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Automated detection of landscape features in historical maps to support sustainability research – towards a nationwide dataset

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Summary: The idea of this article goes back to Roberto Ranzi's article "Land cover changes since the 19th century detected from historic maps for environmental applications: towards a CORINE 1800 project?" (Ranzi et al. 2022) presented at the 15th ICA Conference "Digital Approaches to Cartographic Heritage" and 22nd Conference of the Map and Geoinformation Curators Group. Initially an international project group tried to acquire EU-funding for model areas in different European countries. When these efforts remained unsuccessful, the Federal Agency for Cartography and Geodesy (BKG) took up the topic and funding for Germany. This initiative led to the project that is presented in this paper. As a partner the BKG founded the Leibniz Institute of Ecological Urban and Regional Development (IOER) which has long experience in historical map-based land use analysis. In this paper, we describe the background, challenges, and initial results achieved so far for the case of Germany.

Introduction

Climate research and other Earth science disciplines would benefit from comprehensive high resolution data of land cover and land use of the last centuries. An innovative joint project between Federal Agency for Cartography and Geodesy (BKG) and Leibniz Institute of Ecological Urban and Regional Development (IOER) is using historic topographic maps as a new data source: which as "time capsules" are predestined as unique source of information for the development of land cover. The project is aiming for nationwide coverage of Germany.

The ambitious plan is to systematically capture and analyse the changes in landscapes of Germany since the beginning of the 19th century. Like ice cores in paleoclimate science, wide area data of historic land cover can yield important information, missing in micro- and mesoscale climate models. Focus lays on some land cover classes that are relevant as carbon sinks and play key roles in decarbonisation processes, such as forests, peatlands and mires. The knowledge of their spatial distribution 200 years ago would support renaturation measures.

Scientific results of the last years (CORDIS 2023) show, that not only peatlands, but also old forests are important carbon sinks, absorbing more carbon than they emit. Therefore, describing how forests developed over time, or estimating their age, are goals of this study.

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The challenge - from analogue map to digital analysis

Since decades, back to middle of the 20th century, aerial or satellite imagery provide area wide geodata on landscape change on regular basis. Before these modern Earth Observation (EO) technologies emerged, topographic maps were the only and most important source of information about landscape features.

Topographic surveys are bound to an administrative structure, so a first challenge is the historical fragmentation of today's state territory. This is accompanied by the lack of standardised cartographic practise and methods in Germany until the 1870s, which results in a wide variety of cartographic styles over times. In often hand drawn field surveys, personal drawing styles of the topographers are also leading to differences of maps in a map series or corpus. The historic fragmentation - to some degree - is still apparent today, as the historic maps are held in different federal state data collections, be it archives, libraries or surveying agencies. Hence, a further challenge are their license and copyright terms, which can make the acquisition of map material and clarification of its usage - and that of resulting data - a time-consuming process.

Analysis of such heterogeneous map material is a complex process, that involves various steps, among others georeferencing, semantic harmonisation and map context extraction (MCE). Finally, the data should be represented as vector geometries, ready for further analysis.

Organisational and technical obstacles of this project are considerable. State archives, libraries and surveying agencies may have large collections of documents and maps, but not often the resources to catalogue them across data sources and make them digitally available. To answer the question, who has a specific map, and in what state of digitalisation, can be a tough one. A first task in the project was the compilation of triangulation based historic land surveys in scales 1:12.500 to 1:100.000 for today's territory of Germany, since there was no such overview. This compilation also holds information whether a map is available in analogue or digital form. As a side note, acquisition of a complete map corpus from one source was not possible.

In view of the enormous amounts of data, automated processing is essential. BKG and the IOER are pursuing an 'open-method' approach and are testing various methods of computer vision and machine learning. While computer vision technologies such as template matching automatically recognise and identify map signatures, machine learning algorithms continuously improve their recognition accuracy through training data. Both methods rely on example data, although machine learning to a much higher degree than classical computer vision. Considering the size of some map series (sometimes several thousand sheets per map corpus), efficiency considerations also play a role in the evaluation of the methods. In cooperation with the BKG's Gauss Centre, further AI technologies are being developed for the automated classification, storage and analysis of geodata of varying quality and origin.

Figure 1: Comparison of the map graphic from the Bavarian original position sheet ca. 1860 (upper part, geodata: Bavarian Surveying Administration -www.geodaten.bayern.de, Lizenz: CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/deed.de)) and position sheet from 1950 (lower part. Source: © IOER 2025).

Integration in existing land use monitoring systems

The historical land cover data obtained is incorporated into the established Monitor of Settlement and Open Space Development (IOER Monitor 2025). This web application analyses Germany's topographic data, which has been available in digital form since 2000, and makes the derived information available in the form of interactive maps, among other things (see Fig. 2). Land cover information, which originates from historical maps, is supplemented in the IOER Monitor as part of the co-operation project, going backwards in time. This creates valuable long-term data series.

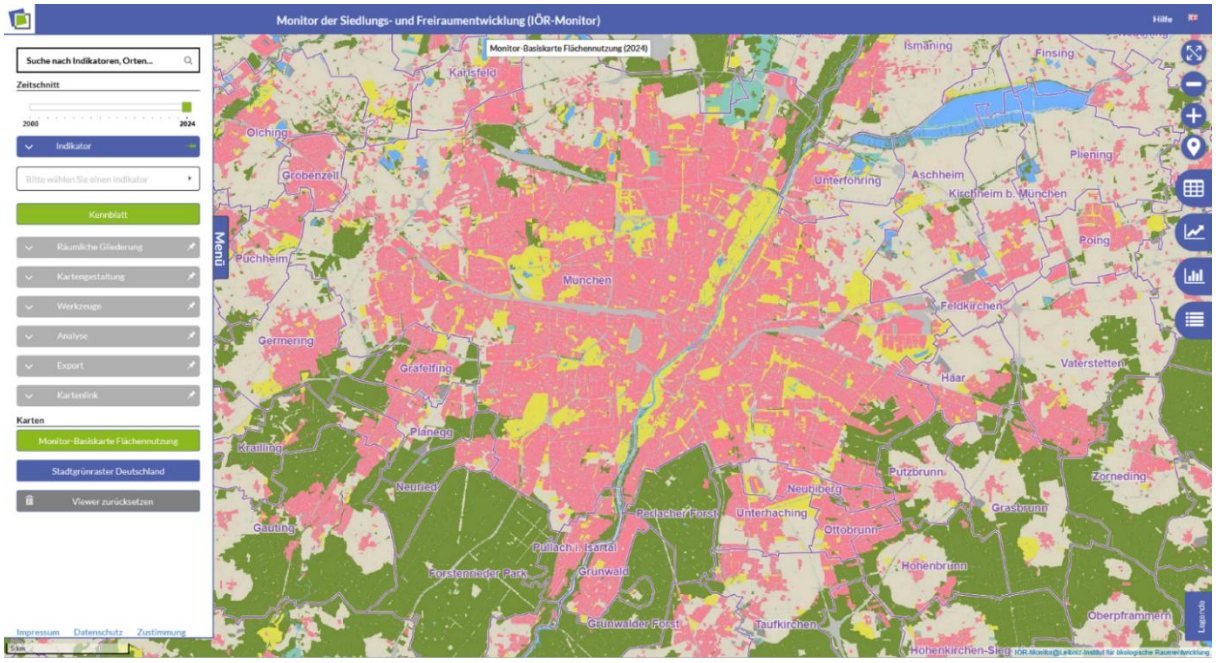

Figure 2: IOER Monitor showing the base map. The integration of historical land use information is currently being prepared. (Source: © IOER 2025)

Initial results

Initial approaches, using classic Computer Vision techniques like Template Matching and Color Image Separation, yielded acceptable results. Especially Template Matching showed good applicability on map corpuses with standardized signatures, or rather easy and similar signatures. The technique uses example images (templates) of map signatures to locate similar parts in a map and was successfully implemented on forest and wet land signatures in map corpuses of the Preußische Neuaufnahme (Prussian New Survey, PNS) from the 1870s to 1940s, as well as the Saxon Mile Sheets from the 1830s.

The validation and improvement of the approaches is ongoing. For the federal state of Brandenburg it was possible to use a manually conducted digitalization of the forest areas from the PNS, to compare the automatically extracted vector geometries. The overall Intersection over Union (IoU) was around 70%, with some map sheets having over 90% of correspondence, some down to 20%, depending on cartographic load of the map sheet. This result was reached with a set of 46 templates (24 leaf trees, 22 coniferous trees), which is a considerably smaller number of examples than for deep learning methods.

However, also deep learning methods have shown their potential in recent studies, and one part of further work is aiming at automated training data generation for deep learning approaches. The

overall outlook leads to a toolbox, which allows for the selection of the most efficient map content extraction tool.

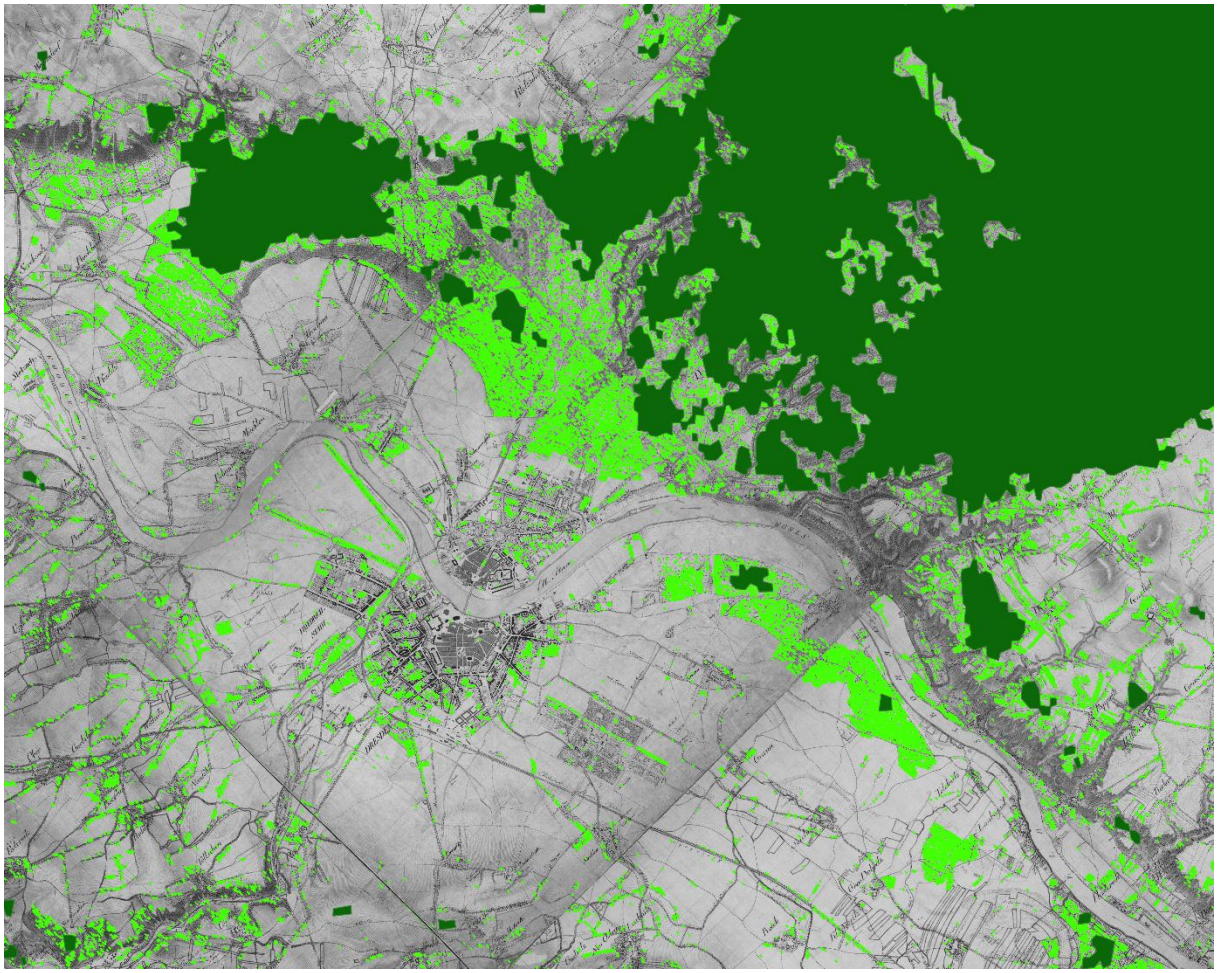

Figure 3: Comparison of forest areas of the 1930s (dark green) from the Prussian New Survey in the region of Dresden and template matching results of the older Saxon Mile Sheets of the 1830s (light green). It is visible that in the northern parts the forest has been reduced, where city area was expanded. Interestingly the areas close to the old city centre are already deforested, even in the 1830s (Source: IOER 2025).

Outlook

Following an initial feasibility study phase (08/2022 to 12/2024) with test areas, the project is currently in a phase in which exemplary investigations are being carried out across the board in certain federal states and for entire topographic surveys. After successful completion, a nationwide expansion is planned. The scientific community (particularly in Italy, Romania, Poland, Hungary and France) has already signalled a strong interest in Europe-wide data.

As the central data provider for the federal government, the BKG fulfils the needs of the federal administration. Federal authorities such as the German Meteorological Service (DWD), the Federal Office for Building and Regional Planning (BBR) and research institutions such as the Greifswald Mire Centre have already expressed their interest in time series with Germany-wide coverage. The establishment of new partnerships with federal authorities and research institutes is planned. A particular focus is on the subsequent provision of all results data as open data as well as software development as open source. This approach recognizes the interdisciplinary nature of Earth system research.

The project opens up new perspectives for the cartographic community to create value from historical map collections as well as for direct cooperation between the project team and the so-called memory institutions. The georeferenced map sheets can be returned to the memory institutions, enabling them to be found much more easily via spatial searches in catalogue systems. The methods developed could also be made available to other institutions in the future for the automated analysis of historical map materials.

References

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