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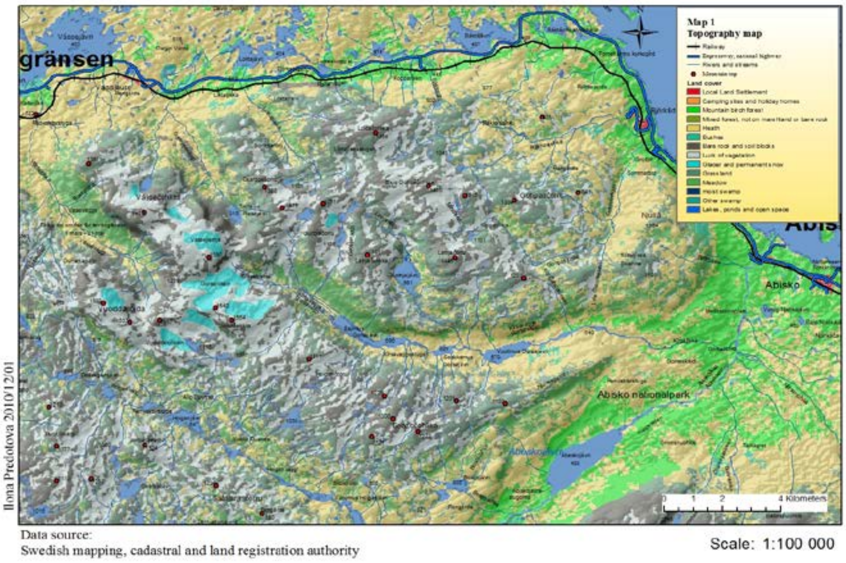

Empirisk utvärdering av alternativa kartografiska gränssnitt för Abisko GIS

Empirical Evaluation of Alternative Cartographic Solutions for the User Interface of Abisko GIS

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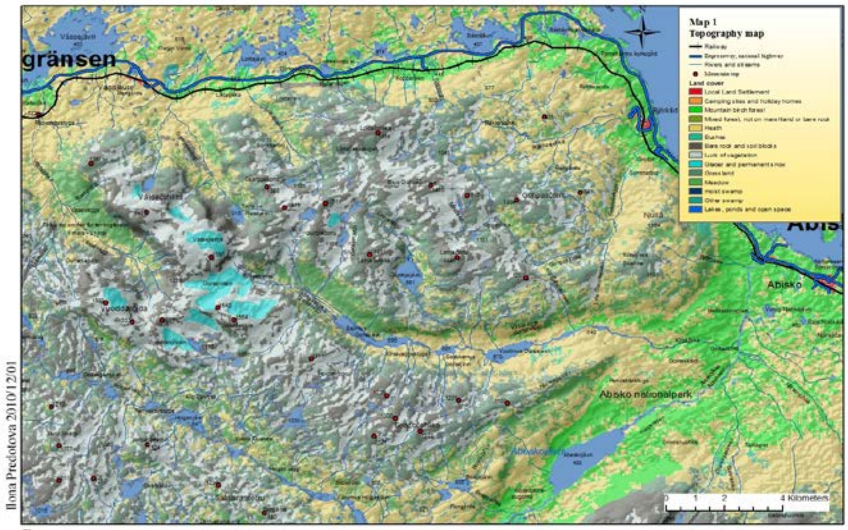

Data source:
Swedish mapping, cadastral and land registration authority

Scale: 1:100 000

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Key words: Cartography, GIS, digital map interface, artistic versus scientific approach, geo-visualisation, empirical testing, statistical inference.

Abstract

Over the last 15 years there has been a rapid increase in the development and usage of digital maps. Methods for assessing the quality of systems for communicating digital geographical information are frequently described in the literature, but few methods have been empirically evaluated. The quality of cartographic products is especially important for resources management and environmental planning, although it may be important in all application areas where spatial information is used. When designing digital communicative systems, it is crucially important to base system development on empirical interactions with potential users.

In this thesis, empirical methods were used to develop a geographic information system (GIS) for environmental research and monitoring in the Arctic – the Abisko GIS. Approximately 30 potential users were interviewed via a questionnaire while testing a number of alternative interfaces to Abisko GIS. This allowed the qualities of alternative cartographic solutions to be evaluated and the optimal combination of cartographic objects to be implemented in Abisko GIS.

Through statistical inference of the questionnaires, it was concluded that Map Design had the greatest effect on subjects during their evaluation. Gender and the Time spent with evaluation had no significant effect, although Time appeared to play some role for experts and those with experience of GIS. On average, the response to questions asked regarding particular aspects of maps varied diminutively across subjects. Other observations are discussed in the text.

Keywords: cartography, GIS, digital map interface, artistic versus scientific approach, geo-visualisation, empirical testing, statistical inference.

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Abbreviations

GIS	Geographic Information System
ArcGIS	Group of Geographic Information System software products produced by ESRI
ESRI	Environmental Systems Research Institute
GPS	Global Positioning System
ANS	Abisko Scientific Research Station
ITRS	International Terrestrial Reference System
ITRF	International Terrestrial Reference Frame
SWEPOS	The Swedish Network of Permanent GPS Reference Stations
WGS 84	World Geodetic System 1984
SWEREF 99	Swedish Reference Frame 1999
PI	Principal Investigator
DEM	Digital Elevation Model
ICA	International Cartographic Association
GSD	Ground Sample Distance
LANDSERF	GIS for the visualisation and analysis of surfaces
SPOT	Earth Observation Satellite System
DMT	Digital Model of Terrain
ANCOVA	Analysis of Covariance
p-VALUE	Prob-value
F-VALUE	Observed F-statistic
DEN. DF	Degrees of Freedom of the Denominator
NUM. DF	Degrees of Freedom of the Numerator
Cart_Beg	Cartography Beginner
Cart_Exp_Art	Experienced in Art Cartography
Cart_Exp_For	Experienced in Formal Cartography
Cart_Pro	Cartography Professional
GIS_Beg	GIS Beginner
GIS_Exp	GIS Experienced
GIS_Pro	GIS Professional

1 Introduction

Designing a convenient and useful user interface to a web-based geographic information system (GIS) is a matter of carefully applying principles of system development. A decision must be made on whether to use empirical input or to simply proceed with respect to some chosen subjective scheme.

Many cartographers are of the opinion that there is not one correct approach to map design. In reality, many perspectives exist about the criteria that should be applied during map creation. Some perspectives are based more on an artistic approach, while others consider science to be the most important approach and still others believe that there should be a balance between the two. Many cartographers appear to have different opinions about how the map should be presented and how it should be improved.

Firstly, design should preferably be decided with respect to the intended purpose. Thus the process would be different depending on whether the map depicts geography (e.g. the classic topographical map) or whether it communicates thematic information (e.g. population density).

The principles in the present study were decided with respect to the intended purpose, which was to communicate information through a user interface designed for Abisko GIS. The objective was to design an interactive map where the user would be able to find information to suit his or her needs. Therefore, in this case empirical data had to be obtained.

In order to collect empirical data, a questionnaire was created consisting of 13 questions about map and geographic object design. Some additional questions were asked at the end to get spontaneous opinions which could improve the subsequent analysis. Approximately 30 respondents were selected and categorised according to a set of semi-random factors.

The statistical methodology used in order to evaluate the empirical data was Mixed General Linear Models (GLM) (Fitzmaurice et al, 2004). When the system was developed test data had to be produced, so six map designs and four object alternatives were developed using ArcGIS software.

Abisko GIS is a portal that is being developed for monitoring and research regarding environmental clime-change effects in the North of Sweden (see http://www.et.slu.se/Abisko_GIS). The aim of the project is to meet the growing need for some effective way of storing and presenting information about research activities that have been carried out in the Abisko area for almost one hundred years by the Abisko scientific research station (ANS).

The Abisko research station is located on the southern shore of Lake Torneträsk. Particular characteristics of the site are the northerly latitude, the inherent character of the mountains and the ude and position with regard to the Atlantic Ocean (Bernhard, 1989).

he most important research activities are spread across a combined area (Areas of Interest 1 and 2) of about 1 220 km2, lying within a rectangle about 49 km in length and 32 km in width (Fig. 1). The overall area of interest stretches from the Norwegian border in the west to beyond the Stordalen mire in the east. Area of Interest 1 was chosen as the area for the current study. The geographical coordinates for the right-hand, bottom corner of the study area rectangle are 18°49´56,631´´E and 68°15´25,179´´N. The whole study area comprised approximately 673 km2. The Latnja valley, which is included in the study area, was chosen as the 'hot-spot' area for experimenting with geographical objects.

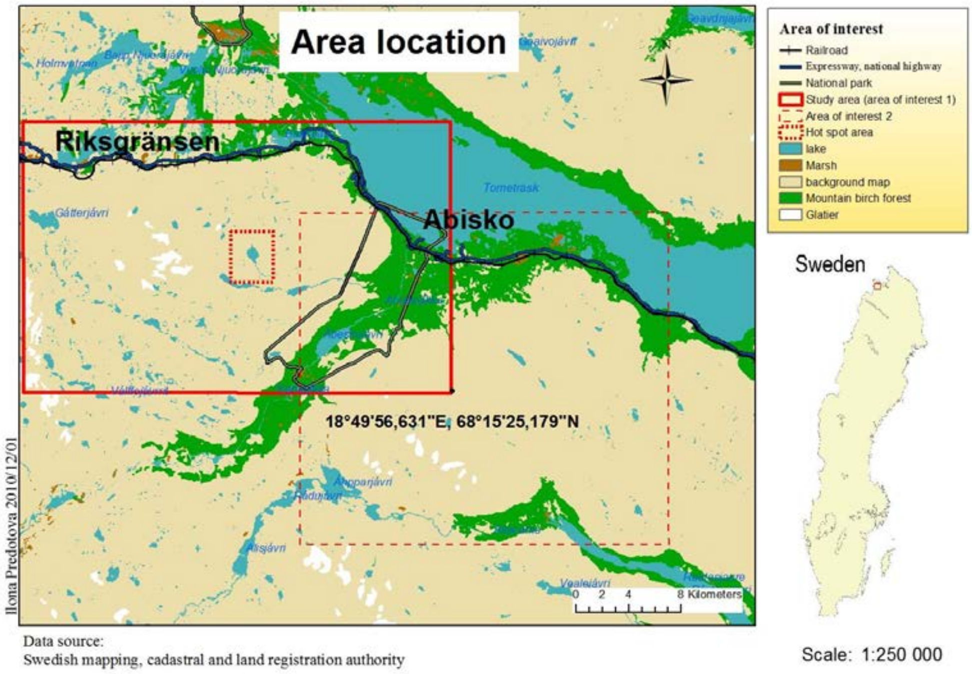

Figure 1. Area of interest with smaller 'hotspot area'. Map source: Swedish mapping, cadastral and land registration authority

1.1 Mapping as art or science

Everything on Earth 'exists or happens somewhere'. If the position can be located, then 'information can be placed on a map and this map then used to organize, search, and analyze the information'. We have the technology (such as spatial geographic information systems) and methods that can process the information, with science also playing an important role. These tools help us understand and perhaps obtain further knowledge (Clarke, 2010).

Cartography offers an interface that presents a window on our world in the form of a map (Field, 2009). Peterson (2009) believes that an elegant display of geographic data makes a map look attractive, and rightly so. A good map is a product of pleasing design which should reflect user needs (Field, 2009).

MacEachren (2004) states that viewing maps as a balance of scientific and artistic content would be a mistake. Instead, he suggests considering an artistic and scientific approach as complementary to be able to study and improve maps. If we compare the artistic and scientific approaches, we can recognise different angles of view on the map design progress. The artistic approach is rather 'intuitive and holistic', where improvement is attained by using experience together with critical inspection from an expert. Art approaches the science in parts: e.g. using 'perspective, understanding of human vision and colour theory'. On the other hand, the scientific approach is more 'inductive and often reductionist', where the main thought is given to the examination of each individual part of the process. Breaking problem into parts is believed to make the whole scenario clear. Science approaches art in the area of ‘developing initial hypotheses about light, shading, colour, type, and more’ (MacEachren, 2004).

The approaches mentioned above are rather modern attitudes to cartography. Some opinions within the map design area can be changed though the progress of knowledge and technology. The technology and software that are used nowadays are very advanced in terms of automation, but still need to be directed and controlled by experienced persons.

1.2 Research objectives

The main aim of the present study was to create a convenient and useful standardised map in ArcGIS software for the user interface of the Abisko GIS. With the Abisko GIS offering an interactive geographic interface for database query, the map produced here should serve as the backdrop whereupon interactive query-tools are situated. As part of this work, the optimal representation of geographic objects such as mountains, rivers, and vegetation were sought. The specific objective was to create a cartographic impression good enough to keep the user interested, but also satisfied by the content of the map. To meet the latter requirement, it was important to also include user needs.

In addition to the design of cartographic alternatives, the study demanded empirical evaluation of alternative map designs for the Abisko GIS interface, with identification of problems arising during the process. In order to empirically evaluate the cartographic solutions, a random sample survey was performed (i.e. a questionnaire investigation).

Geographic scope

The study area was chosen to contain one of the ‘hot spot’ areas that are especially important for research activities in the Abisko region, and that have rich potential for use in many fields. The selected study area also had to be a representative area for the Abisko GIS project.

1.3 Background

1.3.1 Cartography

‘Cartography has constituted our primary representation of geography’ (Fisher and Unwin, 2005). Present cartography view maps as spatial representations rather than well-defined messages (MacEachren, 2004).

Cartography has much to offer the scientific community, but also much to gain from this community. As MacEachren and Kraak (1997) indicate, cartography has a long history of design and production of visual representations of the Earth. This is one of the benefits of cartography, together with the development of geographic information systems and application of digital geographic representations. On the other hand cartography can be further improved by the work of the *scientific visualisation community*, which works on the development of ‘interactive computer tools, interface design, three-dimensional computer modelling and related methods and technologies’ (MacEachren and Kraak, 1997).

Visual representation of the Earth has to deal with geographical (spatial) data. Visualisation of such data is solved in the research area of geographic visualisation (geo-visualisation). Spatial data carry attributes such as space, time and thematic information (ICA, 2007).

Visualisation can also be used to provide feedback to the user about the optimisation process, which can help with future decisions. The authors of one article made experiments which showed that the performance of a simple hill-climb algorithm could be significantly improved by user interaction. This human interaction was used to capture weaknesses and lacking information in the case of optimisation requirements (do Nascimento and Eades, 2008).

In the process of recapturing geographic reality, generalisation is among the most important processes, although it is still not fully understood. Object generalisation is realised by using 'abstraction processes and categorisation of real phenomena' (Fisher and Unwin, 2005).

1.3.2 Projection and coordinate system

Map projections were invented in order to transfer geographic information for an ellipsoidal surface (three-dimensional space) onto the plane carrier of a paper map or a computer screen (two-dimensional space). Each projection has its own coordinate system by which geographic information is projected upon the plane carrier (Yang and Jian, 2009).

Coordinates are a set of numerical values that provide the location of a point in a space with respect to the dimensions used. A paper map is basically a two-dimensional space where coordinates x and y are used to specify a location. Three-dimensional space in the case of a digital elevation model (DEM) is specified by using coordinates x, y and z (Lo and Yeung, 2007).

A position on the Earth´s surface is given by a geodetic coordinate system. Different projections have also different geodetic reference systems. International Terrestrial Reference Frame (ITRF) is a 'geocentric system that can define the centre of mass for the whole Earth, including oceans and atmosphere'. The World Geodetic System WGS 84 was created by the Americans from ITRS in order to apply GPS as real-time positioning. In order to get high accuracy of location, WGS 84 should be compared with data on the ground, which is provided for Sweden by the Swedish permanent GPS network (SWEPOS) (Ivarsson, 2007). SWEPOS currently has 21 fully operating stations (Scherneck *et al*., 1998). From this connection of WGS 84 and SWEPOS, the Swedish reference frame SWEREF 99 was established in 2001 (Ivarsson, 2007).

1.3.3 Maps and their representation

As mentioned above, a map is a medium that depicts locations of features on the Earth in defined geographical space by using coordinates (Lo and Yeung, 2007).

A map is used to communicate spatial information, the effectiveness of which is dependent on quality and the features displayed. Information should be projected 'clearly, rapidly and without ambiguity' (Freeman, 2005).

Map-making was developed and improved over hundreds of years. In this period lots of cartographic skills, conventions and quality standards were achieved (Freeman, 2005). Cartographers as map-makers take responsibility for map content, which is used by consumers to make decisions based on mapped data with knowledge of the map's limitations (Evans, 1997).

The crucial formation of cartography as a discipline emerged during World War II. Resulting from experiences of several U.S. geographers, especially H. Robinson, production of 'efficiency and graphic design' was replaced by 'map functionality'. In addition, two other crucial developments came about during the past four decades, from which a 'research agenda for the study of map symbolisation and design' was established. These two developments were: H. Robinson's 1952 doctoral dissertation entitled *The Look of Maps*, and the paradigm of cartography adopted in the 1970s as a communication science (MacEachren, 2004).

Digital maps, as a very modern form of cartographic product, have the advantage that users can edit the information on the map and choose what should be displayed (Jones *et al*., 2004).

Geographical information is expressed in a mathematical space, where features are distributed with geometrical shape and the real world space/time. Thus the digital map is based on geodetic coordinates that belong to the reference surface of an ellipsoid and determine the spatial position of a definite object (Yang and Jian, 2009).

Some of the features that digital maps offer and how they can be used include:

- Digital maps, as was mentioned above, offer the option to hide or display different information which is provided by 'layers'. Layers contain diverse feature types or variables which can allow users to compare different views and relationships.
- Map users can have the option to choose attributes of the map, such as: 'symbolisation, colour, texture, scale, projection, generalisation', *etc*.
- 'Spatial correlations and other statistical relationships between features or variables can be calculated and displayed' in order to be tested.
- Natural processes (such as floods, erosion, *etc*.) and other phenomena (such as spread of chemicals or diseases) can be modelled and their progress animated with respect to spatiotemporal change.
- Users are not constrained by the frame of the screen, since digital maps have functions where they can zoom in, zoom out or scroll from one area to another.
- Users have the option of selecting displayed objects (*e.g.* buildings) which are placed in a database and getting information about them from a pop-up menu (Jones *et al*., 2004).

The computer screen may be imagined as a window onto an 'infinitely large plane' (Fig. 2) whereupon the electronic map is situated at scale 1:1. The plane is generated in exact accordance with the earth-referenced ellipsoid, with its surface being referenced with the associated latitude/longitude grid. With increasing grid resolution, the surface of the ellipsoid becomes increasingly distinct (Yang and Jian, 2009).

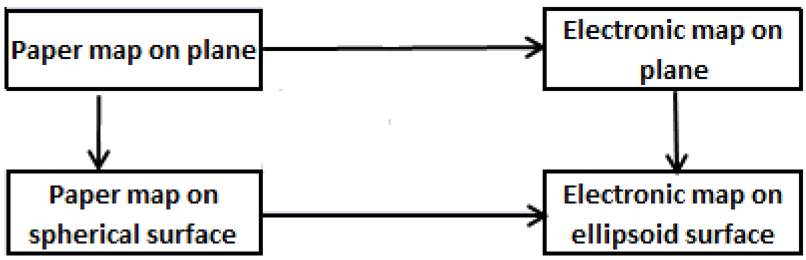

Figure 2. Development of map carrier. Source: after Yang and Jian (2009).

During the construction of digital maps, it is important to consider similar kinds of decisions as in paper map construction, where we can include:

- Map scale/resolution.
- The nature of features that should be placed on the map and their symbols.

- Whether to use text labels for symbols and where these should be placed (Jones *et al*., 2004) (label placement is among the most important steps in a mapping process, but is also time-consuming and often expensive (Barrault, 2001)).
- Attribute representation variable, *e.g.* ‘population density or altitude’,
- Generalisation of features such as rivers or roads, where scale/resolution plays an important role (large scale allows more details to be depicted) (Jones *et al*., 2004).

Maps are produced with respect to the purpose for which they are intended and so they can vary not just in their content and performance, but also with respect to scale and resolution. The scale can differ from 1:1,000 for local areas up to 1:10,000,000 for an entire continent (Freeman, 2005). Large-scale maps mostly range from 1:1,000 to 1:5,000 in scale and are produced for portraying detailed features in the area of *e.g.* ‘engineering construction, land development, and land parcel registration’. In contrast, small-scale maps depict large areas in a scale smaller than 1:100,000. A compromise is represented by medium scales that range from 1:5,000 to 1:100,000 and represent quite reasonable amounts of detail. Common use of these scales is for topographical maps (Lo and Yeung, 2007).

For each map, it generally holds that the content has to be easily readable for a user regarding information density. The map should have appropriate symbols together with an adequate shape and colour scheme. In addition, the data should be generalised with respect to the scale (Häberling and Hurni, 2002).

1.3.4 GIS

GIS (Geographic Information Systems) are tools for solving geographical problems which can be used by the wider society (Longley *et al*., 2005). The fact that geographic information systems are widely applicable has caused an expansion into many neighbouring disciplines (Fisher and Unwin, 2005). GIS and GIS-based decision support systems are used for example in ‘military forces, civil and humanitarian organisations’ (Laskey *et al*., 2010).

Nowadays GIS are very flexible and relatively fast even in non-professional computer systems. GIS provide geographical information that can be stored, processed and displayed on the screen (Brainerd and Pang, 2001).

Any GIS software is the processing engine and its system has three important parts: ‘the user interface, the tools (functions) and the data manager’ (Longley *et al*., 2005). GIS software at present already contains cartographic guidelines and custom practices where priorities about feature placement are adjusted by the user. This interaction also solves problems with ambiguities and placement conflicts over each feature layer (Freeman, 2005).

Data for GIS are acquired in many ways, starting from measuring of the Earth’s surface, paper map digitalisation, vectorisation of map content, airborne laser scanning, remote sensing and many other methods (Rancic and Djordjevi-Kajan, 2003).

Geographical information is represented in a map in the form of three feature types. Areas are depicted as a polygon for features such as lakes, mountains, cities and land use. For point features such as small towns, mountain tops, geodetic points there are a wide range of point symbols. The third feature type is represented by line symbols, *e.g.* rivers, boundaries, roads, *etc*. Features and complementary information are stored in a computer database in a layer frame format (Freeman, 2005).

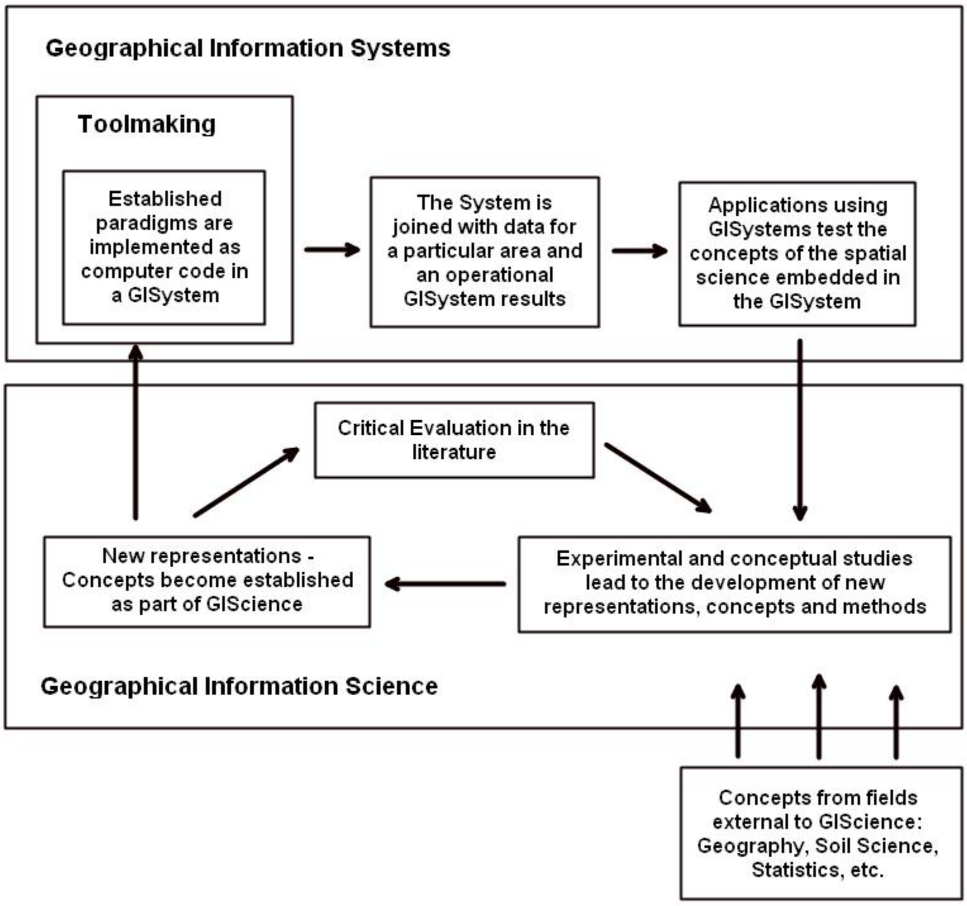

Figure 3. The GI Science-System cycle. Source: after Fisher and Unwin (2005).

A study on GIS by Fisher and Unwin (2005) argued for a separation between the systems and the science. GIS science has lately been significantly improved which has turned numerous experts into preferring a scientific approach to be used with GIS (Longley *et al*., 2005). *GIScience* is concerned with the theory of developing concepts, methods and their use, while *GISystems* are the software usage itself. *GIS* is then considered as 'tool-making', situated in-between the science and the geographic system (Fig. 3).

Diagram 3 describes how GIS concepts (geography, statistics) are applied via experimental and conceptual studies, and finally evaluated through literature. New representations of the concept are embedded in the GIS system, to be tested when tool-making is applied. The final products are then new representations, concepts and methods.

Cartography and GIS

With the progress of technology and science through time, GIS have been greatly implemented into cartography and cartographic products. However, transformation of paper maps, created with the use of pen, ink and lithography, to digital form left many problems (*e.g.* map distortion) for vector-based GIS (Fisher and Unwin, 2005). On the other hand, GIS have always been related to the academic discipline of geography, one of several disciplines that are related to the Earth's surface (landscape planning and its architecture) (Longley *et al*., 2005).

Cartography brought to GIS some important restrictions, where geographical objects (carriers of various information within a different context) are assumed as 'digital incarnations' rather than copies of reality. Geographical objects also ‘shape our thoughts about space, time, and spatial relations’ (Fisher and Unwin, 2005).

1.3.5 Mapping standards and techniques

Throughout history, there have been many attitudes, typologies, approaches, procedures, principles and standards on how to create maps, all of which are more or less appropriate. It is difficult to say which solution is the most convenient, since all of them are based on different conditions and for different purposes. We can say that with standard maps it is easy to follow the rules, but when the purpose of the map starts to be unique in some sense, the best solution is debatable.

It can take a life time to completely master the art of reading maps and expressing them correctly (Jones *et al*., 2004). In his book *The Look of Maps* (1952), geographer H. Robinson makes the following comment: ‘If we then make the obvious assumption that the content of a map is appropriate to its purpose, there yet remains the equally significant evaluation of the visual methods employed to convey that content.’

Cartographic communication as a model showed up in the late 1960s. The fact that communication systems have a great influence on cartography was actually stated by a Czechoslovakian cartographer, Koláčný, in 1969. This discovery represented a major initial step in cartography (MacEachren, 2004).

Cartographic communication often appears in presentations, where both the transfer of some ‘predetermined message’ and approaching the audience can be applied. However, MacEachren and Kraak (1997) argue that presentation should hand over spatial knowledge rather than creating new knowledge.

Over time, communication became the primary function of cartography, where the map represented a tool for such communication. When cartography is considered as a formal communication system, map performance can be amended by reduction of filters or loss of information in the particular parts of the system (MacEachren, 2004).

Figure 4 shows a view of cartography as a process of graphical communication.

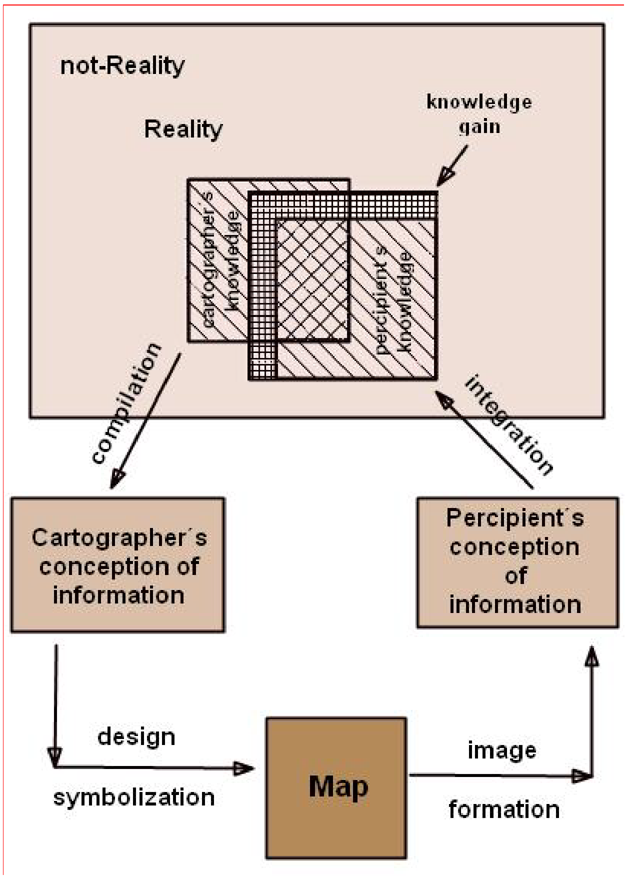

Figure 4. Paradigm of cartography as a graphical communication process. Source: MacEachren (2004).

MacEachren (2004) claimed that models of human-map interaction and human spatial cognition could help us identify and comprehend map symbolisation and design.

The model in Figure 4 shows the possible process of map design where the final product is a map. Before map design and map symbolisation, the cartographer prepares a concept where all his/her knowledge, abilities and other conditions are projected. Map design is taken over by perceivers (users) to create their own conception of the map, again with respect to given conditions, where new knowledge starts to be formed. This model of communication was also used in the present study to communicate a predetermined message and to better understand the needs of the end-users.

The Commission on Geo-visualisation (MacEachren and Kraak, 1997) was established by the International Cartographic Association (ICA) to continue work on visualisation and virtual environments, which was essential for establishing the emerging discipline of ‘Geo-visualisation’ since 1995 (ICA, 2007). To date, the ICA Commission on Geo-visualisation has identified a set of specific research goals. They state that the main concern for the period 2007-2011 will be: the use of interactive maps and cartographical techniques to support visual analysis of complex, voluminous and heterogeneous information involving measurements made in space and time (ICA, 2007).

During map production, many professionals participate with different technologies which are then combined. The mapping process commonly consists of: (1) planning phase, (2) data acquisition, (3) production, and (4) product delivery. The planning phase usually comprises analyses on the product of the study and user requirements. For data acquisition, the most important aspect is to gather and examine existing data sources. Final draft maps have to be proof-read in order to verify accuracy, correctness and conformity with distribution (Lo and Yeung, 2007).

1.3.6 Art mapping approach

To view a two-dimensional map in three dimensions, depth cues can be applied to the map. MacEachren (2004) distinguished three types of approaches: Physical, perspective and non-perspective.

Physical techniques for seeing depth apply opposing colours such as red and green to produce two overlapping views (this technique was already known for maps in 1970).

Perspective approaches comprise four perspective components (oblique projection, linear perspective, retinal image size and texture gradient) that are typically manipulated together on perspective view maps:

- *Oblique projection* is common to all (profile and overhead representation).
- The well-known fishnet plot emphasises *texture gradient* (decreases with distance).
- Layered contours and block diagrams emphasise *linear perspective* (parallel lines converge with distance) and size disparity.
- Solid modelling emphasises *linear perspective* with shading and shadow as additional (nonperspective) depth cues.

To complement these issues, MacEachren (2004) considered *non-perspective* depth cues (shading and/or colour) rather than the others.

Art and cartography start to intersect in the respective fields of design and map efficiency. Interest then belongs to the area of how, when and which maps can be used artistically (Field, 2009). An important part of art and design is creativity. Creativity can mean making decisions about maps in different ways than are traditional, because the old way seems not to work properly in a particular case. When speaking about creativity, we should be able to take on a new challenge or new options and be ready to realise them although this means facing opposition (Peterson, 2009).

Science (as the more theoretical part) and technology (the practical part) are important for the discipline, but a contribution from art is essential as well. As Cartwright (2010) stated, ‘art provides the ‘public face’ of cartography and the cartographer’s passion when designing a particular product perhaps the soul…. Science complements this by ensuring that what is presented is scientifically correct, and what could be called ‘scientifically’ elegant as well’.

High-quality computer interfaces for GIS should apply users’ perceptual and cognitive abilities for visual exploration. An important factor for map design is the pre-attentive visual processes, which emphasise perceptual phenomena such as ‘texture segregation, rapid search for unique objects and the grouping of similar objects into perceptual wholes’. Processing this preattentive impression (first unconscious perception) is reported to be rather rapid, unlimited in capacity and resource-free. The colour is one of the most effective methods (Smith *et al.*, 1995).

Selection of colour scheme is quite different for visualisation purposes in a map and for communicating its content. The ‘banded’ colour palette is mostly created to amplify contrast between contiguous hues to the maximum. We can also support simple colour-value schemes by driving out the profile of features at different places (MacEachren, 2004).

1.4 Research approach

During map design, mapping standards and creativity are basically applied as a ‘concept of duality’ (see Background section). Unless we are following project instructions, in ordinary practice we can apply our own approaches (Peterson, 2009).

According to do Nascimento and Eades (2008), real-world optimisation problems are generally solved by using automated tools, where the solution achieved is personally amended in the post-processing stage. In the present study, both these steps were performed in ArcGIS.

In reality, incorporation of individual creative skills is necessary to solve the problem of application of available unique data and mapping goals that the map-maker has to follow (Peterson, 2009).

The approach chosen in the present study was the use of creativity, inspired by suggested approaches of professionals and their skills. The GI Science-System cycle and communication paradigm (Figures 3 and 4) were used as schemes of progress to approach the issue of user requirements.

In general, the aim was to search for appropriate use of ArcGIS and its tools with respect to available materials and working conditions.

During realisation some basic approaches were followed, especially that of Peterson (2009). Objects of interest were designed according to the basic principles and aspects of art and converted to vector discrete features. In that stage, creativity was used to design the face with respect to fuzzy theory. Accessible sources of data were used in the transformation process to produce backdrop maps with use of basic standards (*e.g*. colours, production techniques).

2 General cartography problems

The need for representation of the reality in an accessible form is crucial, and in fact GIS can be seen as an unproblematic interpretation of geography (Fisher and Unwin, 2005.).

During map design the information has to pass through many obstacles (filters) on its way from reality, through the cartographer to the map and afterwards through the map to the map-user. This reflection is based on the communication paradigm described in section 1.3.5 (Figure 4). Filters that pass through the *cartographer* are mostly: 'objectives, knowledge and experience, abilities and attitudes', and also external conditions such as 'client demands' and factors in map production, *e.g.* geographical 'projection', 'simplification' of reality, symbolism, *etc*. On the side of the map user, the following factors are reported to be filters: *e.g.* 'perceptual abilities, understanding the symbol system, goals, attitudes, viewing time, intelligence, prior knowledge and preconceptions' (MacEachren, 2004).

Topics that appear in GIS science within representation of reality relate to:

1. *Space vs. place.* The idea of absolute Euclidean spaces, where each point can be located by using a couple of numerical co-ordinates, is quite well specified in GI theory, whereas specification of socially-produced place seems to be vague at present.
2. *Entitation.* What features are subjects of interest and is it rational to depict them individually?
3. *Description.* Objects of interest may be 'fuzzy', which means that they cannot be geographically located with high accuracy (*e.g.* cities do not have specific boundaries).
4. *Temporality and change.* 'Digital geographies are usually static descriptions', which also means that changes in time is difficult to capture by technology (Fisher and Unwin, 2005). Time and space are in reality continuous, although in representations are depicted as discrete (MacEachren, 2004).
5. *Creating space and time*. All the above topics are included in a single representation problem (Fisher and Unwin, 2005).

We know that the scale and resolution of feature projection are dependent on space in relation to attributes and time. Firstly, a decision has to be made on the information, the area (country – 'division on county level'), attributes (elevation, *e.g.* 300-500 metres) and time period (year 2010 - monthly) (MacEachren, 2004).

Fisher and Unwin (2005) state the assumption that space exists, without regard to objects and, in parallel, that space is more important than time. Time is then observed just as an object attribute, but it is important content of the map as well.

When features are represented in digital form, different problems can appear. In the case of area, features are *scaled* as a complex, whereas with line features only the length is scaled (the width is symbolised independently on scale, carrying no reality value of width). Point features are demonstrated by symbols without any scaling. Choice of feature type is dependent on the scale as well (*e.g.* building can be represented by polygon within scale 1:5,000 but as a point feature in the case of scale 1:100,000) (Freeman, 2005).

Distortion is a common problem of various types of maps. Distortion starts to be crucial when information is placed on a map and is exacerbated when 3D models are overlaid. Distortions can be distinguished with different types of map projections as angular, aerial and distance distortion (Brainerd and Pang, 2001).

Map quality can also be affected by resolution of data source. Studies on digital elevation models (DEM or 3D model) argue that with DEM cell size increases, 'slope gradients tend to decrease, also ranges in curvature decrease, flow-path lengths tend to decrease and the accuracy of terrain attributes at particular locations tends to decrease' (Smith *et al*., 2006).

Terrain acts as an important instrument to understand the modulation of the Earth's surface and processes in the atmosphere. Therefore GIS researchers have been doing many analyses and attempts at terrain representation (Longley *et al*., 2005). Terrain attributes are influenced by DEM resolution particularly, but also by the neighbourhood operations, which are often computed in GIS (Smith *et al*., 2006).

When we get back to art cartography, the problem of colour discrimination can be observed. The discrimination decreases with a rise in colour numbers. MacEachren (2004) described an example that gives 98% correct discrimination among 10 colours, dropping to 72% for 17 colours. He also argues that the hue is more discriminating for symbols than shape or size. In addition, in combinations of colour and shape or colour and size, colour is stated to be the dominant component (MacEachren, 2004).

3 Materials and Methods

3.1 Materials

The material used for generating maps in the present study was obtained from the Cadastral Authority of Sweden (see: http://www.lantmateriet.se/). Vector and raster data were used to create topographical maps, which could be tested from the aspect of convenience for user interface. These data were given in geodetic datum SWEREF99.

GIS is a tool which provides the option to combine information from several maps. Where maps have objects of hidden uncertainty, this means that such uncertainty is kept through whole process and embodied in the final GIS product (Evans, 1997). For the case of the source data in this study, it was discovered that the vector data were subjects of uncertainty. Layers such as rivers and elevation lines were created from poorly resolved data, which at present time is superseded with considerably higher reliability. The Cadastral Authority of Sweden confirmed that these vector data had been created from a 1:100 000 map and that the contour lines had been automatically generated from an old Cadastral Authority of Sweden elevation database using a 50-metre grid with an accuracy about ±5 metres.

It is clear, as was mentioned above, that the use of old source data in geo-processing was insufficient for an acceptable depiction of reality. Source data introduced a significant source of uncertainty with respect to position, missing data, and production of new geographical data. As already mentioned, the 50-metre grid in the present study could be replaced by much higher resolution grids but this raises the question of computer speed and software ability to process such a capacity-consuming amount of data.

More ínformation, documents and selservices

GSD-Terrain Elevation Databank contains the elevation data required to generate contours and to produce digital terrain models that depict the landscape in 3D.

The information in Cadastral Authority of Sweden databases is generally also used to calculate and analyse, to generate terrain shading on maps or to geometrically correct satellite images (Lantmateriet, 2010).

3.1.1 Vector data (features):

Geographical features represent objects located on or near the surface of the Earth. These features can be formed naturally (such as rivers and vegetation), objects of human activities (such as roads, pipelines and buildings), or subdivisions of land (such as counties, political divisions and land parcels). Geographical features are mostly represented in the map by using icons such as points, lines and polygons (ESRI, 2007).

3.1.2 Raster data:

'A surface is considered as a continuous field containing an attribute that varies from one position to another'. The continuous field is implemented as a raster constituted by a grid that usually contains equally sized cells. Each cell averages the associated attribute value, and also holds information regarding 2D position (ESRI, 2008).

3.2 Methods

1. To create an appropriate map, the communication paradigm was used as an inspirational model on how to create and improve the potentially best map.

   In designing a map or conception for communicating information, the creator needs to have personal skills. In this case, personal skills were combined with the skills of the supervisor in combination with different authors from the literature and internet sources.

2. To test the quality of map design, an empirical experiment was carried out. For this experiment it was necessary to find appropriate respondents, *i.e*. potential users of maps that were also (if possible) mutually independent.

   When the experiment was designed, the respondent's (perceiver's) conceptions were measured by means of a structured questionnaire on projected respondent skills. Respondents expressed their opinions regarding maps by classification of individual questions that dealt with different aspects of map design. Additional questions were voluntary, but they provided concept information on the maps that could be implemented.

   Interaction of personal skills and user skills is a fundamental tool to get good results, where new knowledge can be generated.

3. Analysis of the questionnaire results by statistical methods was used to obtain important information on maps and geographical object quality. The method used was 'Mixed analysis of covariance' in the STATISTICA ver. 9.1 software.

The Communication paradigm starts on the side of the cartographer (in this case represented by the author of the thesis), whose conception and design are applied in the first section, Map Design. The respondents' conceptions and knowledge were garnered in section 2 and 3 from the questionnaire used. The last section, on statistics, provides new knowledge.

3.2.1 Methods in detail

3.2.1.1 Production of an appropriate map

As was mentioned above, map design was used in accordance with the 'Communication paradigm'. Filters of the scheme such as knowledge and experience were supported by the literature, where the most frequently used source for map design was the book *GIS Cartography* by Gretchen N. Peterson (2009), together with internet sources such as http://webhelp.esri.com (in the case of software usage). The Peterson book was particularly useful in the case of legend composition, colour description of geographical features and their representation in the case of fuzziness (fuzzy objects). In the case of land cover depiction, the template of feature description and its colour scheme used in general was taken from the Cadastral Authority of Sweden.

During the selection of appropriate maps, it was taken in consideration which types of maps should be included to satisfy the users. Thus the concept included topographical maps with particular focus on land cover (basically widely used types of maps) and terrain with experimental use of satellite images (see Appendix).

'Terrain is a topographical surface that varies continuously over space'. Terrain is seen as a multi-scale surface across mountain ranges, river catchments and individual slopes. Topography may be represented in the form of a digital elevation model (DEM) (Darnell *et al*., 2008).

The following sections explain layers and techniques that were used to create useful maps potentially needed by users. The user was considered to be any member of the public, but the particular target group consisted of researchers planning activities in the Area of Interest (Fig. 1) or wanting to submit information regarding previous research. Map designs were proposed with respect to the different points of view on land surface, with emphasis on different data sources and data usage.

Digital elevation model (DEM)

Geo-morphologists and cartographers both use elevation data to derive the shape or structure of a topographical surface (Kennelly, 2008). The topographical surface is often depicted with a DEM, which is the digital expression of regional terrain. DEM data exist in the form of discrete distribution and grid distribution (Peng and Jing, 2009). Discrete distribution in the form of contours is represented by lines of constant elevation at equidistant intervals, whereas a grid represents elevation with regularly spaced points assigned to the pixels defining the grid (Raaflaub and Collins, 2006). The usual process of DEM creation uses interpolation of a discrete number of points within a regularly gridded surface (Darnell *et al*., 2008).

The grid size is dependent on the resolution of the corresponding digital map, with high resolution of the digital map allowing higher accuracy of terrain. In this case, complexity plays an important role for regional map topography; the more complex the terrain to be expressed (without distortion), the higher grid resolution is required (Peng and Jing, 2009).

Elevation data are widely used for multi-purpose processing of geographic systems, for example to classify the land formation or to describe its morphology. Large numbers of researchers focus on recognition of a common set of drainage features consisting of pits, peaks, passes, channels, divides and hill-slopes (MacMillan *et al*., 2004). This was exactly the aim of this thesis – to find a good way to depict some of these features. In the case of this thesis the whole procedure was performed in ArcGIS software, although there are some easy-to-use products available, *e.g*. Landserf software. With the use of terrain classification, we can also compute and analyse hydrological flow (MacMillan *et al*., 2004).

With the use of neighbourhood operations, we can create many types of maps, including first derivative slope or aspect, which provide improvements to hill-shaded maps, and second derivative planimetric or profile curvature. For example, hill-shading and curvature in combination can also improve perception of reality, especially in strongly illuminated areas (Kennelly, 2008).

Slope

Slope is the first-order distance-derivative of altitude, i.e. the horizontal-distance gradient of elevation. This attribute provides terrain steepness.

The associated ArcGIS function was used to generate steepest slopes in Map 2 (see App. 1). The idea was to create the map with complex elevation information and terrain changes. Red colour was chose in order to distinguish between other colours in the map and point out the fact 'there is something important'.

Aspect

Aspect refers to the direction of the steepest slope with respect to compass direction. This attribute was used in Map 6 (see App. 1) to depict terrain exposition toward the points of the compass. Exposition in legend was represented by stretched colour scheme from 0 to 360. North was located at both sides of the scheme (like on the compass), south was situated in the middle, west closer to 360, and east closer to zero. Colours were chosen with respect to user perception as smoother shades, where colours such as green (naturally vegetation colour) were excluded, although some additional colours would make a higher distinction.

Contour lines

In the "topography context", contour lines are equidistant planes cutting through topography at constant altitude (Kennelly, 2008).

Contours (elevation lines) are generally used for 3D terrain impression, giving information about heights and also creating a perception of slope (contour density).

Elevation lines were created for three different equidistance classes, since their feasibility depend on map scale. Elevations with 25 m spacing were appointed from scale 1:5 000 to 1:25 000, elevations with 50 m spacing from 1:25 000 to 1:50 000 and elevations with 100 m spacing from 1:50 000 to 75 000. At lower resolution they were left out, because they do not provide much information. Contours were applied to raise a 3D impression of maps with geographical objects (in resolution 1:50 000).

As mentioned above, contours (together with rivers, lakes and glaciers) were not located in exactly the right place.

DEM grid

Elevation grid was used in one of the test maps (Map 2) (see App. 1) for depicting elevation across a mountain area. Slopes can differ very intensively and with elevation contours it is not always possible to depict the correct effect. Classification of elevations allows the user to very quickly see which mountain is the highest and also gives an impression of valleys and peaks.

In order to obtain a complete effect of altitude, it is good to use complementary data on *e.g.* slope that provides information about the steepest inclinations. This in turn provides information about locality very effectively also at low resolution, whereas contours cannot be projected with high density in low resolution (it does not look good). Colours were chosen here with respect to standard elevation colours.

Hill-shade and topography map

Hill shading was chosen for Map 1 (see App. 1) to amplify its impression of topography, when the light was cast from an appropriate angle. Thus for light rays hitting the surface perpendicularly, the shading is white, while for rays entering horizontally, the surface appears black. The topography map was composed from land cover raster data downloaded from the Cadastral Authority of Sweden. To the grid were assigned unique values in colours that were mostly used by default for particular objects with some adjustments having impact on aesthetics. Missing values were removed.

Satellite images

'The information in SPOT (Satellite Pour l'Observation de la Terre) Imagery gives an objective, reliable picture of the Earth's surface' (MapMart, n.d.).

Satellite images were used as background maps in three of the designs. They are really powerful in the sense of analysing land cover. Satellite images are often used for vegetation mapping, but also *e.g.* for water or snow detection.

For the purposes of this thesis, three different ranks of SPOT-5 imagery bands were chosen, with combination to land-cover layer in the case of Maps 3 and 4 (see App. 1). SPOT-5 imagery was dated to July 2009 with cell-size 10 metres and four colour spectrum bands (green, red, near infrared and shortwave near infrared).

Standard compositions of bands were not applied because the goal was to emphasis the particular map designs with respect to different angles and to see whether people can distinguish different angles and whether particular designs would fit their needs. The choice to use satellite images was made with respect to the fact that they are rather new in comparison with the other data sources used.

In Map 4 (see App. 1), the wavelength bands of satellite imagery were targeted to make different impressions on modelling the land surface in combination with land cover. The aim was to show terrain from satellite image, rather than using hill-shade effect, with respect to angle of light coming from the south. In this case, the combination of bands 4, 4 and 4 was used, which gave an impression of shading to the land cover layer.

Another combination, in Map 3 (see App. 1), the spectrum of green, red and near infrared was used as bands 1, 2 and 3 with land cover combination too. This combination seemed to depict snow, water and roads, but vegetation was not visible in this combination of layers. For vegetation, infrared colour (which is reflected by vegetation) is commonly used in combination of bands 2, 3 and 4. Snow, on the other hand, reflects light in the visible part of the spectrum and water absorbs red parts of spectrum. In this composition of bands it is also good to point out the graduation of colours in lakes (which depict presence of snow or ice), which could show some attributes of the lake, *e.g*. depth.

The last combination was depicted on Map 5 (see App. 1), where a spectrum of colours from short-wave near infrared, near infrared and red was used as bands 4, 3 and 2. This is reversed use of the common vegetation mapping rank. In this image water courses and lakes, vegetation and snow were clearly visible. This image was left without older land cover layer in order to be able to compare previous maps with the pure, attractive new satellite image.

Mountains

A mountain can be one peak of a mountain range or the whole mountain range itself. It is often not possible to decide the borders of a particular mountain. To depict a mountain as an object it needs to be clear and not fuzzy, *i.e*. the mountain should have a beginning and an end. It was decided to follow the elevation lines when considering delineation borderlines. Thus for border delineation, the closed elevation line that most obviously circumnavigated and accompanied the top of the mountain was selected. Elevations with 25 m equidistance were used to extract the appropriate contour.

Valleys

Three complementary aspects of valleys were considered: the lower, flat part, the bedrock walls enclosing the flat part and the whole valley formation. In maps, all these variants applied. It is difficult to decide the proper depiction of valley reality, especially when talking about discrete vector data.

One variant that was created was fairly simple compared with the others, *i.e*. the depiction of the valley as watershed delineation. This is not exact, but the user can easily see where the valley is located. A disadvantage with this form is that valleys do not always coincide with rivers.

Rivers

All features in the map depend on the purpose of the map and the need for zooming in. Higher proximity demands higher resolution and also higher precision. In this project, with the current lack of river data with accurate position and the lack of source data from which new rivers could be created, it was decided to use rivers from the Cadastral Authority of Sweden database. For improvement when zooming in to the area, high resolution colour orthophotos with 0.5 x 0.5 m pixels were obtained for 'hot spot' areas. These orthophotos were considered for use as base maps for a small area, where every user could see the terrain and what is situated on its surface in details.

Glaciers and lakes

Glaciers are mostly shown as white with a black boundary, although on maps created for this study they were blue. This is because the cover layer (hill-shading) made them darker and because of the contrast required to create comparisons to neighbouring features.

For glaciers the layer used was also taken from the Cadastral Authority of Sweden. A disadvantage with these glacier vector data is that they were collected in the early 1980s, so are more than 25 years old.

Glaciers are very special since their proportion is changing with time over a period of melting. Some researchers are engaged in the creation of models that calculate and simulate the amount of ice decrease per year. Since glaciers are changing relatively fast in comparison with the old vector data available for the Abisko area, that is also the subject of uncertainty.

As glaciers are the source of water that supplies lakes and rivers, they can also cause water fluctuations, together with snowmelt. That means that rivers and lakes can easily change over time as well. Seasonal water fluctuations in a mountain area are easy to discern. These changes also make features (glaciers, lakes, *etc*.) fuzzy.

The major increase in water in lakes (orthophoto picture probably taken during late summer) was compared against the vector layer of lakes (probably early spring or late autumn) (see Figure 5). With some cooperation from Cadastral Authority experts, probable dates of layer origin were identified. The orthophoto picture was from 2008 and the vector maps were about 25 years old.

Another reason for feature dislocation could be the different coordinate system used in data generation. Transformation to the new system can cause some feature distortion or shifting.

Figure 5 shows one example of how data can differ with time, in this case by dozens of metres.

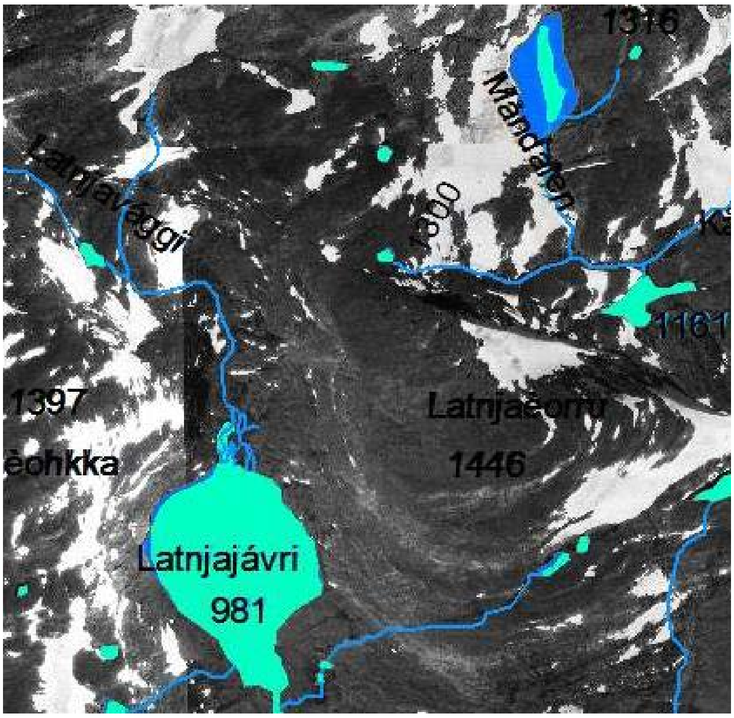

Figure 5. Water fluctuation in a mountain area as an example of source data diversion.

Ortophoto image

Vector layer of lakes

Watershed

Watersheds are 'areas that are delineated via topography and define an area in which water flows downward towards a common point'. Watersheds are also referred to as 'basins' and 'catchments' (Peterson, 2009).

Red is the most common colour used for delineation of watersheds. Peterson (2009) also recommends the use of *e.g.* green, blue, grey or brown. It also looks better to have narrow delineation lines with decreasing size of catchment or increasing transparency of polygon.

Watersheds were generated in order to examine them as an option of feature (valley and river) depiction.

The tools that were needed to create the watershed are located in the 'Spatial analyst' toolbox, under the toolset called 'Hydrology'. There are two possibilities, automatic and partly manual. The process can be automated by two or three steps, using the tools 'Flow direction', 'raster to polygon' and 'flow length', where the DEM is needed as a source data.

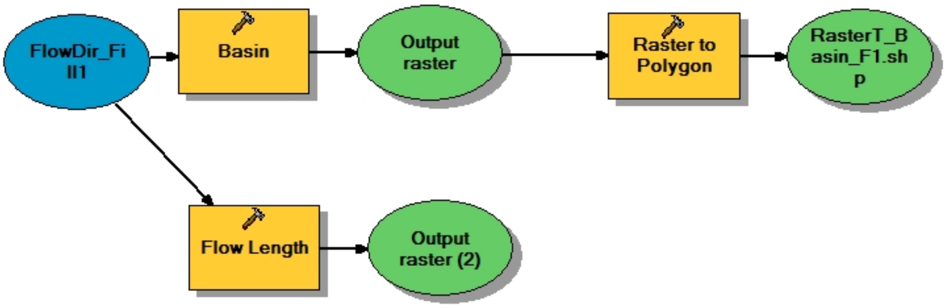

Figure 6. Automatic watershed building model.

Figure 6 shows just a part of the process, starting with Flow direction as a source data.

The automatic procedure is simple and very quick, but there is a problem in that a watershed cannot be created for any point of the river. Thus automatic watershed generation is more for orientation or for just illustrating where the catchments for main streams are located.

Creation of sub-basins from appropriate areas is fairly difficult, as it has to consider the location of the point at which water flows out of the area. Such points are called Pour points.

First, a digital model of terrain (DEM or DMT) that gives information about surface is needed and then sinks in elevation raster need to be filled in order to remove small imperfections in the data. Sinks are cells that lack drainage and hence will be filled with water. In Arc GIS there is a tool call 'Fill' that identifies and removes local sinks.

The next step is to find the flow direction of the stream and also flow accumulation. Those two tools are used to locate pour points. As was found out by personal experience in this study, the easiest way is to set more pour points on the flow accumulation raster, exactly where the stream is located. Flow direction just helps to identify the size of area the watershed occupies and the direction the water takes from the pour point. The model used is shown in Fig. 7.

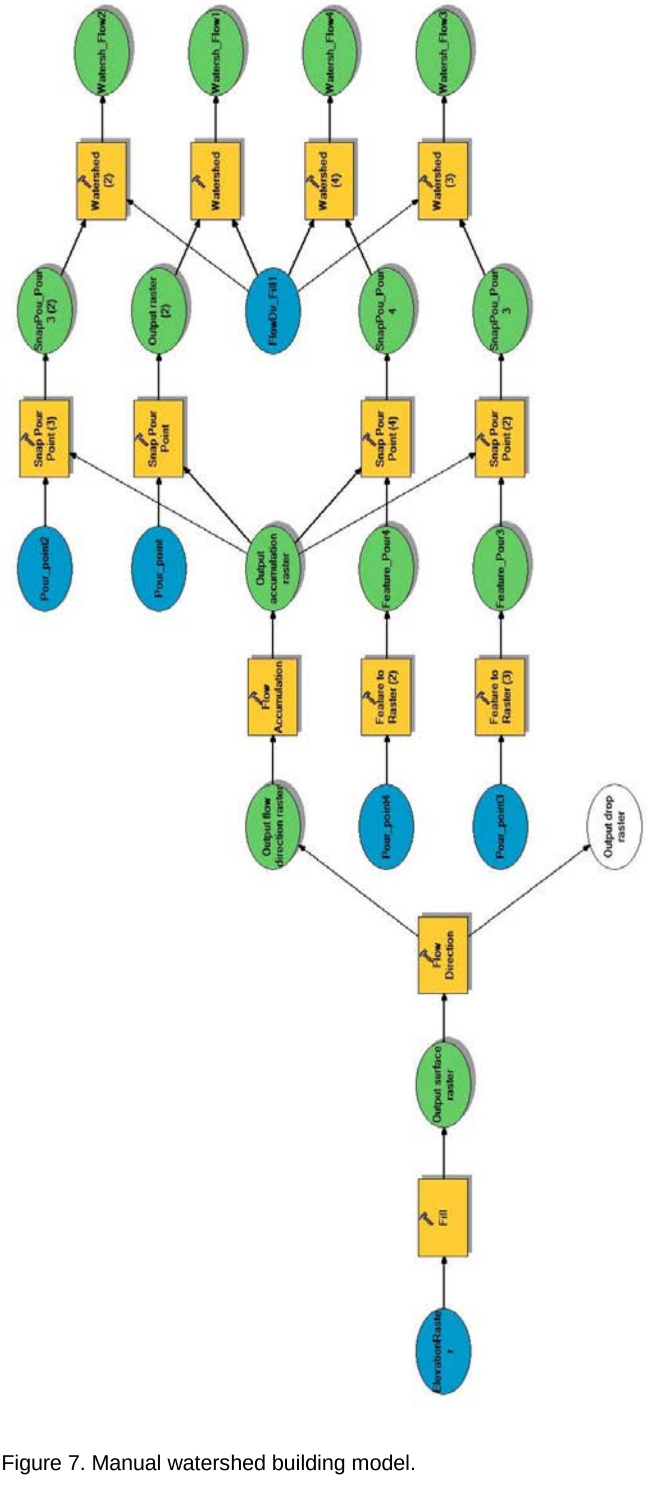

Figure 7. Manual watershed building model.

Legend

'The legend is a standard element for most layouts'. In the legend we can mostly find symbol key and colour depiction for the map elements. Legend contains items (icon, point, line, and polygon) and the labels which describe these items (Peterson, 2009).

For legend description, the book by Peterson (2009) and other sources were used as an aid. Hydrology colours were expressed in hues of blue, which is most common. After blue, green or grey can also be used. Roads have many colours, from hues of black over brown to red. However, there can be others, for example blue was chosen for testing maps with respect to the Landscape Authority usage. All colour and shape selections depend on road type. Cities, townships, and other urban areas are mostly coloured red, which was chosen during the selection too. Peterson (2009) also recommends some other colours such as grey, brown and black. Colour was not considered as something predetermined for fuzzy objects, but for the structure of features some recommended methods were used. Fuzzy objects can be lakes, mountains, rivers, valleys and everything that changes itself in time or does not have exact boundaries or location. Peterson (2009) recommends using dashed lines for boundary or points that highlight feature location, or shaded colour that changes hue over the space. Hill-shade colours are stretched as a standard scheme in a spectrum of hues from white to black. Elevation can have a spectrum of colours from white, over grey, brown, yellow, green to slightly blue, according to Peterson (2009). ArcGIS provides stretched colours already sampled for continuous surface. In testing Map 2 (see Appendix 1) classified elevation was created as continuous elevation divided into six classes, with different colours for each. The ArcGIS colour sample was used for this purpose.

Other compiled models to be used for reconstruction of map layers:

When new map layers are compiled from existing data, the first step is to generate proper data as a reliable source for creation of the new layers, in particular with respect to raster resolution and the spatial extent of the map. Resolution can be distinguished with respect to size of layers that one would like to derive. For example it is hard to create contours from very high resolution elevation raster data that cover a large area, because of the software memory capacity. Settings should be decided with respect to circumstances. Figure 8 shows the example of starting with DMT.

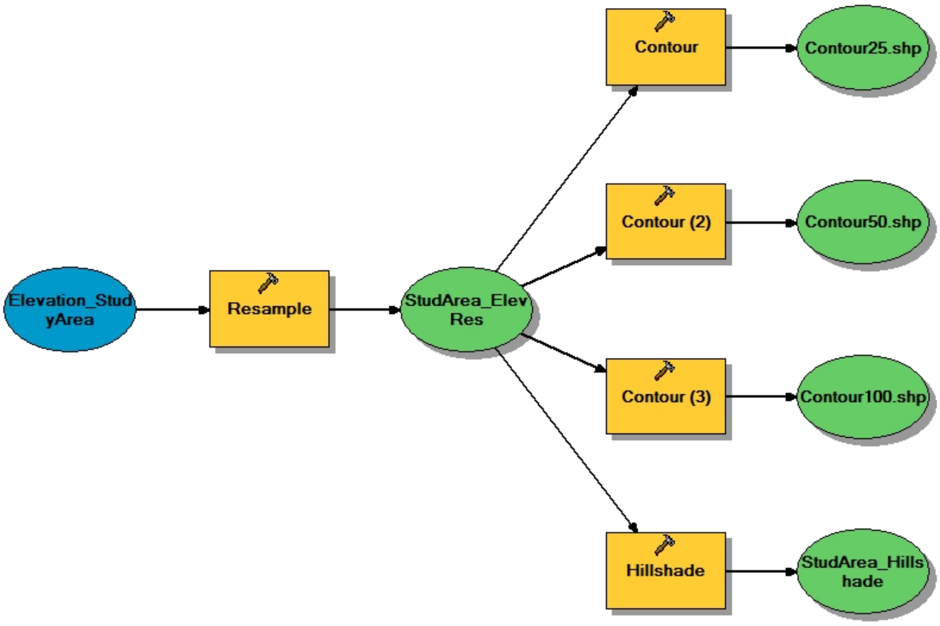

Figure 8. Procedure for getting better quality data results.

The elevation raster was resampled from 50 x 50 m pixels to 5 x 5 m, which created much more effective reality depiction. Elevation lines (contours) were created with continuity of 25, 50 and 100 m, with respect to the resolution of the map. The last step of creating hill-shade layer completes the digital model of terrain.

Another example of a model is elevation raster extracted by mountain polygon, which creates a mountain polygon with information about elevation (Figure 9). That principle was used also for mountain top depiction that contained aspect information.

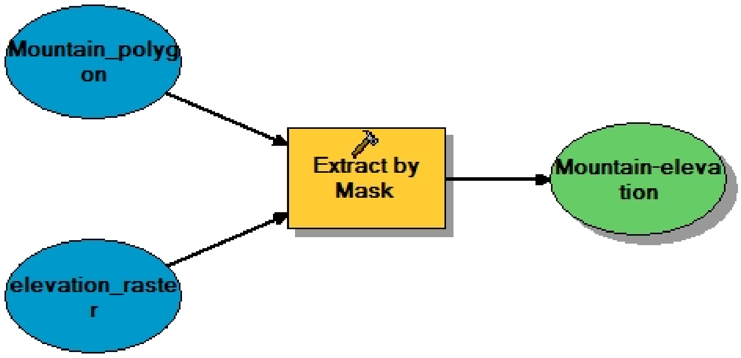

Figure 9. Model of mountain polygon with information about elevation.

The mountain polygon and polyline were created by using elevation lines, from which the lowest contour, that surrounded the mountain top as a closed line, was chosen and extracted. The same principle was used for generation of the mountain top with aspect information.

The colour chosen for mountain tops was mostly brown (evoking colour of ground), plus pink (to create contrast with environment) and elevation colours.

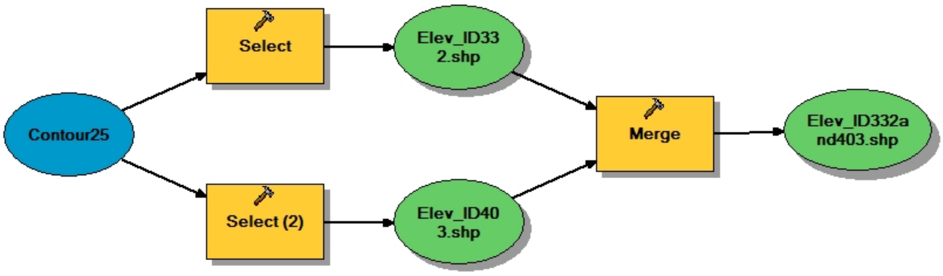

Figure 10. Model of valley polygon creation.

Creating a valley was the most sophisticated procedure of all objects. Two elevation lines with ID (identification number) were first selected and merged in one layer (Figure 10). Then the function ‘Trim feature’ in Editor was used to cut the valley where the elevation line changed angle towards the outside of the valley. With a few more adjustments, the structured valley was converted to a polygon. To finish design of the valley, Editor and its function ‘Cut polygon’ were used to gain two separate layers with valley bottom and valley walls.

For valley, two contrasting colours (light and dark) were chosen to evoke difference in elevations, the dark colour evoking steepness and the light colour having a better transparency effect. Watershed colour (as the option of valley depiction) has already been described.

3.2.1.2 Empirical experiment

1. Selection of respondents

In the selection of respondents, it was important to find independent individuals working or studying in fields connected to geography. This meant that the respondents would be experienced in at least one of the fields of cartography, agriculture, landscape planning, GIS, environment, ecology, geology or geography. Such individuals are potential users.

A total of 29 respondents with different levels of experience in cartography and GIS were selected for the study. Some of these were international students, which can also show different aspects of answers across countries. The sample also included researchers working in the area who knew the locality very well. These aspects were important during the selection, to get diversified samples.

2. Design of questionnaire

The questionnaire was designed with respect to independence of the questions. For *background maps*, a sequence of questions was constructed to ask about positioning in the map, map clarity for user, colour balance, map usability, map complexity, aspect of evoking the interest of an end-user, and map correctness. For the same map, questions were also asked about which maps should be used and which map was suitable as a standard map for detection of objects with respect to the resolution, which is rather low in that stage of searching. To evaluate *object interpretation* in the map, respondents were asked to judge all designs for the aspect of preference. The objects represented were mountain top, valley, lakes and rivers in the Latnja valley hot-spot area.

For the above questions, a visual analogue 10-point scale was used. In the questionnaire this scale was rated from best (score 1) to worst (score 10).

For question 1 and question 13 (see below), a binary scale (yes or no) was used that addressed the six maps for which it was decisive to find the preferred options.

Questions on the gender of the respondent, time of questionnaire completion and level of experience were asked to test whether the respondent's assessment of design was dependent on these factors or not.

The following questions were asked in the questionnaire:

Question 1:

Which map (from Maps 1 to 6) would you choose as the option that should be considered on the map server? Choose one or more.

Questions 1 and 13 used the same principle of evaluating as mentioned above. The only difference was that question 1 asked about which designs (maps) of background should be used as different layers, while question 13 asked which map should be the one for initial background.

Question 2:

How would you rate Maps 1 to 6 from a positioning perspective (trying to find your way)?

Positioning is very powerful when we already know what the map should look like and which kind of map should be used. We know that without any clue in the map, positioning is practically impossible. It is necessary to find an orientation point, *e.g.* the road map name of a street or number of a road, perhaps with some other information. Getting an idea of one's position is a bit more difficult, especially in smaller resolution topographical maps, where no details are apparent. As respondents remarked in the questionnaire, topographical maps need to show roads, railroads, buildings, footpaths, rivers and streams, lakes, land cover, height curves and other clearly visible objects. In the six maps tested, only some of these objects were considered, since the maps needed to be kept simple for the small layout.

Question 3:

How would you rate Maps 1 to 6 from the aspect of map clarity (understanding map legend, colour meaning, object representation, etc.)?

Map clarity is probably fundamental in making maps work. Without understanding the legend and features in a map, that map would be useless.

Question 4:

How would you rate Maps 1 to 6 from the aspect of colour balance?

Maps 1, 2 and 5 were not created with discrete colours, because these maps were intended to attract and hold user attention. Colours should not be allocated in an illogical sequence but in art cartography there is no restriction on how sharp colours should be. Formal cartography is more restrictive in that sense. Colour should not distract too much, of course, because the purpose of map should be to communicate effectively. Here, user opinion about these matters was tested.

Question number 5:

How would you rate Maps 1 to 6 from the aspect of map ***usability*** *(as a tool for exploring and discovering)?*

This is the question that should probably have been communicated with subjects first. It is generally important to get ideas about what end-users need to know, what they will potentially look for in the map, and whether it really fulfils their needs and expectations.

Question 6:

How would you rate Maps 1 to 6 from the aspect of map ***complexity*** *(does the map need some other layers, objects or their parts, etc.)?*

In general, complexity has some connection to usability. A map needs to have purpose and utility, but it also needs to contain appropriate objects, properties, descriptions and this makes it complex.

Question 7:

How would you rate Maps 1 to 6 from the aspect of evoking the interest of the end-user?

In order to design the proper face for map, it is necessary to attract the end-user. Interest is an indicator of whether the map looks good.

Question 8:

How would you rate Maps 1 to 6 from the aspect of cartographical correctness (do you think it is produced with the same standards as topographical maps)?

Question 8 examined the aspect of correctness. It is hard to say what cartographical correctness is, because there are so many varying opinions on optimal cartography. Formal cartography has standard ways to present maps and many cartographers comply with these, but when it comes to art cartography it is hard to say how far we can go. The best solution was assumedly to ask users what they would like to work with and what was too clichéd. For that purpose, we also asked the respondents about their knowledge of art cartography and formal cartography.

Questions 9, 10, 11, 12:

How would you rate the visual representation of Latnja mountain top, valley, lake, river (when the map explorer finds the name in the database and depicts them on the map)?

Queries were kept simple for these questions, with a clear winner and no speculations. Respondents were intended to react impulsively in order to get their first perception, which is generally the most important one.

Question 13:

Which map (from Maps 1 to 6) would you choose to be the standard map used for the previous purposes (finding cartographical objects as a valley, lake, river, etc.)? Choose one.

This question is explained under question 1.

3. Statistical analysis

The principles of statistical processing applied to all map options, although these options differ with respect to scale type and objective. For the binary scale questions (1 and 13), the yes or no scale applied to all map alternatives. In questions 2-8, a visual-analogue scale (VAS) was used to capture different aspects of map design, while for questions 9-12, a visual-analogue scale was used to capture different aspects of object design.

To test which map was better, or rated more important, the questionnaire was evaluated with a Mixed General Linear Model where the covariance assumed to prevail within subjects was addressed with a random SUBJECT factor. The VAS observations generated with the questionnaire, together with the binary observations made with questions 1 and 13, were used as response variables. With Maps 1-6 exposed to each subject across all questions, DESIGN was considered as a fixed six-level factor. In addition, TIME was considered as a covariate in linear combination with the random SUBJECT and fixed DESIGN factors. We also tested the significance of complementary factors such as SEX, GIS_BEGINNER, and LEVEL of GIS experience.

All statistics were performed with the STATISTICA ver. 9.1 software package using its Variance Estimation and Precision toolbox. All estimations were made with restricted maximum likelihood technique, using type V sums-of-squares decomposition. All significance thresholds were set to $p=0.05$. Subjects were chosen in accordance with a semi-randomised scheme, where they were enrolled on an *ad hoc* basis in the order of random appearance.

4 Results

From a summary of p-values (Table 1), it can be seen that the effect of map design was significant through all questions. In contrast, the subject level of experience played a role for a few questions only. Gender, as another factor, with 14/29 males and 15/29 females, appeared non-significant and for that reason a decision was made to exclude it from Table 1 and any other comments. Time as a covariate was tested together with each level of experience, with only a weak effect in one of the cases (see below). The average time spent on the questionnaire was 32 minutes.

The factor with the second most frequent effect (after design) was Art_exp_Art (art cartography experience), which appeared in four questions of 13 (questions 1, 2, 5 and 12 – Table 1). For question 1, this may explain a need for knowledge of art in the choice of map design. Other factors had almost no significance, although the effect of GIS_Pro (GIS professional) appeared significant in three questions (8, 10 and 11).

Question number 10 provided an anomaly since most factors seemed to have a significant effect. Most of the experience factors appeared to be significant except Art_Exp_Art. For this reason, it was decided to focus solely on map design in question 10.

Table 1 also shows the numbers of subjects participating through the experiment. With only 2 out of 29 subjects being beginners in cartography or GIS, the sample of subjects was significantly biased with respect to the corresponding factors.

Table 1. P-values obtained for effect of different factors on Questions 1-13 and number of subjects per factor.

	p-value for Effect								
Question	Design	Cart_Beg	Cart_exp_Art	Cart_Exp_For	Cart_Pro	GIS_Beg	GIS_Exp	GIS_Pro	Design*Cart_Exp_Art
1	0.000012		0.074087						
2	0.000000		0.011081						
3	0.000002								
4	0.000000								
5	0.000000		0.003175						
6	0.000025								
7	0.001432								
8	0.000000							0.006045	
9	0.000000								
10	0.015441	0.000284		0.000962		0.017680	0.049831	0.038467	
11	0.002871							0.022499	
12	0.000059		0.001139						0.005240
13	0.000000								
n/29 subjects per factor	/	10/29	10/29	8/29	6/29	5/29	15/29	10/29	/

*others/Cart_Exp_Art

Graphs were used to show the potential winners (backdrop maps and objects) in particular questions, which were also created to test different perspectives on maps. They are presented in the Questionnaire section and their results (based on mean values) are summarised in Tables 2 and 3.

After presentation of the responses obtained for questions 1-13, the results for all questions with the exception of 9-12 are discussed in greater detail in the more detailed Final Results section.

4.1 Results for questions 1-13

Table 2. Overall rating given to Maps 1-6 and objects in response to questions 1-13

number of maps ordered from the grade 1 (best) to the grade 6 (worst) from aspect of design with						
	Grades					
question	1	2	3	4	5	6
1	1	4	3 and 6		2	5
2	1	4	3	5 and 6		2
3	1	4	3	2	6	5
4	1	4	3	6	2	5
5	1	4	3	2	6	5
6	1	4	3	2	6	5
7	1	4	3	6	2	5
8	1	4	3	6	5	2
9	1	2	3	5	6	4
10	1	4	2	3		
11	2	3	1			
*12	2	3/1	1/3			
13	1	4	3 and 6		2 and 5	

*others/Cart_Exp_Art

Table 3. Mean rating given to Maps 1-6 and objects in response to questions 1-13

Mean value for each map ordered from the grade 1 (best) to the grade 6 (worst) from aspect of design						
	grades					
question	1	2	3	4	5	6
1	0.72	0.45	0.24		0.14	0.07
2	3.21	3.59	4.79	5.62		6.24
3	3.31	3.62	4.24	4.38	4.93	6.17
4	2.90	3.86	4.10	4.69	6.10	6.34
5	2.99	3.70	4.33	5.74	5.81	5.88
6	3.66	3.97	4.17	5.07	5.24	5.79
7	3.24	4.03	4.86	4.97	5.10	5.31
8	3.19	4.17	4.51	5.10	5.92	5.99
9	4.14	4.41	4.59	4.66	5.79	7.14
10	4.24	4.37	5.04	5.74	/	/
11	3.79	4.41	5.54	/	/	/
*12	3.35/4.34	3.63/6.79	5.90/7.70	/	/	/
13	0.59	0.28	0.07		0.00	

*others/Cart_Exp_Art

As Table 3 and 4 show, the best design for map background was Map 1, with 100% success. Second, also with 100% success, was Map 4 and third, with almost full success, was Map 3. It has to be mentioned that these results are generated from mean values. The winning map is shown below (Figure 11).

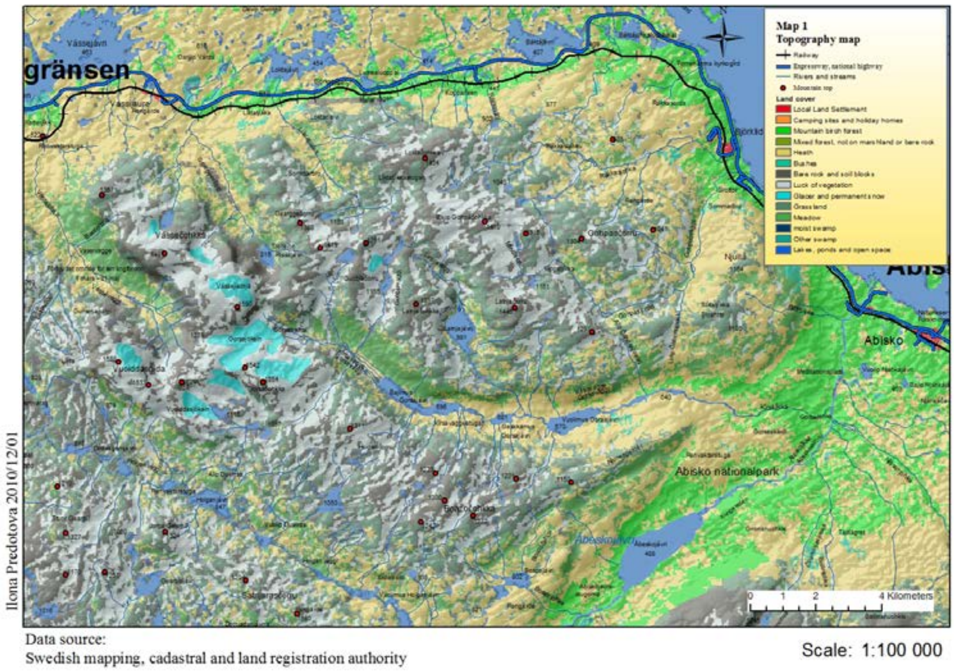

Figure 11. Best rated map design: Map 1.

For objects, mountain tops and valleys, Map 1 was rated the best design (Figures 12 and 13). For lakes and for rivers, Map 2 was rated highest (Figures 14 and 15, respectively). The best objects had to be chosen with respect to the mean values, because their levels of significance were overlapped for almost all designs.

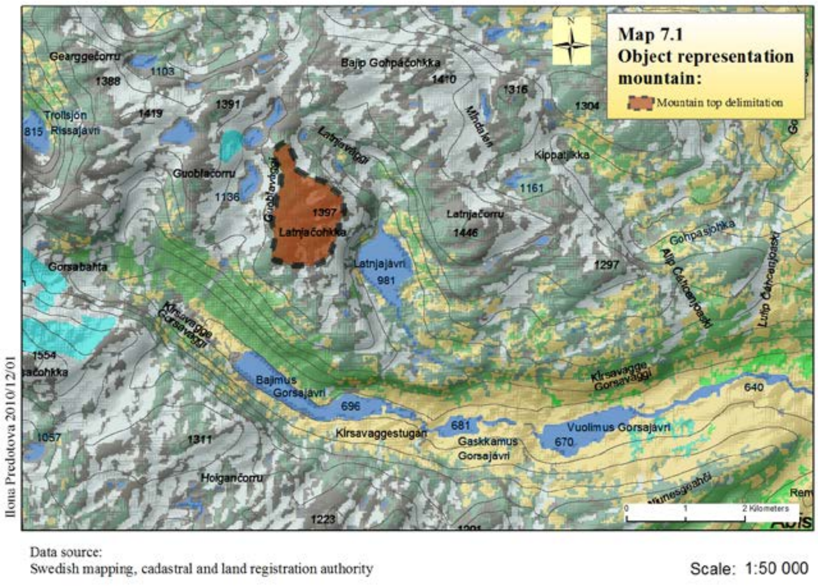

Figure 12. Best rated mountain top design: Map 1.

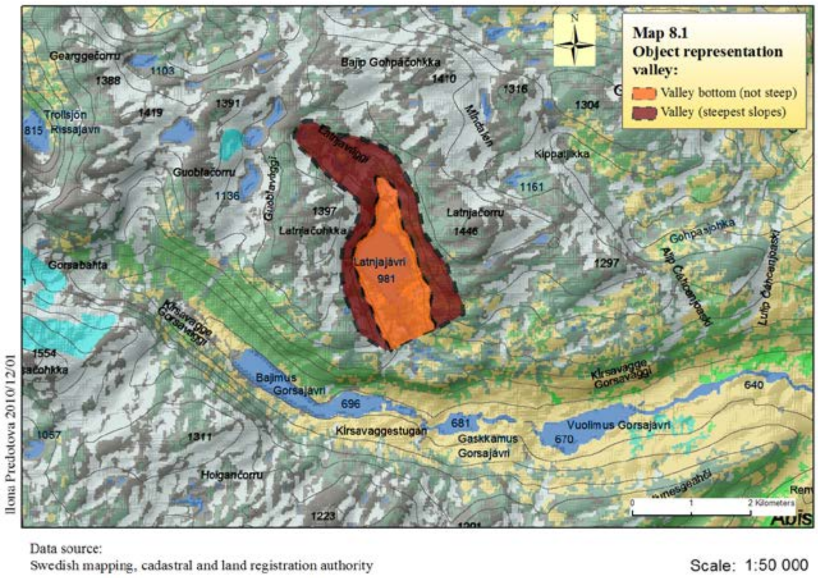

Figure 13. Best rated valley design: Map 1.

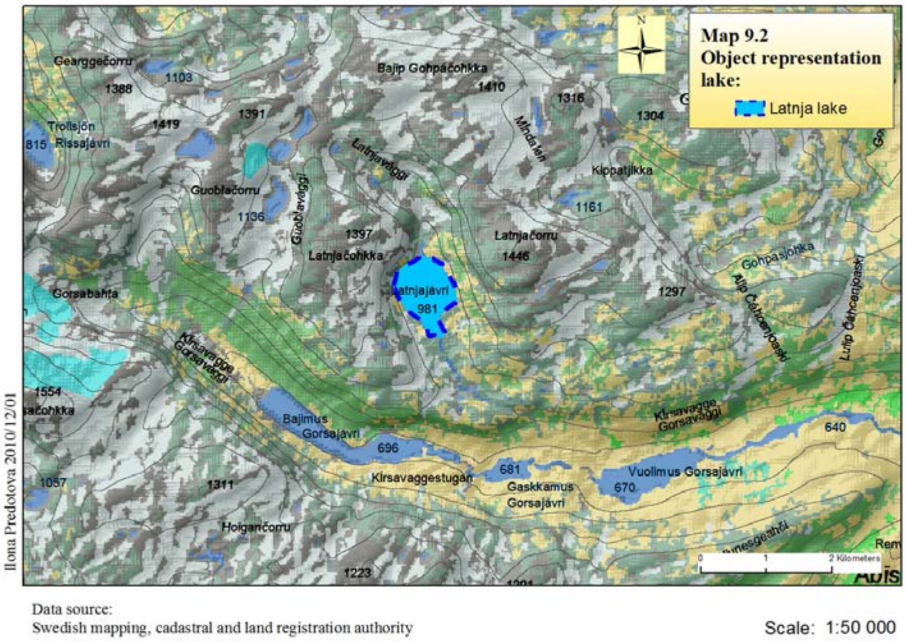

Figure 14. Best rated lake design: Map 2.

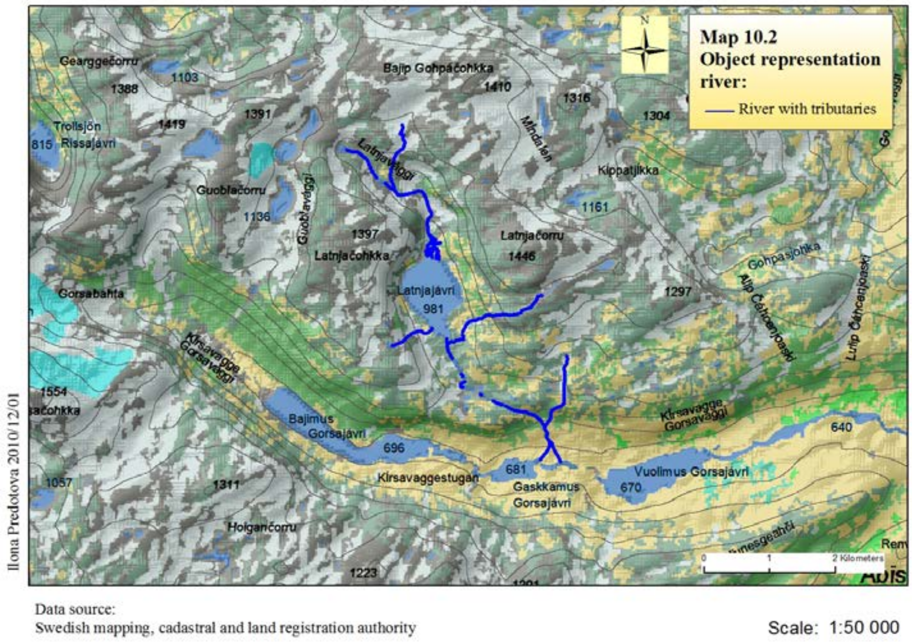

Figure 15. Best rated river design: Map 2.

4.1.1 Questionnaire section

Question 1:

As shown in Table 1, map design had a significant effect on subjects and Cart_Exp_art had a tendency in a few cases. When comparing design and Cart_Exp_art in the case of question 1, their interactive effects were not significant. This means that design had similar effects on subjects with respect to experience in artistic cartography.

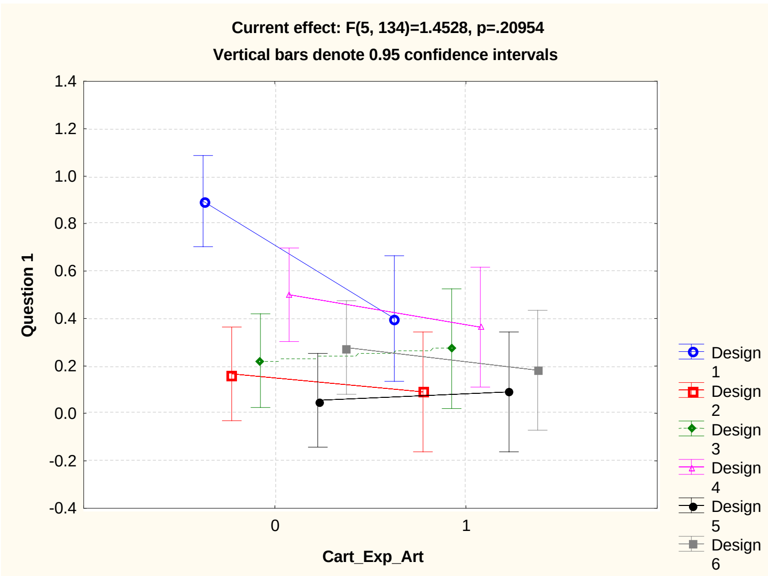

Figure 16. Binary scale breakdown across questions and Cart_Exp_Art for question 1.

As illustrated in Figure 16, a significant majority of the subjects experienced in artistic cartography preferred map design 1, whereas no significant Cart_Exp_Art effect could be found regarding any other design. Those with experience in cartography are placed under 1 on the x-axis and others (non-Cart_Exp_Art) under 0.

Figure 17 shows the rating of Maps 1-6 across the categories of Cart_Exp_Art. As in Figure 16, Map 1 was the preferred option, but in this case together with Map 4, which lay within the level of confidence of Map 1.

Question 2: Positioning

Questions 2-8 shared scale types (AVS) and designs, but referred to different aspects as compared with questions 1 and 13. A significant effect was again found for map design and Cart_Exp_Art. Design averaged across the categories of Cart_Exp_Art had no significance, as noted in Table 1.

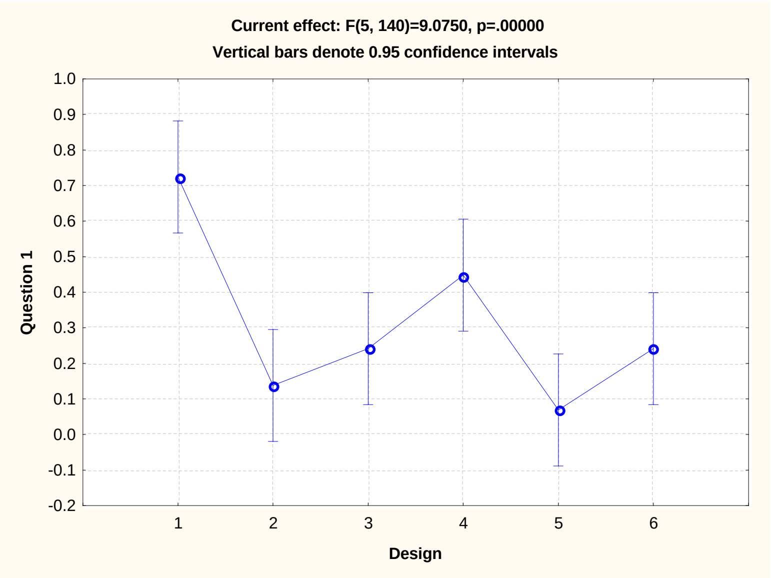

Figure 17. Binary scale per design (Maps 1-6) for question 1.

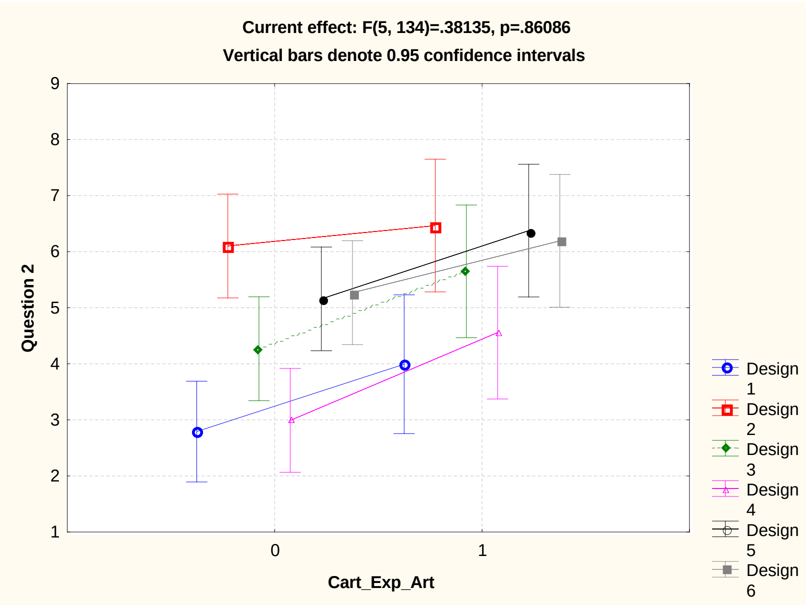

Figure 18. AVS breakdown across questions and Cart_Exp_Art for question 2.

Figure 18 shows the effect of Cart_Exp_Art and design on subjects, which was insignificantly small. The only difference appeared for Maps 5 and 6, which switched positions with respect to

Cart_Exp_Art and non Cart_Exp_Art. The maps rated best from the aspect of positioning were 1, 4, and 3 for non Cart_Exp_art and 1, 4, 3 and 5 for Cart_Exp_art.

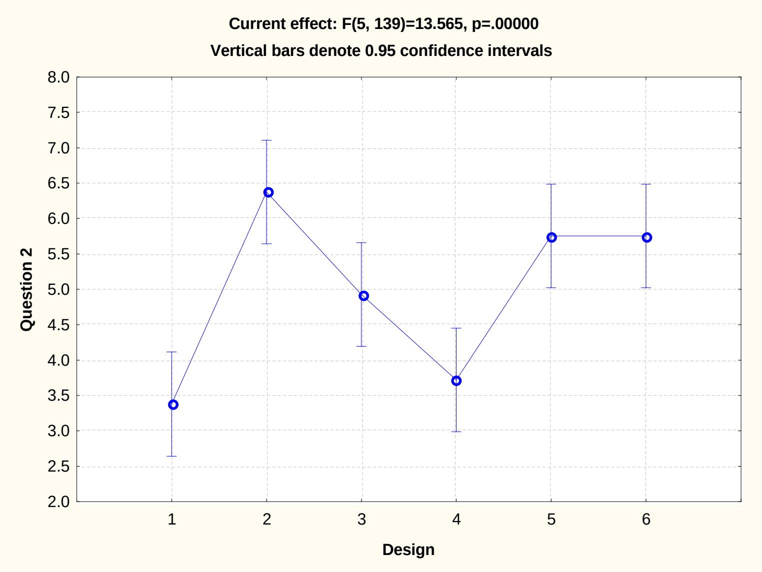

Figure 19. AVS per design for question 2.

Average analogue visual scale (AVS) per design provides the preferred map design from the aspect of positioning (Figure 19). As Table 2 shows, the preferred designs were Map 1 and 4. As Figure 19 indicates, Map 1 received the best ratings (in mean values), across all questions 2-8.

Question 3: Map clarity

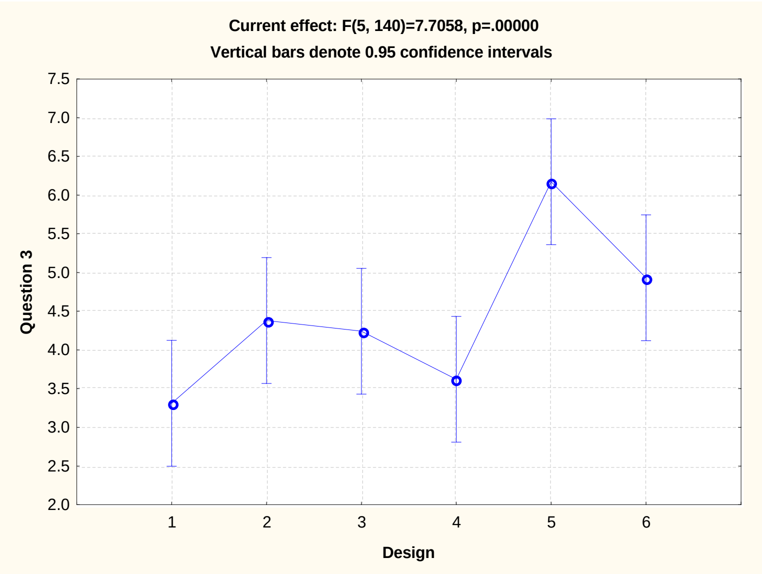

Figure 20. AVS per design for question 3.

Figure 20 shows that within map clarity, Map 5 had extremely high ratings as compared with the others. However, these extreme values can mean bad interpretation of design, wrong description or just unknown image for users. The map clarity results were the best, in mean values, for Maps 1, 2 and 3. The generally best map clarity could not be decided, since the levels of confidence overlapped.

Question 4: Results for colour balance

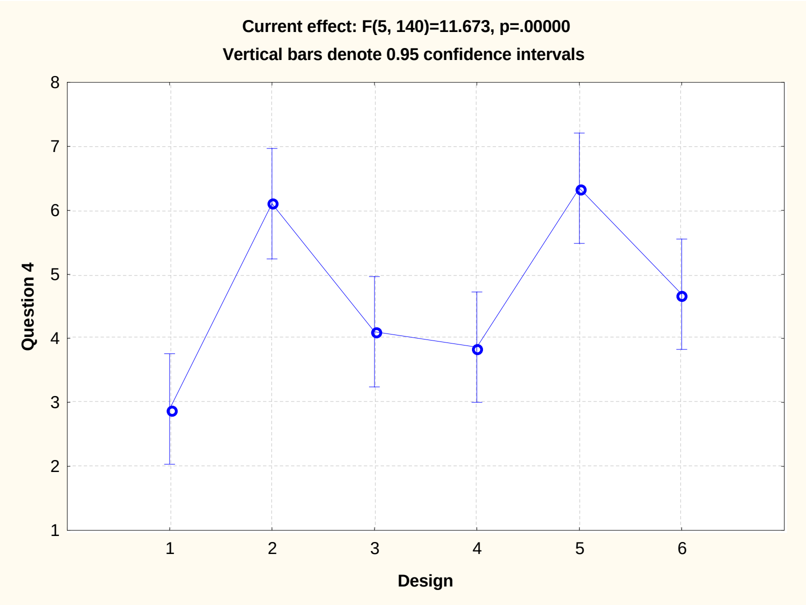

Figure 21. AVS per design for question 4.

As Figure 21 indicates, Maps 1, 3 and 4 had the best rating in colour balance. These maps had the same base map (land cover) but different overlapped layers (hill-shading and satellite images). Maps 2 and 5 were made with rather sharp colours, as mentioned previously, which may be the reason for the poor rating.

Question 5: Map usability

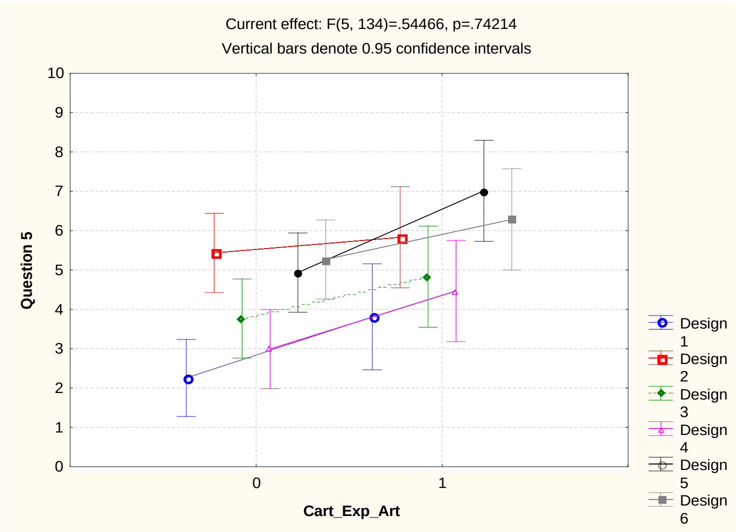

Figure 22. AVS breakdown across questions and Cart_Exp_Art for question 5

Figure 22 shows that all designs were rated with similar effects of Cart_Exp_Art, with the exception of Maps 2 and 5 which appeared to be reversed in rank. The best rated maps for non Cart_Exp_Art were Maps 1, 4 and 3 and for Cart_Exp_Art Maps 1, 4, 3, 2 and 6, for which level of confidence still overlapped.

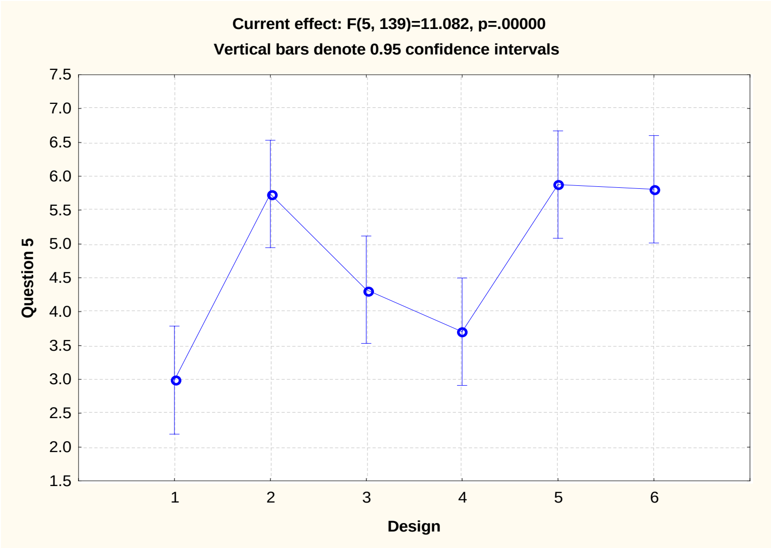

Figure 23. AVS per design for question 5.

Without the effect of Cart_Exp_Art, the best rated maps were Maps 1, 4 and 3.

Question 6: *Complexity*

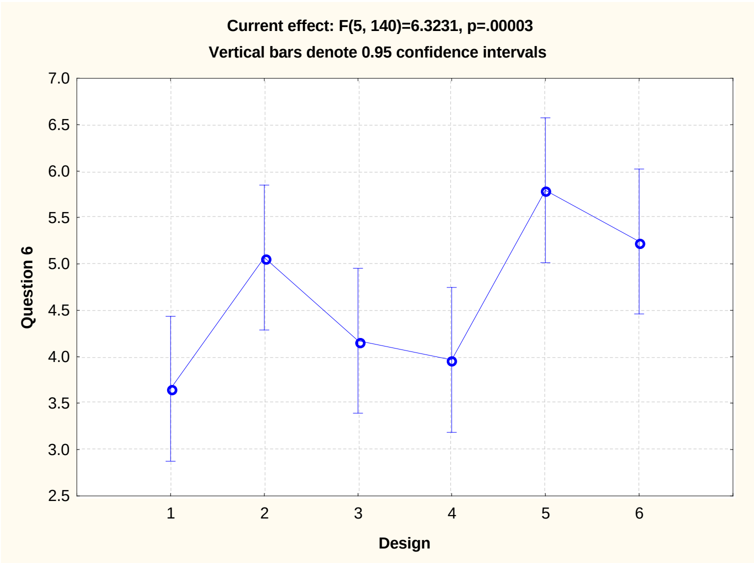

Figure 24. AVS per design for question 6.

Maps from the complexity aspect were again evaluated with rather low confidence. The best rated maps were Maps 1, 4, 3 and 2.

Question number 7: *Interest*

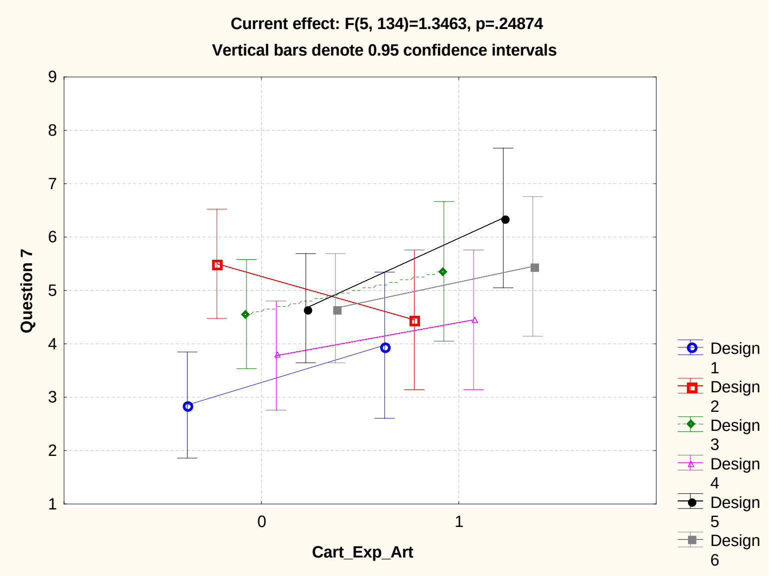

Figure 25. AVS breakdown across questions and Cart_Exp_Art for question 7.

Map design was ranked similarly for the first two positions within Cart_Exp_Art and non Cart_Exp_Art (Figure 25). First position belonged to Map 1 and second to Map 4. This shows that people experienced in art cartography were not as interested as the others, and also that they had different opinions regarding the interest rating of particular designs. However, these outcomes cannot be taken as results for the general population, because level of confidence in the case of Cart_Exp_Art was rather wide with respect to the low number of respondents. In the general case, for Cart_Exp_Art all maps have to be considered the 'best' with the exception of Map 2, which was outside the level of confidence. The best maps for non Cart_Exp_Art were not specified at all.

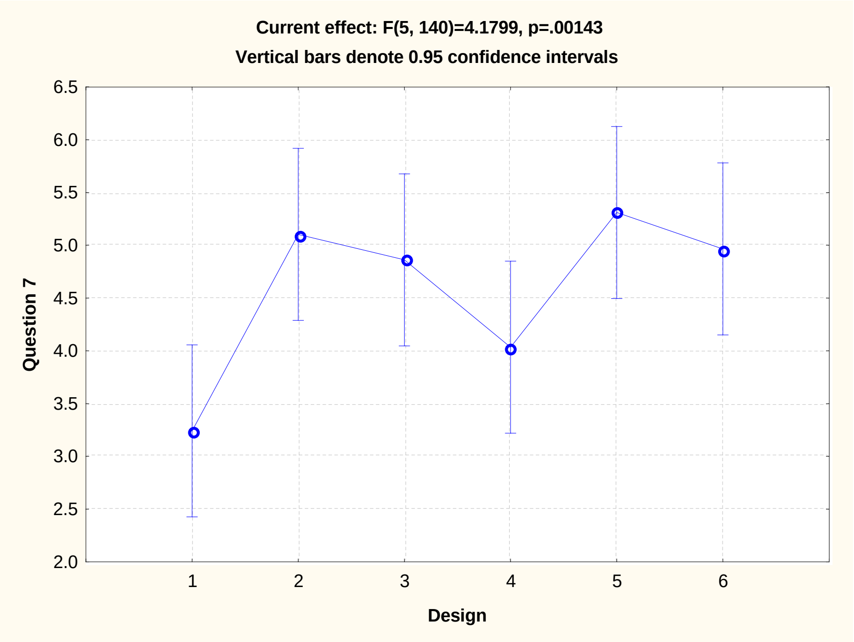

Figure 26. AVS per design for question 7.

When averaged across the categories of Cart_Exp_Art, the best rated maps were Maps 1 and 4.

Question 8: Cartographical correctness

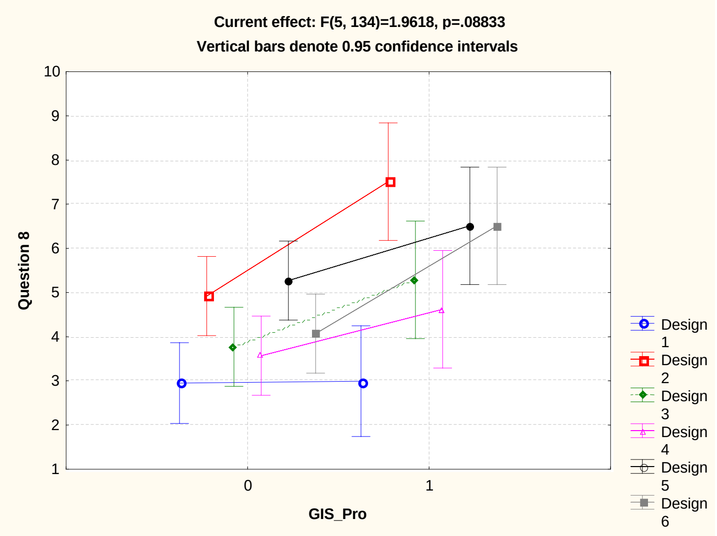

Figure 27. AVS breakdown across questions and GIS_Pro for question 8

There was a significant effect of GIS professionals (GIS_Pro) for this question (Figure 27). It seems that GIS_Pro saw Maps 2 and 6 as particularly different to non GIS_Pro. In this case, the GIS_Pro gave these designs lower ratings.

The best ratings for non GIS_Pro were received by Maps 1, 4, 3 and 6, and for GIS_Pro by Maps 1, 4 and 3.

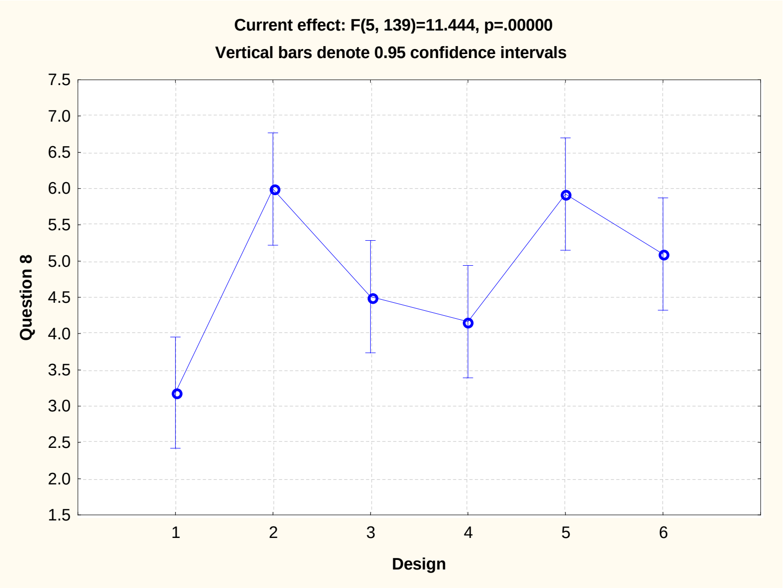

Figure 28. AVS per design for question 8

In the graph (Figure 28), averaged across the categories of GIS_Pro, the best ratings were received by Maps 1, 4 and 3.

Question 9: Mountain top

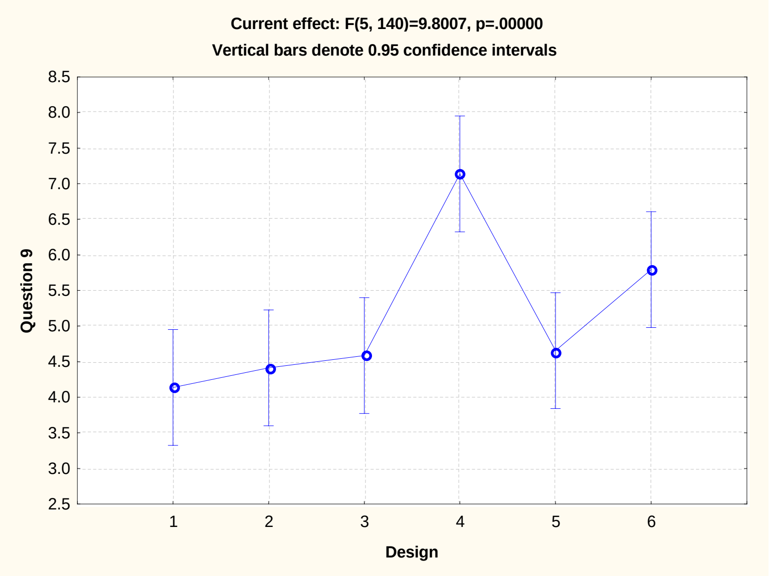

Figure 29. AVS per design for question 9. * Design 1 = Top 1, Design 2 = Top 2, Design 3 = Top 3, etc.

Mountain top 4 seemed to be outside the range of the others for question 9 (Figure 29). To point out a mountain top in this design, a flag was used as a simple sign. It seemed that people preferred more elaborate results that are also in a sense more interesting.

In the general case, the mountain top designs that can be considered best are 1, 2, 3 and 5, although the most people voted for Top 1.

Question 10: *Valley*

This question was a slight anomaly in p-value results (see Table 1). This is why just one design was chosen for classification of ratings (Figure 30).

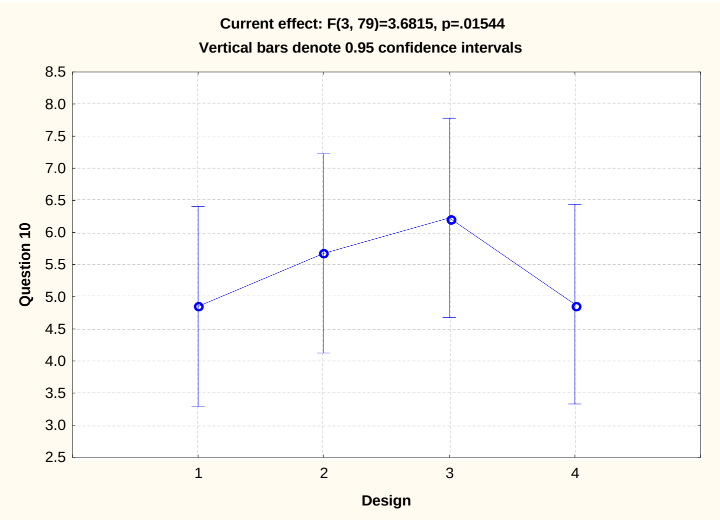

Figure 30. AVS per design for question 10. * Design 1 = Valley 1, Design 2 = Valley 2, Design 3 = Valley 3, Design 4 = Valley 4.

Most of the designs were generated in similar ways, with slight differences regarding reality perception. This can be the explanation for the quite similar ratings (Figure 30). From the results we cannot generally state which map was the best, because of overlapping confidence intervals. Based on only the mean values, the best rated design was Valley 1, which differed very slightly from Valley 2.

Question 11: *Lake*

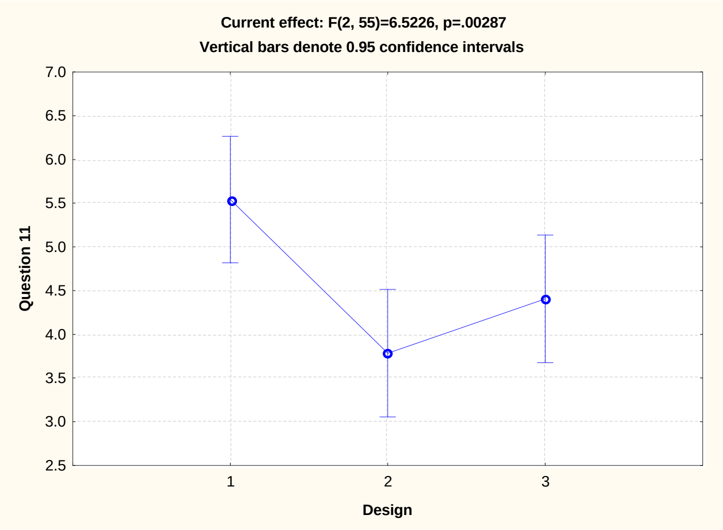

Figure 31. AVS per design for question 11. * Design 1 = Lake 1, Design 2 = Lake 2, Design 3 = Lake 3.

The graph (Figure 31) indicates that the best designs were Lakes 2 and 3, although the point estimate (the mean value) indicated that it was Lake 2.

Question 12: *River*

Table 4. Table of effect significance for Figure 32

Effect	Fixed Effect Test for Q12 (Dotazník) Restricted Maximum Likelihood (REML) Type V decomposition Include condition: Design <= 3 Exclude condition: Subject=30			
	Num. DF	Den. DF	F	p
Design	2	53	11.76107	0.000059
Cart_Exp_Art	1	53	11.83856	0.001139
Design*Cart_Exp_Art	2	53	5.80801	0.005240

Table 4 shows results that did not appear in other questions. Design and Cart_Exp_Art were significantly different and thus can be used in just one complex graph.

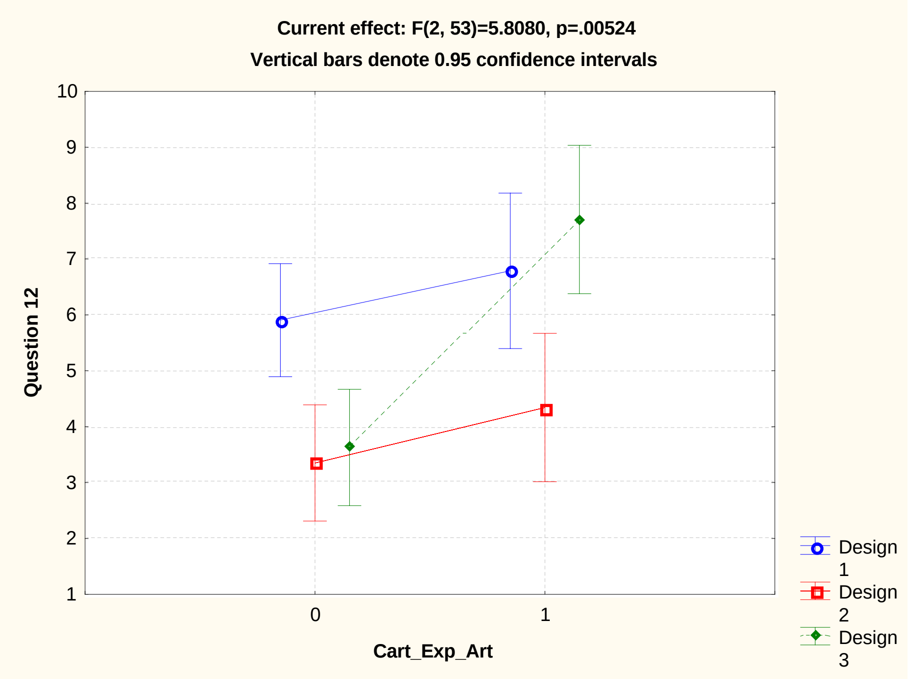

Figure 32. AVS breakdown across Designs and Cart_Exp_Art for question 12. * Design 1 = River 1, Design 2 = River 2, Design 3 = River 3.

Figure 32 shows a trend where subjects experienced in Art cartography gave worse ratings than those not experienced in art. Map 3 was rated significantly differently across the categories of Cart_Exp_Art.

In general, we can say that the best results for Cart_Exp_Art were Rivers 2 and 1, but for non Cart_Exp_Art the best were Rivers 2 and 3.

Mean values indicate the best rated design was River 2.

Question 13:

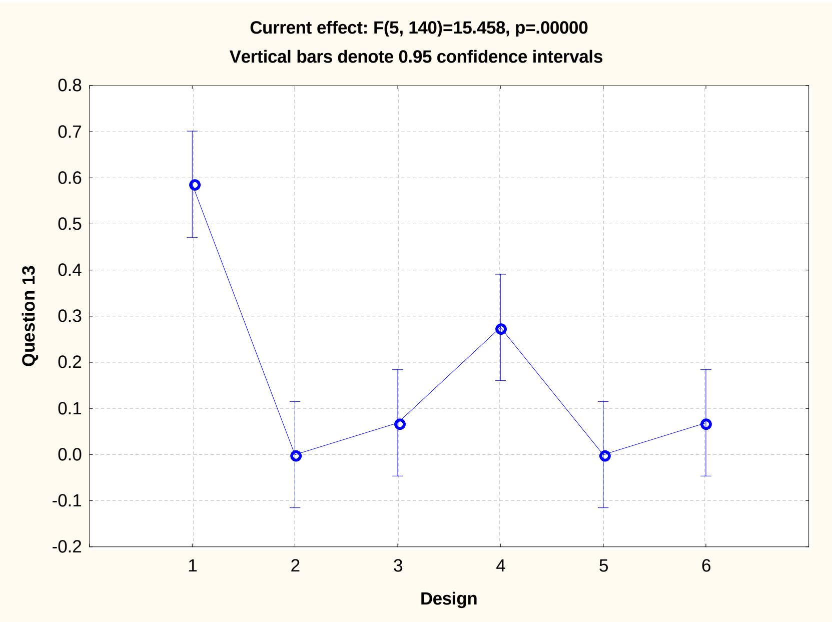

Figure 33. Binary scale per design for question 13.

Map 1 had a significant difference in rating for question 13 (Figure 33). This was the best candidate as the main user interface backdrop map.

4.2 Summary results

Questions 1 and 13 were examined as though their results related to each other, although the questions were formulated from different points of view. The aim was to see whether they would give the same winner and whether respondents could be affected by continuous work across the questionnaire, so that they changed their opinion (see Table 5 and Figure 34).

Questions 2-8 examined the same six maps as questions 1 and 13, but from seven different aspects (*e.g.* colour balance, map correctness, *etc*.), which appeared in particular questions (see Table 7). It is interesting to see how aspects were judged on each individual map, but more interesting to see how the sum of aspects per design affected the ranking of all maps. This let us see map ranking with respect to the aspects that were applied (see Figure 35).

Table 5. Table of effect significance for Figure 34

	Fixed Effect Test for Value (Breakdown) Restricted Maximum Likelihood (REML) Type V decomposition Exclude condition: Selection = "Object" OR Selection = "Aspect" OR Subject = 30			
Effect	Num. DF	Den. DF	F	p
Question	1	307	13.12879	0.000340
Design	5	307	21.70756	0.000000
Question*Design	5	307	0.16722	0.974476

The effect of question and design was significant, but not interactive.

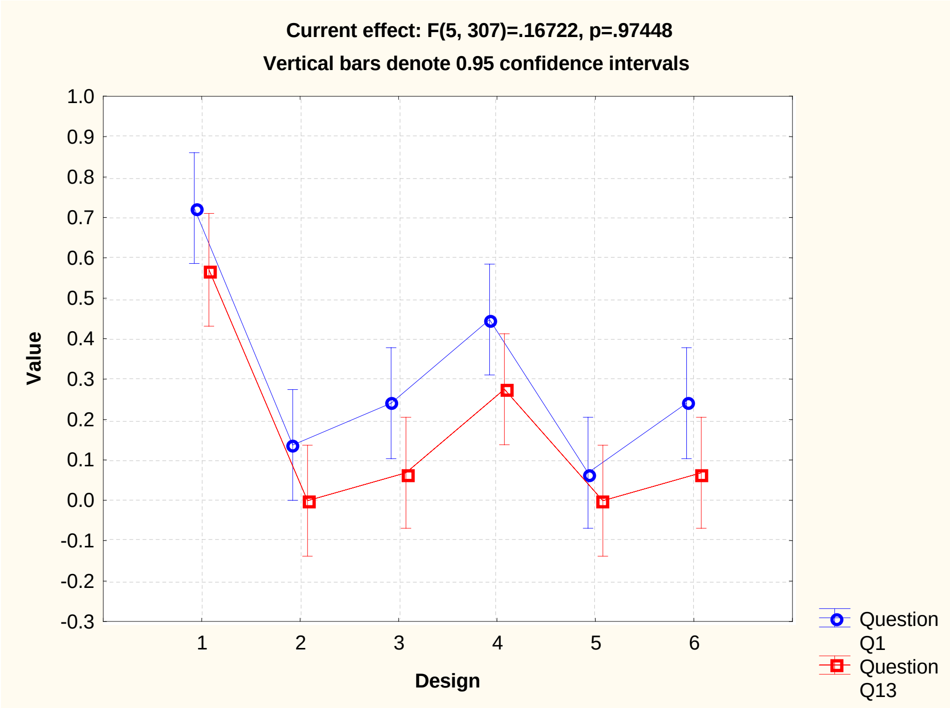

Figure 34. Effect of design across questions 1 and 13.

Table 6. Table of effect significance for Figure 35

Effect	Fixed Effect Test for Value (Breakdown) Restricted Maximum Likelihood (REML) Type V decomposition Exclude condition: Selection = "Object" OR Selection = "Q1" OR Selection = "Q2" OR Subject = 30			
	Num. DF	Den. DF	F	p
Question	7	1315	128.3694	0.000000
Design	5	1315	52.5520	0.000000
Question*Design	35	1315	2.8098	0.000000

Even the interactive effect of factors was statistically significant.

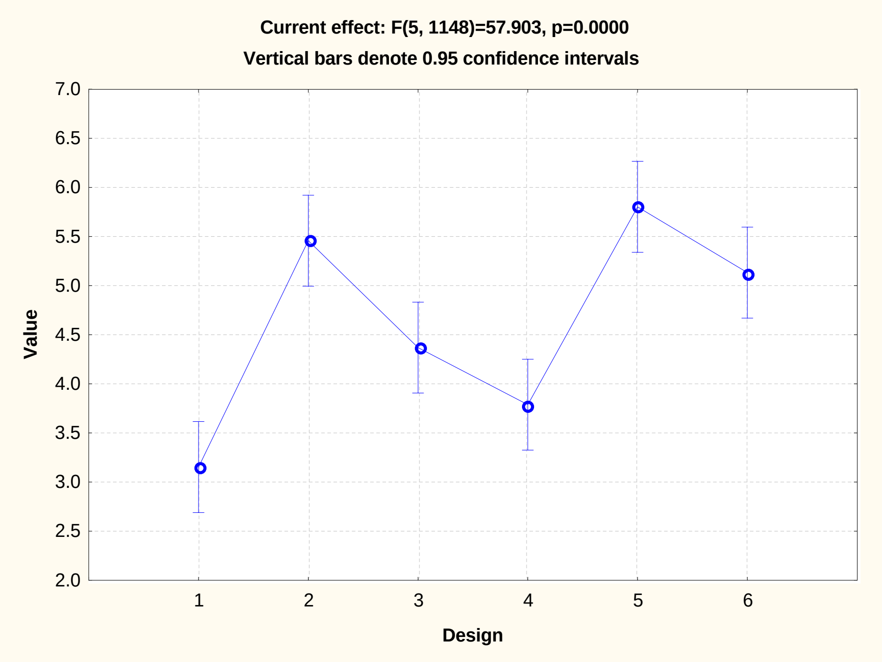

Figure 35. Effect of design on the mean of questions 2-8

By comparing Figures 34 and 35, we conclude that their results are very similar. The least preferred designs had the same trend. This leads us to the interesting conclusion that respondents carried their early opinion through the whole questionnaire.

Since in questions 1 and 13 and 2-8 the same six maps were rated, we were able to compare how perception of overall design differed across perception of averaged single aspects (compare Figures 34 and 35). This means that we were able to estimate which map design had greater importance for subjects with respect to map aspects and also which aspect has greater importance for subjects (see Figure 36, Tables 2 and 3).

A significant difference across questions (i.e. across aspects such as colour balance, map quality, complexity, etc.) would tell which aspect of a map has greater importance. This would indicate what aspects people prioritise in working with a map. Table 7 compares values in the ±95% confidence intervals to find significance aspects. Since most intervals overlapped, there was almost no statistical significance of aspect difference. Only question 3 had a tendency to be significantly different.

Table 7. Mean values and rate of significance within questions 2-8

	Question; LS Means (Breakdown) Current effect: F(6, 1148)=.72485, p=.62963 Type V decomposition Exclude condition: Selection = "Object" OR Selection =					
Cell No.	Question	Value Mean	Value Std.Err.	Value -95.00%	Value +95.00%	N
1	Q2	4.844828	0.242284	4.369459	5.320196	17
2	Q3	4.442529	0.242284	3.967160	4.917897	17
3	Q4	4.666667	0.242284	4.191298	5.142035	17
4	Q5	4.580460	0.242284	4.105091	5.055828	17
5	Q6	4.649425	0.242284	4.174057	5.124794	17
6	Q7	4.586207	0.242284	4.110838	5.061576	17
7	Q8	4.551724	0.242284	4.076355	5.027093	17

From Figure 36 (breakdown across questions and design) we can see how the rank of each design changed through questions 2 - 8 (aspects) and where different views were given on maps.

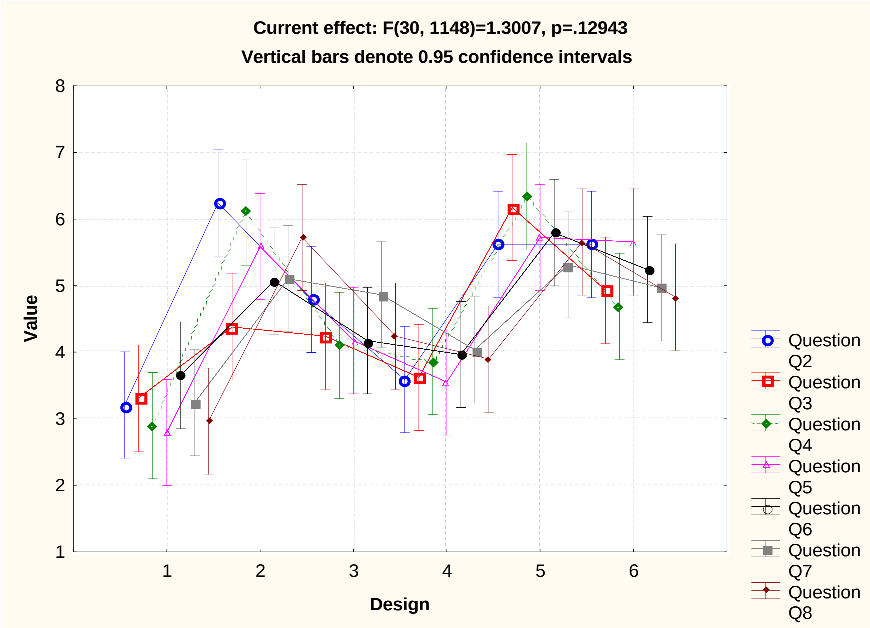

Figure 36. Effect of design across questions 2-8

The graph of Fig. 36 seems reasonably well correlated since map aspects (particular questions) had very similar trends within designs. This graph is a version of Figure 35, but in greater detail. It can be seen that rank of map aspects (concerning mean values and overlapping level of confidence) do not change much across Maps 1-6, and also that aspects follow very similar ratings within maps. This means, as we can see from Table 7 (also Table 3), that aspects were equally important for subjects. They also rated all designs with similar trends.

The last analysis was to test the effect of experience on processing time of questions.

Table 8. Effect of factors on time spent answering questions

Effect of experience on time				
	Beginner	Expert	GIS_Beg/GIS_Exp	Cart_Beg/Cart_Exp
p-value	0.97	0.08	0.08	0.98

As shown in Table 8, there was no significant effect of beginners and cartography beginners/cartography experience on time, but there was a tendency towards time-dependence regarding Expert and GIS beginner/GIS experienced.

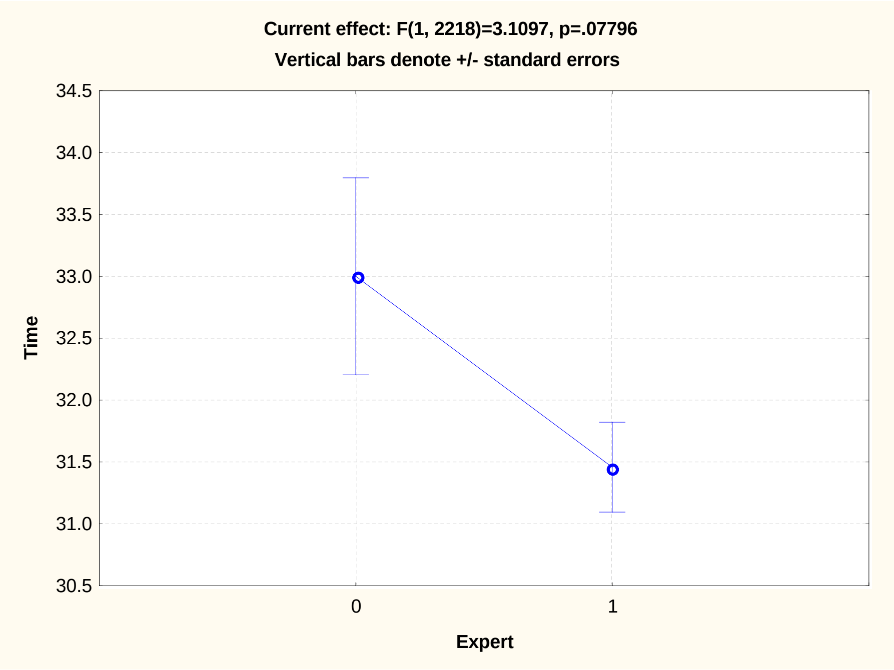

Figure 37. Effect of factor Expert on time spent answering questions. * Expert = 1 (experienced and professional in Cartography and GIS), Beginner = 0 (Beginner in Cartography and GIS)

Experts were on average faster in completing the questionnaire than beginners (Figure 37). The mean time for all subjects lay in a range from 31.5 min to 33 min, or approx. 32 min. A lot of people worked for 60 minutes and others for around 20. A few respondents answered the questions in 10 minutes.

Confidence level was wider for beginners, because the group of beginners was much smaller than the group of experts.

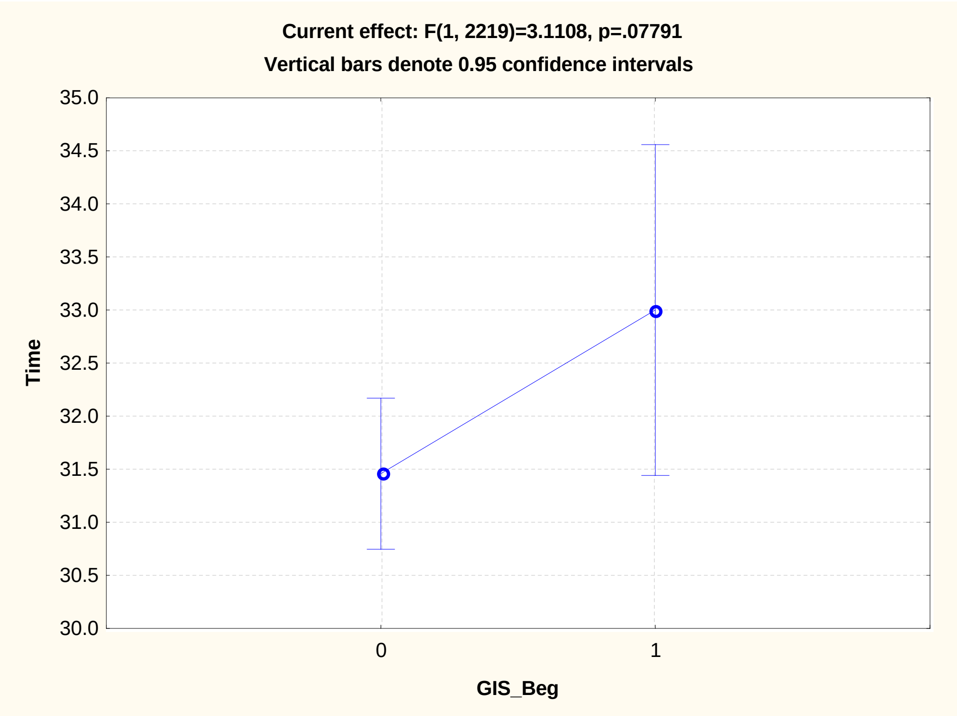

Figure 38. Effect of factor GIS_Beg on time spent answering questions. * GIS_Beginner = 1, GIS_Exp = 0 (cartography experience + GIS_Pro + GIS_Exp)

GIS beginners took few more minutes on average than the GIS_Exp (the others).

5 Discussion

The results show a significant effect of factors in choosing map design quality with respect to needs (prioritising experience or not). Careful consideration has to be given to preferences and the type of subjects concerned. In this case we would expect to have no high priority on experience, since potential users can have different skills and experience. In addition, level of experience was found to be significant for much fewer questions than design. With respect to this finding, Design is the most important in the process of map generation.

The result of map aspect preference (preference of map attributes, such as colour balance, map clarity, *etc.*) turned out not to be significant for the end-users, since they judged all aspects in a same way. For this reason, we would not choose to prioritise any aspect mentioned in questions 2-8 during the map design and probably handle them as equal attributes of the map. However, it has to be mentioned that the results were potentially biased since the sample of subjects was unbalanced with respect to factors such as GIS experience etc.

Some weaknesses appeared from respondents' comments. It seems that some of them preferred more discrete colours, although colour brightness has an impact on spatial distinction. The question is what is more important for the project: Is it preferable to show map features distinguished by colour hues, or is there some other method that would give the same effect as colour and would not be so disturbing for the sensitive eye of the user? Is it necessary at all to make colour transitions so sharp for cognitive abilities? This could be discussed later with project leaders or possibly form the basis for another study.

On some semitransparent multilayer maps, problems arose with depiction of colour, which seemed to change into darker shades. An example is 'land-cover' layer and the overlapping layer of 'hill-shading'. This has already been commented upon in the Methods section. The effect can be confusing for users and for that reason those maps should be used with special care.

As mentioned above, some source data were not of the best quality, being either old or not in the exact position. Sometimes two layers differed in relative position by tens of metres. This is probably a question for the project leader to decide the size of deviations that can be accepted without confusing users too seriously. From a practical point of view there should not be any major problem in using these displaced data, but for closer views it would be convenient to use high resolution aerial pictures. It has to be decided whether to invest more money for better source data, wait for free new data, or be satisfied with the data that are currently available.

Better source data can be very demanding in terms of server capacity and can cause slow processing of data. Therefore consideration should be given to how many and which layers are necessary, which can be done with help of these test results.

At present, the Cadastral Authority of Sweden (Lantmäteriet) is working on a new system for airborne laser scanning, from which the result will be a new Digital Elevation Model (DEM). DEM will have much higher resolution in which the altitude standard error is better than 0.5 m for grid points in a 2-metre grid. This can take a few more years, but it would make the whole map creation process much more accurate and the maps more attractive.

During the processing of map and object solutions, models were compiled that could be reused for generating particular geographic features like those tested here. These models were unfortunately in some cases not sufficiently compact and probably too complicated. For the future, it would be good to work on simpler features which could easily be applied on the whole area.

The responses to the questionnaire included a request to have Sami place names on the map too, since the Sami constitute a significant minority living in the North of Sweden. This is a matter for the future and was not considered important within the scope of this thesis.

Cartography work during the design period was carried out with the best impression of map reality and perception of user needs. The observations (results) and results above indicate that the subjective opinion of the cartographer (author) in this thesis was not the same as public opinion. Personal experience in this case was to realise slightly different opinions within map preference. The author's personal opinion about the best map was that it was Map 1 or 2, but in fact Map 2 was rated one of the worst by respondents. However, Map 1 seemed to be a good match and was designed to truly depict the reality as much as possible. Map 1 reflects land cover with realistic colours pleasant to the eye, terrain modelling and positioning points (roads, railway). These map properties seem to be preferred and, as was mentioned earlier, also demanded by users.

In the questionnaire there were some weaknesses. The not-so-independent questions together with the uneven number of participants on levels of experience levels caused problems with overlapping confidence levels in some cases. Therefore some results were not produced with high confidence.

Permanent or temporary geographic objects resulting from scientific work (like monitoring equipment) were not included in this thesis, although they are good positioning points. They require special attention to each case separately, which is also time-consuming. It is also more than adequate to check the location of installations with PIs (principal investigators) leading the research work in particular fields.

'Multimedia technology changes the visualisation of spatial data'. At present, traditional presentation of spatial data is often followed by other media such as 'pictures, animation, sound and video'. With such media, we can see the information that is communicated (Dransch, 2000). This also gives an idea on how the user interface could be modified and improved. There is a need for spatial data visualisation and an attractive display to capture the interest of the end-user. These media could be good instruments to use for future information systems.

6 Final conclusions

Our results showed that Map 1 was the most favourite backdrop map and was rated highly throughout the entire questionnaire. This topographical map was a simple 3D model of terrain with land cover features, which was perceived as a good representation of reality. When broken down to the level of map constituents (mountain top, valley, lake, river), it is obvious that people preferred more complex but clear maps. The best rated geographical objects for mountain top, valley, lake and river were objects 1, 1, 2, and 2, respectively.

An interesting observation was made about the six designs when examined from the point of map preference in questions 1 and 13. Statistical analysis showed that people had the same opinion about Maps 1-6 in the beginning and at the end of the questionnaire, perhaps since their opinion was set at the beginning.

Classification of preferred aspects of maps (map clarity, colour balance, correctness, etc.) proved to be non-significant. This means that no aspect could be considered more important.

Map design, as a factor, had the strongest significance of any effect on subjects' decision-making, being mentioned through all questions. Other factors appeared significant in a few cases, but overall there was no reliable trend.

It was found that experience had no strong significance on the time spent answering questions. There was a tendency, although not significant, for a difference between 'experts' (those with experience and experts) and GIS beginners. However, there were many more experts than beginners, *i.e.* a low level of confidence for beginners.

The issues identified here could probably form the basis for further studies or provide inspiration for future work. They may also play a role during the selection of appropriate backdrop raster maps and shapefile layers for the user interface of AbiskoGIS.

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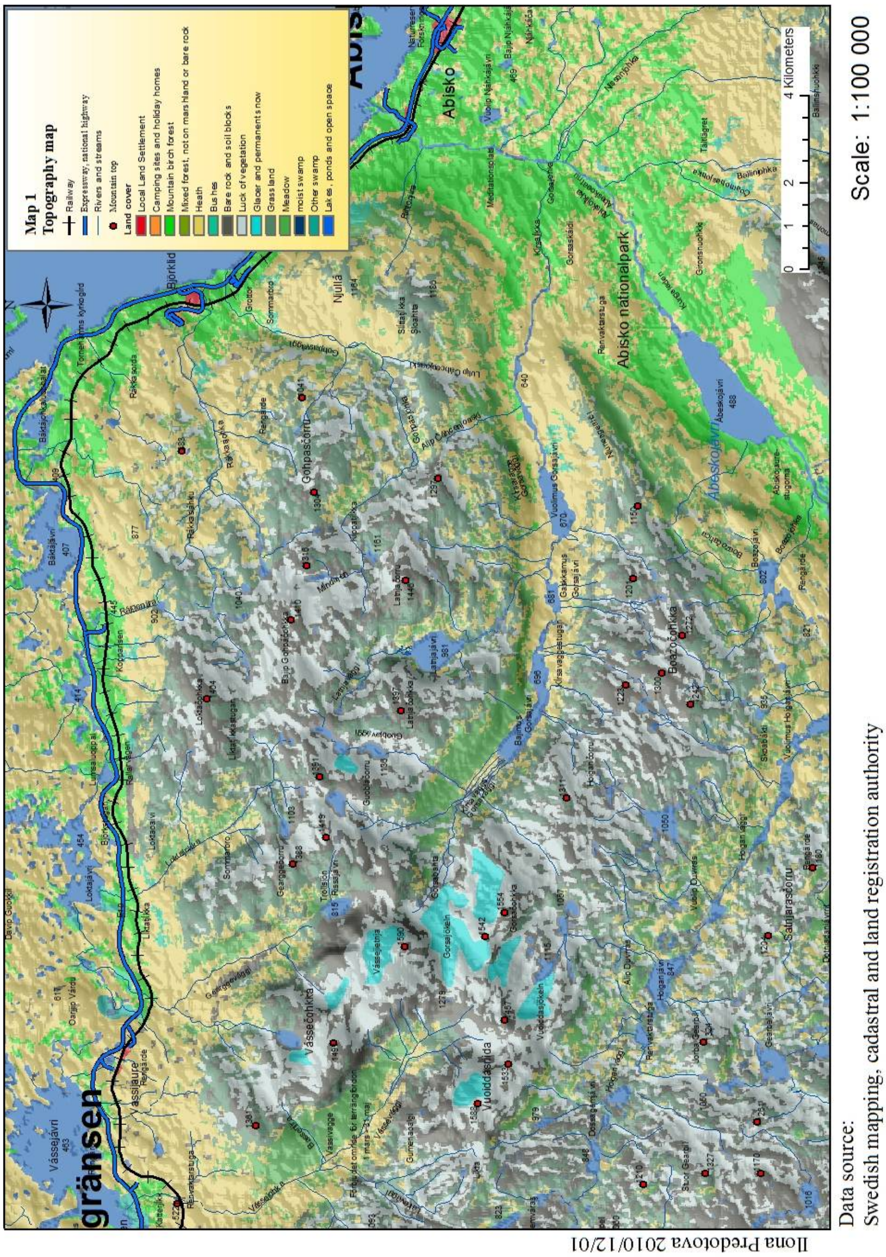
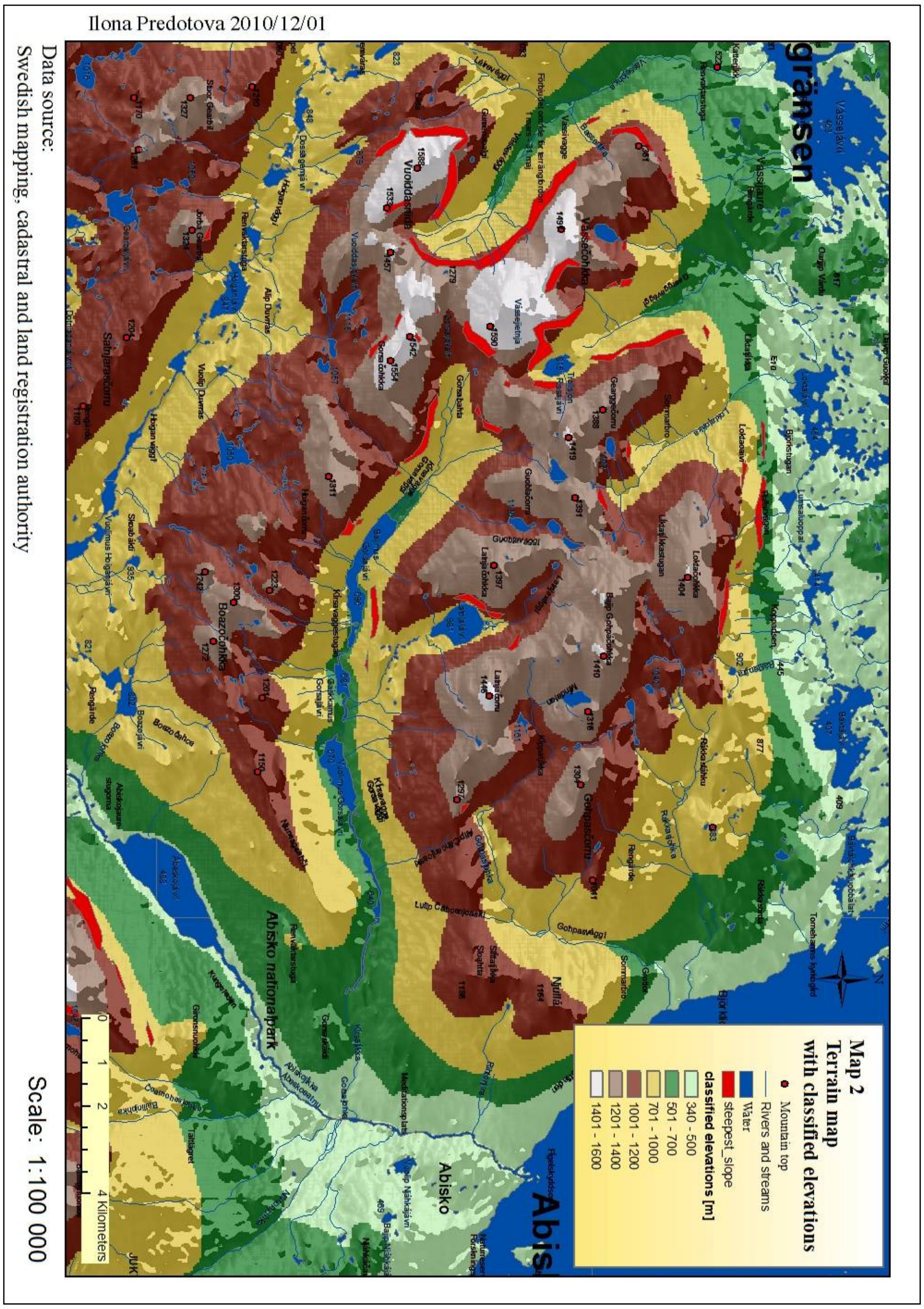
Appendix 1

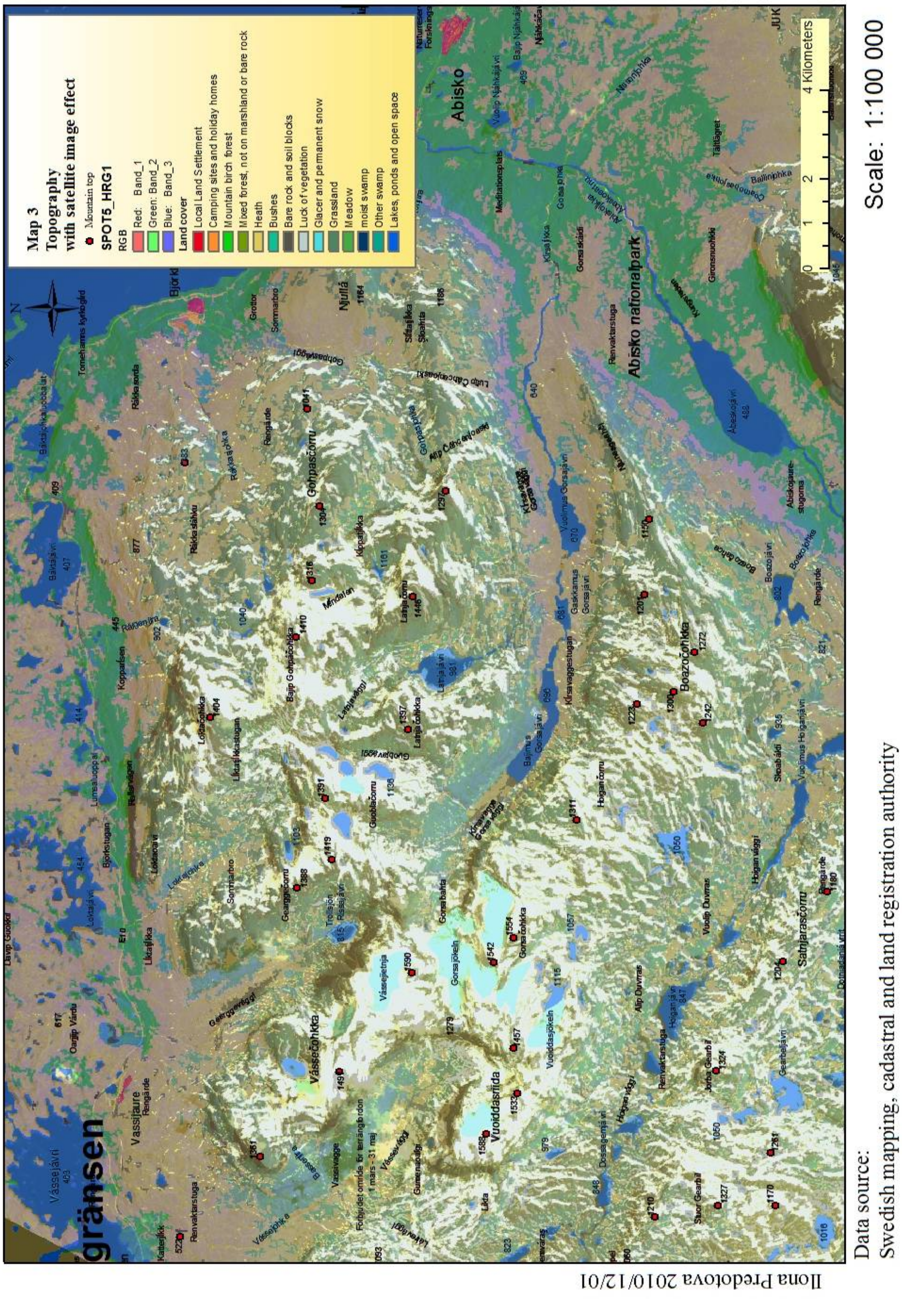
Map designs



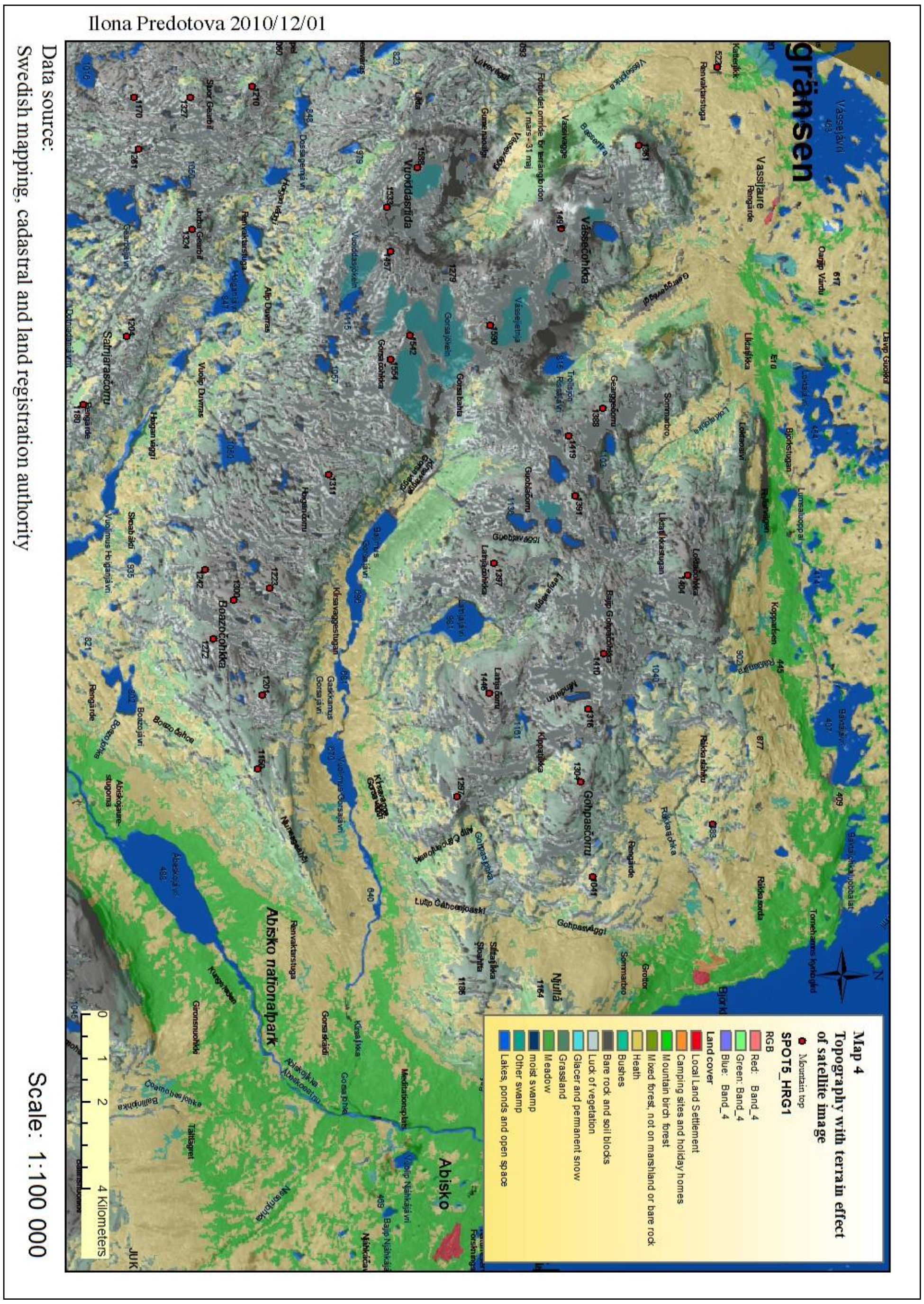
Map 1, topography map



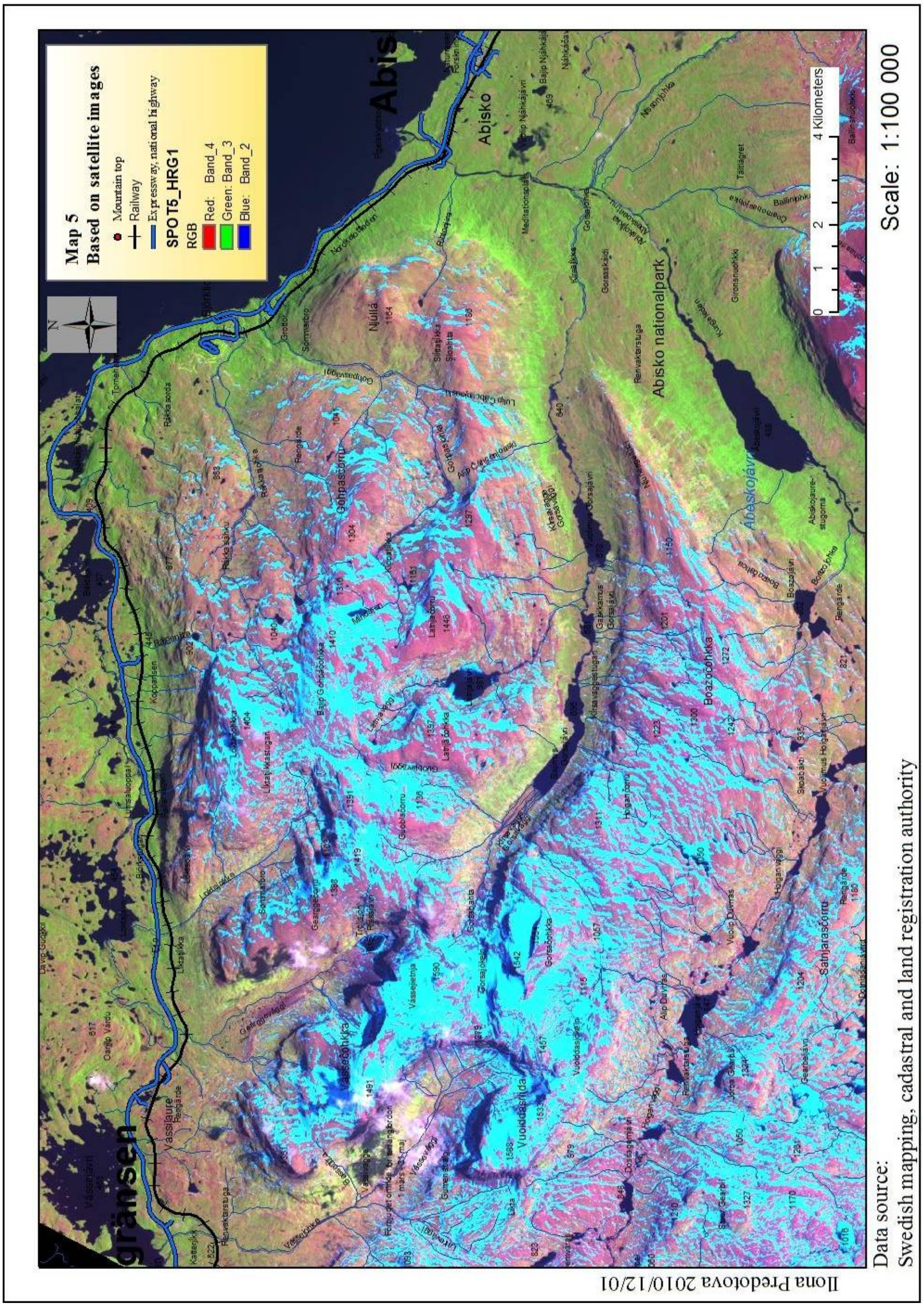
Map 2, terrain map with classified elevation



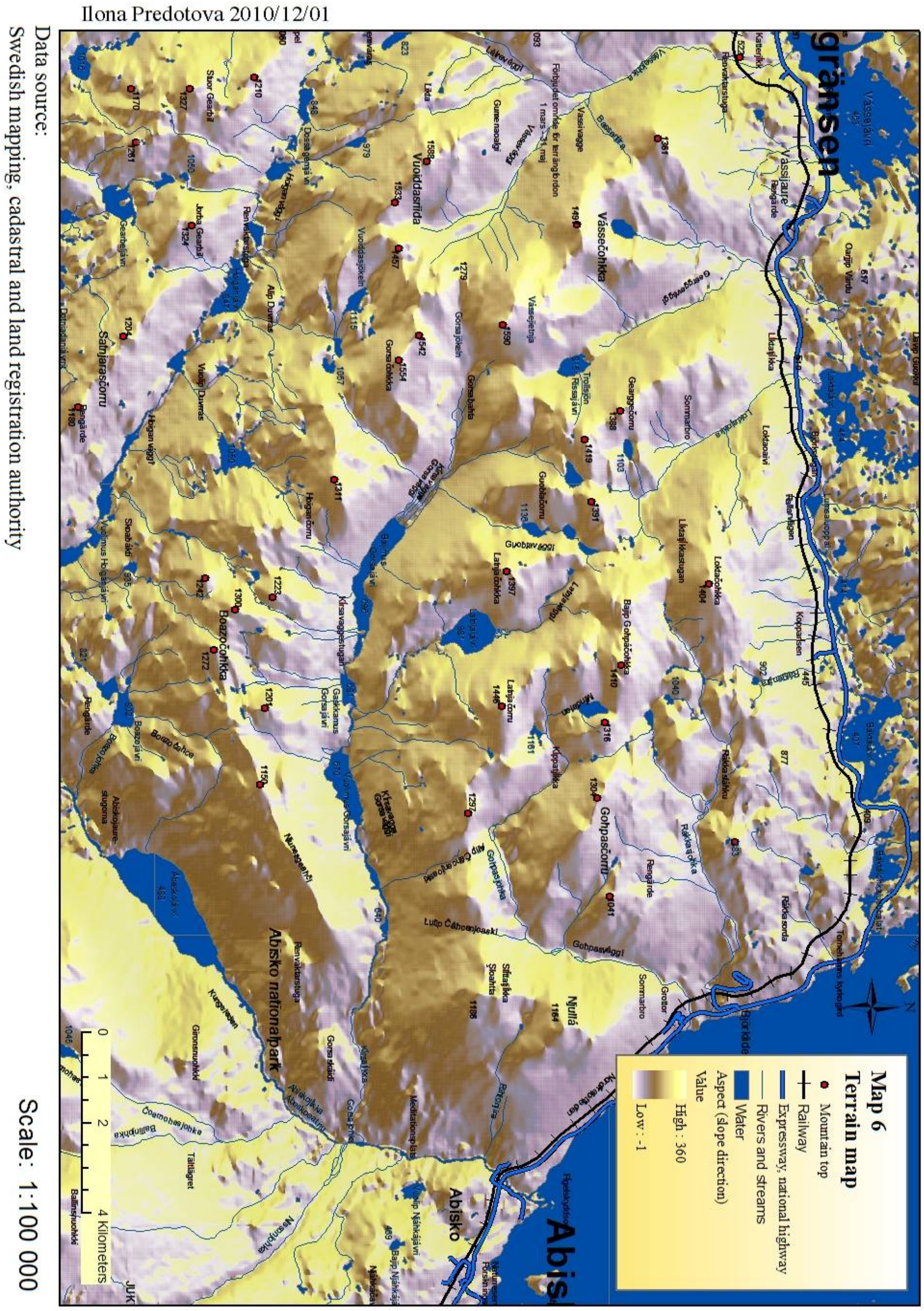
Map 3, topography with satellite image effect



Map 4, topography with terrain effect of satellite image

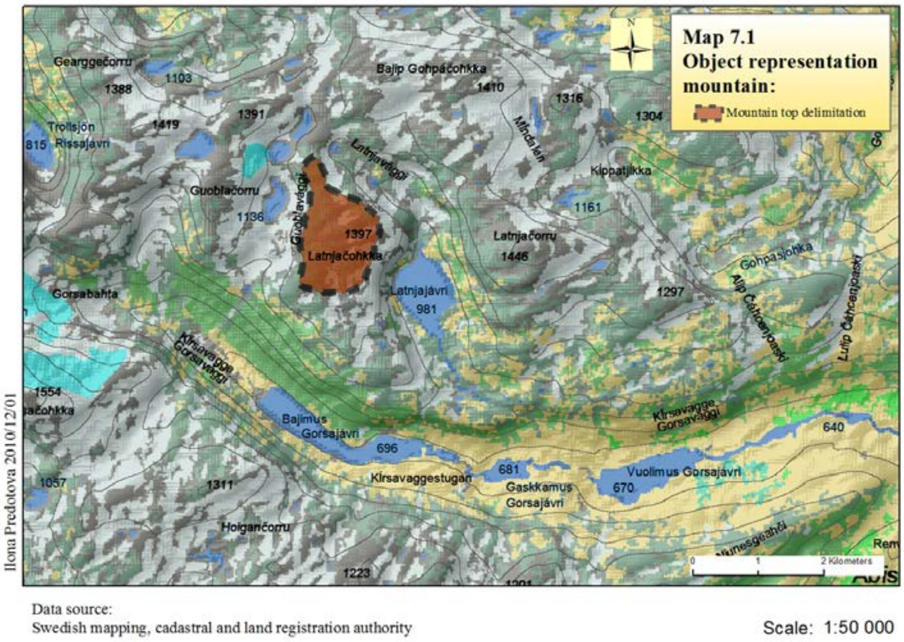


Map 5, based on satellite images

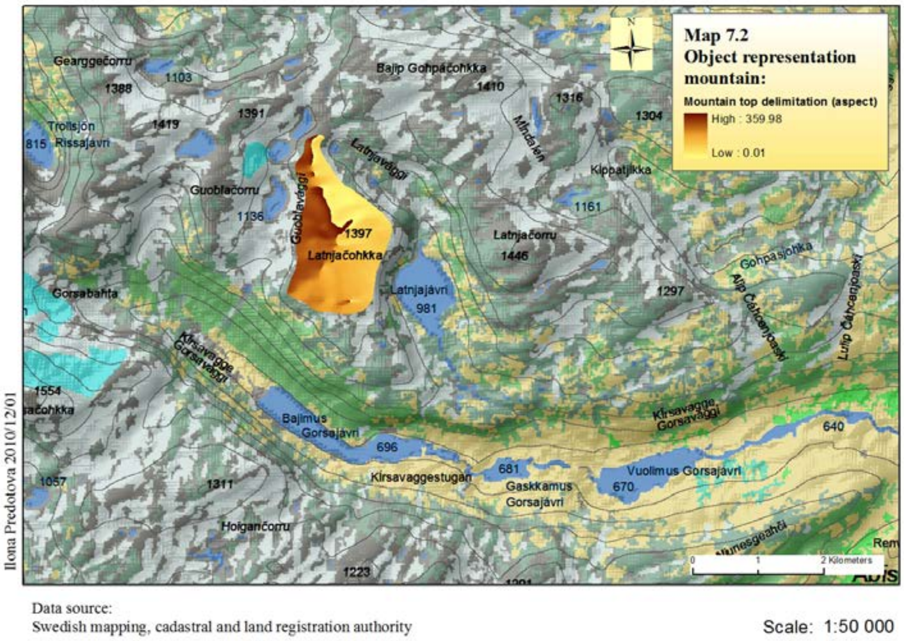


Map 6, terrain map

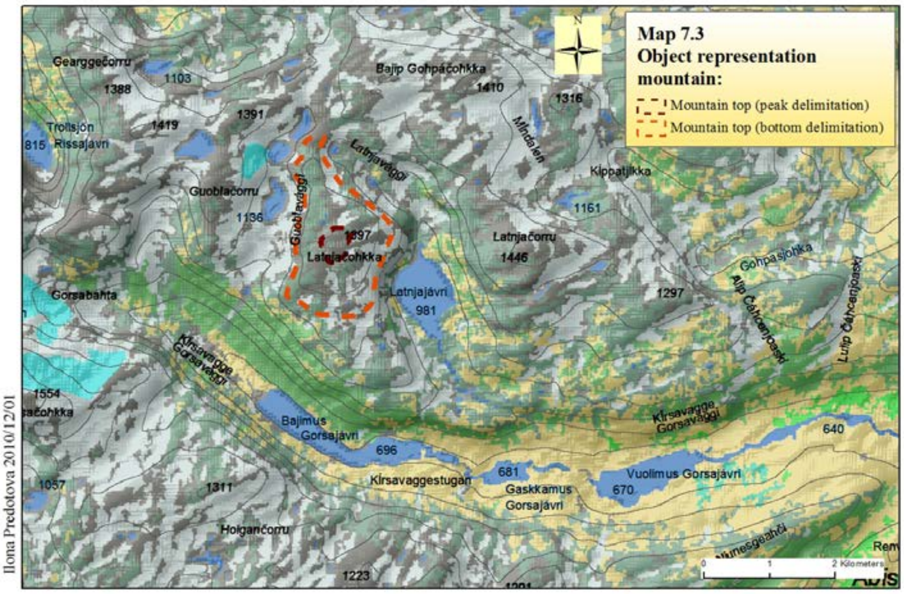
Geo-object designs on Map 1



Top 1, mountain representation



Top 2, mountain representation



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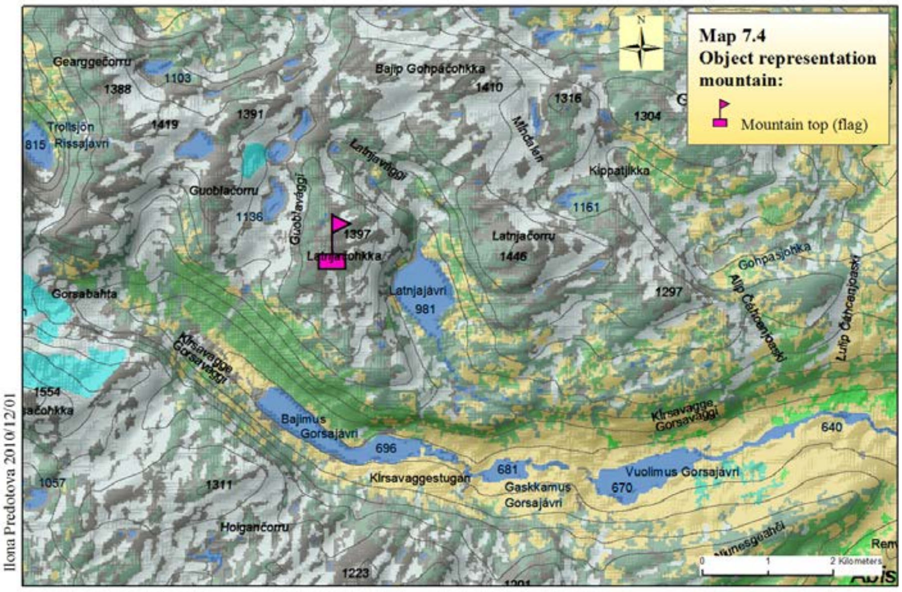
Top 3, mountain representation



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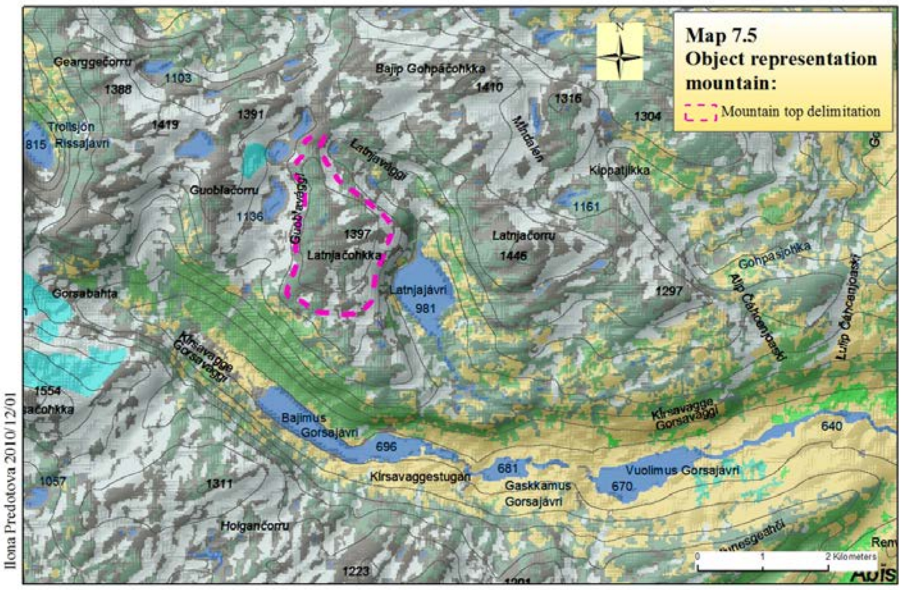
Top 4, mountain representation



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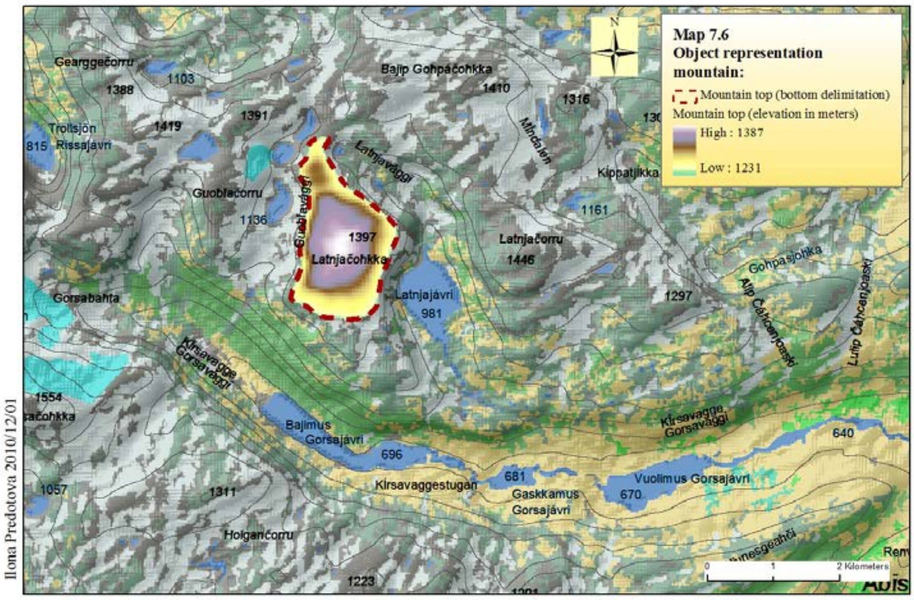
Top 5, mountain representation



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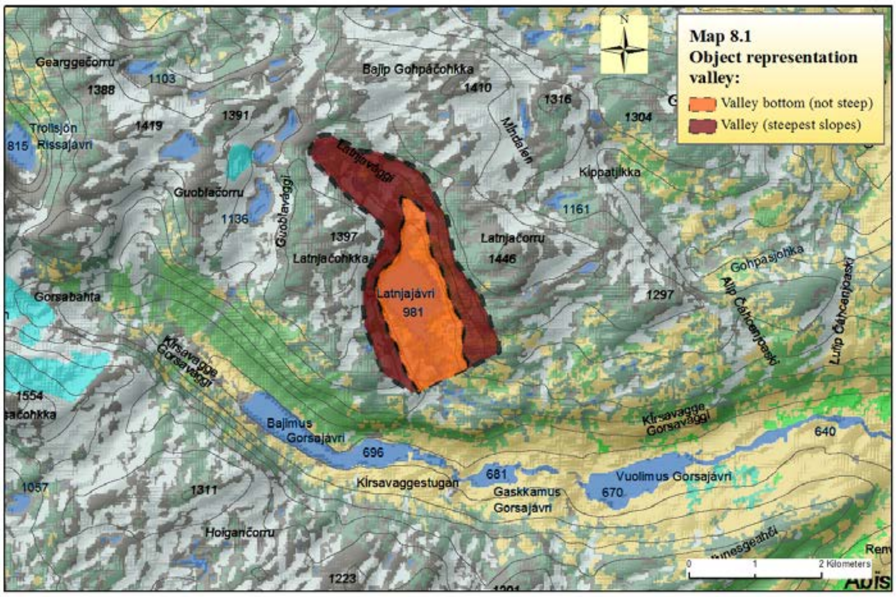
Top 6, mountain representation



Ilona Predotova 2010/12/01

Data source:
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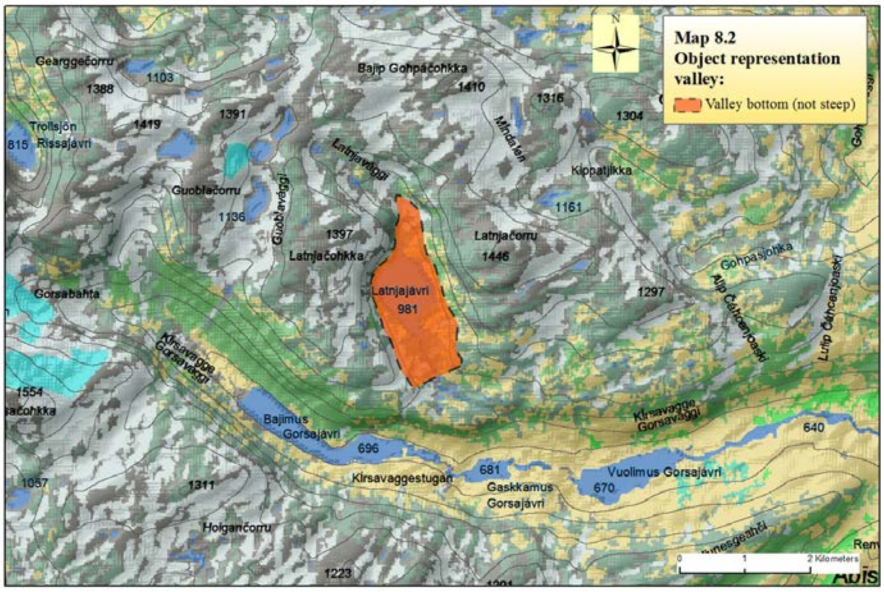
Valley 1, valley representation



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Data source:
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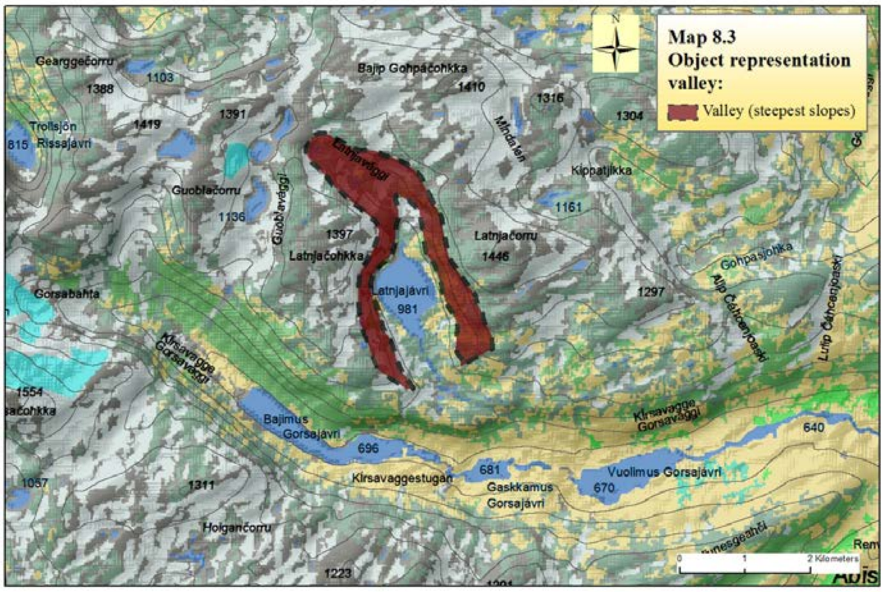
Scale: 1:50 000

Valley 2, valley representation



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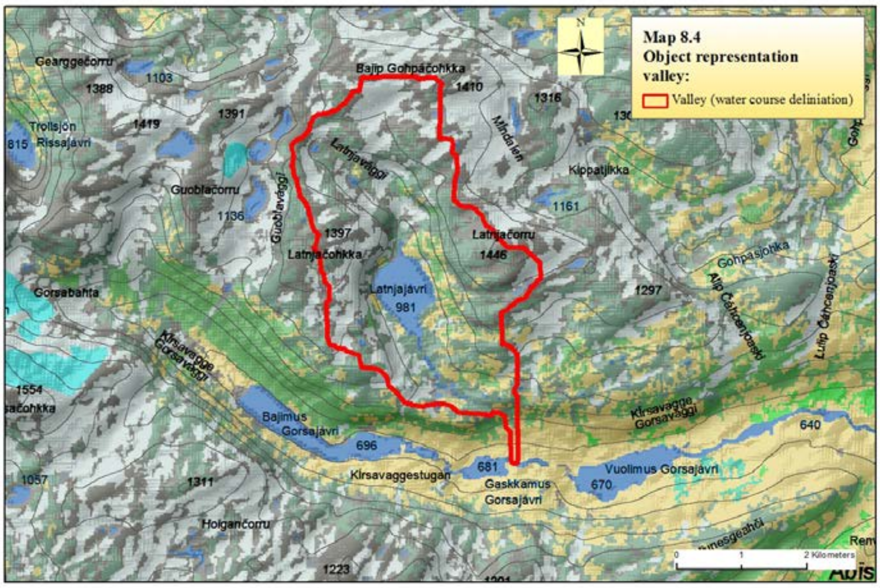
Valley 3, valley representation



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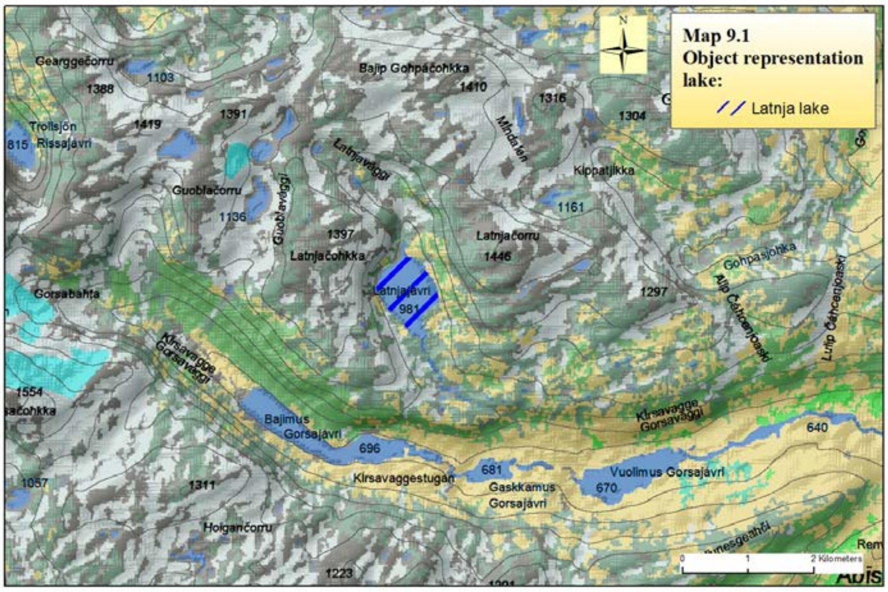
Valley 4, valley representation



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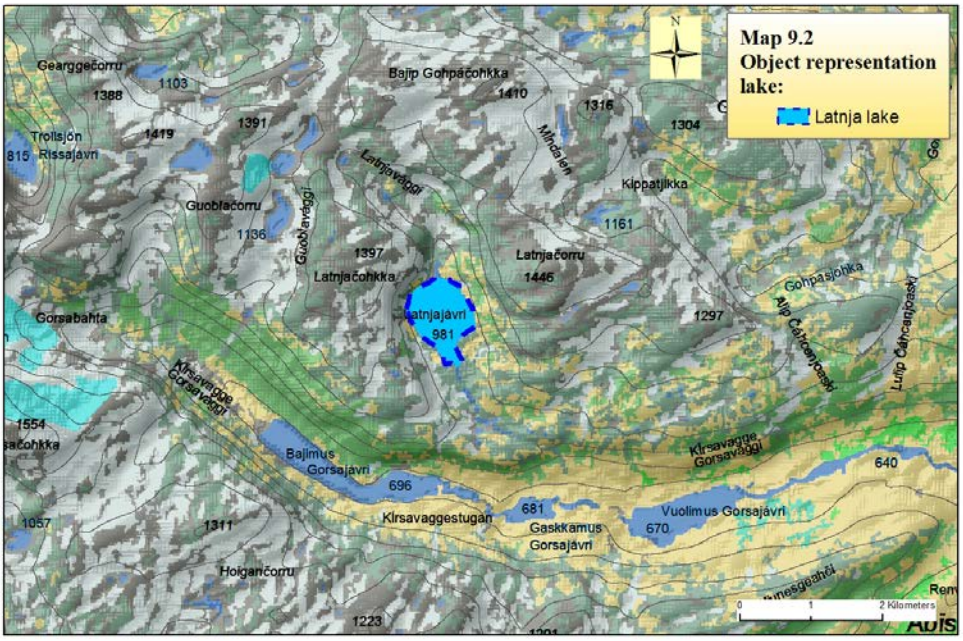
Lake 1, lake representation



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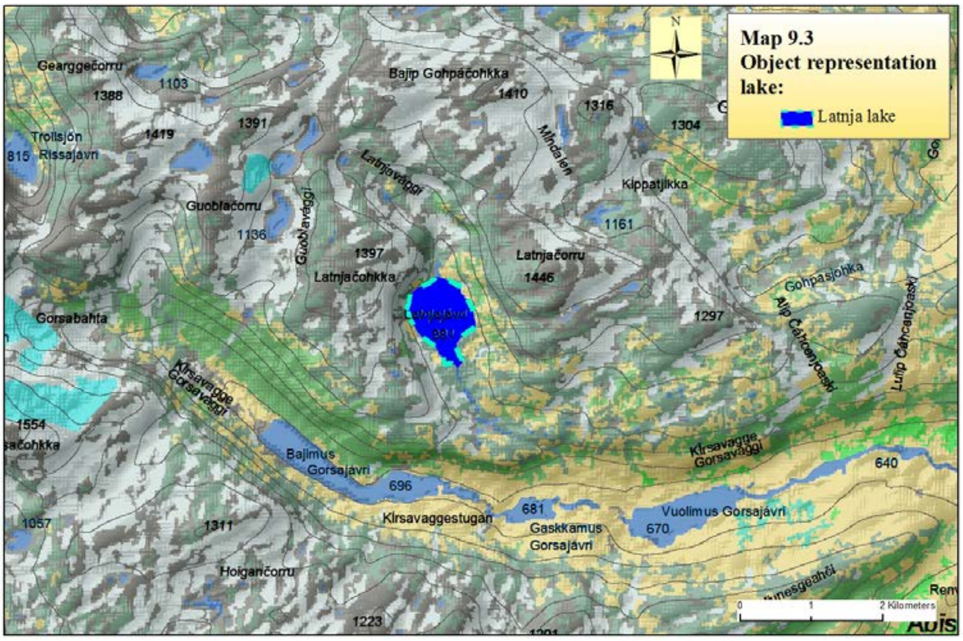
Lake 2, lake representation



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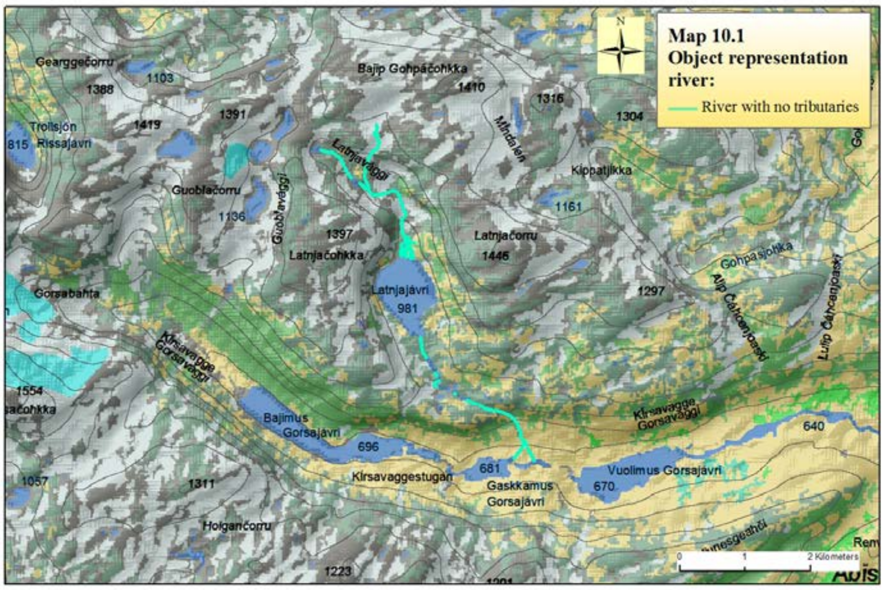
Lake 3, lake representation



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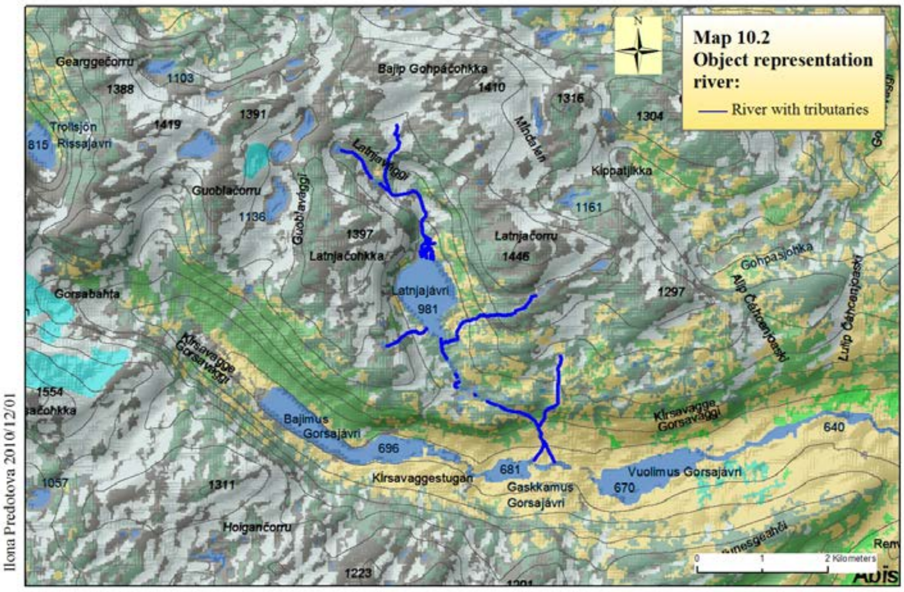
River 1, river representation



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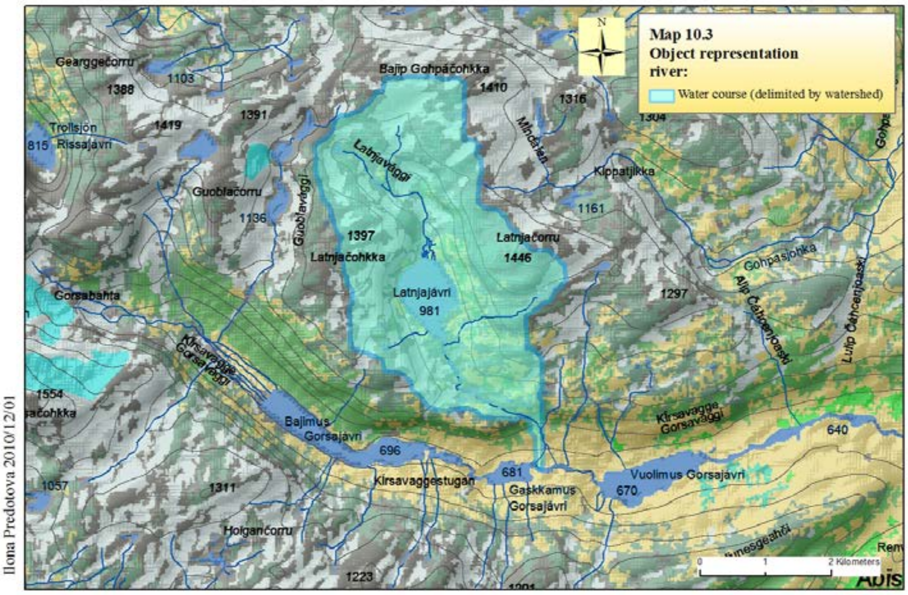
River 2, river representation



Data source:
Swedish mapping, cadastral and land registration authority

Scale: 1:50 000

River 3, river representation

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