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Editorial

Applications of GIScience for Land Administration

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Abstract: Land administration is an essential part of public administration. Geographic Information Science (GIScience) deals with the concepts, principles, and models of geographic information. Land administration has always adopted new technological and scientific developments and thus it is reasonable to check, which results from GIScience can be used to improve land administration systems. This editorial paper introduces the key research areas for land administration. After that, 12 original papers are presented, which provide a general picture of recent trends in land administration research. This Special Issue shows that land administration as a scientific field is still evolving and adopting to the changing societal needs.

Keywords: GIS; GIScience; Land Administration; Land Value; LADM; 3D

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1. Introduction

Land administration is one of several linked concepts related to the use of land [1]. It is an essential part of public administration in many countries. It serves as an administrative basis for land markets [2] and provides the basis for sustainable development [3], but it is also a valuable concept to protect land rights in developing countries [4]. Some of the currently existing systems developed over centuries. The Austrian land administration system, for example, was initiated in 1817 and was based on experiences from an older system in the province of Milano created in 1718 [5]. Throughout the centuries, new scientific developments including measurement and information technology were adopted to improve the system. A scientific branch highly relevant for land administration systems is Geographic Information Science (GIScience). The term was first defined in 1992 by Goodchild [6] and over 15 years later he presented a review of the major achievements and failures [7]. Nowadays, research topics in GIScience range from still hot topics like spatial analysis, multi-criteria analysis, or visualization to the application of novel technologies like extended reality and deep learning.

2. Land Administration

Land is a resource that cannot be produced. Thus the use of this resource needs to be managed. Land administration systems provide information on land to enable good management. The information stored in land administration systems varies between countries but typically includes identifiers for non-overlapping pieces of land, rights, restrictions, and responsibilities on these pieces of land and other information like use or value. Land administration is typically connected to land use planning, land market, and landscape protection since all these tasks depend on information about the current status.

In many jurisdictions, the technical and legal documentation is separated, i.e., there is a cadastre as a technical description of pieces of land and a land register dealing with rights, restrictions, and responsibilities. This may result from the historical development, the different legal background between the parts (public vs. private law), or from a country's approach to split powers between different administrative bodies to balance power. However, there are also countries where both parts of land administration reside in the the same body. There is also no worldwide consent, which ministry should be responsible for land administration. Examples can be found where the ministry of economy, the ministry of law, or the ministry of interior are responsible. It would even be historically legit that the ministry of defence is responsible since maps in the 18th and 19th century were required for and created by the military and the creation of cadastral maps is based on the same principles.

Land administration combines many different tasks since it combines determination of geometrical properties with documentation of rights, quality assurance, and a constantly changing reality. As a result, the field requires interaction between numerous scientific fields, from surveyors to lawyers, from computer scientists to mathematicians. In addition, land administration data is used in many procedures like market value assessment for land parcels, architectural design, or spatial planning. This adds experts in economy and design to the mix of professionals working in the context of land administration.

Data collection is still a challenge for land administration. Developed countries with working land administration systems have procedures in place to keep the data up-to-date. This is already a challenge that often relies on good cooperation between all stakeholders. However, the challenges increase dramatically if the system is not yet implemented. Initial data collection may take decades. The use or demarcation of land will not remain stable for such a time, though. Thus, the already existing data needs to be updated while data for new areas a re collected. The approached developed in the 19th century are still used but novel concepts to speed up the initial survey and simplify the update management are necessary.

3. Geographic Information Science

The scientific field nowadays known as GIScience started in the late 1960s, when the endeavour to create maps and perform spatial analysis with computers was started in the Harvard Laboratory for Computer Graphics and Spatial Analysis [8] (p. 1). In general, GIScience aims at a better understanding and modelling of spatial and spatiotemporal phenomena to enable applying this knowledge in manifold situations. The field is cross-disciplinary and brings together experts from cartography, computer science, geodesy, geography, law, linguistics, mathematics, philosophy, or psychology, just to name a few. Two examples from the past 20 years show the development of the field.

In the early 2000s, positioning technology became simple enough to enable laypeople to use it and provide geographical coordinates with a precision in the range of metres. In parallel, the Internet transformed from a set of static pages to an interactive medium that allowed the creation of content with little or no computer science skills. This led to geographical data sets created purely by laypeople. This concept is called Volunteered Geographic Information (VGI) [9] and one of the most prominent representative is Open Street Map. VGI enables experts from domains other than GIScience to collect data and improvements in the user interfaces of the tools made it possible for them to analyse the data themselves.

Another concept recently gaining attention is machine learning. Tedious tasks like manual classification of remotely sensed data are one obvious case where machine learning has been successfully applied [10]. In combination with semantic information, it may be able to produce even more than simple classifications [11]. However, there is still much work to do since currently the goal is mainly prediction whereas explanation of spatial phenomena would be required [12].

Not all novel technologies can solve all problems in a complex system like land administration. The discussion on the blockchain technology provides a good example: It can help dealing with problems of corruption, lack of trust, insecure data, or vulnerability to cyberattacks. However, other problems like inaccurate records, informal titles, or a lack of institutional capacity cannot be solved with this technology alone [13]. Nevertheless, various approaches from GIScience drive the development of new applications and the papers published in this Special Issue show some examples of this for land administration.

4. Impact of GIScience on Land Administration as Presented in This Special Issue

The papers in the special issue reflect three different research directions in land administration influenced by research in GIScience. The first group of papers deals with the basics of land administration, the data, their quality and capture. The second group of papers investigates questions related to the development of land administrations systems related to 3D cadastre. The third and final group is related to various applications. In the following sections, I briefly summarize these papers to reflect these trends.

4.1. Land Administration Basics

Land administration has a number of basic prerequisites. The first is a solid geographical reference. Geographical data can only be combined with data from other sources if the reference frames are either identical or a transformation between the reference frames is possible. Bielecka et al. [14] address a problem connected to the realization of the reference frame with control points. Differences in the spatial distribution can serve as reference for network maintenance.

A traditional problem of land administration closely related with the reference frame is the improvement of measurement technology. Novel equipment with better results reveal distortions caused by the limited measurement quality. Satellite positioning is a current example since it was the first technology that enabled distance measurement over hundreds of kilometers. When applying it to previously measured reference frames, distortions become evident and contradictions between old and new data need to be solved. Čeh et al. [15] show the application of membrane adjustment for the Slovenian cadastral maps. They achieved a positional improvement from 2–5 m to below 1 m.

Once the reference frame is fixed, a land administration system needs data. Most developed countries started to do this in the 19th century. This process required 45 years for the Austro-Hungarian monarchy or 15,000 km^2 per year. Assuming the same rate, the data colleciton for a country like Ethiopia would require 73 years. VGI may be an alternative to the traditional methods of cadastral data collection, if it produces reliable and accurate results. Reliability is addressed by Potsiou et al. [16] for Romania and Greece. They compared the positional accuracy of data collected by VGI with respect to data collected by experts. The results showed positional accuracy of 0.4 m for urban areas and 1.0 m for rural areas. This satisfies the requirements of the Greece cadastre. Data collection using a VGI approach needs to fulfil security criteria if data concerning land rights and their delineation are collected. Mourafetis and Potsiou [17] present a system architecture and IT services implemented for this purpose using both, a web page and a mobile application. The services raised the percentage of digital data submissions from below 1% to approx. 33%.

Xu et al. [18] show, how land administration administration in China can be modeled using the Land Administration Domain Model (LADM) [19]. The paper contributes to a national standard for land administration under the Chinese national conditions and in accordance with the international standard. The authors show, how the different elements of the Chinese land administration fit into the standard and identify some aspects that require further attention. One of them is the problem of the third dimension, which is the focus of the papers in the next section.

4.2. Land Administration in 3D

Increased demand for land leads to densely used space in urban areas. This requires vertical stacking of services, e.g., transportation and parking below ground, pedestrian bridges and even buildings above ground-level infrastructure. The rights required to govern these situations cannot be represented in the traditional, two-dimensional land administration systems. Thus, in the early 2000s, the term of 3D cadastre was coined [20]. Višnjevac et al. [21] present a database model to store 3D cadastral data in a NoSQL database. and visualize it with JavaScript. They argue, that mainly used relational database management systems do not natively support 3D topology. They show code for querying, updating, and visualizing data. The concept of NoSQL includes shortcomings in terms of consistency, which the authors expect to address when implementing a 3D cadastre using a NoSQL database. The current implementation is a prototype only and requires further development. Visualization of 3D cadastral data is also addressed by Aditya et al. [22]. They rely on a more traditional database management system and use it to integrate 2D and 3D cadastral data with their corresponding legal data.

4.3. Application Using Land Administration Data

One of the original applications of land administration was the land tax assessment. Closely related to this is the determination of land value. Cellmer et al. [23] apply hierarchical spatial autoregressive models to assess the land value in urbanized areas and compare the results with the classical linear model. They show that hierarchical models outperform models not taking into account spatial hierarchy. Cellmer et al. [24] show, how to model the impact of a specific feature, in this case an airport, on the land value. They apply a classic multiple regression model, a spatial autoregressive model, and a geographically weighted regression model. They prove, that the excessive noise caused by the airport and the legal land use restrictions associated the airport have a negative effect on the price levels.

Greenhalgh et al. [25] take the step from land value to land market analysis. The show how GIS can be used to analyse the distribution, stock and value of commercial and industrial property and how to visualize the results. The study identified agglomerations for retail and office in the city centre, but also significant clusters of commercial floorspace on the peri-urban fringe. It was thus possible with the GIS-based approach to distinguish between different type and sizes of property, allowing for a more detailed analysis and other approaches.

The geographical frame provided by the land administration data can also be used to manage network data. Radulović et al. [26] show, how data on utility networks can be modelled based on the LADM. Since the utility lines are either above or below the ground, some aspects of 3D cadastres are relevant here as well. The authors show, how the utility network in Serbia is currently modelled and how it could be included in the LADM. Ogryzek et al. [27] discuss visualization of utility networks as an example. They demonstrate the possibility of developing maps showing both, the utility network and the land rights registered by the utility company. The SWOT analysis shows the usefulness of the solution for many entities like real estate market services. The major threat is the current lack of statutory obligation to maintain such a database. Thus, there is no guarantee that the data will be updated.

5. Conclusions

Research on land administration will never end. Land administration is reflecting the needs of the society and changing needs will require adaptations of the cadastre. This needs to be done in a way that current applications (like the support of the land tax assessment or the documentation of land rights) are not negatively influenced. Already in the past, land administration systems have applied results from GIScience. Without such a connection, digital management of land administration data would be impossible. The papers in this Special Issue have shown, that the knowledge transform is ongoing. This allows the assumption, that future developments in GIScience will also have an impact on land administration. The examples of land value assessment and land market analysis show, that the term "land administration" may not be explicitly used in some applications but it still needs to provide a reliable spatial reference to combine the various aspects of land. I am expecting more novel ideas and innovative solutions in the next decades.

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References

1. Mattsson, H.; Mansberger, R. Land Governance/Management Systems. In *Land Ownership and Land Use Development*; Hepperle, E., Dixon-Gough, R., Mansberger, R., Paulsson, J., Hernik, J., Kalbro, T., Eds.; vdf Hochschulverlag AG at ETH Zürich: Züruch, Switzerland, 2017; pp. 13–24.
2. Enemark, S.; Williamson, I.; Wallace, J. Building Modern Land Administration Systems in Developed Economies. *J. Spatial Sci.* **2010**, *50*, 51–68. [CrossRef]
3. Williamson, I.; Enemark, S.; Wallace, J.; Rajabifard, A. Land Administration for Sustainable Development. In *Proceedings of the XXIV FIG International Congress*; FIG: Sydney, Australia, 2010; p. 16.
4. Zevenbergen, J.; Augustinus, C.; Antonio, D.; Bennett, R. Pro-poor Land Administration: Principles for Recording the Land Rights of the Underrepresented. *Land Use Policy* **2013**, *31*, 595–604. [CrossRef]
5. Lisec, A.; Navratil, G. The Austrian Land Cadastre: From the Earliest Beginnings to the Modern Land Information System. *Geod. Vestn.* **2014**, *58*, 482–516. [CrossRef]
6. Goodchild, M.F. Geographical information science. *Int. J. Geogr. Inf. Syst.* **1992**, *6*, 31–45. [CrossRef]
7. Goodchild, M.F. Geographic information systems and science: today and tomorrow. *Annal. GIS* **2009**, *15*, 3–9. [CrossRef]
8. Chrisman, N. *Charting the Unknown: How Computer Mapping at Harvard became GIS*; ESRI Press: Redlands, CA, USA, 2006.
9. Goodchild, M.F. Citizens as sensors: the world of volunteered geography. *GeoJournal* **2007**, *69*, 211–221. [CrossRef]
10. Lary, D.J.; Alavi, A.H.; Gandomi, A.H.; Walker, A.L. Machine learning in geosciences and remote sensing. *Geosci. Front.* **2016**, *7*, 3–10. [CrossRef]
11. McCutchan, M.; Özdal-Oktay, S.; Giannopoulos, I. Urban Growth Predictions with Deep Learning and Geosemantics. In Proceedings of the VIENNA Young Scientists Symposium (VSS 2019), Wien, Austria, 13–14 June 2019; Ehrmann, K.; Mansouri Khosravi, H.R., Artner, G., Hans, P., Krebs, H., Shahabian, A., Wipp, D., Eds.; Book-of-Abstracts.com: Gumpoldskirchen, Austria, 2019; pp. 30–31.
12. Gahegan, M. Fourth paradigm GIScience? Prospects for automated discovery and explanation from data. *Int. J. Geogr. Inf. Syst.* **2020**, *34*, 1–21. [CrossRef]
13. Robustelli, T. Evaluating the Hype: The Current Potential of Blockchain for Land Resistries. In Proceedings of the 2019 World Bank Conference on Land and Poverty, Washington, DC, USA, 25–29 March 2019; The World Bank: Washington, DC, USA, 2019; p. 16.
14. Bielecka, E.; Pokonieczny, K.; Borkowska, S. GIScience Theory Based Assessment of Spatial Disparity of Geodetic Control Points Location. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 148. [CrossRef]
15. Čeh, M.; Gielsdorf, F.; Trobec, B.; Krivic, M.; Lisec, A. Improving the Positional Accuracy of Traditional Cadastral Index Maps with Membrane Adjustment in Slovenia. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 338. [CrossRef]
16. Potsiou, C.; Paunescu, C.; Ioannidis, C.; Apostolopoulos, K.; Nache, F. Reliable 2D Crowdsourced Cadastral Surveys: Case Studies from Greece and Romania. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 89. [CrossRef]
17. Mourafetis, G.; Potsiou, C. IT Services and Crowdsourcing in Support of the Hellenic Cadastre: Advanced Citizen Participation and Crowdsourcing in the Official Property Registration Process. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 190. [CrossRef]
18. Xu, Z.; Zhuo, Y.; Liao, R.; Wu, C.; Wu, Y.; Li, G. LADM-Based Model for Natural Resource Administration in China. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 456. [CrossRef]
19. Van Oosterom, P.; Lemmen, C.; Uitermark, H. ISO 19152:2012, Land Administration Domain Model published by ISO. In Proceedings of the Environment for Sustainability—FIG Working Week 2013, Abuja, Nigeria, 6–10 May 2013; Villikka, M., Ed.; FIG (International Federation of Surveyors)—Nigerian Institution of Surveyors: Abuja, Nigerian, 2013; pp. 1–22.
20. Stoter, J.E.; van Oosterom, P. *3D Cadastre in an International Context*; CRC Press: Boca Raton, FL, USA, 2006; p. 356.
21. Višnjevac, N.; Mihajlović, R.; Šoškić, M.; Cvijetinović, Z.; Bajat, B. Prototype of the 3D Cadastral System Based on a NoSQL Database and a JavaScript Visualization Application. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 227. [CrossRef]
22. Aditya, T.; Laksono, D.; Susanta, F.F.; Istarno, I.; Diyono, D.; Ariyanto, D. Visualization of 3D Survey Data for Strata Titles. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 310. [CrossRef]
23. Cellmer, R.; Kobylińska, K.; Bełej, M. Application of Hierarchical Spatial Autoregressive Models to Develop Land Value Maps in Urbanized Areas. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 195. [CrossRef]

24. Cellmer, R.; Bełej, M.; Konowałczuk, J. Impact of a Vicinity of Airport on the Prices of Single-Family Houses with the Use of Geospatial Analysis. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 471. [CrossRef]
25. Greenhalgh, P.; King, H.; Muldoon-Smith, K.; Adebayo, A.; Ellis, J. Using GIS to Explore the Potential of Business Rating Data to Analyse Stock and Value Change for Land Administration: A Case Study of York. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 321. [CrossRef]
26. Radulović, A.; Sladić, D.; Govedarica, M.; Ristić, A.; Jovanović, D. LADM Based Utility Network Cadastre in Serbia. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 206. [CrossRef]
27. Ogryzek, M.; Klimach, A.; Niekurzak, D.; Pietkiewicz, M. Using Cartographic Documents to Provide Geoinformation on the Rights to Real Estate—Taking Poland as an Example. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 530. [CrossRef]