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Methodologies and prospects of historical land use/land cover studies in Lithuania

Eglė Piškinaitė*, Darijus Veteikis

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Abstract. The relevance and number of land use/land cover (LULC) studies have significantly increased over recent decades. Census, statistical and cartographic data represent the main information sources for researchers. Short-term LULC change studies are improving faster and are more numerous than the long-term ones. The aim of our study was to review the available methodology for assessing changes in LULC based on historical sources. Old maps are the tool for long-term LULC studies as they allow tracking all LULC changes. However, in Lithuania, old maps are not much exploited for this purpose, which can be explained by the fact that the findings obtained using old maps are not always worth the technical and time inputs required. Our analysis revealed that only a small part of studies into LULC in Lithuania deal with the identification and analysis of LULC change trajectories. Therefore, some methods for determining LULC change trajectories are overviewed in this article, too.

Keywords: *georeferencing, orthophotographic maps, old maps, historical geography*

Eglė Piškinaitė (egle.piskinaite@chgf.vu.lt) https://orcid.org/0000-0002-9142-5308, Darijus Veteikis (darijus.veteikis@gf.vu.lt) https://orcid.org/0000-0002-8774-2917, Institute of Geosciences, Vilnius University, M. K. Čiurlionio Str. 21, Vilnius, Lithuania*
**Corresponding author*

INTRODUCTION

Extensive studies in geography and topography revealing the disastrous anthropogenic impact on landscape emphasize the necessity to analyze land use/land cover (LULC) (Sajane, Wadkar 2016). Under the impact of natural processes and anthropogenic factors, landscape undergoes persistent changes, which has been long considered to be the reason for the growing relevance of landscape change studies (Plieninger *et al.* 2015; Bürgi *et al.* 2004; Skokanova *et al.* 2016; Parveen *et al.* 2018). Recently, the thematic scope of LULC change studies has expanded to include a variety of issues ranging from spatial and temporal land change modeling to understanding the causes and consequences of LULC changes (Parveen *et al.* 2018). In European countries, landscape studies have been receiving considerable attention since the adoption of the European Landscape Convention in 2000 (Plieninger *et al.* 2015). In Lithuania, changes in political, social and economic conditions after the restoration of independence in 1990 brought about changes in LULC and encouraged research into it. Entry into the European Union (2004) and increased applicability of information technologies made landscape LULC studies particularly relevant at the beginning of the 21st century (Veteikis, Piškinaitė 2019; Bauža, Baužienė 2008).

A significant increase in the relevance and number of landscape studies has also highlighted the methodological problems in the field. Landscape research overlaps with a wide range of studies into various components and subsystems of the environment, therefore it is characterized by a wide variety of directions. According to Plieninger *et al.* (2015), differences in long-term historical landscape development is another important area of landscape research. Research into historical landscape changes reveals

how it changed or remained intact with the dominant processes and temporary changes being revealed. Decision-making processes influencing landscape, evaluation of landscape values, support or incentive policies etc. can be analyzed in order to determine landscape transformations (Stürck *et al.* 2018). Scientific-methodological problems of historical landscape research are sufficiently specific: technologies can restore the landscape structure and its change processes in the past by combining the information from humanities and social sciences (history, archeology, economics, politics) and natural sciences (geography, ecology, biology, especially botany) with the use of modern remote sensing and geographic information systems (GIS). Historical landscape research can be characterized as a multidisciplinary study that is performed using different methods in combination (Mačiukas 2005).

Historical and archival sources are among the most important ones in landscape change studies (Dolejš, Forejt 2019) and can be used by researchers working in different fields of research. According to Frajer and Geletič (2011), in recent years, researchers specializing in different subfields of geography have been showing increasing interest in antique and historical maps.

GIS tools are commonly used for spatial analyses of both vector and raster datasets. Historical maps are the main source for various spatial analyses of the past land use. However, to be used in comprehensive research, old map data have to be digitized. Hence, old maps have to be integrated into the GIS environment, this part of the research process being the most important and at the same time the most complicated one. Among other major problems associated with historical maps is inconsistency in map legends, techniques of cartography as well as poor knowledge of the projections used (Podobnikar *et al.* 2006).

Historical studies into LULC changes require additional labor and time resources for gaining the understanding of the LULC condition in the past. The LULC change processes that took place in the past have shaped the current landscape forming the basis for the future landscape (Brunckhorst *et al.* 2011).

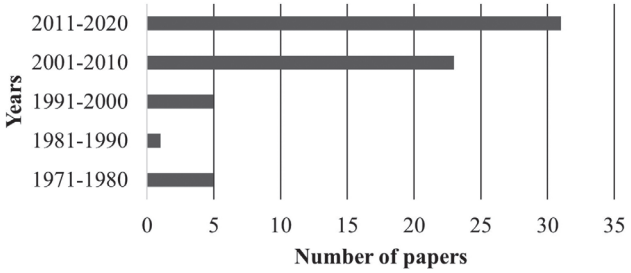

Fig. 1 Number of open access papers on the subject of LULC changes in Lithuania (summarized from Veteikis, Piškinaitė 2019)

Landscape change is well represented by LULC transformations, although the functional link between them still needs exploring, especially in relation to historical context.

The aim of this study was to review the available methodology for studying landscape and LULC changes based on historical sources. To achieve this aim, it was necessary to: (1) review Lithuanian studies into landscape and LULC changes, and (2) determine the advantages and disadvantages of the methods employed. Terminological aspects, methods for tracing and evaluating historical LULC changes as well as those for determining the driving forces of LULC changes are analyzed in the following sections of the article. We expect that results of this study will contribute to the quality improvement of landscape and LULC change studies.

TERMS INHERITED FROM PREVIOUS STUDIES

A remarkable surge of interest in LULC, which was evidenced by appearance of a highly increased number of publications, has been observed in Lithuania since the beginning of the 21st century (Veteikis, Piškinaitė 2019) as illustrated in Fig. 1. Although the number of studies into LULC changes in Lithuania is constantly growing, studies covering long historical periods are not numerous, which can be explained by some methodological aspects discussed below.

First of all, the margin between a historical study and the retrospective one is somewhat blurred. Singh (1989) defines the process of LULC change detection as the identification of differences in the state of an object or phenomenon by observing it at different points of time (Singh 1989). The perception that research is historical stems from the fact that at least two reference periods are considered: the landscape in period X and the landscape in period Y, where period X is the reference point. Results determine the change in the state of the landscape that has taken place over a period of time. The periods of LULC change identified in the study can span several years, decades or several centuries.

According to the currently available sources and spatial information, short-term (up to 50 years) LULC change studies are improving faster and are more numerous than the long-term ones (Fig. 2). Lack of detailedness and accuracy in historical spatial information sources also aggravate their comparison with modern data, which is also pointed out by Milius and Ribokas (2004). According to these authors, the main problems of land accounting sources are (1) land terminology, (2) land typology, and (3) differences in land accounting and statistics.

LULC and its changes are dealt with in different

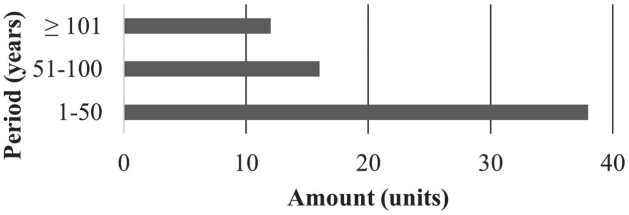

Fig. 2 Number of studies in Lithuania by the length of the period covered (summarized from Veteikis, Piškinaitė 2019)

fields of science, e.g., geography, biology, history, employing different methods and data depending on specific tasks. There are a number of specific terms/disciplines that are related to LULC studies or their findings. *Landscape archeology* describes the interrelationship between a particular area and the cultural development therein (Gkiasta 2008). *Historical landscape* is defined as a cultural landscape where features of the past are dominant. *Landscape history* is a study that seeks to reveal the artifacts of human activities in nature and the consequences of human behavior on the environment (Fox 1996). The term *historical geography* is also used. In her review of the historical geography development, Eitmanavičienė (1981) pointed out that since the middle of the 20th century, the appearance of systematic works in historical geography related to settlement development and landscape features, territorial housing, agriculture and forestry problems and special purpose objects (such as protected areas, important recreational, aesthetic and historical sites) has been on the increase.

Furthermore, the definitions of such study objects as landscape, land use, land cover have undergone several changes. Moser (1996) noted that the term *land cover* originally referred to the type of vegetation covering the land surface. Later, the meaning of the term expanded to include other aspects of the physical environment such as soils, biodiversity as well as surface and ground-water bodies (Moser 1996). In general, terms *land use* and *land cover* are close in meaning and are used synonymously. The term *land cover change* is dominant in studies by Lithuanian scientists, the terms *landscape and land use studies* being less common. In general, the terms *land use*, and *land cover* are often confused. Both study objects share similarities in research methods, content and research purpose. It is not easy to distinguish changes in land use from those in land cover because they are interrelated. In this article, the term *land use* is used in the sense of *land that differs from other land in its natural characteristics or economic uses*, i.e. as it is defined in Land law of the Republic of Lithuania. The meaning of the term *land cover* used in this paper coincides with that of the term used in the Corine Land Cover (Coordination of Information on the Environment Land Cover, CLC). CLC provides information on the biophysical characteristics of the Earth's surface (CORINE…, 2017) that is considered to be *land cover*. In their comprehensive review, Milius and Ribokas (2004) highlighted that the typological description and terminology of land types in urban and rural areas are not standardized. For this reason, specialists in different research fields demonstrate different approaches to the statistical land data including differences in terminology, typology, precision in land survey and statistics of land types (Milius, Ribokas 2004).

In this paper, the areas of research denoted by *LULC change studies* and by *landscape change studies* differ. However, results of LULC change studies can be used in landscape change research.

OVERVIEW OF THE METHODS AND DATA SOURCES USED IN HISTORICAL LULC ANALYSIS

Our current study dealing with methodological aspects of historical land use/land cover studies in Lithuania is in fact a continuation of our previously performed study, results of which were summarized in the article under the title „Geographical research of land use change in Lithuania: development, directions, perspectives". It was based on the analysis of 161 scientific articles selected from Lithuanian journals by the keywords *land use* and *land use change.*

Our current study was undertaken with a view to make a comparison between LULC change studies in Lithuania and those performed in foreign countries as well as between the methods applied for studying LULC related issues in these countries. Hence, our current study covers the research material of 55 Lithuanian LULC change studies, which were selected from the above mentioned 161 articles, and that of 24 LULC change studies in foreign countries, additionally selected from open access websites by the keywords *land use change* and *historical land use* studies. The Lithuanian LULC studies reviewed in our study are both empirical (and at the same time more applicable) and theoretical, whereas foreign studies, which are mainly focused on the overview of LULC research results, represent theoretical research. When selecting LULC change studies in foreign countries, priority was given to those performed by researchers from countries of Eastern and Central Europe because of the similar political and economic history and landscape.

Census and statistical data use

In Lithuanian LULC change studies, the most commonly used method is statistical data analysis (Fig. 3).

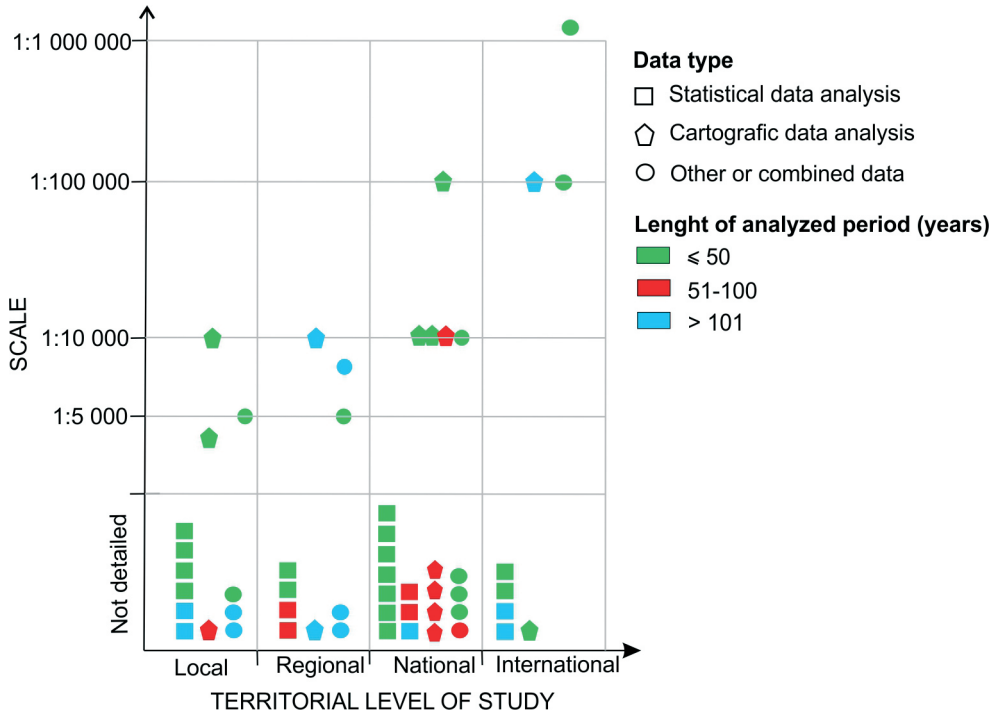

Fig. 3 LULC studies in Lithuania since 1950

Statistical data can be used as the main source with cartographic material as a supplement (Eringis, Milius 1976; Ribokas, Milius 2001; Milius, Lukštaitė 2005; Česnulevičius *et. al.* 2005; Ribokas, Milius 2008; Ribokas, Zlatkutė 2009) or *vice versa* – conclusions from cartographic material can be supported or corrected based on statistical data (Bauža 2005; Bauža, Baužienė 2008; Orlonas, Veteikis 2016). Statistical data are usually obtained from various surveys, censuses, registers as well as from the Lithuanian Department of Statistics. When conducting studies into LULC status changes since the beginning of the 20th century, researchers use data of the first national agricultural census, 1930 (Ribokas, Milius 2001, 2008; Milius 2004; Milius, Lukštaitė 2005). Agricultural statistics (crop area, crop condition, yield, number of animals and workers' wages) of this census were based on the data obtained from the population survey (Agricultural census). Data of the 1930 census are an informative and easily accessible source of information on the structure of land use in Lithuania at that time. Prior to this census, agricultural data were provided by individual farms. In Soviet times, data on the population and agricultural plots were recorded in separate collective-farm register books of the district executive committees. This information is inconsistent, and its availability and traceability is more complicated today. Subsequent general agricultural censuses were carried out in 2003 and 2010. These censuses were geographically not accurate, because they were conducted chiefly for economic and political purposes. In spite of that, today they represent the main information sources for conducting LULC change studies within the area of administrative units. In addition, older, but inconsistent textual and statistical information can be found in church metrics as well as in historical sources such as city descriptions and manor documents.

Census, national statistics and methods of cartographic analysis are often supplemented with information from population surveys. The latter are more often used in social studies of rural settlement landscapes, with land use reflecting rural population activities and determining further development of rural settlements (Mačiulytė 2006; Ribokas, Milius 2008; Ribokas, Zlatkutė 2009; Ribokas 2010). Data from various censuses and surveys allow confirming or correcting the information recorded in cartographic sources. In addition to the above mentioned methods and information sources, analysis of territorial planning documents and legal basis can be conducted (Aleknavičius 2017). Other data sources such as soil and palaeobotanical studies have been employed to learn about a more distant past of the landscape under study (Kavoliutė 1994; Kabailienė 2006; Sarcevičius 2009).

Cartographic and geospatial methods

Cartographic data analysis is widely used as a major data source and method in research (Eitmanavičienė 1994; Bauža 2005; Bauža, Baužienė 2008; Orlonas, Veteikis 2016).

Although this method is convenient and suffi-

ciently accurate for determining changes in LULC, it is efficient only for studying short-term and relatively recent changes. The oldest aerial photographs of the territory of Lithuania date back to 1940. Aerial photographs taken during the World War II (WWII) can be compared with the latest orthophotographic maps, but the number of extant aerial photographs of this period is limited. Only part of the Lithuanian territory is captured in aerial photographs and their accessibility is complicated. An aerial photograph of one part of the territory of Lithuania was taken by the Soviet military in 1945–1948, and the area stretching from south-eastern part of Lithuania to the south-western part of Samogitia was aerially photographed in 1951–1952. The entire territory of Lithuania is not documented in aerial photographs of 1945–1952. Part of Klaipėda and Šilutė districts, the border near Vištytis, Kybartai, Vilkaviškis, areas around Kaunas, Vilnius, Šiauliai remained unphotographed. Aerial photography was used to create the first post-war contour map of Lithuania at a scale of 1:10 000 (without relief). As a result of the ongoing changes in the area, which were accelerated by the collectivization of agriculture, the contour map made at a scale of 1:10 000 soon became outdated. The map was updated using an aerial photograph of Lithuania of the1958–1960 period, which had been taken for forest management purposes.

The first digital raster orthographic map representing the entire territory of Lithuania was created on the basis of aerial photography of the1995–1999 period (geoportal.lt). Official and relevant geo-reference information on land use in Lithuania is freely available through the Internet portal www.geoportal.lt, although data on the entire territory and all types of land use are available only as of 2010 (Veteikis, Piškinaitė 2019). The Lithuanian CORINE land cover database is another valuable information resource extensively used by researchers for the determination of changes in land use structure (Litvinaitis 2011; Tarvydienė 2009). However, despite their reliability and detailedness, these data (aerial photographs, orthographic maps, CORINE database) can be used for detecting LULC changes over the period of just a few decades. For detection of long-term LULC changes, old maps, plans, projects and other cartographic material have to be used.

In the historical past, the territory of Lithuania has suffered occupation by different powers numerous times. Because of differences in map purpose, territorial coverage, creation time, and scale, the historical cartographic heritage is diverse and inconsistent. Most maps were created for military purposes. The number of maps covering the territory of Lithuania as well as diversity of map scales increased during the 1920–1960 period (Fig. 4). Since 1980, the scale of

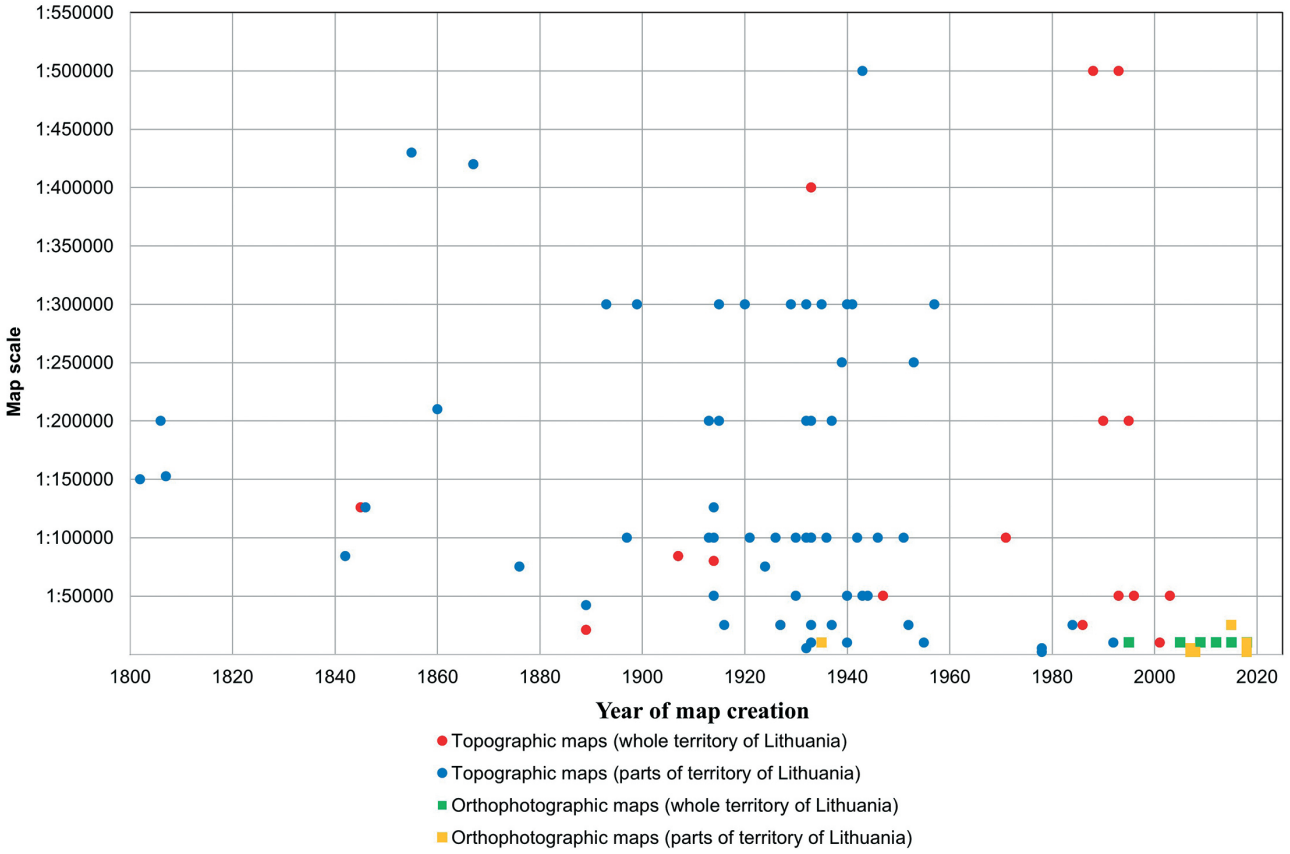

Fig. 4 Time and scale section of maps covering the territory of Lithuania since 1800s

maps has become smaller (less than 1:100 000) and large-scale maps (more than 1:200 000) were created less frequently than ever before. Nowadays, due to the technological progress and economic growth, orthophotographic maps are produced in digital formats over gradually shortening periods of time, approximately every two years. For more detailed LULC change studies, the authors of the current study focus on small-scale maps, therefore maps of the scale larger than 1:500 000 were not included into this analysis. Only a small part of the analyzed maps represent the whole territory of Lithuania (Fig. 4).

Digitization of old maps is frequently used by foreign researchers (Palang *et al*. 1998; Stäuble *et al*. 2008; Statuto *et al.* 2016; Bender *et al.* 2005) for analyzing historical landscape changes. However, in Lithuania, map digitization is still not sufficiently employed, so only a few cartography popularization projects can be mentioned. In 2018–2019, the Wrublewski Library of the Lithuanian Academy of Sciences implemented the project „Lithuania in topographic maps of 1914–1945“, which was aimed at presenting its collection containing approximately 400 maps of the above mentioned period to the public. For that purpose, maps were digitized, linked to the coordinate system, and made available online.

Information technologies allow combining maps of different periods by means of transparent overlaying. Geoportal.lt, the internet domain containing free to public, digital maps of Lithuania, presents the WWII German military aerial photographs taken in 1944 and transposed into the Lithuanian coordinate system LKS-94. A similar project has been carried out by the Central State Archive of Lithuania. The portal contains aerial photographs of the current territory of Lithuania that were taken during the WWII. These projects allow comparing aerial views of the Lithuanian territory recorded at different times (www.ekultura.lt).

LULC changes can be assessed visually using old photography sources, although mostly as an auxiliary tool for research substantiation. Old photographs are popular in social media, especially when personal connections are found. Old Lithuanian photographs are accessible to public on social networks (e.g., „Lithuania in old photographs“ on Facebook), in museums, library exhibitions and in archives.

Foreign authors use modern technologies not only for the digitization of old maps, but also for creating landscape reconstructions, three-dimensional images of the studied areas (De Boer 2010). In Lithuania, similar work is done by historians and archaeologists, but not extensively. One example is a publicly available visualization of the Neris River 15,000 years ago based on the report of the archaeological research in the Dainų Valley within the State Cultural Reserve of Vilnius Castles (Neris…). Such visualizations serve as science popularization as they introduce the public to the landscape that prevailed in the past and demonstrate how it has changed. Archeological reconstructions can be used as an additional information source in LULC change studies.

Monitoring is also an important process for tracing environmental changes. In Lithuania, the retrospective local level landscape monitoring was performed and its findings were summarized in 2008. The retrospective analysis of changes in the land use structure consisting of 100 reference areas (2.5 km² area each) over the period lasting from 1976–1986 (most maps dating back to1977, the Soviet period) to 2005 (15 years of independence) was performed. Land use was analyzed by comparing the situation represented on Soviet topographic maps with the one recorded in 2005–2006 orthophotos. The aim of the project was to compare land cover data and to make conclusions about LULC changes. In pursuit of the national landscape policy, the Lithuanian environmental agency commissioned the second stage of local scale landscape monitoring in 2015, the outcome of which was the assessment of the land use situation in the 1977–2013 period (Veteikis *et al.* 2015).

Problems related to LULC monitoring and distinguishing of urban environment elements were emphasized (Veteikis, Jankauskaitė 2004).

METHODS FOR EVALUATING LULC CHANGES

The understanding of the evolutionary trends in landscape, especially in areas of urban/rural contacts, is of crucial importance for sustainable landscape planning (Di Fazio *et al.* 2011). LULC studies performed in Lithuania most often focus on the description and explanation of landscape change trends. The spatial dimension is an inherent method used by researchers and it is a valuable source of knowledge for physical, biological and social sciences, including history and archaeology (Etter *et al*. 2008). The studied period requires broader and deeper interdisciplinary knowledge including that of history, cartography, and biology. A researcher's competence and his/her worldview may also strongly influence study results and conclusions. On the other hand, landscape itself represents a valuable source of the objective information, which is not recorded in any written sources, on past interactions between natural and anthropogenic processes (Mačiukas, 2005).

LULC changes can be evaluated through the description of landscape or LULC elements in the process of change. The typological description of LULC elements in different historical periods continues to retain both statistical and cartographic expressions. LULC elements and their description as well as the

stored statistical data on them are unique to that particular historical period. Moreover, the statistical and cartographic information available on LULC in a particular historical period corresponds to the needs (Milius, Ribokas 2004), worldviews and the technological development level in that period.

Therefore, in historical LULC change studies, data generalization and comparison are indispensable. In European LULC studies, the CORINE Land Cover (CLC) inventory listing 44 different land cover classes represents one of the most often used information resources. Although CLC has a large coverage of European countries, the local-scale LULC data presented therein are of limited accuracy. The information on land cover provided by other data sets is more detailed, but is restricted either to part of Europe or thematically (Rosina *et al.* 2020).

LULC change data allow determining LULC change trajectories, which requires that LULC data should be summarized and grouped into 3–5 main classes. Changes in these classes are recorded by constructing change matrices (Hernandez et al. 2016). LULC change trajectories show not only the extent of changes but also the drivers of these changes (Fig. 5). Changes in LULC can be recorded at more than two points of time (Milius, Ribokas 2008). The use of this method in Lithuanian LULC change studies is not widespread. In contrast, foreign researchers are mainly focused on analyzing LULC change trajectories (Hernandez *et al.* 2016; Jaworek-Jakubska *et al.* 2020; Stürck *et al.* 2018). However, LULC change trajectories highlight the directions and extent of LULC changes, but not their reasons.

There is no single, universally accepted methodology for tracking LULC changes, and sometimes the choice of the methodology, especially the choice of periodization, sampling, etc., can bear signs of subjectivity, which may be also conditioned by objective reasons such as the availability or unavailability of cartographic or statistical materials. This fact in turn causes comparability problems in terms of territories or historical periods.

In Lithuania, studies dealing with the determination of LULC change trajectories are lacking. Most of the studies on LULC changes in Lithuania are restricted to the identification of actual changes illustrated by the descriptive statistics presented in the form of tables or diagrams (Bauža 2005; Česnulevičius *et al*. 2005; Bauža, Baužienė 2008; Ribokas, Milius 2008; Bauža 2011; Orlonas, Veteikis 2016). The percentage change (increase / decrease) in the land use structure compared to that at the beginning of the survey can be also represented in a cartographic way, i.e., in the form of a map of change (Stürck 2018; Jaworek-Jakubska 2020). Lithuanian researchers rarely use cartographic methods to present research results and to depict LULC changes. These methods, however, are quite common in final theses of geography students (Veteikis, Piškinaitė 2019), which indirectly indicates the potential of researchers to contribute to LULC studies.

DISCUSSION

Correctness of research results largely depends on comprehensiveness and accuracy of the cartographic material used. Rapid development of remote sensing and computational technology in recent decades has led to the increased use of space imagery and aerial photography in the analysis of LULC changes. The frequently updated remote sensing data allow observ-

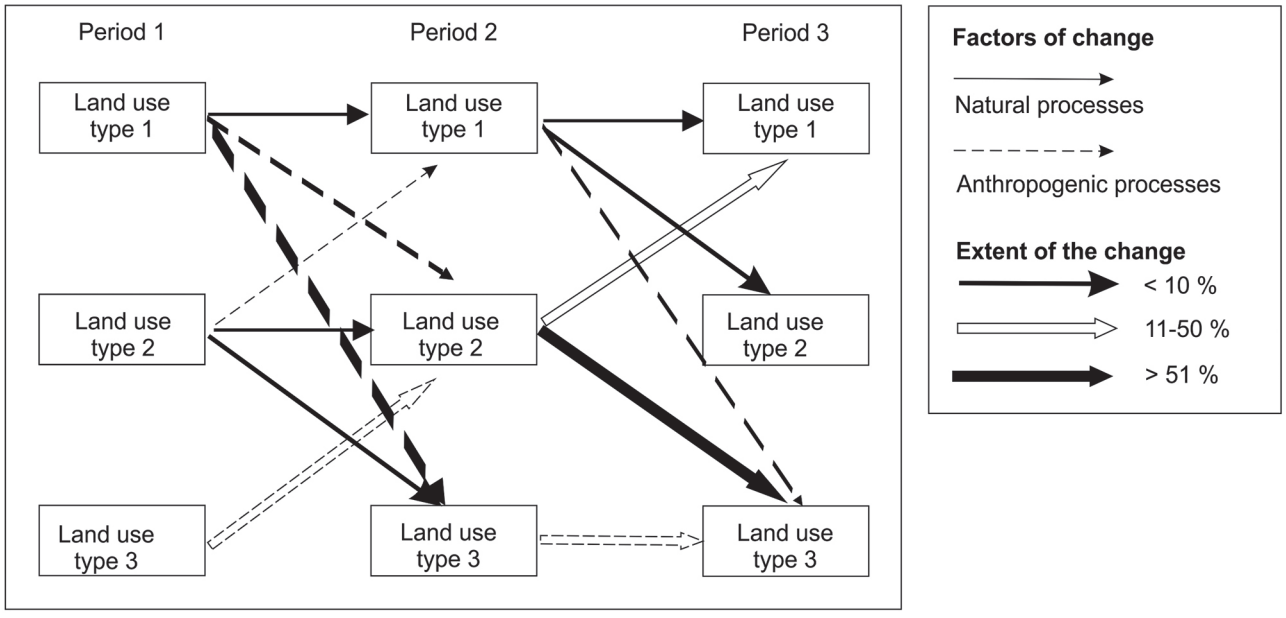

Fig. 5 Graphical representation of LULC change trajectories during three periods of LULC data collection

ing actual Earth's surface changes. Unlike aerial photographs, satellite images can provide more frequent data collection on a regular basis. Aerial photographs may provide geometrically more accurate maps although there are limitations in respect to their coverage extent and the expenses involved. (Parveen *et al.* 2018). Aerial photos provide detailed evidence of landscape changes (Gennaretti *et al.* 2011). They represent a valuable research tool for areas where other information sources are not available (Godziemba-Maliszewski 2010).

One of the most important issues in historical LULC studies is the accuracy and availability of cartographic sources. Small extent, large scale cartographic sources were compiled only for exceptional areas such as manors or parishes. Information presentation in these documents was very schematic. Cartographic data sources covering the entire country were small-scale and highly generalized, which limits their effectiveness in comparative analysis. The choice of the method for LULC change analysis depends on several factors: size of the study area, scale of assessment, size of statistical data units, availability and accuracy of cartographic data, and expertise of the researcher in history, cartography, GIS, and in some cases, in soil science or botany. Research results directly depend on the availability and completeness of historical maps and competences of the researcher. It took years or even decades to create historical maps, therefore they represent LULC not at a specific point of time, but rather during a specific period. Over time, cartographic methods and techniques of map making have improved, the accuracy of maps increasing accordingly. The older the map is, the greater discrepancy between the mapped and actual LULC is. Hence, one should not rely on old maps completely.

To improve the accuracy and comprehensiveness of LULC studies, and thus to ensure their better quality, various methods and various data types should be used in combination. For gaining a comprehensive understanding of the LULC changes that have occurred over recent centuries, Yang suggests implementing an interdisciplinary approach in LULC change studies, i.e., the integration of knowledge and methods from different disciplines. So far there have been relatively few LULC change studies performed either by foreign or Lithuanian authors that are based on the integrated knowledge of geography, ecology or other disciplines (Yang *et al.* 2014). Adoption of interdisciplinary approach in LULC change studies would improve their quality and boost collaboration among researchers in different fields of science (Fig. 6).

Only a small part of the LULC change studies in Lithuania deal with LULC change trajectories, the identification and analysis of which can be performed using a wide range of methods.

Lithuanian LULC change studies lack predictions of future LULC changes. The growing number of studies on LULC and significance of their findings create suitable conditions for pursuing studies into future LULC changes. Historical LULC change studies have not been accomplished and still demand more scientific attention. The potential of old maps as a unique source of information has not been exploited to the full, which is, probably, due to the following challenges that their use poses: a variety of scales, poor quality of old maps and extensive geography of the areas covered. Therefore, LULC change reconstruction based on old maps requires methodological elaboration involving both technological and epistemic approaches.

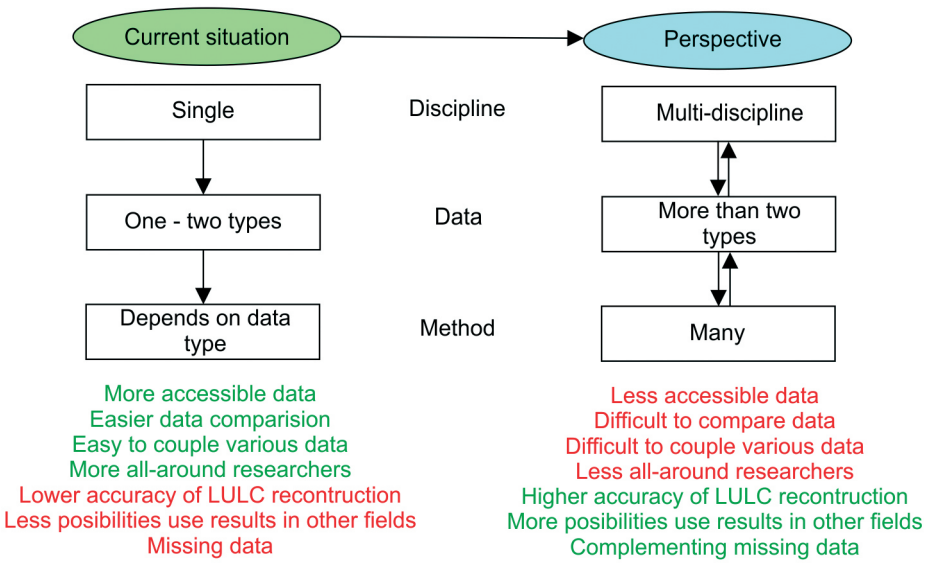

Fig. 6 Possible development of historical LULC studies in Lithuania (with reference to Yang *et al.* 2014)

CONLUSIONS

1. The main advantages of historical maps are unique visual and spatial information about LULC in a specific area during a specific period and abundant spatial quantitative information. The main disadvantages are errors occurring while georeferencing and digitizing old maps, accuracy of old maps, equalization of historical and modern map LULC classes.

2. The main advantages of using census and statistical data are their accessibility, comprehensiveness, and the possibility of using these data for different purposes. The disadvantages include absence of link to spatial data (lost connection with geography), differences in definitions and identification of LULC structures in different periods, changes of the recorded administrative units over time.

3. Our study has revealed that historical LULC change studies performed using old maps by Lithuanian researchers are not numerous, which can be explained by the following reasons: (1) absence of suitable and/or sufficiently accurate maps of specific areas and/or (2) technically extremely difficult or time-consuming processing of map information, not to mention some methodical aspects.

4. There are various cartographic data (especially for the period 1900-1950) in Lithuania and so far their potential has not been fully exploited.

5. To compensate for the shortage of historical datasets and to improve the quality of historical LULC change studies, statistical records should be used in combination with historical maps.

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