitative differences. However, quantitative aspects are often represented by the size of the symbols. The following figure shows an example.



Source: (Spiess 2004)

Point symbols

There is a countless number of different point symbols. Nevertheless, three different types can be distinguished:

- Geometric symbols
- Pictographs
- Letters and numbers

Explanations and examples of thematic maps using point symbols are shown in the following interaction.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Selection of the symbol form

The aim is to design the symbols as small as possible in order to avoid overloading of the map and to allow a highly accurate placement of the symbol. On the other hand the symbol must be large enough in order to provide a good readability which allows the user to recognize symbol variations in its colour and form. The choice of the symbols is closely linked to the purpose, scale and content of the map. The four following rules provide support in the selection process.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Combination of different symbol types

Often different symbol types are used together. The following figure shows an example of a thematic map in which all three symbol types are used. Click on each type to show the corresponding legend.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

1.5.2. Network maps

Definition

Network maps depict networks of truly existing or imagined linear objects in their spatial context. The forms of the network elements depend on the characteristics of the lines in the real world. For instance the layout of a road network is different than the layout of a river network. This has to be taken into account for the visualisation as well as for the generalisation. The symbolisation of a network is realised through the layout, the type of junctions and the interweaving as well as by the colour and form of the lines.

Street map 1:200'000, reproduced with permission from swisstopo (BA057224)

Opposite street map is an example of a network map.

Network types

There is a variety of network systems that can be depicted as network maps. The most common and most important ones are listed as follows (c.f. (Imhof 1972, p. 109)):

- **Network of supporting, construction and measurement lines**
  Map grids, triangulation diagrams, radar networks, networks of line-of-sights and influence line fall in this category.
- **Networks resulting from the generalisation of area objects**
  Examples are river networks, networks of paths, railway networks and supply networks. Also imagined networks like ship routes, travel routes or lines of fire fall in this category.
- **Boundary lines**
  This category includes property boundaries, political boundaries and language boundaries. This kind of network is often used but the focus of such maps lies mostly on the areas which are limited by the boundaries and not on the boundaries itself.
- **Value, iso and gradient lines**
  These kinds of networks are used to visualise continua. They represent a special case within network visualisations and are therefore explained in a subsequent section.

The following animation shows different examples of network visualisations of the above mentioned network types.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

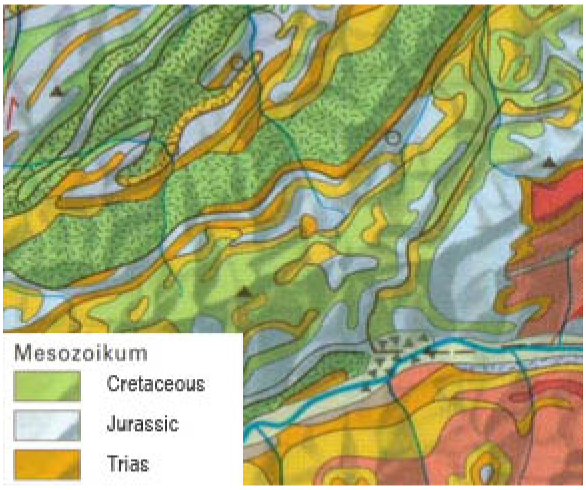
1.5.3. Area-class maps

Definition

Area-class maps depict phenomena or objects which are extensively distributed. Imhof (1972, p. 115) distinguishes three types:

Truly areal areas

e.g. rocks, waters, glaciated areas, forest areas and areas of arable lands, etc.



(Spiess 2004)

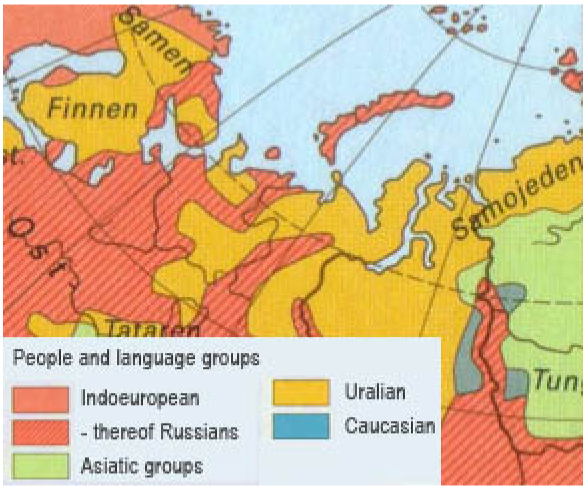
Fictitious areas

e.g. areas with political or legal properties, areas of influence, etc.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Areas as a form of generalisation of scattered and isolated single objects

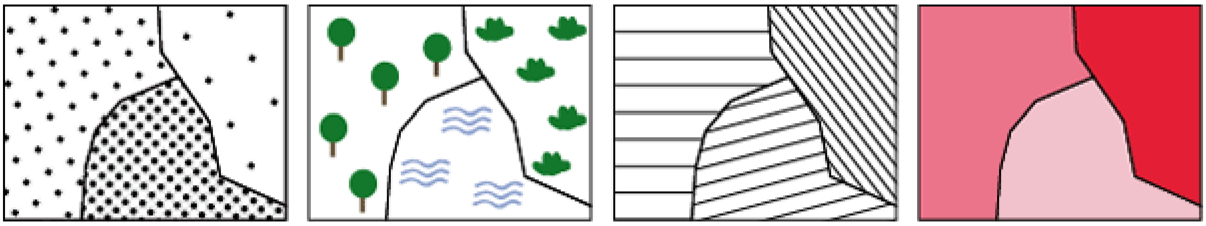
e.g. limits of human occurrence, occurrence of animals, plants, diseases, etc.



(Spiess 2004)

Area patterns

Several graphical display elements can be used for the distinction of areas of different characteristics. The possibilities for variation depend on the chosen pattern type. The most common patterns are dot grids, scattered figures, line screens and fill colours.



The following table shows an overview of the possible display elements and their variation possibilities.

	Distinction with graphic variables				
Area fill with	Brightness	Screen ruling	Direction	Form	Colour
Point raster	x	x			
Gritted small figures		x		x	x
Line raster	x	x	x		x
Area colour	x				x

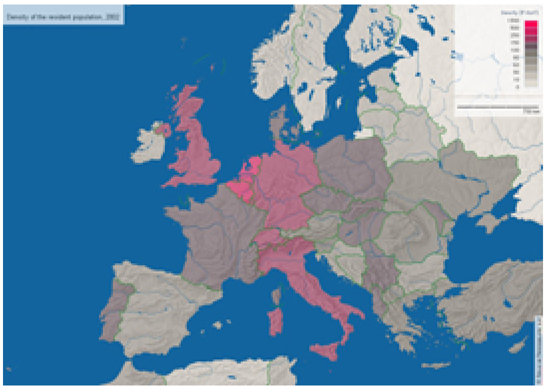
Conceptual differences of individual areas are mostly represented by varying their brightness. Thereby, darker colours indicate higher importance and lighter colours lower importance. If there are no differences in the importance, big differences in brightness should be avoided.
According to the form of the area patterns the items presented in the following interaction should be respected.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

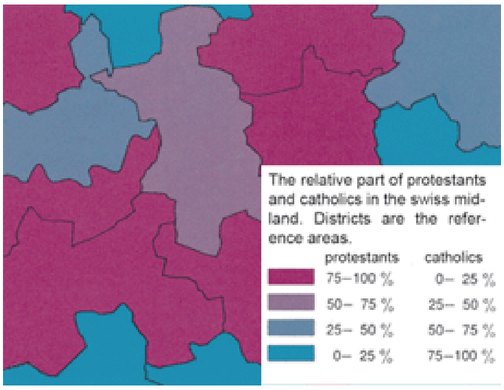
1.5.4. Choroplethic maps

Definition

Chorophletic maps are used to show relations, also called ratio numbers, between two values. In most of the cases the denominator is an area. However, ratio numbers can also be calculated from two non area-related values, but the absolute numbers somehow have to be in relation with their reference area, as it is styled depending on the value of the ratio number. An example of the first-mentioned variant is the population per square kilometre (population density) on community level. An example for the second variant is the ratio between protestants and catholics on district level Choroplethic maps (Witt 1967, p. 186).



Choroplethic map according variant 1 (Institut für Kartografie 2004)



Choroplethic map according variant 2 (Imhof 1972)

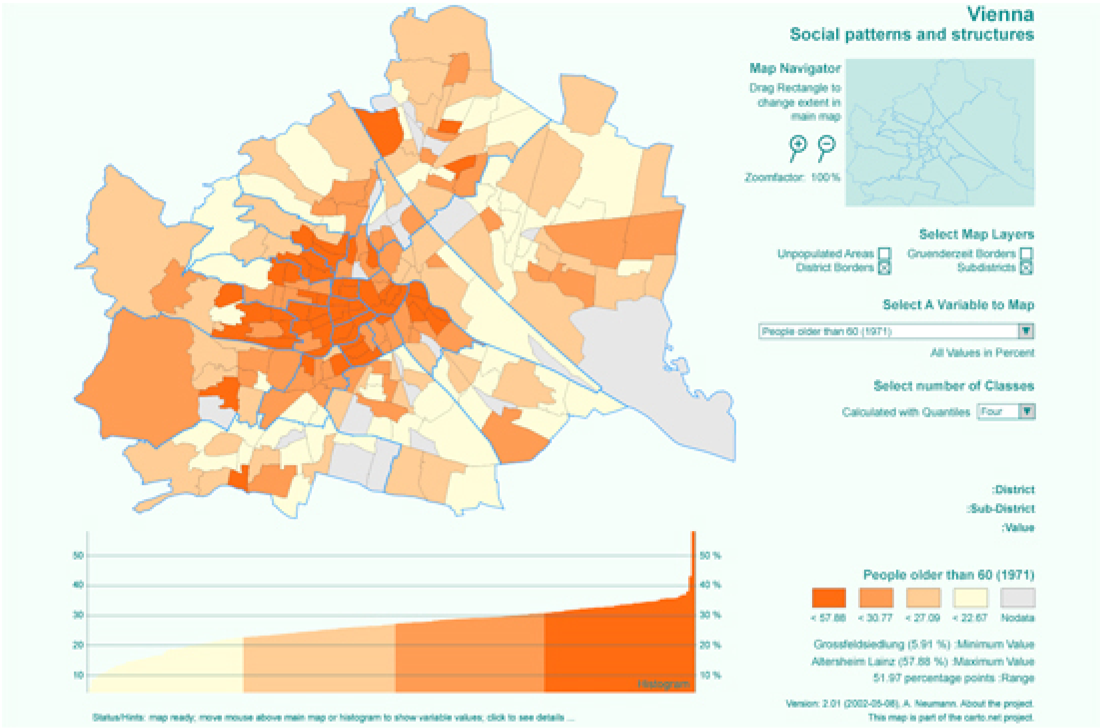
Choroplethic maps are unsuitable for the symbolisation of graded absolute values. They distort the message of the map because the map viewer automatically takes into account the size of the areas. In this case large areas with a low absolute value get too much importance whereas the importance of small areas with a high absolute value is too small. For the depiction of absolute values diagram maps should be used (see the following section). A similar case occurs when the denominator of ratio numbers is not the corresponding area. The figure above shows, which confession dominates in a specific area. The map tempts the viewer to interpret a high absolute value for large areas with a high density.

Characteristics of choroplethic maps

Representation

The areas, to which the ratios are related, are styled with different fill colours or patterns. The more dense an object is distributed within an area the darker the colour or the more dense the pattern should be.

The following figure shows an example of a choroplethic map. With a click on the map you get to the corresponding interactive map. On its basis you can get familiar with the characteristics of choroplethic maps.



Interactive quantitative choroplethic map (Andreas Neuman, IKA ETH)

Value classes

The ratios or densities are normally classified in value classes. Areas get the same styling if their values are in the same class. The optimal number of classes varies for each dataset. To maintain a good readability of the map, the colours of the classes have to be clearly distinguishable.

Types of choroplethic maps

Choroplethic maps are classified by their reference areas:

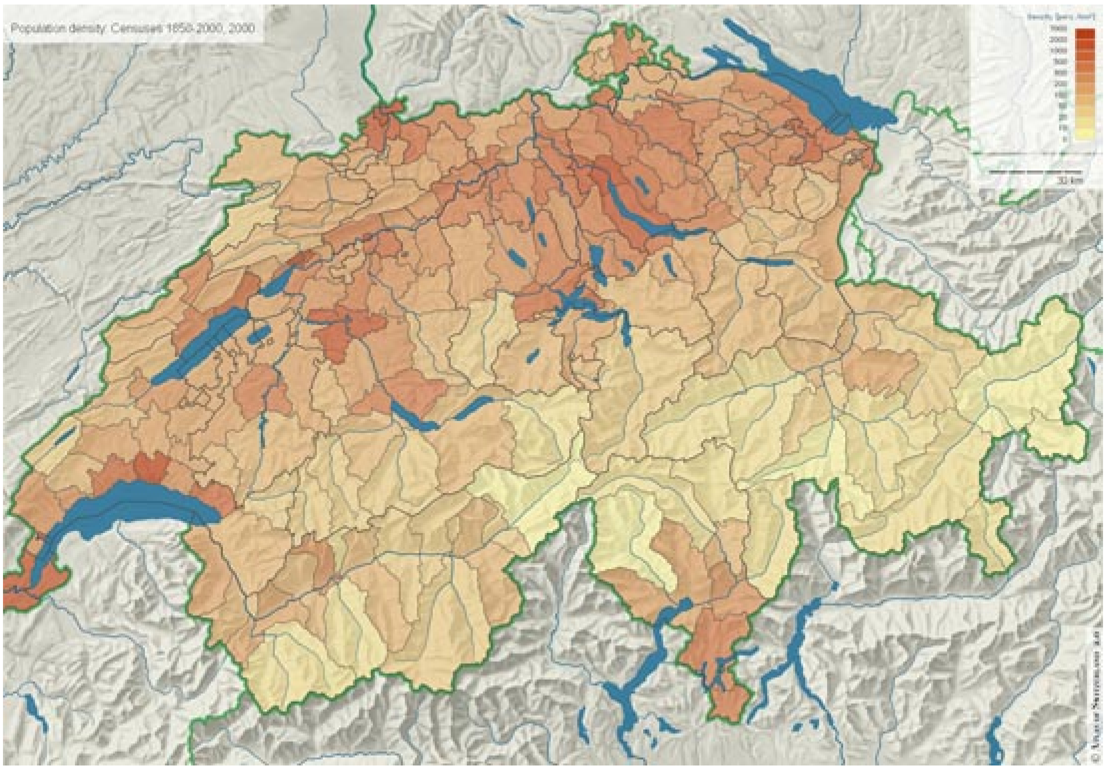
- Choroplethic maps based on **administrative areas**.
- Dasymetric maps show densities of areas regarding **geographic properties**.
- Choroplethic maps in relation to geometric areal units such as **grid squares**.

Below all three map types are described in details.

Choropleth maps

Properties

The shown densities in these maps are relative to given administrative areas such as communities, districts, cantons or even countries and continents. The following figure is an example of this map type and depicts the population density of Switzerland on district level.



Population density of Switzerland on district level (Institute of Cartography 2004)

The selection of the administrative reference area, the value classes and class limits play an important role during the mapping process. With a specific selection of these parameters the appearance and significance of a map can be highly influenced. Density differences can be emphasized or suppressed.

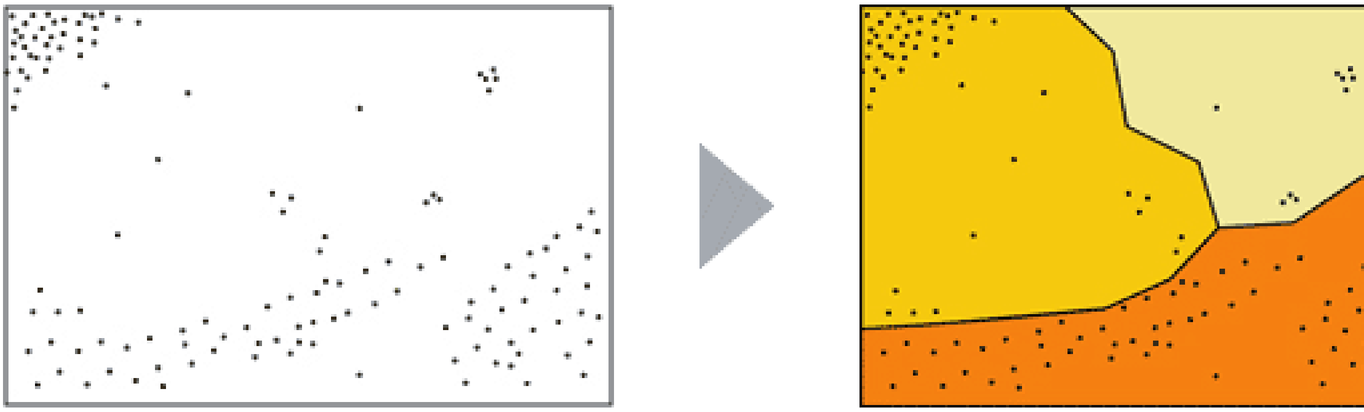
Advantages and disadvantages of choropleth maps

Advantages

- Statistical data can be visualised quickly as they are generally related to administrative areas.
- The choropleth method is applicable to any scale, as long as the individual areas are not getting too small. If this is the case, there is the possibility to switch to a higher administrative level (Imhof 1972, p. 166).

Disadvantages

- Choropleth maps assume a constant density within the depicted area. If the real object density varies, the expressiveness of the map gets distorted. For the example of the population density this is the case in mountain regions, where the populated area is usually only a fraction of the administrative area. The following example demonstrates this problem: the most dense area is not visible, because it gets cancelled out by less dense areas within the same administrative area.
- Comparisons of different datasets from different years are possibly difficult because administrative areas may vary over time (communities can be consolidated or split up etc.).

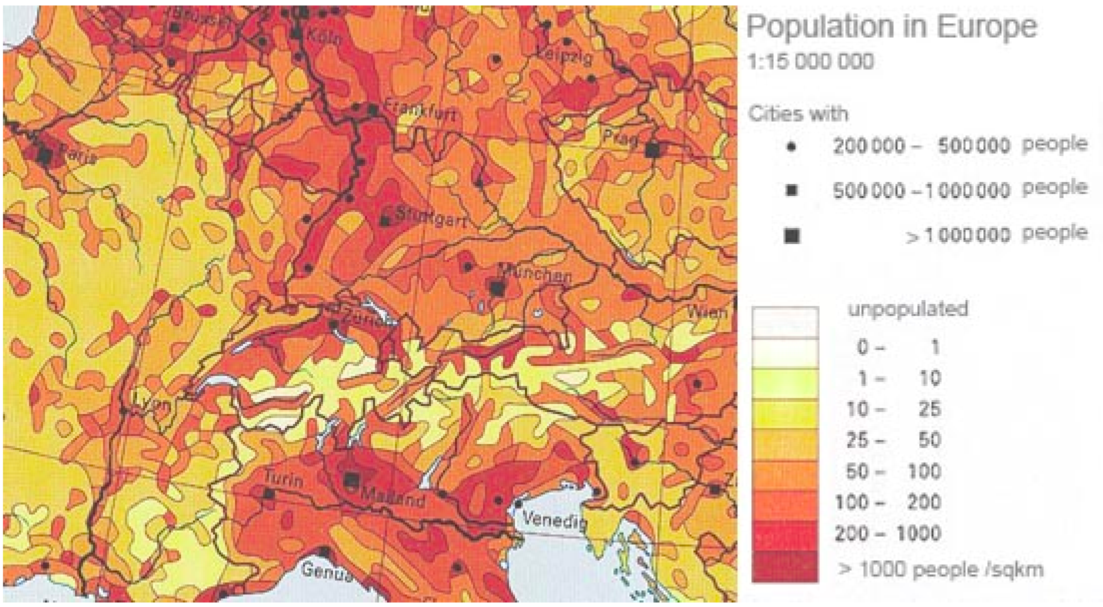


Dasymetric maps

Characteristics

Dasymetric maps are also called "choropleth maps according to the geographic method" (Imhof 1972, p. 167). In contrast to choropleth maps this map type does not use administrative but geographical areas which are formed by considering the real distribution of the objects.

The following part of a map depicts a dasymetric visualisation. Click on the figure to view the whole map.



Soruce: (Spiess 2004)

Construction methods

There exist several methods to construct dasymetric maps. Most of them use dot maps as a basis. Detailed explanations of the different construction methods can be found **here** (http://www.gitta.info/ThematicCart/en/image/Konstruktionsmethoden.pdf) (only available in German).

Advantages and disadvantages of dasymetric maps

Advantages

- In contrast to choropleth maps dasymetric maps allow a more precise representation of areas of the same density.

- There is no risk that more dense and less dense areas cancel each other out and areas with a high density are no longer visible.

Disadvantages

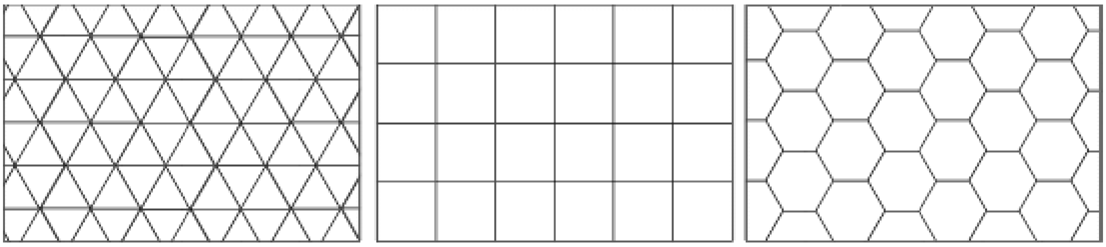
- The resulting map depends on the cartographer
- The creating of dasymetric maps is time and cost consuming
- The limits of the reference areas can be uncertain.
- Dasymetric maps are not suitable for large scales because the uncertainties during the construction of the reference areas are too high.
- Direct comparison between different periods is not possible.

Choroplethic maps in relation to geometric areal units such as grid squares

Properties

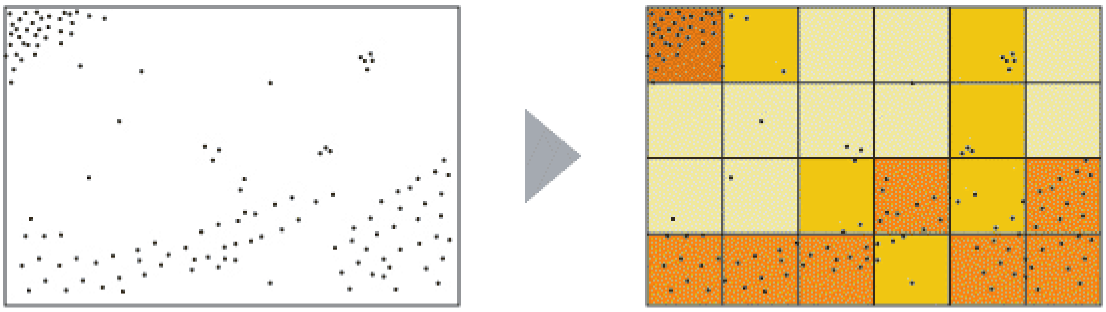
Choropleth maps with regular patterns structure are also called "*Choropleth maps according to the geometric method*" (Imhof 1972, p. 171)

The reference areas are built by a regular network of identical polygons like squares, triangles or hexagons. The dimensions of the polygons may vary depending on the scale and the dataset. Conceivable are hectare or square kilometre grids or even wider meshed grids. The tighter the grid, the more representative is the resulting map. If a square grid is used, it should be aligned to the national coordinate grid. Furthermore it allows an expansion to additional areas.



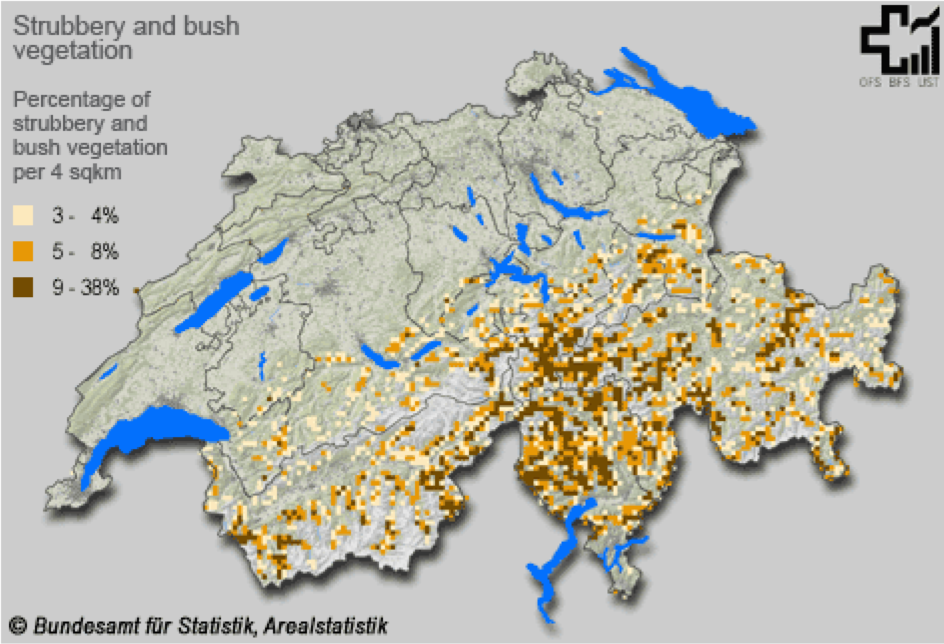
Triangle, square and hexagon grid

The square grid is the simplest and most widely used form of grids. The following example shows a choroplethic map using a square grid and its basic data.



Point data with coordinates are preferably used as a basis. The Swiss Federal Statistical Office offers some raster data sets (hectare grid of the population density) which facilitates the preparation of such maps.

In the following visualisation you can see a choroplethic map based on a square grid. It depicts the percentage of shrubland per 4 km^2 in Switzerland in the years 1992/1997.



Advantages and disadvantages of choroplethic maps in relation to geometric areal units

Below the advantages and disadvantages are listed.

Advantages

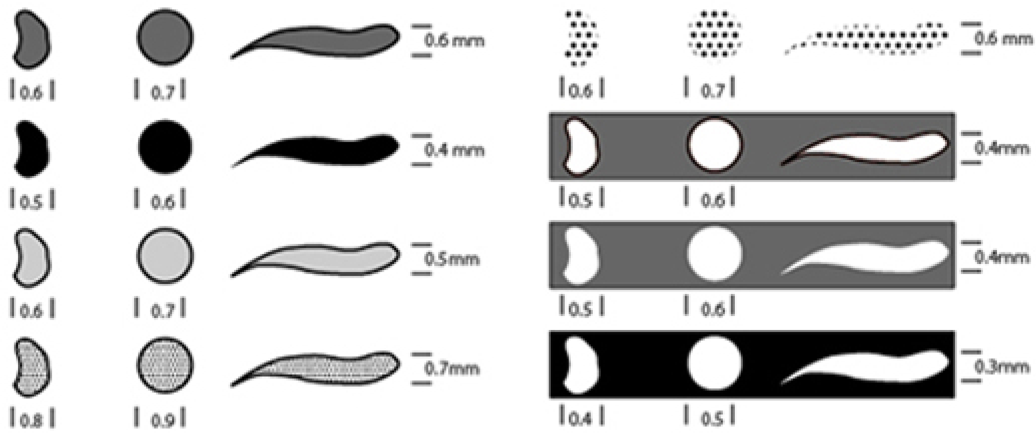
- It is very simple to compare specific areas because of the constant grid.
- The comparison of different periods is possible because the reference areas do not change in time.
- An automatisation of the mapping process is possible with state of the art data processing methods (e.g. GIS) (Hake et al. 2002, p. 478).
- Because of the constant reference areas this method allows the visualisation of absolute values.

Disadvantages

- Most data are not raster data.
- The data collection process for raster data is expensive.
- The density values may vary depending on the positioning of the raster, particularly if the mesh width is large. Therefore a small mesh width is recommended.
- Natural limits (e.g. timber line) are no longer recognizable due to the raster based representation.

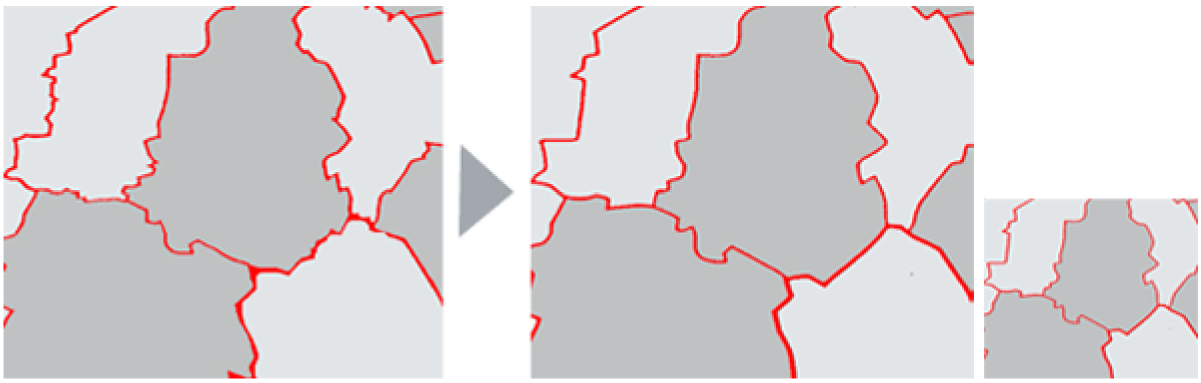
Generalization of choroplethic maps

For the generalisation of choroplethic maps different methods can be used individually or in combination with each other. In any case it is important to respect the minimum dimensions, which are depending on the following factors: form, colour, pattern and contour of the area. The following figure gives an overview.



Minimal dimensions for choroplethic maps (Spiess)

If you get below the minimum dimensions generalisation is needed. If administrative areas are used, it is considered to summarize the data on a higher administrative level (summarize communities to districts, etcv). If inhomogeneities occur, it is also possible to group certain areas. Too small but important areas can be enlarged while maintaining an analogous shape or aggregated with bigger neighbouring areas if the density value is only related to settlement areas. In the second case the density value has to be recalculated. In the case of choroplethic maps in relation to geometric areal units the mesh width can be increased. E.g. four squares are summarized to one and the value is recalculated. In addition the number of classes can be reduced for any choroplethic map. The contours of the density areas have to be simplified and smoothed according to the scale. For choroplethic maps in relation to geometric areal units this is not necessary because the geometries are already simplified. In general it has to be considered that the fundamental form of the areas should not get lost during the generalisation process and that original structures should be preserved.



Map extract before and after the generalisation (Spiess)

Map examples

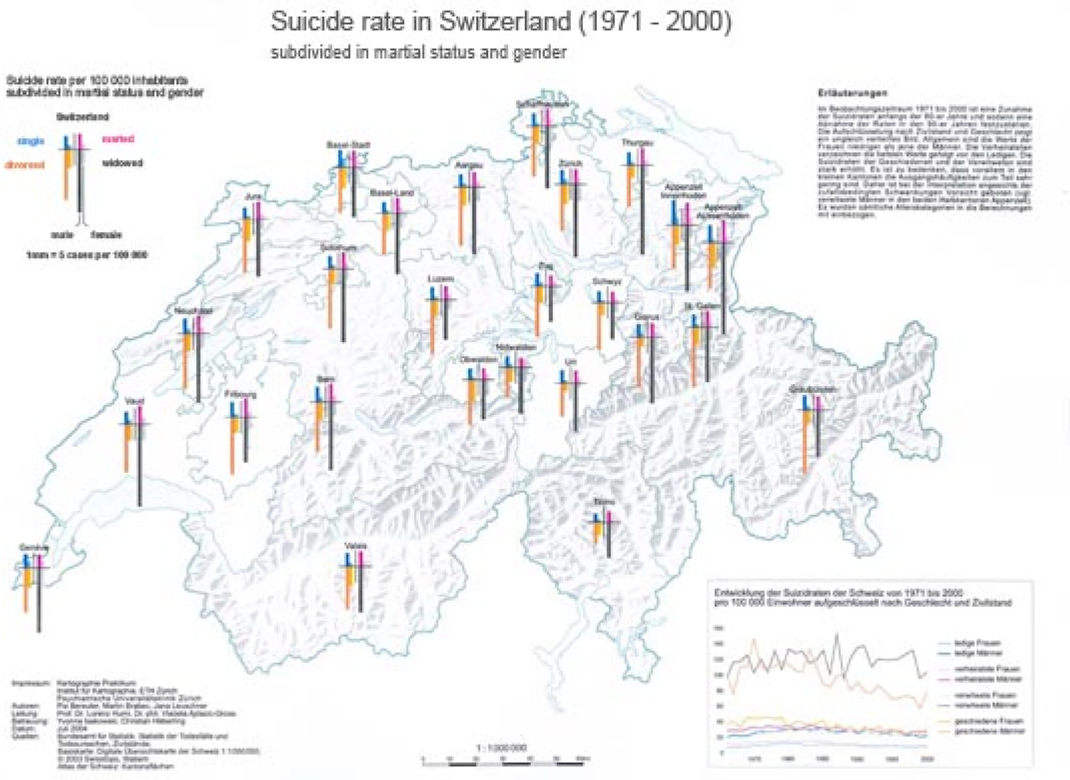
Now you can become more familiar with some complex examples of choroplethic maps.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

1.5.5. Diagram maps (cartograms referring to a specific point or area)

Definition

In this section first the general aspects of diagram maps are described. Further on details of cartograms referring to a specific point and referring to a specific area are presented. Diagram maps or cartograms are cartographic forms of expression where values or properties are visualised in the form of diagrams on top of a simplified topographic map. The diagrams, which graphically refer to a certain point or area, are not aligned highly accurate but are correctly positioned. Absolute values as well as ratios or value intervals can be displayed. Relative values which correspond directly to the reference area should not be visualised with diagrams. For this purpose choroplethic maps are more suitable. The following figure shows a diagram map with cartogram referring to a specific area.

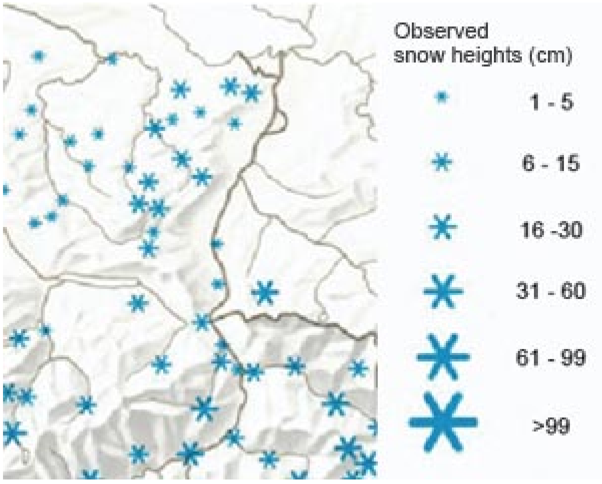


Area related diagram map (student work, IKA, ETH Zurich)

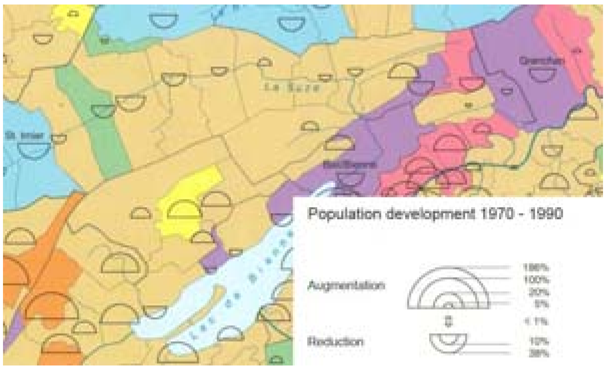
Characteristics of diagramm maps

Visual representation

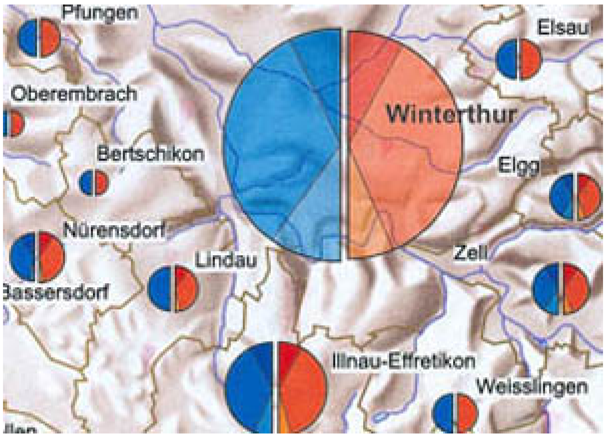
As visual representations for diagram maps symbols and diagrams are used (Hake et al. 2002, p. 467). Depending on the topic and the dataset a continuous quantity display or a diagram representation is used.



Local signatures with classified values (student work, IKA)



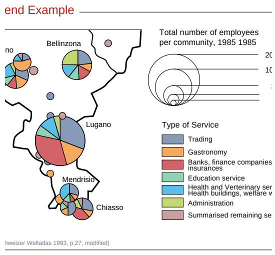
Continous value representation (student work, IKA)



Diagrams (student work, IKA)

Legend

To make the map understandable for the map reader a legend with detailed explanations of the diagrams is essential. In the following figure an example of a diagram legend is shown. You can explore it interactively.



Object relation

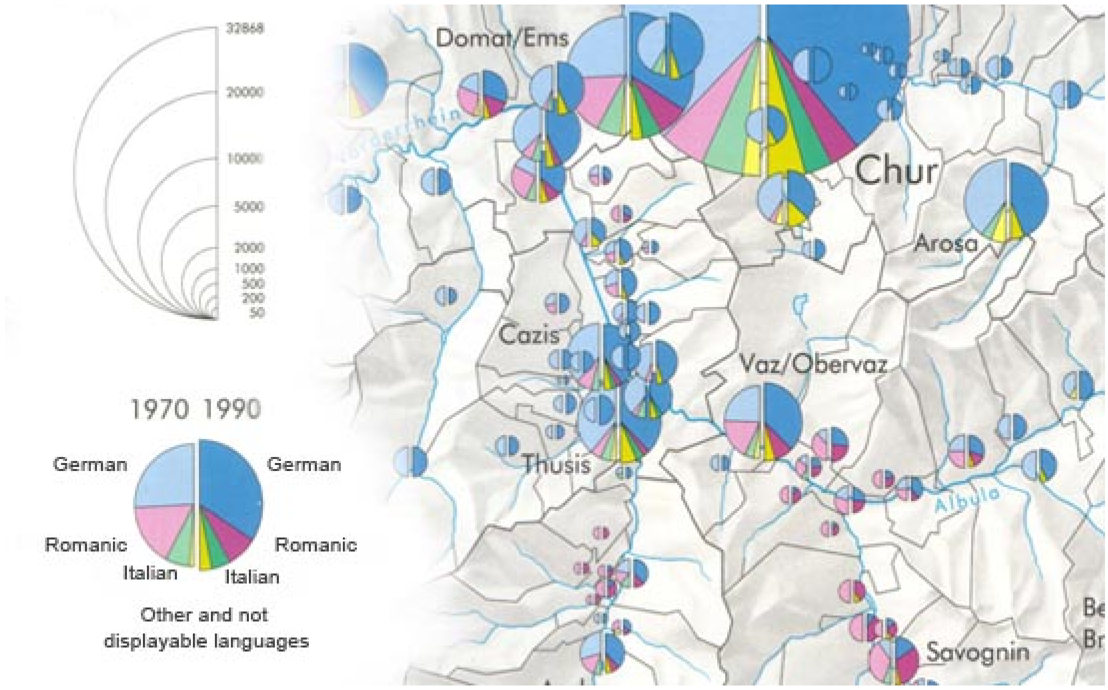
Statistical data in diagram maps may have relations to particular points or locations like cities or areas. Therefore point related and area related diagrams are distinguished. The cartographic possibilities of these two map types differ in some cases. The following two chapters explain point related and area related diagram maps.

Map with point symbols

Properties

Point related diagram maps are always related to certain points. The diagram can be placed close or on top of the related point symbol. Most of the time it even replaces it. Though it is important that it is clear to which point the diagram is related to. For a better orientation the base map usually is rather detailed. The most important map elements are the point symbols as far as they are not overlayed by the diagrams. Furthermore the river network, the shaded relief and depending on the thematic content of the map, also the road and railroad network as well as administrative boundaries are relevant.

The following map is an example of a point related diagram map.



Point related diagram map (student work, IKA, ETH Zurich)

Diagrams

Due to the limited space in the map, the diagrams should be rather small, simple and easily adjustable to the center. Large and complex diagrams make the spatial allocation imprecise and favour interferences among the diagrams. Not all diagram types are appropriate for point related diagram maps. In the following interaction you can learn more about diagram types for point related diagram maps.

Map with area patterns

Properties

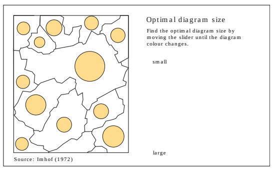
Statistical values are often related to well defined areas like districts or communities. Area related diagram maps are perfectly suitable for displaying such data. The diagrams are placed within the boundaries, in the centre of the related area or in the centre of gravity of the related urban area. As there is more space available in area related diagram maps the diagrams may be a bit bigger and more complex (Imhof 1972, p. 184), which offers the opportunity to include more information into the map. One has to consider that depending on the related areas there might also be small areas in which the diagrams also have to be placed. This is particularly the case within small scaled maps. The basemap for area related diagram maps can be simple. For the spatial orientation only the boundaries of the related areas as well as a simple river network are necessary.

Display of relative values

There is the possibility to also display relative values within area related diagram maps. In this case some rules have to be observed, to not communicate a false message. If one wants to display relative values which are not directly related to the area in which the diagram is placed there is the potential danger that the map reader interprets the size of the diagram as the size of the corresponding area. This can also be the case if in the legend the diagrams are explained explicitly. Figures of the related areas which are placed inside or around the diagrams can be a solution to that. This can be done in different ways as the following interaction shows.

Diagram size

The size of the diagrams in area related diagram maps play an important role within the map appearance and readability. If the diagrams are too small it is difficult to estimate the displayed values. If the diagrams are too big and even overlap the boundaries of the related areas, they overlay elements for orientation and make the map difficult to read. In the following visualisation the optimal size of the diagrams in the given map can be found interactively.



Cartographic conflict resolution in point and area related diagram maps

Diagram overlays

In diagram maps it often happens that diagrams overlay in dense areas or that one diagram is that big that it overlays all other diagrams and the basemap in a certain area. There are different methods to solve such problems. Basically big diagrams should be placed in the background, small diagrams in the foreground. This ensures that all diagrams are at least partly visible. To prevent the situation that one diagram gets too big and makes the map difficult to read one of the following tricks can be applied.

- all diagrams keep their size and position, but the bigger diagrams are visualised transparent. The base map will still be visible which is positive for the readability and the orientation. In addition the small diagrams get emphasized.

- for the bigger diagrams only the contours but not the fills are visualised. This is often used for simple pie- and rectangle diagrams which are not stacked.
- particular diagrams which overlay different others are placed outside of the map. An indicator should show their original position.
- very big diagrams are replaced by smaller ones which are still clearly bigger than the small ones. The values of these diagrams are noted directly in the map or in the legend. This method should only be used in exceptional cases.
- Diagrams with extreme values are split up in two or more separate diagrams. A unit diagram is to be defined. As many unit diagrams are then displayed as the original one can be split into. The remaining part will be shown in a corresponding smaller diagram. The unit diagrams can be stacked tightly which saves space on the map and makes it more readable.

The following interaction includes some examples in which the above mentioned techniques are presented.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Generalisation of point and area related diagram maps

For the generalisation of point and area related diagram maps both the related areas and the diagrams have to be adjusted to the map scale. In the following interaction you will interactively become more familiar with the different types of generalisation of area and diagram maps.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Map examples

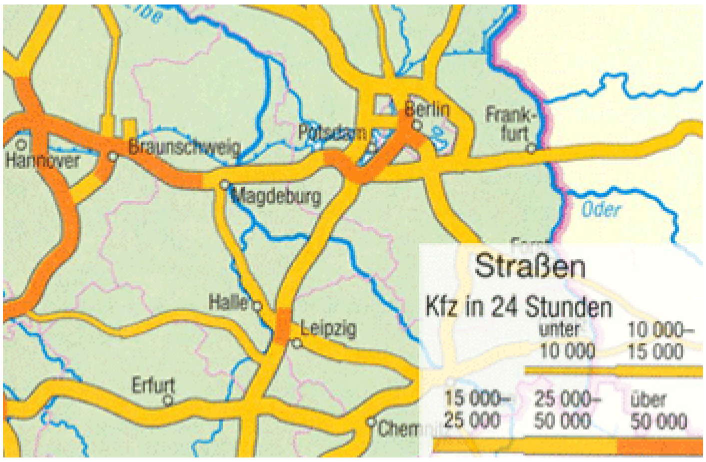
Below you can explore interactively four examples of point and area related diagram maps.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

1.5.6. Line and vector related diagram maps

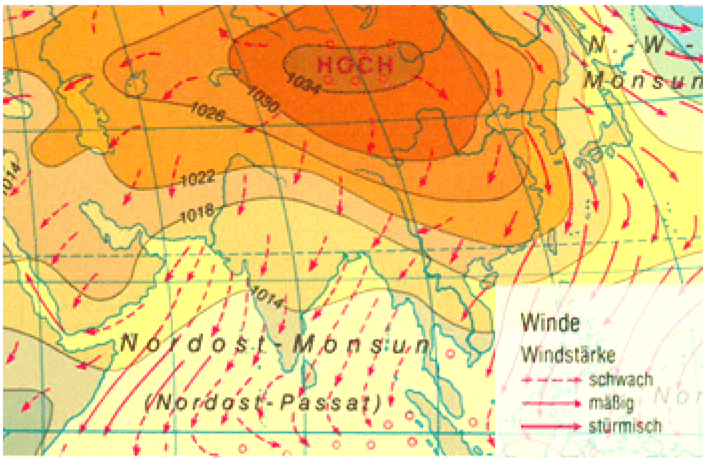
Definition

Line and vector related diagram maps allow to visualised how much of something can be transported in which time or speed on what way and in which direction by means of lines and vectors. Most of the time not all of these variables are visualised together but rather only relevant information are represented. The difference of line and vector related diagram maps lies, among others, mostly in the emphasis of which information is depicted.



Example of a flow map using band diagrams (Michael 2002)

For line related diagram maps the emphasis is the quantitative or qualitative information about the transported or moved object. Furthermore starting and ending points of the movements as well as the course are important components. Line related diagram maps are often used in the field of traffic and trade relations.



Example of a flow map using vectors (Michael 2002)

Vector related diagram maps emphasise on the directions of movements and forces by using arrows to visualised them. For example they are used to show wind directions or historical processes. The arrows can also show quantitative information like number of persons or streams of commuters.

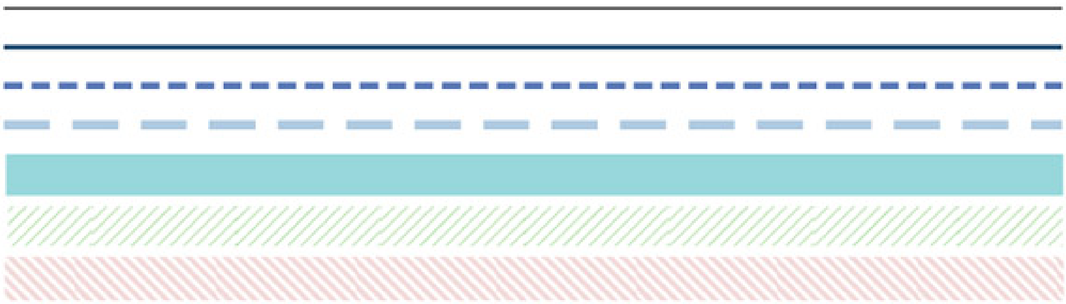
The differentiation of line and vector related diagram maps is not always easy. Often combined variants are seen. This is the reason why these two map types are discussed together in one chapter.

Properties of line and vector related diagram maps

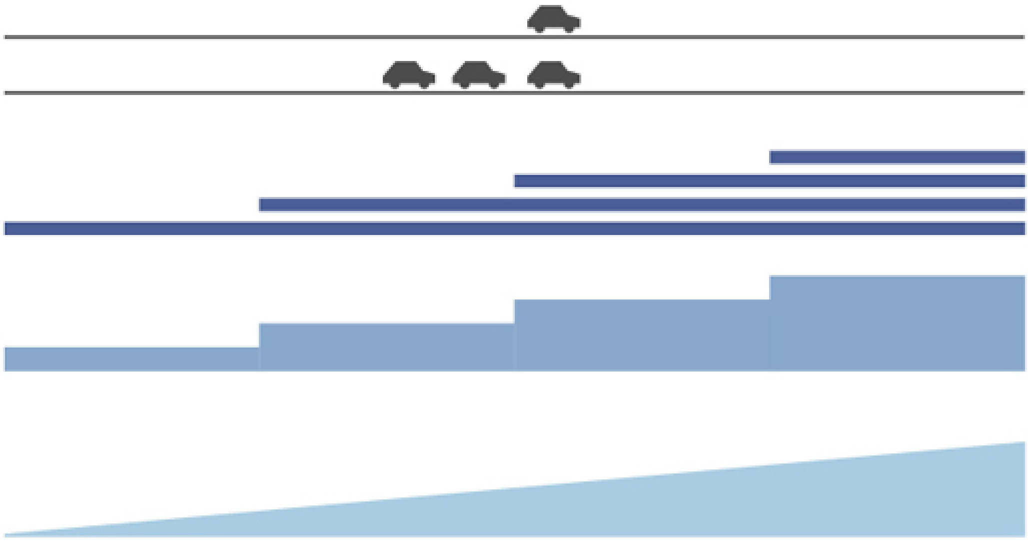
Specific aspects of line and vector related diagram maps are explained below.

Quality

In line and vector related diagram maps movements are distinguished by clear symbols. The symbols can vary in colour, line width, brightness and texture.

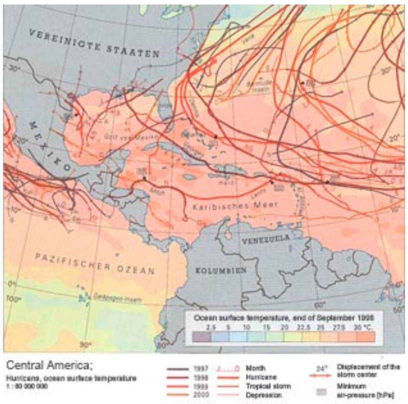


Quantity
The amount of the moved objects is one of the main points of a line related diagram. It can be visualised by varying the line width or the number of parallel unit lines (Imhof 1972, p. 96). The transition of different amount values can be done in two different ways: the line width changes continuously or in steps. Stepwise changes comply more with real transport situations and are also prefered regarding the graphical visualisation. Continuous changes are used to generalise high numbers of successive change in the line width. To show the transport volume even more clear, symbols on the lines can be used in addition.



In vector related diagram maps the quantitative value of the movement is often secondary in contrast to the direction and the quality of the vectors, like for wind maps. But if quantitative values are relevant, they can be visualised with different line widths.

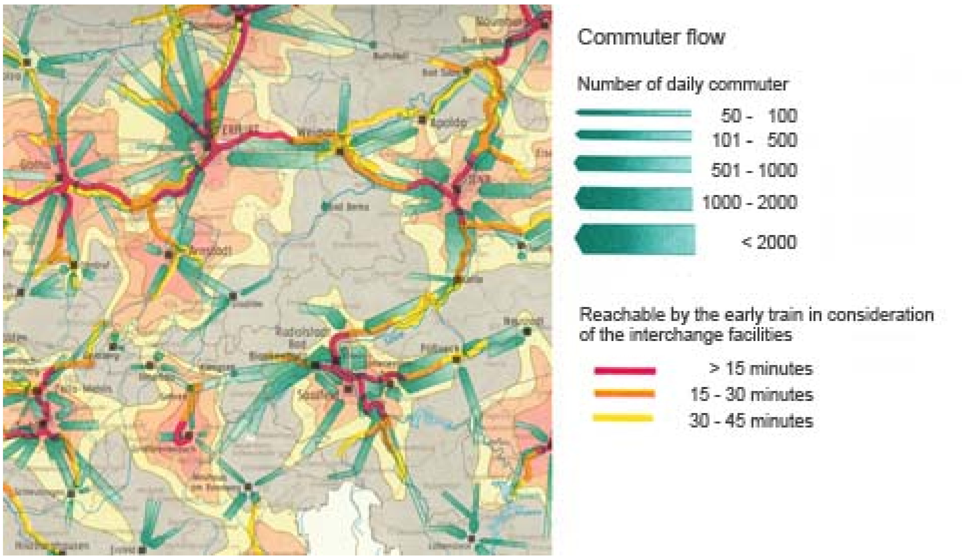
Direction, velocity and duration
The direction of a movement is the main point of a vector related diagram map. Usually it is visualised with arrows. Different speeds can be displayed by a number of arrows in a row. If several parallel arrows are displayed, a decreased distance between them relates to a higher speed. If the duration is relevant, it can be noted as text along the vector or with timestamps on the arrows. In line related diagram maps the direction is mostly secondary, but could be also indicated with arrows.



The duration is indicated by arrows (Spiess 2004)

Legend

The explanation of the lines and vectors in the legend is inevitable. The unit of value, line widths and the qualitative divisions should be illustrated. The line width can visualise both, a fixed value or an interval. The unit of values is related to the displayed dataset and the message which should be communicated via the map. To save space and to make the map more readable, *progressive scale* [1] are useful. Within a progressive scale the value interval increases progressively, but the change of the line width remains constant. The danger is that the user may incorrectly interpret the map. To read the diagrams correctly, the legend must be consulted.



Legend of a flow map (Lehmann 1972)

Design of line and vector related diagram maps

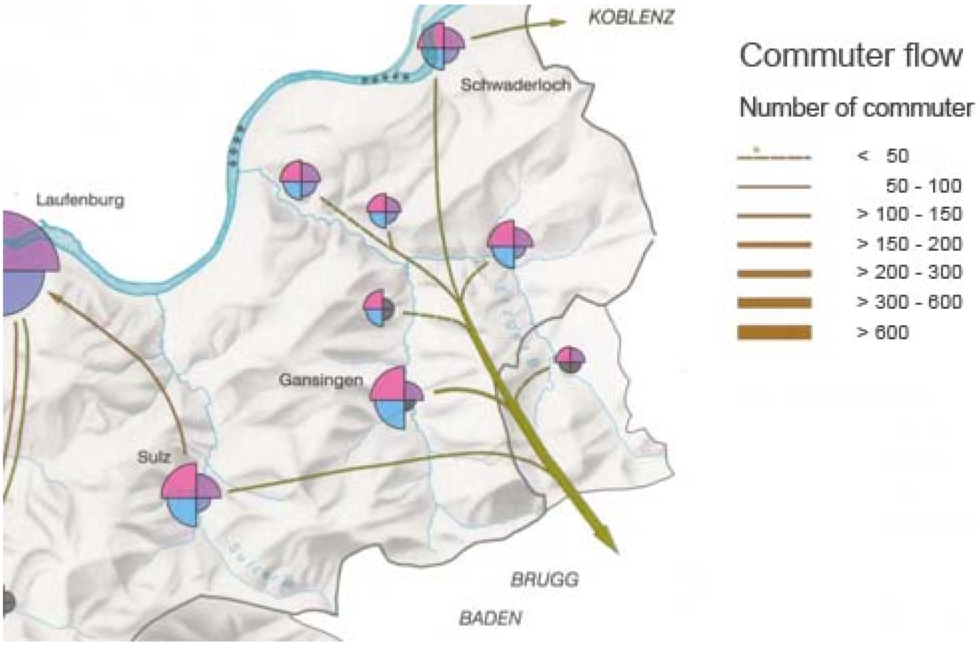
This section includes important aspects which should be respected when designing a line or vector related diagram map.

[1] A scale is called progressive, if scale intervals rise as values rise. If for example scale intervals rise exponential then you are dealing with a progressive scale.

Precise representation in plan of the outline of a feature

Line and vector related diagram maps, unlike topographic line representations like railways or roads, do not claim to be precise in the representation in plan of the outline of a feature. Starting and ending points of movements are often the main content of line related diagram maps, but the precise course of the line is mostly of secondary importance. If this is the case, a straight or slightly bended line between the two points is sufficient. If the lines are directly related to the transport route (roads, sea route, power line, etc.) they are displayed heavily generalised in the place of the topographic symbols. Depending on the line width additional shifts in positions are necessary to provide a readable map.

Vector related diagram maps emphasise on the direction of the arrows which represents only a direction but not a real linear arrangement. If there is a relation to a linear object in the real world, but which is not important, only the approximate direction of a movement is depicted. The precise course can be neglected. This is the case in the following example. The commuter flows are not shown along a road but show only the rough directions.



Visualisations of trade and traffic statistics

Within line related diagram maps Imhof (1972) distinguishes between the visualisation of trade and traffic statistics. For visualisations of trade statistics only the start and ending points of a transport are important. The exact route between these points can be neglected. Therefore the start and ending point of movements will be connected when visualising trade statistics. The diagrams show the value of the moved goods. The exact route can not be understood. In contrast the exact routes play an essential role when visualising traffic statistics. Therefore not only a simple starting point to endpoint connection is visualised but also the route in-between. The transported volume is depicted for each section. This type of visualisation is often used to show traffic volumes. The following examples will show the difference between visualisations of trade and traffic statistics. Hover the mouse over the graphics to see the corresponding examples.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Nodes

If several lines of a line related diagram map connect to each other in a node (e.g. traffic streams into a city) it often results in graphical conflicts which impair the readability of the map. The closer you get to a city, the higher is the traffic volume which results in a thicker line width what makes it difficult to differentiate the particular lines. The principle to choose the line width cautious and restrained helps to avoid this problem. Another difficulty are junctions of point symbols and lines. A good quality of visualisation can be achieved by using simple point symbols like circles or squares. Furthermore a good readability can be achieved through an appropriate generalisation.

Map examples

Below four examples of different types of line and vector related diagram maps are shown.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

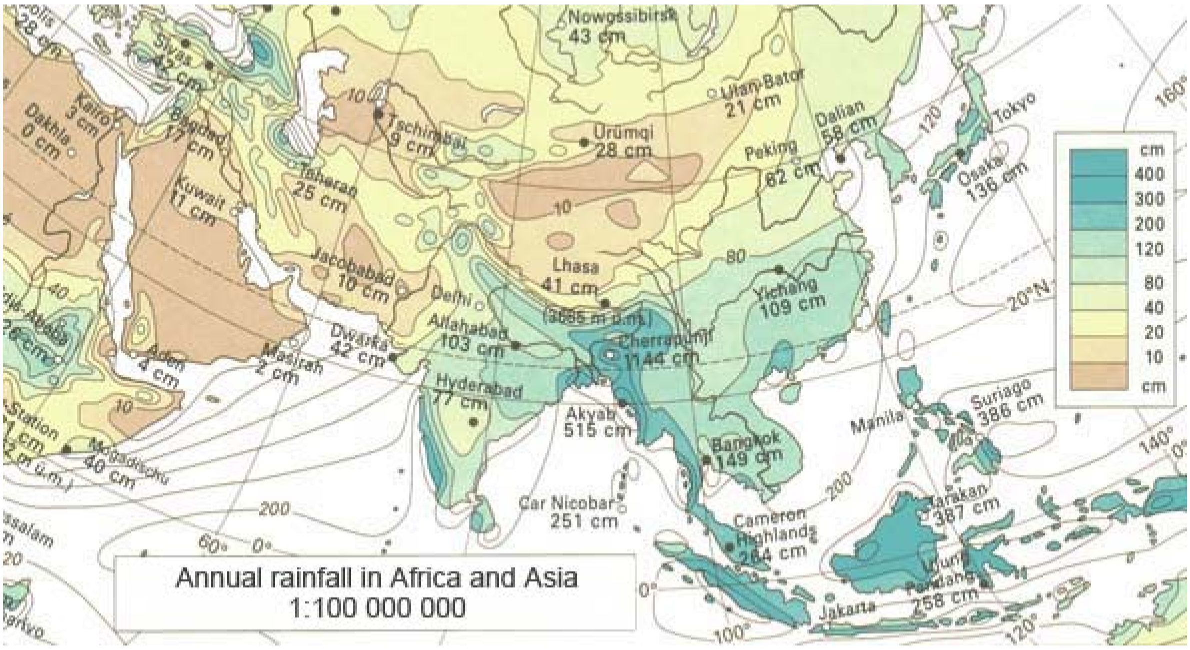
1.5.7. Isoline maps

Definition

The isoline representation is the most used method to visualise quantitative phenomena which occur comprehensively and which values vary continuously in space. They are therefore called **continua**. Examples for such continua are temperature, air pressure, precipitation heights or ground elevations.

Isolines are lines which connect points with identical values inside a continuum. Isolines are virtual and abstract. Gradients are related to isolines and show the direction of the biggest value differences at a specific point. Gradients are always perpendicular to isolines.

The map below shows an example of an isoline map.



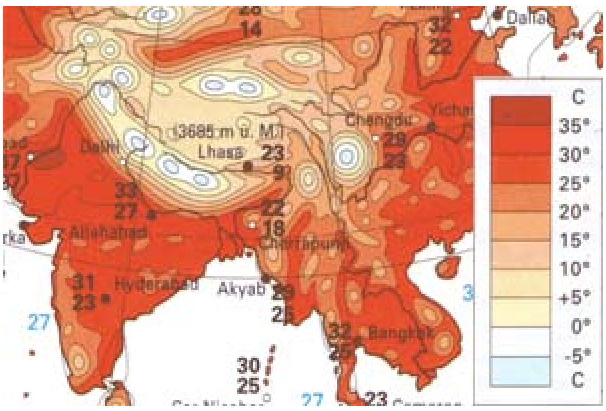
Source: (Spiess 2004)

Natural and geometrical continua

Imhof (1972, p. 127ff) distinguishes between natural and geometrical continua

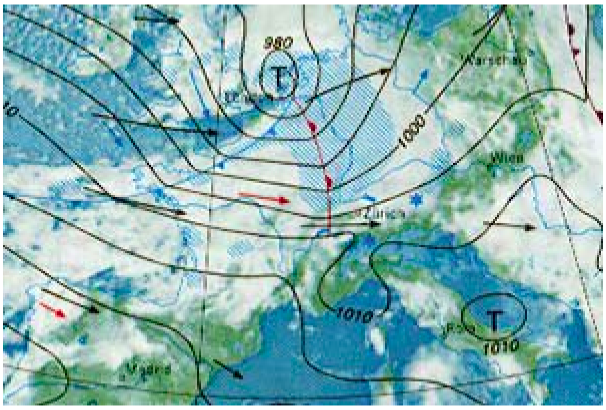
Isolines of natural continua include in particular geophysical, geochemical and other continuous natural phenomena. In the fields of climate and meteorology isoline maps are often used. There are particular names for isolines of specific continua. Here are some examples:

Isotherme: lines of same temperatures



(Spiess 2004)

Isobar: lines of same air pressures

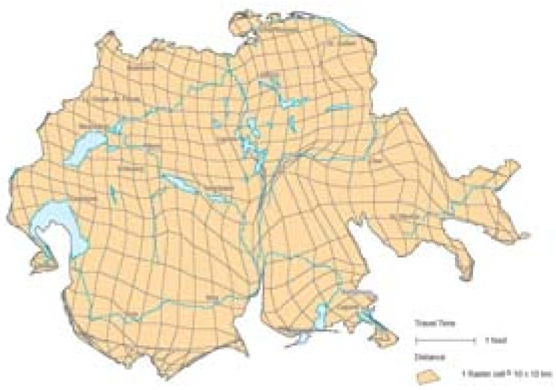


(Spiess 2004)

More examples can be found on the following **link** (http://www.gitta.info/ThematicCart/en/image/typenIsolinien.pdf) (German version only).

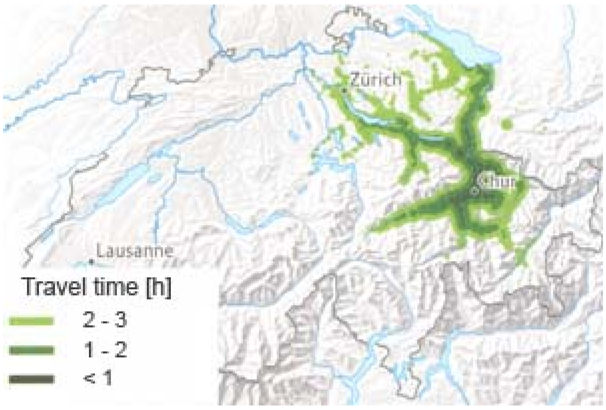
Isolines of geometrical continua do not exist naturally. They are calculated or constructed. Examples of geometrical continua are:

Isodistants: line of same distant to a reference line or a point



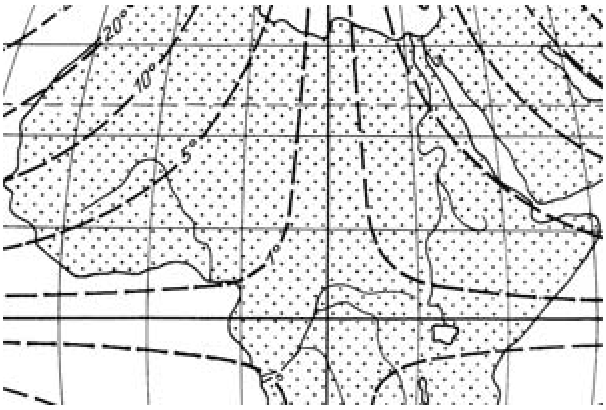
(Axhausen et al. 2005)

Isochrome: line of same temporal distant (time maps)



(Axhausen et al. 2005)

Distortion isograms: lines of same distortion



(Imhof 1972)

Design forms of isolines

Value gradations

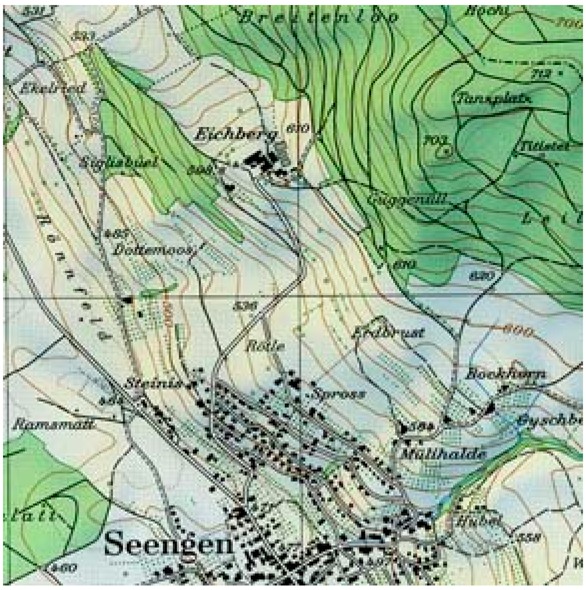
For visualisations with isolines mostly equidistant gradations are used. Depending on the topic or the data also other forms of gradations are possible. For contour lines in areas like Switzerland, which include steep as well as flat regions, a combination of two equidistant gradations are suitable.

Each of the following two pictures shows an extract of the Swiss National map 1:25’000.

The left image shows a steep area in the Valais alps. To reach a good readability an equidistance of 20m is used.

Landeskarte 1:25000, reproduced with permission from swisstopo (BA057224)

For the more flat area in the Swiss midland a smaller equidistance of 10m is more suitable.



Landeskarte 1:25000, reproduced with permission from swisstopo (BA057224)

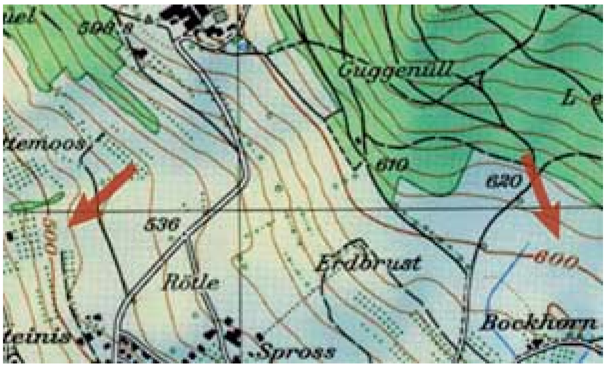
Besides this possibility also progressively increasing or random gradation can be used, whereby the second one is not recommended.

Fill colours

To increase the readability different levels of values can be summarised and coloured with a fill. The colours should be selected regarding the visualised topic. E.g. warm and cold regions could be coloured with reddish and blueish colours respectively (see isotherm map above).

Labelling

(Spiess 2004)



Landeskarte 1:25000, reproduced with permission from swisstopo (BA057224)

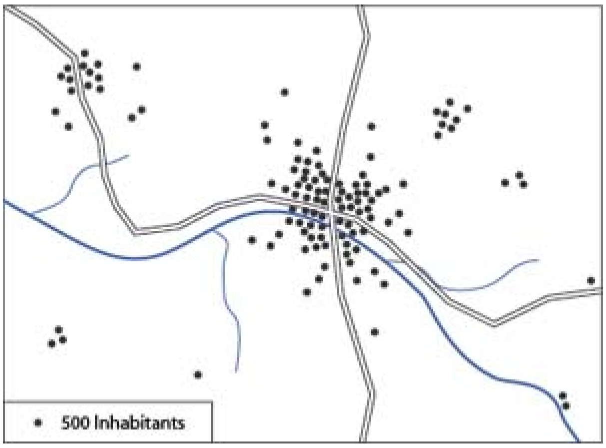
If there is an isoline map with different fill colours between the isolines there should be an explanation in the legend.

Isolines without fill colours are labelled directly in the map with their corresponding values. Depending on its length and geometry a isoline can by no means have multiple labels. This prevents the map reader from laborious search for the label. If there is not enough space to label each line, only main isolines can be labelled (e.g. only 100 or 1000). These main isoline should also be emphasized with a slightly greater line width.

1.5.8. Dot maps

Definition

Dot maps are used to visualise distributions and densities of a big number of discrete distributed single objects whereas, in contrast to location maps, not every single object is depicted but one symbol represents a constant number of objects. For this visualisation simple or pictorial point symbols can be used. Widely used are points which leads to the name of this map type. Population density maps are often dot maps.



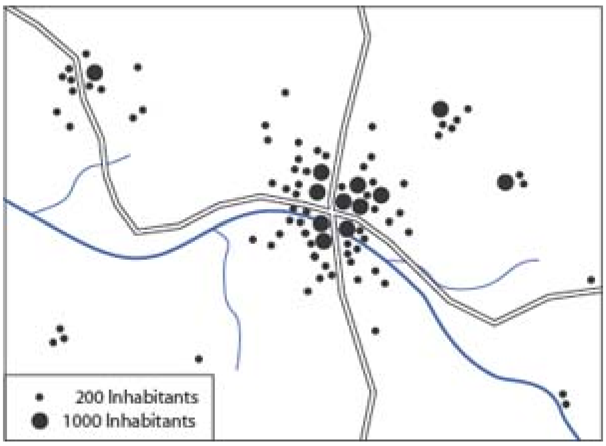
Quantitative symbols of fixed size

The most simple dot map uses a point symbol for a defined number of identical objects like in the previously shown image. The difficulty is to find an appropriate shape and size for the symbol as well as the value of it. The following interaction demonstrates how different a map can look like with different parameter settings.

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Quantitative symbols of variable size

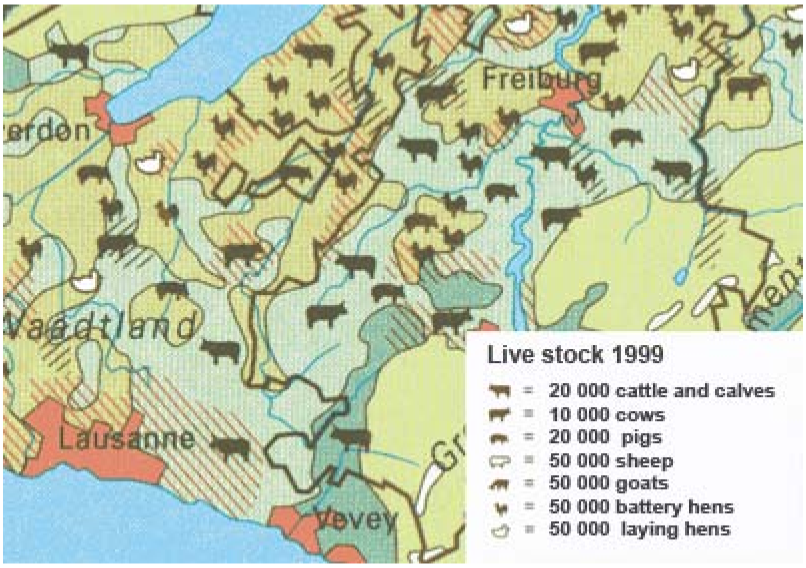
Quantitative symbols of variable size can be used if the map depicts an area where the object density is heterogeneous and where it is difficult to find and appropriate symbol of fixed size. Therefore different sizes of the symbol can be assigned to different values.



Maps with several thematic layers

Until now the shown examples of dot maps where all monothematic. But it could be different. It is also possible to combine different thematic layers which are related in some aspects. The differentiation of the objects is done by different shapes, sizes or colours of the symbols. It is important that the different layers do not compete with each other and the readability is still guaranteed.

The following example shows the distribution of seven different animal species.



(Spiess 2004)

Advantages and disadvantages of dot maps

Advantages

- Dot maps are easy readable, also for laymen
- Are perfectly suitable to show density distributions
- By counting the symbols it is possible to determine the original data

Disadvantages

- The data have to be georeferenced with coordinates
- The map design is time-consuming and expensive

1.5.9. Summary

Imhof (1972) distinguishes ten different main map types. In the previous sections they have been organized into eight groups:

- Thematic maps using point symbols
- Network maps
- Area-class maps
- Choroplethic maps
- Point and area related diagram maps
- Line and vector related diagram maps
- Isoline maps
- Dot maps

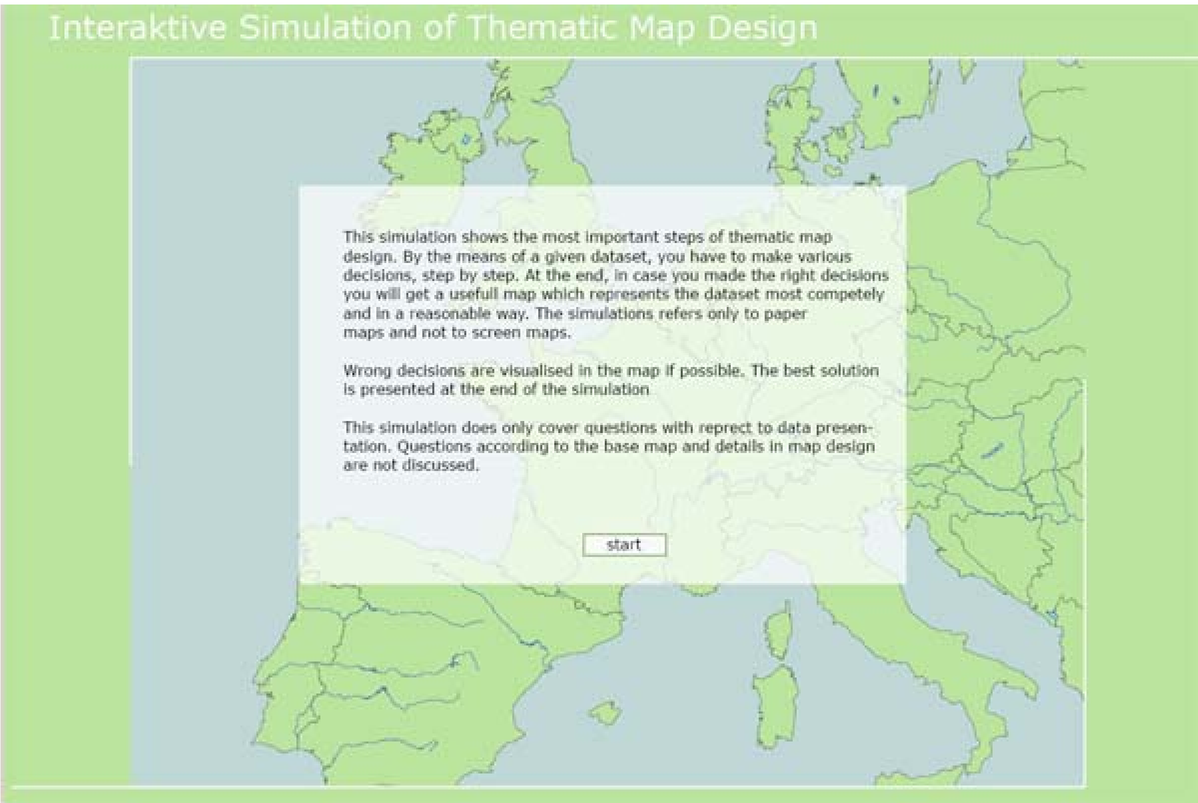
Depending on the data and the message the map should transport to the map reader one or another map type more is suitable for the visualisation.

1.5.10. Self Assessment

Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

1.6. Self Assessment

Examine your learning success with the following test. You can do that either directly with the following application or open the application in a new window here.



1.7. Recommended Reading

- **Imhof, E.**, 1972. *Thematische Kartographie*. Berlin - New York: Walter de Gruyter.
  Kapitel 13 und 25
- **Witt, W.**, 1967. *Thematische Kartographie - Methoden und Probleme, Tendenzen und Aufgaben*. Hannover: Gebrüder Jänecke Verlag.
  Kapitel 2.2.7

1.8. Glossary

progressive scale:

A scale is called progressive, if scale intervals rise as values rise. If for example scale intervals rise exponential then you are dealing with a progressive scale.

1.9. Bibliography

- **Arnberger, E.**, 1993. *Thematische Kartographie*. Braunschweig: Westermann Schulbuchverlag GmbH.
- **Axhausen, K. W., Hurni, L.**, 2005. *Zeitkarten der Schweiz 1950 - 2000*. Zürich: Institut für Verkehrsplanung IVT, Institut für Kartografie IKA, ETH Zürich.
- **Hake, G., Grünreich, D., Meng, L.**, 2002. *Kartographie*. Braunschweig: Westermann Schulbuchverlag GmbH.
- **Hochrein, W.**, 1986. *Modell zur Entwurfsgestaltung von Diagrammkarten*. ( ). Institut für Kartografie, ETH Zürich.
- **Hufnagel**. *Vorlesungsskript Kartenkunde*. Technische Universität München.
- **Imhof, E.**, 1972. *Thematische Kartographie*. Berlin - New York: Walter de Gruyter.
- **Institut für Kartografie, ETH Zürich** (2004). *Atlas der Schweiz interaktiv*. [CD-ROM]. Version 2. Bern: Bundesamt für Landestopographie.
- **Klauer, R. H.**, 2000. *Raumbezug in Kartografie und GIS - Kartographische und Geodätische Netzentwürfe*. Fachhochschule München, Fachbereich Geoinformationswesen.
- **Lehmann, E.**, 1972. Atlas Deutsche Demokratische Republik. Leibzig: Akademie der Wissenschaften der DDR.
- **Loy, W., Stuart, A., Buckley, A. R., Meacham, J. E.**, 2001. *Atlas of Oregon*. second edition. Oregon: University of Oregon Press.
- **Michael, Th.**, 2002. *Diercke Weltatlas*. Braunschweig: Westermann Schulbuch Verlag GmbH.
- **Quitt, X.**, 1997. *Einführung in die Statistik – Überblick, Definition und Zweckbestimmung der Statistik, Skriptum zur Vorlesung Statistik für die Kartografie*. Fachhochschule München, Fachbereich Vermessungswesen und Kartographie.
- **Schröder, P.**, 1985. *Diagrammdarstellung in Stichworten.*. Hirt's Stichwortbücher, Verlag Ferdinand Hirt.
- **Schulze, Dr. H.**, 1983. *Alexander Weltatlas*. Stuttgart: Ernst Klett Verlag.
- **Slocum, T. A.**, 1999. *Thematic Cartography and Visualization*. Upper Saddle River, Mew Jersey: Prentice Hall.
- **Spiess, E.**. *Generalisierung in thematischen Karten*. Institut für Kartografie, ETH Zürich.
- **Spiess, E.**, 1993. *Schweizer Weltatlas*. Konferenz der Kantonalen Erziehungsdirektoren.
- **Spiess, E.**, 2004. *Schweizer Weltatlas*. Konferenz der Kantonalen Erziehungsdirektoren.
- **Spiess, E.**, 1995. *Vorlesungsskript 'Thematische Kartographie'*. Institut für Kartografie, ETH Zürich.
- **Witt, W.**, 1967. *Thematische Kartographie - Methoden und Probleme, Tendenzen und Aufgaben*. Hannover: Gebrüder Jänecke Verlag.