

TRIGLAV NATIONAL PARK HISTORICAL MAPS ANALYSIS

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Abstract: *Triglav National Park has been on the frontier of empires most of the time and borders delineation has been a constant issue. The historical maps are commonly the most important database for various spatial analyses of the historical landscapes, urban development, influences of the economy development, toponymes changes, land use, etc. Principal data sources for our study are Austrian maps from the end of 18th century, Italian and Yugoslav maps from the mid 20th century and Slovenian maps from the end of 20th century. Major drawbacks are uncommon map legends together with different techniques of cartography even in the same time and poor knowledge of projections used. The other problems include low details for the mountainous area. We decided to analyse old cartographic techniques and to establish methodology for georeferencing and mosaicking for our purposes. GIS-based study is going to use the historical maps to analyse social processes such as depopulation, deagrarianization and urbanization, as well as tourism development and political influences through the examination of land use changes as a part of Interreg IIIB, SISTEMaPARC European project in the near future.*

INTRODUCTION

Triglav National Park covers an area of 838 km² and is one of the oldest and largest national parks in Europe. At least four different countries have claimed and divided the region in the last two hundred years. The park has been on the frontier of countries most of the time and borders delineation has been a constant issue. Cartographical methods and techniques of the area have consequently varied widely in time and space. Nevertheless, the historical maps are commonly the most important database for various spatial analyses of the historical landscapes, urban development, influences of the economy development and wars, toponymes and land use changes, map production technology, etc.

Nowadays more and more reprinted or scanned old maps of different sources, covering the territory of Slovenia, are available (Korošec 1974, Rajšp 1996, NLS 2002, NUK 2004, ARS 2004). Big progress has been done with increasing the accessibility of the old maps but interpretation of such datasets is possible only visually: comparing two or more datasets laying beside each other. Combination with other maps using transparent overlaying principles is impossible. The powerful solution is transformation the scanned maps to the common coordinate system, to georeference them. With this approach, the maps can be combined also with the satellite images, orthophotos, modern digital raster and vector maps, databases as digital elevation models (DEMs), land covers, land cadastre maps, urban plans and other thematic layers. For example, Franciscan cadastre can be combined with current cadastre data. These two layers could be analysed also regarding pedology, exposition of landscape (using DEM), aerial photographs from last half of previous century, documents of evaluation of cadastre incomes, etc. Such approach enables plenty of spatial analyses using common geographical information systems (GIS) tools. Its also make possible time series analyses and powerful visualisations using different visual effects and 3D techniques. With vectorisation or advanced methods of reclassification of historical maps to acquire specific thematic data layers could be employed more sophisticated spatial analyses (Podobnikar and Šinkovec 2004).

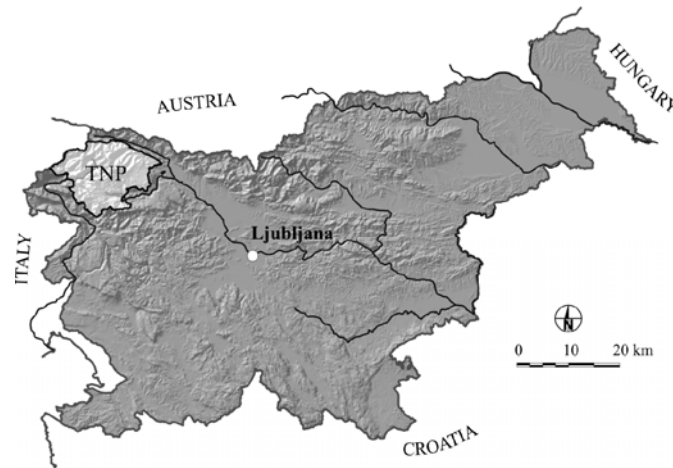


Figure 1: Location of Triglav National Park (TNP) in Slovenia.

Principal data sources for our study are Austrian military survey maps (Josephine military topography) from the end of 18th century, Italian, Yugoslav and Slovenian maps of scale 1:25,000, from the beginning to the end of 20th century. Major drawbacks are twofold. On one hand, they are systematic and include uncommon object catalogues (map legends), different techniques of cartography (in the same period) and lack of projection and transformation parameters. For example, origins of cartographic projections are based on Paris, Rome, Greenwich, the Ferro Island, and other local origins. Another problem is emphasized by rugged terrain and by the common lower importance of details for the mountainous area. Therefore, the area is sparsely measured and less accurately mapped, especially on the oldest maps. Many cartographic details show that the maps are more pieces of art than technical work. The details are not measured or they are succumbed to gross errors. The entire conglomerate of uncertainties is not simple to consider, especially when those old maps used as a rich spatial database within GIS. We decided to analyse the old cartographic techniques and establish methodology for georeferencing and later mosaicking of the maps at different scales.

Our GIS-based study assess the usability of historical maps to analyse social processes such as depopulation, deagrarization and urbanization, as well as tourism development and political influences (border changes), through the examination of land use changes as they are a major indicator of human impact on environment. Incorporation of the maps into a GIS will broaden the spectre of possible analysis and make the results comparison of similar studies, undertaken as a part of Interreg IIIB, SISTEMaPARC program, possible.

HISTORICAL MAPS USED IN THE STUDY

The first presentations of the Earth's landscape originate from at least 30,000 years ago when the people got capability to express themselves with symbols. For more effective presentation, geometrically and metrically correct presentations were demanded. It seems that need of land surveying is based on demands for measuring the land for agriculture purposes from around 5000 years ago (Čeh 2002). These are foundations for cartography as science and technology.

Historical maps were produced with various data acquisition techniques regarding development of cartography and land surveying techniques. Very important factor for the quality the final maps was the purpose of mapping. In general the quality of military mapping and mapping for land tax collection was much better than other, which is not surprising considering the budget and interest. In the paper, historical topographical maps are divided regarding time-scale spatial analyses. The stages are three: ~1800, ~1930, and ~2000. We tried to find maps in two different scales for the analyses at every stage. For the entire area of entire Triglav National Park desired scale was 1:25,000 to 1:50,000 and for selected case study areas we tried to find maps in scale around the 1:5000. The selected case study areas were Bohinj Alpine pastures and lake area, Pokljuka high moors and area around Čadrg village.

~1800

Josephine military topography 1:28,800

In 1763, just after Austro-Hungarian monarchy lost the war against Prussia (Grabnar 1994), empress Maria-Theresa gave an order to produce military topographic maps of the entire monarchy. Her son, Emperor Joseph I, supported and finished these mapping in 1787 that lasted a very short time. This mapping and surveying was the first measurement of the whole territory of Slovenia (Triglav 2003). The 1st mapping was done without precise (geodetic) surveying measurements and cartographic projection. Accuracy may differ from area to area as a result of different landscape characteristics, variable time periods and quality of mapping, etc. Insufficient quality of maps from 1st military mapping led to new surveys in the 19th century by the emperor Franz II. The 2nd military mapping is considered as relatively accurate, based on good geodetic and surveying foundation. This mapping was done from 1807 to 1869 (Zimová et al. 2006) on the basis of common terrain measurements of land cadastre and maps for topographical purposes (Korošec 1974). There was also a 3rd military survey. Both, 2nd and 3rd military mapping were so precise surveyed that unique transformation parameters could be obtained for larger area. These military maps are locked in Vienna archives; however there is hope that they will be soon accessible to scholars. Some characteristics of the Josephine military maps:

- mapping period 1763–1787,
- they cover a whole territory of the former Austro-Hungarian monarchy,
- Casini-Soldner equidistant cartographic projection (transverse cylindrical),
- positional error is worse than 250 m regarding our experiences and Zimová et al. (2006) (theoretically 15 to 50 m); precision and accuracy is low especially in the mountainous area
- nice cartography, less precise (very “creative”)
- difficult to interpret land use, except for rivers, roads, build up and in places forest
- control points used for georeferencing were mostly churches, some characteristic bridges, towers and seldom distinguishable summits (we were very attentive to possible landscape changes and aware that the highest peaks in the Alps were still not scaled and most of areas have not been reached).

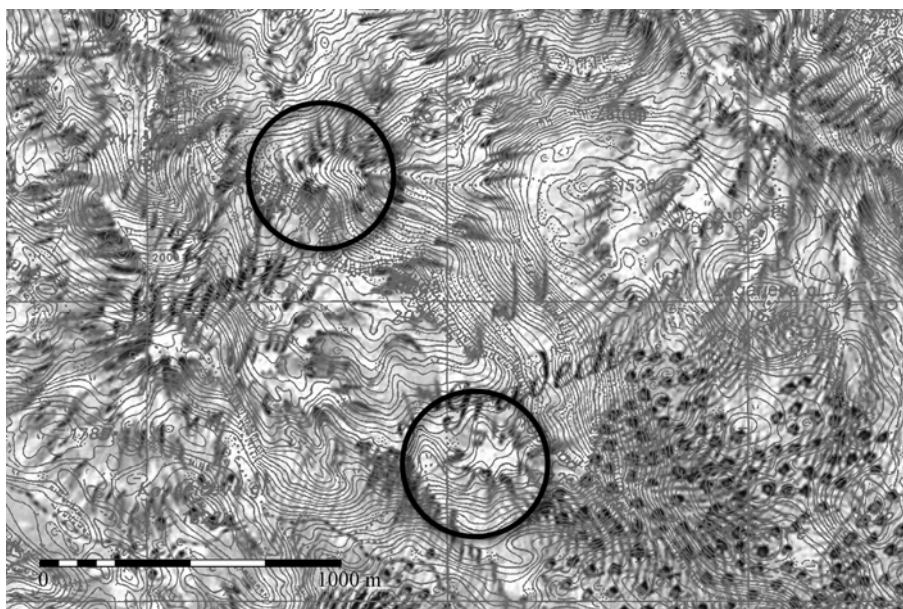


Figure 2: Some peaks evident on the Josephine military maps can not be identified on contemporary maps. One of the reasons is that that time most of the peaks (including Triglav) were not climbed yet.

Franciscan cadastre 1:720 to 1:5760 (large scale for case study)

The oldest official land register in the territory of today's Slovenia is the Franciscan cadastre from the first half of the 19th century. It distinguishes six basic land categories or types of land use (road and housing, field, meadow, pasture, forest, and vineyard) as well as land with mixed use and land with special use (for example moor or quarry). The main scale was 1:2880. For mountainous area scale 1:5760 and for cities 1:1440 or 1:720

was used. The Franciscan cadastre was produced in Cassini cartographic projection, with Krim coordinate system (in Vienna fathoms or later in meters) as the origin of measurements in the most present Slovenia. Later, Gauss-Krueger cartographic projection was adopted on the bases of the Bessel ellipsoid. Some characteristics of the maps:

- mapping period 1823–1826 for Kranjska region, where Triglav National Park is (Triglav 2003)
- maps cover a whole territory of former Austro-Hungarian monarchy
- Cassini cartographic projection with the origin on the Krim mountain (in places in local coordinate systems)
- positional error is approximately 10 m
- borders between map sheets are not on the edges of maps, but on the limits between cadastral communes
- control points of contemporary borders of cadastral communes were used for georeferencing; around 90% of the border hadn't been changed until present time



















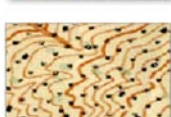

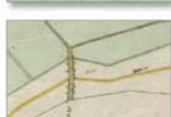

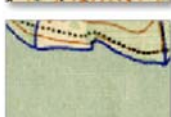
~1930

Yugoslav maps 1:50,000

- mapping period 1934–1937
- cover the whole Triglav National Park area
- Gauss-Krueger projection, meridian of origin is Greenwich, maps are mapped mostly in the 5th zone and partly in the 4th zone (at the Italian border)
- ~ 50 m positional error (10 m theoretically)
- maps were first matched according to the printed coordinate grid and later georeferenced to better fit the reality
- control points used include bridges, crossroads and prominent peaks

The first presentations of the Earth's landscape originate from at least 30,000 years ago when the people got capability

Table 1: Legend keys of selected maps.

	Josephine military topography	Franciscan cadastre	Italian 1:25,000	Yugoslav 1:25,000
transitional woodland shrub				
forest				
bare rocks				
urban fabric				
pastures				
inland waters				

Yugoslav maps 1:25,000

- mapping period 1934
- cover the area east of the Rapal border
- Gauss-Krueger projection, meridian of origin is Paris (maps have coordinates according to Greenwich overprinted)
- ~ 7 m positional error (5 m theoretically)
- less precise in the mountainous area (Podobnikar 2001)
- maps were georeferenced to the target coordinate system according to the printed coordinate grid

Italian maps 1:25,000

- mapping period 1932–1937
- cover the area west of the Rapal border
- unknown projection, meridian of origin is Rome
- lack land use categories distinction as they are not printed in colour
- relatively good in topographic details
- ~ 50 m positional error (5 m theoretically)
- maps were first matched according to the printed coordinate grid and later georeferenced to the target coordinate system
- control points used were peaks, crossroads, bridges, churches and other prominent buildings

Aerial photographs ~ 1:15,000 – 1:30,000 (large scale for case study)

The photographs acquired are from the year 1956 and are contact copies from original films or fingerprints. These images are from the very beginning of later systematic aerial photographing. Average flight height was 3300 m. Fortunately they cover all the areas of interest, however they have not been systematically scanned yet and are subject to decay. They contain stains of old fingerprints, scratches, pen writings, etc. Some of them are also bended or crumpled.

~2000

Slovenian databases in scale 1:25,000

Contemporary data used includes scanned of scale 1:25,000 and vector-based Slovenian Topographical Database 25. Positional error is supposed to be the same as accuracy of the media (5 m), but is in fact bigger (~13 m) (Podobnikar 2001). Maps are in Gauss-Krueger projection, with Greenwich as the meridian of origin.

Slovenian databases in scale 1:5000 to 1:10,000 (large scale for case study)

Scanned large-scale Slovenian topographic maps in scale 1:5000 and 1:10,000, and digital orthophotos (DOP5) were used for comparison purposes. Digital orthophotos were also a source for vector land use map produced by the Ministry of agriculture, forestry and food. Average positional error is around 3 m (Podobnikar 2001), but higher in the mountain area.

GEOREFERENCING AND MOSAICKING

Tested historical maps were produced in different projections, coordinate systems, scales, etc. Their metrical quality is also inhomogeneous and they are cartographically different or inexact. Generalisation methods used for producing maps are mostly unknown and different. Some maps have their coordinates marked on their edges.

The target coordinate system was current Slovenian coordinate system that is based on Bessel ellipsoid 1841 and Gauss-Krueger rectangular plane coordinates (conform, transverse cylindrical). The mean meridian is 15° and scale factor is 0.9999. The coordinate system is local, so it fits well to the geoid. Approximate shift to WGS84 ellipsoid is about 30 m (~1'') towards to north and 400 m to east (~17'') (Podobnikar 2001).

For the small scales and low accuracy, we can use priory known transformation parameters (Podobnikar 2001) – for example transformation parameters from Krim coordinate system to Slovene coordinate system. However, the problem is local deformations or distortions of the old maps, caused by faults in measurement and scanning that should be omitted. In this case we can use transformation parameters only for course transformations. For the fine transformations that are usable for large scale and fine details we should homogenise the maps with other techniques.

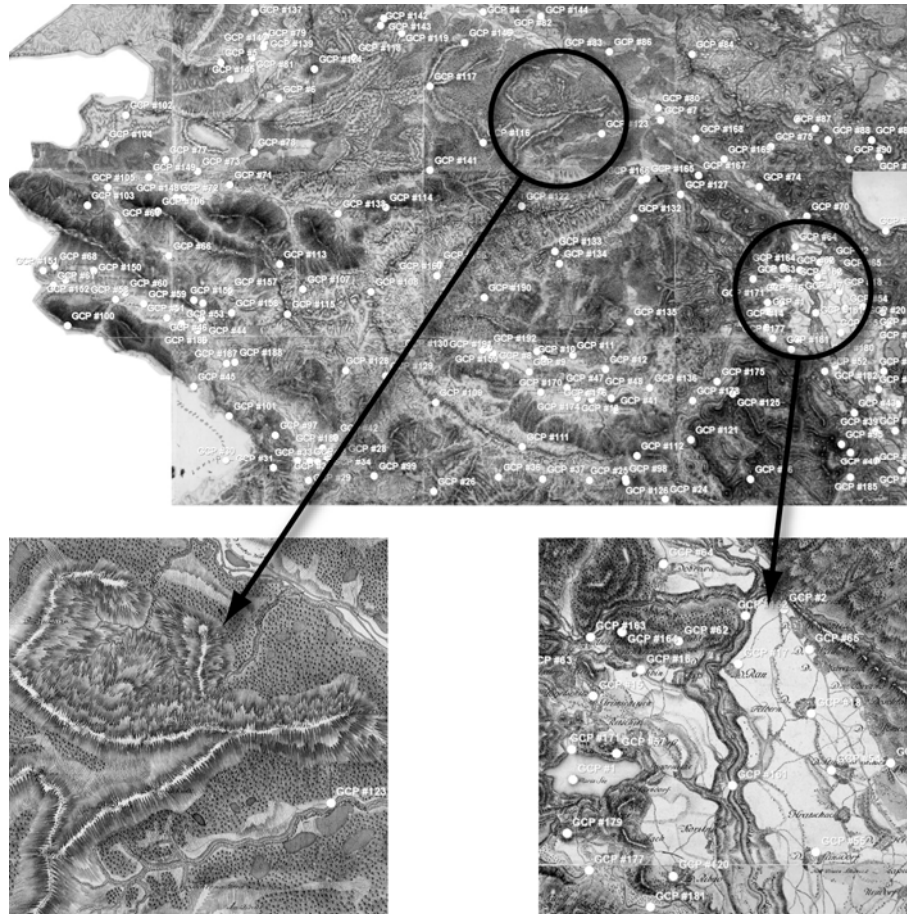


Figure 3: It is obvious that some areas are more suitable for control points selection than others.

The approach is based on finding of the identical points that should be as much as possible at same geographical position simultaneously on old maps and on reference layers (orthophotos and plenty of contemporary digital maps). Identical points should be chosen very carefully (figure 2). On the old maps geometrically best points are the ones that were triangulated. These points are mostly churches or towers. We could also be confident on the locations of some bridges, river confluences, crossroads, castles, summit, distinctive meanders, etc. Characteristic points were sometimes difficult to identify due to toponyms in different languages (Slovene, German, Italian) used on the maps. For the oldest maps it is better to find identical points for even poorly detected details to cover all mapped area, as the distortions are locally very large. However, this recommendation can not be always taken in account because some places simply lack any clinging detail (figure 3). Most of the details on the maps were recorded with unaided eyes. Quality of such maps therefore depends on experience of the cartographer and his semantic comprehension. To transform such map we should recognize a “stile” of a particular cartographer and cartographic elements including level of generalisation.

Reference control points were selected on contemporary maps of the same or similar scale. When enough control points are identified we can transform the map to the target coordinate system. We tried the following methods: polynomial order 1, polynomial order 2 and rubber sheeting transformation. The first method works perfectly if

scanned maps do not contain many local distortions and is therefore usable only for modern maps (not older than ~30 years). There are relatively many identical points required for transformation using polynomial order 2, but overall quality of transformed maps is acceptable. The polynomial transformations are approximate, contrary to rubber sheeting, so the position of control points changes after the transformation. Using even higher order polynomial transformations can produce better result at the control points, but unpredicted distortions can appear between them. Rubber sheeting requires the highest number of control points and areas not covered by such points are subject to irregular distortions. Regardless of this, rubbersheeting proved to work best with the chosen data. It was used to georeference Josephine military maps, cadastral maps, and for binding together maps with printed coordinate grid.

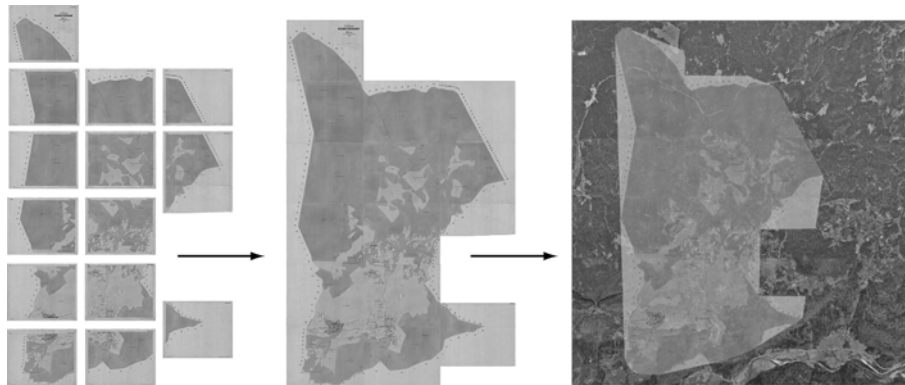


Figure 4: Georeferencing cadastral maps in two stages; combining the maps of a cadastral commune and later georeferencing the combined map.

Some of the maps were tied together before georeferencing (figure 4). Specific problem in georeferencing historical maps is that they must fit to each other with their edges. It helps that the maps were divided systematically. The main idea of mosaicking is that particular map sheets should be rectangular, resembling their original shape, and that they should match together seamlessly along their edges. For example it would be a daunting job to georeference Josephine military maps or Franciscan cadastre maps individually. Binding them together first and then finding the appropriate control points was a much easier task (Figure 4). The same procedure was also used for Italian and Yugoslav maps. However, these maps were combined by georeferencing the coordinate grid. Yugoslav maps were georeferenced directly to the target coordinate system. Maps with scale 1:50,000 were later georeferenced again because the positional error was too big and was non-systematic. Reprojecting with 3rd order polynomial worked best. Italian maps, were first combined to a local coordinate system and later georeferenced to the target coordinate system. 2nd order polynomial transformation gave the best results for reprojecting the combined map.

There was another issue with Yugoslav 1:50,000 maps. The area west of 13°30' lies in the 4th zone of the Gauss-Krueger coordinate system, whereas the rest is in the 5th zone. The part lying in the 4th zone was therefore reprojected to the 5th zone and then georeferenced.

The next step is homogenisation of the different colour cast that could be a consequence of scanning or more commonly an outcome of original print. Using different methods of colour approximation it is possible to get a map seemingly to be seamless. However, because colour homogenisation was not important for our GIS-based analyses, but on the contrary would do more harm than good, we did not use it.

PRINCIPLES OF GIS ANALYSES

Comprehension of the historical maps is necessary for analysis of their particular data layers or attributes. This process is basics for better understanding the nature of spatial data that are going to be derived from them. In the previous part of the paper historical maps were evaluated from different views using different statistical and

visual methods. For further effective GIS-based analyses, quality of the maps was evaluated.

The consequence of variety in map legends was formation of a common object catalogue. Data for recent land cover was obtained by analysing digital orthophotos and is therefore reasonably precise and accurate, as well as distinguishes more land cover classes than needed. This data was thus generalized in two ways. Firstly, more than 20 original land cover classes were combined into 14 classes. The majority of them are distinguishable on all the maps, however some barely (e.g. transitional woodland shrub), and some no on the maps of older origin (e.g. vineyards). Secondly, vector data was generalized to be suitable for smaller scales (1:25,000).

Four sections were selected to serve as test areas for detailed land use changes observation. The area around the high mountain village Čadrg is interesting as the local aging population is helped by a community of treated drug addicts. The village is prosperous also as a tourist destination as it is a centre of eco-farming. Bohinj Alpine pastures have experienced intensive land use changes, especially overgrowing, mainly due to lack of work force to maintain the pastures. There have also been relatively big changes of road network especially because of transformation of cattle huts into tourist cottages. Lake Bohinj area is rapidly becoming a major tourist destination and the pressures on available land are intensifying. Several new houses have been built as well as hotels and ski runs on the slopes of mountain Vogel. Pokljuka high moors are influenced by vacation homes construction, grazing and forestry. With changing land use over the centuries the impact has varied.

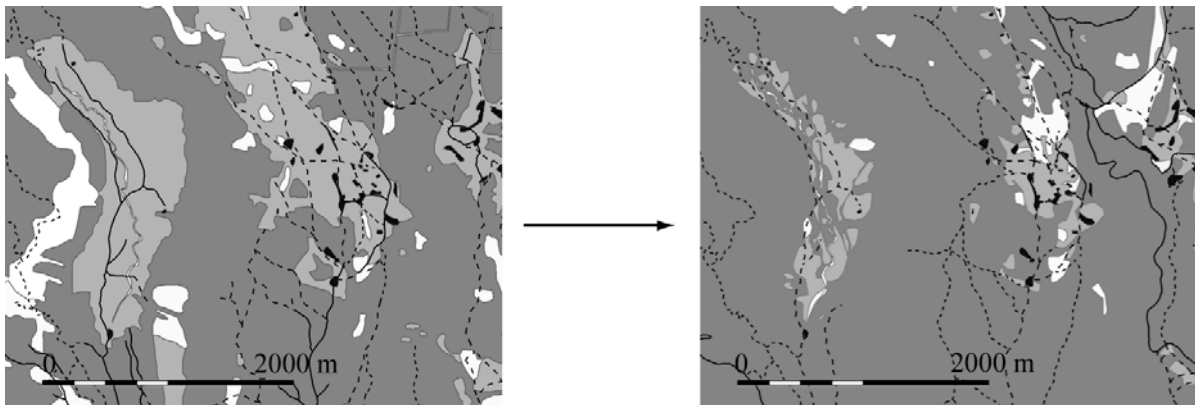


Figure 5: Changes of land use between 1934 (left) and 1995 (right) on high alpine pastures northeast of Bohinj lake.

Digitizing the land use information from the historical maps was done by the “backward editing method” (figure 5). The basis for the editing is contemporary vector map of land use. This is then overlaid to an older map. Features are compared and dissimilarities mended. The process has to be repeated for each map series. Because of the differences in object catalogues used for different maps it is difficult to distinguish all the desired land use categories. Compromises have to be made and it is extremely important to be aware of these compromises and acknowledge them in future analyses.

Expected results of the land cover analyses include new views on the questions such as where and why alpine pastures are overgrowing on the Bohinj side of the Julian Alps and not on the Tolmin side, what are tourism development and infrastructure construction influences, are there any recognisable first world war effects on land cover, have border changes affected the land cover, and similar. From maps of smaller scale it is possible to obtain trends in developments of land functions and land use structure. Analyses are going to include visual interpretation of land use changes as well as investigation of statistical examination results.

CONCLUSIONS

Spatial data georeferenced to the same coordinate system is indispensable for interpretation of various spatial phenomena aspects in different time periods. Historical maps are rare but nevertheless offer precious information about the past. Unfortunately they are of different and sometimes unpredictable quality and they are not always easily comparable to modern maps or other spatial datasets. Different topographic keys or object catalogues were used and maps are frequently inhomogeneous. Because of the poor homogeneity, transformations with known and unique parameters can not be employed for most of the old maps. Therefore, georeferencing methods have to be applied. We discovered that mosaicking of systematically divided maps before georeferencing gives much better results than trying to match the edges of individual maps. We tried to find the most suitable method for georeferencing each of the historical maps and to recognize characteristics and nature of the particular map. The results are simulative especially for small scales and for urban areas, but very inaccurate for mountains.


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