



The potential of old maps and encyclopaedias for reconstructing historic European land cover/use change



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ABSTRACT

Continental to global reconstructions of historic land cover/use are important inputs for many environmental, ecological and biogeochemical studies. While local to regional reconstructions frequently make use of old topographic maps and land use statistics, continental to global reconstructions are mostly model-based reconstructions. As a result they are subject to large uncertainties. A wealth of historic land cover/use maps and statistics have been produced and these are now more accessible due to the ending of copyrights and secrecy statuses, enthusiastic hobby communities and national cartographic institutes or cadastres that have a strategy towards data sharing with society. In this paper we made use of historic statistics and old topographic maps to demonstrate the added value for model-based reconstructions of historic land cover/use for Central Europe back to 1900. We harmonized these diverse data types and different types of historic land data were incorporated into the land use reconstructions. The added value of using these data was evaluated using historical maps by performing a reconstruction with and without the historic information. The accuracy of the land allocation in the historic reconstruction was improved by 16.5% using historic maps. Additionally, historic maps improved the representation of the spatial structure of landscapes. The historic land cover/use statistics used showed a strong agreement with independent estimates, like historic maps.

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Introduction

Historic land cover/use data at large scales (Hurtt et al., 2006, 2011; Kaplan, Krumhardt, & Zimmermann, 2009; Klein Goldewijk, Beusen, & Janssen, 2010; Klein Goldewijk, Beusen, Van Dreht, & De Vos, 2011; Pongratz, Reick, Raddatz, & Claussen, 2008; Ramankutty & Foley, 1999) have improved our understanding on how humankind altered our planet during the Anthropocene (Ellis et al., 2013) and helped to study effects of land change trends and transitions on environmental and ecological processes (Foley et al., 2005). Information on historic land cover/use provides insights in the cultural heritage of landscapes (Plieninger, Höchtl, & Spek, 2006). Moreover, historic reconstructions are a fundamental data source to estimate greenhouse gas emissions and to understand the evolution of the biogeochemical cycle (IPCC, 2013). Many local to

regional reconstructions are based on old topographic maps and land use records (Bicik, Jelecek, & Štěpánek, 2001; Carni, Jarnjak, & Ostir-Sedej, 1998; Godet & Thomas, 2013; González-Puente, Campos, McCall, & Muñoz-Rojas, 2014; Jawarneh & Julian, 2012; Marull et al., 2014; Orczewska, 2009; Petit & Lambin, 2002; Skaloš et al., 2011; Skokanová et al., 2012). However, at continental and global scales, most reconstructions of historic land cover/use are modelled based on population statistics and scarce historic land cover/use data. As a result, there is a large uncertainty in these reconstructions (Klein Goldewijk & Verburg, 2013). Several authors have mentioned that more historic data are needed to reduce the uncertainties in reconstructions (Fuchs, Herold, Verburg, Clevers, & Eberle, 2014; Gaillard et al., 2010; Klein Goldewijk & Verburg, 2013).

A broader use of available historic input data would help to verify, correct or withdraw assumptions used in historic reconstructions. It is hypothesized that the use of multiple harmonized land cover/use statistics and maps would lead to improved estimates of change trends and better spatial allocation of historic change.

The current use of historic data is limited due to a number of constraints: the need for harmonization across different

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inconsistent data sources, the different acquisition techniques used (sampling, aerial photographs, remote sensing) and the data formats (from analogue prints to digital data and from hand drawn survey maps via aerial photographs to digital remote sensing data). In addition, in many cases land cover/use data were published in local languages, requiring local knowledge to read them. Copyright, national interest, competition and secrecy (e.g. military maps) prevented the accessibility. Furthermore, changing country borders, especially in Europe, made it hard to compare any area related statistics.

Despite these constraints, a wealth of historic land cover/use data have been produced over decades and centuries. Nowadays, this type of data is becoming more and more accessible due to the ending of copyrights, e.g. for historic land cover/use maps (Schlueter, 1952, 1953, 1958) and encyclopaedias with statistical information (Bibliographisches Institut, 1909; Chisholm & Phillips, 1911). The ending of secrecy statuses for historic military maps eases accessibility, e.g. for soviet military topographic maps (Vlasenko, 2008). Many enthusiastic communities have started to collect and share historic land cover data (e.g. Rumsey, 2014). National cartographic institutes and cadastres have an increased willingness for transparency, open data policy and data sharing with society (Bundesamt fuer Kartografie und Geodaesie, 2014; Centro Nacional de Informacion Geografica, 2013; Eötvös University Department of Cartography and Geoinformatics, 2013; Geoportail, 2013a, 2013b; Koninklijke Bibliotheek van België, 2014; Mapster, 2014; National Library of Scotland, 2013; University of Stockholm, 2013a, 2013b).

The objective of this paper is to make use of historic statistics and topographic maps to improve a historic reconstruction of land cover/use for Europe and evaluate the added value of using such additional data. In this paper the focus will be on the forest/non-forest classification. Section 2 describes the methods used to harmonize historic statistics and incorporate historic maps into land use reconstructions for Europe. Section 3 explores the added value of such data in reconstructions of land cover/use. This is followed by a discussion in Section 4.

Material & methods

Study area and period

The different data types (historic statistics and maps) explained in this section were available for almost whole Continental Europe for different time steps. However, in order to demonstrate the application of the methods and their added value we focused for this paper on the time around 1900 and an area that we defined as Central Europe. This area comprised in our definition the following countries: Germany, Luxemburg, Poland, Czech Republic, Slovakia, Austria, Hungary, Romania, Bulgaria and Slovenia (Fig. 1). In total, the study area covers more than 30% of the EU27 area. We have chosen this study area to prove the added value of historic maps and statistics, first, for a considerable large area of Europe and, secondly, to avoid the explanation of too many different data sets that otherwise would have been required for this study. Furthermore, we focused on the year 1900 since this year was the starting year of our model reconstruction of historic land cover/use, later on explained in this paper.

Data

Historic maps

For our analysis we used historic maps from two large scale surveys: The 'Generalkarte' (general map) of the 3rd Military Mapping Survey of the Austrian-Hungarian Empire (Eötvös



Legend

■ Study Area

Fig. 1. Overview of the study area.

University Department of Cartography and Geoinformatics, 2013) and the Central European land cover map of the protohistoric settlement areas in Europe (Schlueter, 1952, 1953, 1958). Table 1 gives an overview of the features of the maps and Fig. 2 illustrates the coverage for each data set. The Schlueter map was scanned full colour with 600 dots per inch (dpi) in TIFF and A0 format in order to get a digital version. A high number of dpi assured that linear features in the map (letters, roads, land cover class borders) could be represented with enough detail and later on be classified separately. Furthermore, a high number of dpi prevented blurring of colours around edges of land cover classes. The map tiles of the Austrian-Hungarian Empire were already scanned. The 'Generalkarte' of the Austrian-Hungarian Empire map is the coarsest map (1:200000) with the largest area coverage of all three mapping activities of the 3rd Military Mapping Survey (namely 'Aufnahmeblaetter' (1:25.000), 'Spezialkarte' (1:75.000) and 'Generalkarte'). The 'Generalkarte' consisted in total of 265 map sheets of which the first tiles were printed in 1887. The Schlueter map only consisted of one map sheet that was printed in the 1950's. Both maps display the land cover/use around the year 1900, the starting date of our historic reconstruction.

Statistics

We used sub-national statistics of the Meyers Conversation Encyclopaedia of 1909 (Bibliographisches Institut, 1909), which refers to official statistics around the year 1900. The encyclopaedia is digitally available at www.zeno.org and statistics can be found under the German name of the countries and provinces. A list of available statistics for countries and provinces within today's territory of the European Union can be found in Appendix A. We provided their German and English name. For this paper we only made use of country and province statistics that fall within our study area.

Overview of the methods

The methodological approach of this paper consists of three major steps (Fig. 3). The first step comprised the georeferencing and

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