



The Intersection between GIScience and History: an Overview of an Emerging Scientific Field

Hannah Meyer¹ and Johannes Scholz ¹

¹ Research Group Geoinformation, Institute of Geodesy, Graz University of Technology, 8010 Graz, Austria

Correspondence: Johannes Scholz (johannes.scholz@tugraz.at)

Abstract. Using the methods of Geographic Information Science and Technology (GIS&T) to analyze historical data has been of increasing interest to the scientific community of History in the last two decades. The spatial turn in the Humanities fueled this development and led to a number of scientific initiatives that utilized GIS&T to store, analyze and visualize historical data accordingly. This article, documenting ongoing work, outlines the scientific developments, main research foci, and past and current research interests of the emerging field of historical GIS from the beginning of the spatial turn in the social sciences to the present day. The article is using a literature review in the fields of Geographic Information Science and History as core methodology. Our main findings are centered around the fact that historical GIS research is spread out over a variety of disciplines and journals. Hence, building a methodological and theoretical core, and forming cohesion in the field has been challenging. Current research trends underpin this trend. Nevertheless, a number of promising research initiatives are pursued at the intersection of GIS&T and History – which documents an intensification of the collaboration between both fields.

Keywords. GIS, history, digital humanities, historical GIS, literature review

1 Introduction: why use GIS in history?

Considering that history happens in both space and time, it is no surprise that the disciplines that deal mostly with space and time – geography and history – have been converging both in their broader research questions and methodology. Or, as Knowles (2002: 12) notes:

“Geography is the study of spatial differentiation, history the study of temporal differentiation. Historical GIS

provides the tools to combine them to study patterns of change over space and time.”

Over recent years, many researchers (see for example Baily and Schick, 2009; Knowles, 2000: 453) have demonstrated this endeavour to be worthwhile in producing new insights in historical research. Geographic Information Systems (GIS) are especially well equipped to handle and integrate fuzzy and ambiguous historical data.

Up to now, a single definition of the term Geographic Information Science has been the subject to discussion within the scientific community and not one single, conclusive definition has been found yet. However, the community agreed upon core features of GISystems that relate to their ability to input, store, manage, analyze, map, and output spatial data with computer technology (Baily and Schick, 2009) including both hardware and software components. The key to any geographic analysis functionality is the fact that the data in question is stored with its geographic location. In addition, GIScience – as the theory underneath the purely functional methods that GIS programs offer – has been recognized as its own academic field. Contributions to GIScience have come from geographers, social and computer scientists since the beginnings of the 1990s (Longley et al., 2005) and have evolved alongside progresses in computer and information technology. As the concept and importance of space have pushed into the social sciences and humanities, in a process that is known as the spatial turn, research approaches and methods in these fields have followed suit.

The objectives of the article are centered around the question which role GIScience plays in the field of History and to explore the interdependencies between those two fields. The authors conduct a literature analysis and review to answer the research question. Hence, the

article intentionally has no software and data availability section. The article is structured as follows. In section 2 we discuss the development of historical GISc up to now, based on literature in the field. Section 3 contains a systematic literature review concerning GIS and History, which is followed by a conclusion.

2 The development of historical GISc over time

The goal of this section is to trace the development of historical GIS as an academic field across the last two decades. For this purpose, selected overview articles about historical GIS will be discussed along which articles that reveal trends and core research topics.

2.1 The spatial turn and the beginnings of historical GIScience in the 2000s

The term “spatial turn” as a shift in perspective towards the spatial can be traced back to Jameson (1998), where he states:

“A certain spatial turn has often seemed to offer one of the more productive ways of distinguishing postmodernism from modernism proper”.

In 1989, the concept of the spatial turn was picked up by Soja (1989: 39) who applied it to a geographical context with the goal of reestablishing the spatial in critical theory. He argued for space to be seen as a product of social processes rather than simply a physical container in which these processes take place (Soja, 1989: 80).

In the following decades, Roskamm (2016) argues, this perspective of space took hold and is to this day well established in social geography (Soja and Hooper, 1993: 192; Soja, 1996). In Carter et al. (2009) the authors emphasize social science’s turning away from space as simply a “predefined territorial container of political life” or a “fixed backdrop to the political”.

This turn towards space in the social sciences and humanities in general and historical science in particular over the last decades has certainly been a paradigm shift and has facilitated the use of GIS in historical research to this day. As early as 2005, Dix (2005) and Knowles (2005) have pointed out a trend towards increased academic interest in the intersection of history and geographical methods. Dix traces this development back to early connections of geography and historical science in the 1950s and 60s in the field of agrarian history. By the end of the 1960s however, this connection was fading as historical geography turned toward topics of environmental history, spatial planning, and historic preservation.

Knowles (2005) points out the existing “new generation” of researchers, of whom many had not previously worked with GIS and calls historical GIS an “emerging field”. This gives some indication around which time historical GIS gained traction in historical scholarship, and matches the upward trend of publications around that time which will be discussed later in the article. As expected from a field as young as historical GIS, Knowles (2005) notes the high diversity research topics. Historical GIS research varied wildly in the region of study within historical science as well as scale, type(s) of data used, theoretical framework and encompassed examples from simple cartography to sophisticated spatial analyses. Themes around the uncertainty of data and error propagation were already points of discussion in GIScience at this point in time (Zhang and Goodchild, 2002). Knowles (2005) also points out the seeming incompatibility of the traditionally qualitative methods of historical science and the more quantitative, positivist leaning GIScience, but emphasizes that both of these disciplines are actually more flexible and overlap significantly. Especially the ability to integrate various data sources is a trend in historical. Knowles (2005) closes with an optimistic outlook and posits that the “trend of applying GIS to history is clearly accelerating” and has “tremendous possibilities”.

To illustrate the possibilities of using GIS for historical science, Gregory and Healy (2007) reference to Gregory et al. (2001) which already lays out three main advantages that GIS offers for the study of history. First, seemingly incompatible data can be brought together through its location in space (see Baily and Schick, 2009); second, the visualization of data in the form of maps, animations, or virtual landscapes in and of itself can produce new insights into history by making data more intuitive and accessible; and third, GIS facilitates the spatial analysis of data. In addition, Gregory and Healy (2007) identify three domains in which GIS offers the greatest chances for its contribution to historical science: 1) the creating of GIS databases, 2) performing spatial analyses, and 3) the study of underlying conceptual questions.

2.2 Historical GIS after 2010

DeBats and Gregory (2011) analyze the evolution of historical GIS. Their assessment that historical GIS had been an established part of historical research for about a decade at that time also points to the late 2000s as its emergence as a distinct scientific field (see also Gregory and Ell, 2007 and Knowles, 2008). Like other researchers before them, DeBats and Gregory (2011) pick up the most commonly cited reasons for the integration of GIS in historical science. These advantages include 1) the ability to produce maps quickly, easily, and in large volumes, 2) visualization as a means of exploring historical data and opening new research questions, 3) the integration of

diverse data sources (e.g. Talbert, 2000; McCormick, 2001; Donahue, 2004; Cunfer, 2005; Gordon, 2008; Olson and Thornton, 2011), and 4) the use of spatial analysis (Fotheringham et al., 2000; Maguire et al., 2005) in the exploration of historical phenomena. In terms of drawbacks, they mention the apprehension of some historians regarding the time it takes to create a spatial database and the technical skills required. According to DeBats and Gregory (2011), the ability to think spatially in the context of history has been increasing among students and researchers of history as its importance becomes more apparent in historical scholarship.

Sui and DeLyser (2012) argue for the integration of quantitative and qualitative methodological approaches and research methods in the social sciences after the spatial turn. The divide into a human and a physical geography realm is apparent. The authors argue, that this divide hinders transdisciplinary, collaboration, and diversity in geography and highlight recent trends towards hybrid geography both from the physical and the social side of geography. Especially GIScience which has long maintained an image of itself as an interdisciplinary field (Blaschke and Merschdorf, 2014) could offer important contributions, as the emphasis on mixed methods research to integrate human and physical geography increases. Other authors conclude that the spatial turn fosters the methodological integration of GIS (see Bodenhamer et al., 2010; Fisher and Mennel, 2010; Knowles, 2008; Van Manen et al., 2009; Warf and Arias, 2008). Just as mathematics, physics, computer science, and ecology contribute to GISci in addition to recent advances in GIS, remote sensing, location-based services, and GeoAI, these developments should be applied in the social sciences and humanities alike.

In a review essay Knowles (2014) discusses the main points of criticism and overarching themes in historical GIS. As of 2014 it is becoming clear, that the number of researchers in the field of historical GIS is lagging behind expectations, and no paradigm shift or actual scientific inclusion can be reported yet. Knowles (2014) explains why historians might not have been more enthusiastic in their appropriation of GIS methodology: a lack of clear reasons why GIS is useful for historians, persistent critiques of the alleged unquestioned positivism of GIS methodology might discourage historians. To bring scholars of historical GIS together, Knowles (2014) proposes to reconceptualize GIS as not only a technology for analysis, but as a uniting “spatial language”. In this way, maps would not only be seen as visualizations of spatial data but as actual objects of study, like texts or images.

3 Historical GIS today

3.1 Systematic literature review of an emerging field

This section aims to be an approximate assessment of the current state of the science of historical GIS. This literature review of publications is intended to be an indication of the development and current topics of the field, of course under the awareness of the limitations an approach like this brings with it.

For this analysis, a query of the Scopus database for the term “historical GIS” was performed across all search fields (i.e., title, abstract, key words, etc.). As of the day of writing this article, the query returned 1,235 results. The first publication containing the phrase “historical GIS” is Gregory and Gilham (1998) reporting on a methodological framework for the study of historical GIS. Of course, this does not mean there were no publications related to GIS methods in the field of history before then, but it is the first article to use this exact phrase.

Figure 1 shows how the number of publications in historical GIS. The number has increased from 1998 all the way to 2021. Knowles’s (2005) early assessment that the year 2005 marks a time of increasing interest in the field proves to be accurate – when looking at the results from Scopus. The time of this starting point as well as an overall emergence in the recent years become especially apparent in the number of citations (Fig. 2) of the same articles. Especially the increasing number of citations per year but also the rising number of publications suggest a steadily growing academic interest in the field of historical GIS.

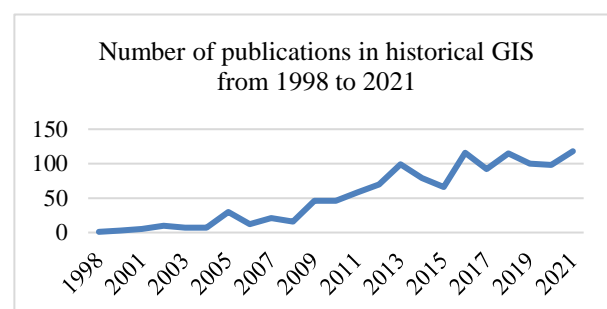


Figure 1. Number of publications in historical GIS in Scopus, found with the search term “historical GIS”.

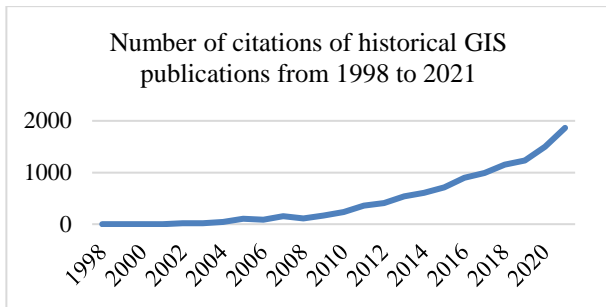


Figure 2. Number of citations of historical GIS publications.

We analyzed which disciplines have contributed to the field, since its emergence. This quick evaluation shows: the top contributors are the social sciences, arts and humanities, earth and planetary sciences, computer science, and environmental science (see Fig. 3).

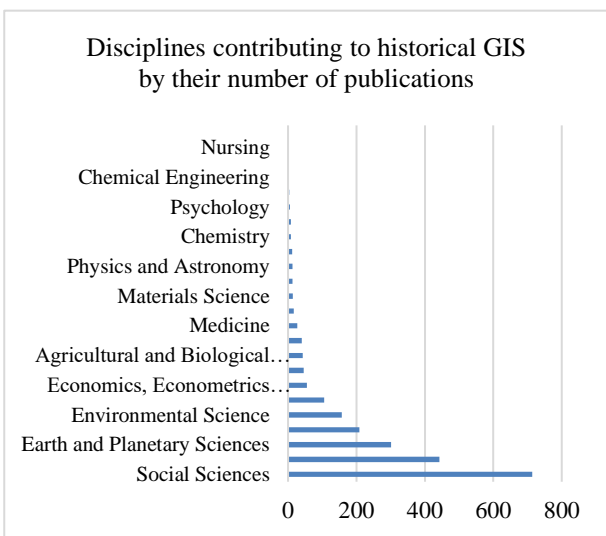


Figure 3. Contributing disciplines to historical GIS in Scopus, found with the search term “historical GIS”.

In the realm of conferences, a similar trend is noticeable. Two conferences in particular, namely Spatial Humanities and the Linked Pasts Symposium, have been at the center of current historical GIS research. In terms of research focuses, Spatial Humanities is a conference for more general themes of „computational approaches to spatial questions in the humanities” (Spatial Humanities, 2022) and “geospatial technologies in humanities research, methodological innovations, and applied research”. More specifically, studies involving “urban gazetteers, artificial intelligence, geographical analysis of text and image, database development, linked open data, IIIF applications for maps and spatial data, metadata and the development of sustainable data workflows” are accepted at the conference. In 2022, the 4th Spatial Humanities conference will be held. The Linked Pasts Symposium offers researchers an even more specific conference in the study of historical GIS with a focus on Linked Open Data in the context of history and will be held for the 8th time in 2022 (Linked Pasts Symposium, 2022)

These conferences are an indication of a dynamic research community and show a wide cross section of interest and the current research trends among scholars of historical GIS.

3.2 Current research questions

In this section, the wider topics at the center of the current research both in terms of methods being used and in their historical topics will be described in more detail. To that end, the 18 posters from the Linked Pasts Symposium from 2021 and the 20 most cited publications in historical GIS from 2015 to 2021 are analyzed in search of common threads in the research.

In general, the posters presented at Linked Pasts VII Symposium in 2021 show similarities in their methodological approaches. Overarching topics are: the creation of databases, data integration and visualization and Linked (Open) Data. A variety of spatial analysis methods and the implementation of ontologies are also of importance according to the publications. An overview of the overarching topics that could be identified can be seen in Fig. 4.

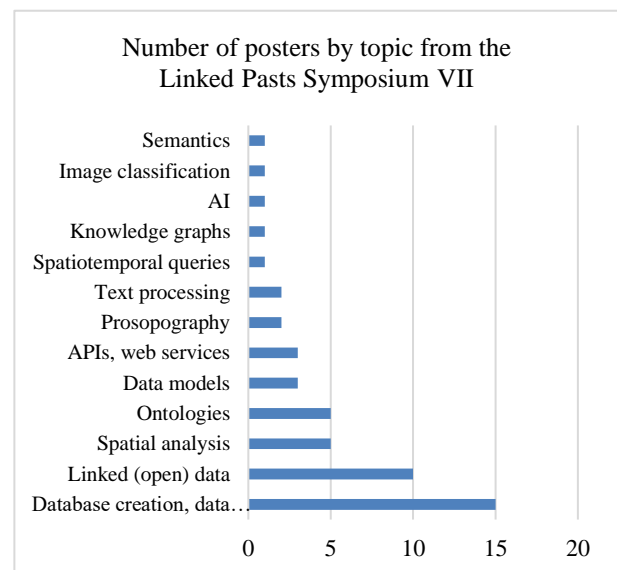


Figure 4. Themes from scientific posters from the Linked Pasts Symposium VII.

In addition to the collection of scientific posters from the Linked Pasts Symposium, a similar analysis was performed with the 20 most cited publications in historical GIS from 2015 to 2021. Of these 20, three publications (Bennett et al., 2017; Melo and Martins, 2017; Graham et al., 2015) are review publications. In terms of the methods used, most of the publications feature one or more kind of spatiotemporal analysis (Viña et al., 2016; Baude et al., 2019; Pindozzi et al., 2016; Logan et al., 2015; Sadler and Lafreniere, 2017; Lafreniere and Gilliland, 2015; Ku, 2016; Cats, 2017; Lee and Lin, 2018; Twinam, 2017) or general spatial analysis (Lourinho and Brito, 2015;

Cunningham and Savage, 2015; Birkin et al., 2017). The use of statistical data (Viña et al., 2016; Pindozi et al., 2016; Logan et al., 2015; Sadler and Lafreniere, 2017) as well as georeferencing (Melo and Martins, 2017; Pavelková et al., 2016) and classification of data in general (Yang et al., 2019; Bruno and Roncella, 2019) are also common. Semantics (Bruno and Roncella, 2019; Melo and Martins, 2017), database design (Bruno and Roncella, 2019), big data (Graham et al., 2015) and simulations (Ku, 2016) are other methodological approaches (see Fig. 5).

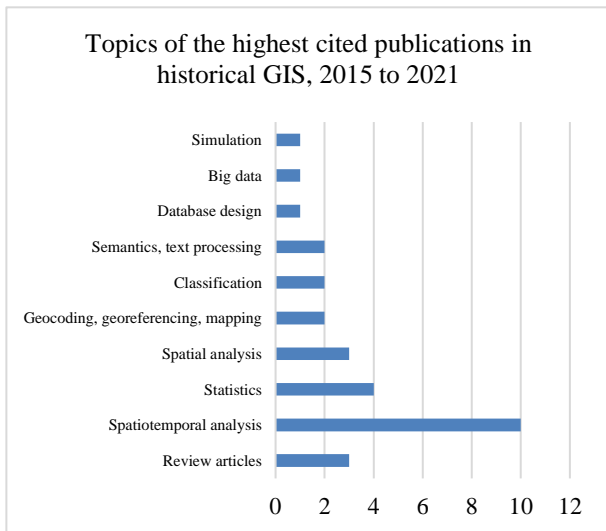


Figure 5. Topics covered by the highest cited publications in historical GIS from 2015 to 2021.

The selected publications are diverse in their methodology. Very broadly, the fields of study can be summarized as 1) environment, conservation, climate or land use (Bennett et al., 2017; Yang et al., 2019; Viña et al., 2016; Ku, 2016; Baude et al., 2019; Lourinho and Brito, 2015; Pavelková et al., 2016; Pindozi et al., 2016), 2) political history (Ziblatt, 2017; Cunningham and Savage, 2015; Lee and Lin, 2018; Twinam, 2017; Logan et al., 2015; Sadler and Lafreniere, 2017), 3) cultural heritage or preservation (Bruno and Roncella, 2019; Graham et al., 2015), and 4) transport, planning or urban studies (Cats, 2017; Birkin et al., 2017; Lafreniere and Gilliland, 2015).

In addition to the mentioned articles, there are several ongoing historical GIS initiatives. These include the global historical GIS database World Historical Gazetteer (Mostern and Grossner, 2020), the project HGIS de las Indias for historical data for Hispanic America from 1701 to 1808 (Stangl, 2019) as well as the Pelagios Network, an initiative for geo-annotated historical data (Pelagios Network, 2022).

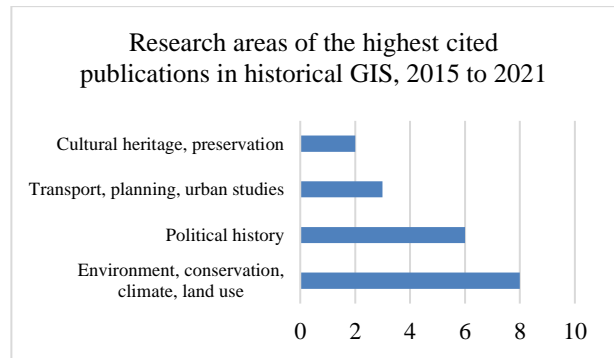


Figure 6. Research areas of the highest cited publications in historical GIS from 2015 to 2021.

4 Conclusion

This article traces the development of GIS in the research of History over the past two decades and outlines its main topics and challenges. It is apparent, that the field is and always has been very heterogenous and multidisciplinary – both in terms of methodology and research topics. Nevertheless, a recent trend points towards the emerging nature and increasing scholarly interest in the intersection of GIS and History.

One of Knowles's (2014) criticisms is, that because historical GIS research is spread out over a variety of disciplines and journals, building a methodological and theoretical core, and forming cohesion in the field has been challenging. When looking at current research trends today, this difficulty still holds true. The ambition and willingness of future scholars will decide if this diverse and dynamic field has a more coherent set of research questions. Looking at the promising projects currently going on – like World Historical Gazetteer (Mostern and Grossner, 2020), HGIS de las Indias (Stangl, 2019) or Pelagios Network (Pelagios Network, 2022) – which are placed at the intersection of GISc and History we can witness an intense collaboration between the fields. This is underpinned by the increasing number of publications, scientific conferences and workshops in the field of digital humanities and digital history. Key point is, that both fields could benefit from each other. In particular, as spatio-temporal questions are still regarded as core research questions in GIScience. For History, the spatial data storage and analysis methodologies as well as Geospatial Semantic Web could be of interest to further analyze the large datasets at hand.

References

Bailey, T. J., & Schick, J. B. (2009). Historical GIS: Enabling the collision of history and geography. *Social*

- Science Computer Review*, 27, 291-296. doi:10.1177/0894439308329757
- Baude, M., Meyer, B. C., & Schindewolf, M. (2019). Land use change in an agricultural landscape causing degradation of soil based ecosystem services. *Science of the Total Environment*, 659, 1526–1536.
- Bennett, N. J., Roth, R., Klain, S. C., Chan, K., Christie, P., Clark, D. A., . . . others. (2017). Conservation social science: Understanding and integrating human dimensions to improve conservation. *biological conservation*, 205, 93–108.
- Birkin, M., Clarke, G., & Clarke, M. (2017). *Retail location planning in an era of multi-channel growth*. Routledge.
- Blaschke, T., & Merschdorf, H. (2014). Geographic information science as a multidisciplinary and multiparadigmatic field. *Cartography and Geographic Information Science*, 41, 196–213.
- Bodenhamer, D. J., Corrigan, J., Harris, T. M., & others. (2010). *The spatial humanities: GIS and the future of humanities scholarship*. Indiana University Press.
- Bruno, N., & Roncella, R. (2019). HBIM for conservation: A new proposal for information modeling. *Remote Sensing*, 11, 1751.
- Carter, D., Pugh, J., Thien, D., Marres, N., Featherstone, D., Griffin, L., . . . others. (2009). What are the consequences of the 'spatial turn' for how we understand politics today? A proposed research agenda. *Progress in Human Geography*, 33, 579–586.
- Cats, O. (2017). Topological evolution of a metropolitan rail transport network: The case of Stockholm. *Journal of Transport Geography*, 62, 172–183.
- Cunfer, G. (2005). On the Great Plains: agriculture and environment. *Texas A&M University Press No. 20*.
- Cunningham, N., & Savage, M. (2015). The secret garden? Elite metropolitan geographies in the contemporary UK. *The Sociological Review*, 63, 321–348.
- Debats, D. A., & Gregory, I. N. (2011). Introduction to historical GIS and the study of urban history. *Social Science History*, 35, 455-463. doi:10.1215/01455532-1381814
- Dix, A. (2005). „Cultural Turn“ und „Spatial Turn“. Neue Berührungsebenen von Geographie und Geschichtswissenschaft. *Geographische Zeitschrift*, 93, 2–4.
- Donahue, B. (2004). *The great meadow: farmers and the land in colonial Concord*. Yale University Press.
- Fisher, J., & Mennel, B. C. (2010). *Spatial turns: space, place, and mobility in German literary and visual culture* (Bd. 75). Rodopi.
- Fotheringham, A. S., Brunson, C., & Charlton, M. (2000). *Quantitative geography: perspectives on spatial data analysis*. Sage.
- Gordon, C. (2008). *Mapping decline: St. Louis and the fate of the American city*. University of Pennsylvania Press.
- Graham, S., Milligan, I., & Weingart, S. (2015). *Exploring big historical data: The historian's microscope*. World Scientific Publishing Company.
- Gregory, I. N., & Ell, P. S. (2007). *Historical GIS: technologies, methodologies, and scholarship* (Bd. 39). Cambridge University Press.
- Gregory, I. N., & Healey, R. G. (2007). Historical GIS: Structuring, mapping and analysing geographies of the past. *Progress in Human Geography*, 31, 638-653. doi:10.1177/0309132507081495
- Gregory, I. N., Kemp, K. K., & Mostern, R. (2001). Geographical Information and historical research: Current progress and future directions. *History and Computing*, 13, 7–23.
- Gregory, I., & Gilham, V. (1998). Historical GIS: a framework for mapping the past. *Bulletin of the Society of Cartographers*, 31, 9–16.
- Jameson, F. (1988). Postmodernism and Utopia. In *Utopia Post Utopia: Configurations of Nature and Culture in Recent Sculpture and Photography January 29-March 27, 1988* (S. 11-32). The Institute of Contemporary Art/Cambridge, MA: The MIT Press.
- Knowles, A. (2014). The contested nature of historical GIS. *International Journal of Geographical Information Science*, 28, 206-211. doi:10.1080/13658816.2013.850696
- Knowles, A. K. (2002). Introducing historical GIS. In A. K. Knowles (Hrsg.), *Past time, past place: GIS for history*. Redlands, CA: Environmental Systems Research Institute.
- Knowles, A. K. (2000). Introduction. *Social Science History*, Vol. 24, No. 3, 451-470.
- Knowles, A. K. (2005). Emerging trends in historical GIS. *Historical Geography*, 33, 7-13. Von <https://www.scopus.com/inward/record.uri?eid=2-s2.0-77951671258&partnerID=40&md5=f38712b18434651622cf0d2b3664f365> abgerufen
- Knowles, A. K. (2008). GIS and History. In A. K. Knowles (Hrsg.), *Placing history: How maps, spatial*

- data, and GIS are changing historical scholarship* (S. 1–25). ESRI Redlands.
- Ku, C.-A. (2016). Incorporating spatial regression model into cellular automata for simulating land use change. *Applied Geography*, 69, 1–9.
- Lafreniere, D., & Gilliland, J. (2015). “All the World’s a Stage”: A GIS Framework for Recreating Personal Time-Space from Qualitative and Quantitative Sources. *Transactions in GIS*, 19, 225–246.
- Lee, S., & Lin, J. (2018). Natural amenities, neighbourhood dynamics, and persistence in the spatial distribution of income. *The Review of Economic Studies*, 85, 663–694.
- Linked Pasts VII Symposium. (2022). *Linked Pasts VII Symposium*. Von <https://www.ghentcdh.ugent.be/linked-pasts-vii-symposium> abgerufen
- Logan, J. R., Zhang, W., & Chunyu, M. D. (2015). Emergent ghettos: black neighborhoods in New York and Chicago, 1880–1940. *American Journal of Sociology*, 120, 1055–1094.
- Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science*. Chichester, UK: John Wiley & Sons.
- Lourinho, G., & Brito, P. (2015). Assessment of biomass energy potential in a region of Portugal (Alto Alentejo). *Energy*, 81, 189–201.
- Maguire, D. J., Batty, M., & Goodchild, M. F. (2005). *GIS, spatial analysis, and modeling*. Esri Press.
- McCormick, M., & others. (2001). *Origins of the European economy: communications and commerce AD 300-900*. Cambridge University Press.
- Melo, F., & Martins, B. (2017). Automated geocoding of textual documents: A survey of current approaches. *Transactions in GIS*, 21, 3–38.
- Mostern, R. & Grossner, K. (2020). World Historical Gazetteer. <https://whgazetteer.org> (v1.0, July 2020) [April 10, 2022].
- Olson, S., & Thornton, P. (2011). *Peopling the North American City: Montreal, 1840-1900* (Bd. 222). McGill-Queen’s Press-MQUP.
- Pavelková, R., Frajer, J., Havlíček, M., Netopil, P., Rozkošný, M., David, V., . . . Šarapatka, B. (2016). Historical ponds of the Czech Republic: an example of the interpretation of historic maps. *Journal of Maps*, 12, 551–559.
- Pelagios Network (2022). <https://pelagios.org/> [April 10, 2022].
- Pindozi, S., Cervelli, E., Capolupo, A., Okello, C., & Boccia, L. (2016). Using historical maps to analyze two hundred years of land cover changes: case study of Sorrento peninsula (south Italy). *Cartography and Geographic Information Science*, 43, 250–265.
- Roskamm, N. (2016). Das Reden vom Raum. Zur Aktualität des Spatial Turn–Programmatik, Determinismus und „sozial konstruierter Raum“. *PERIPHERIE–Politik• Ökonomie• Kultur*, 32.
- Sadler, R. C., & Lafreniere, D. J. (2017). Racist housing practices as a precursor to uneven neighborhood change in a post-industrial city. *Housing studies*, 32, 186–208.
- Soja, E. W. (1989). *Postmodern geographies: The reassertion of space in critical social theory*. Verso.
- Soja, E. W. (1996). *Thirdspace: Expanding the geographical imagination*. Blackwell.
- Soja, E., & Hooper, B. (1993). Some notes on the geographical margins of the new cultural politics. In Keith, & S. Pile (Hrsg.). Routledge London.
- Spatial Humanities 2022. (2022). *Spatial Humanities 2022*. Von <https://www.ghentcdh.ugent.be/spatial-humanities-2022> abgerufen
- Stangl, W. (ed.) (2019). HGIS de las Indias (Proyect FWF, P 26379-G18, 2015-2019), www.hgis-indias.net [April 10, 2022].
- Sui, D., & DeLyser, D. (2012). Crossing the qualitative-quantitative chasm I: Hybrid geographies, the spatial turn, and volunteered geographic information (VGI). *Progress in human geography*, 36, 111–124.
- Talbert, R. J. (2000). *Barrington Atlas of the Greek and Roman World: Map-by-map Directory* (Bd. 1). Princeton University Press.
- Twinam, T. (2017). Danger zone: Land use and the geography of neighborhood crime. *Journal of Urban Economics*, 100, 104–119.
- Van Manen, N., Scholten, H. J., & Van de Velde, R. (2009). Geospatial technology and the role of location in science. *Geospatial technology and the role of location in science*, 96, 1–13.
- Viña, A., McConnell, W. J., Yang, H., Xu, Z., & Liu, J. (2016). Effects of conservation policy on China’s forest recovery. *Science advances*, 2, e1500965.
- Von Lünen, A., & Travis, C. (2012). *History and GIS: Epistemologies, considerations and reflections* (Bd. 9789400750098). doi:10.1007/978-94-007-5009-8
- Warf, B., & Arias, S. (2008). *The spatial turn: Interdisciplinary perspectives*. Routledge.

Yang, J., Jin, S., Xiao, X., Jin, C., Xia, J. C., Li, X., & Wang, S. (2019). Local climate zone ventilation and urban land surface temperatures: Towards a performance-based and wind-sensitive planning proposal in megacities. *Sustainable Cities and Society*, 47, 101487.

Zhang, J., & Goodchild, M. F. (2002). *Uncertainty in geographical information*. CRC press.

Ziblatt, D. (2017). *Conservative political parties and the birth of modern democracy in Europe*. Cambridge University Press.