remote sensing

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Editorial

Remote Sensing for Land Administration 2.0

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Abstract: Contemporary land administration (LA) systems incorporate the concepts of cadastre and land registration. Conceptually, LA is part of a global land management paradigm incorporating LA functions such as land value, land tenure, land development, and land use. The implementation of land-related policies integrated with well-maintained spatial information reflects the aim set by the United Nations to deliver tenure security for all (Sustainable Development Goal target 1.4, amongst many others). Innovative methods for data acquisition, processing, and maintaining spatial information are needed in response to the global challenges of urbanization and complex urban infrastructure. Current technological developments in remote sensing and geo-spatial information science provide enormous opportunities in this respect. Over the past decade, the increasing usage of unmanned aerial vehicles (UAVs), satellite and airborne-based acquisitions, as well as active remote sensing sensors such as LiDAR, resulted in high spatial, spectral, radiometric, and temporal resolution data. Moreover, significant progress has also been achieved in automatic image orientation, surface reconstruction, scene analysis, change detection, classification, and automatic feature extraction with the help of artificial intelligence, spatial statistics, and machine learning. These technology developments, applied to LA, are now being actively demonstrated, piloted, and scaled. This Special Issue hosts papers focusing on the usage and integration of emerging remote sensing techniques and their potential contribution to the LA domain.

Keywords: UAV; LiDAR; automated feature extraction; cadaster; land registration; land use planning

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1. Introduction

The United Nations sustainable development goal (SDG), particularly indicator 1.4.2, promotes tenure security for all [1]. Despite this, the majority of the world lacks formal land and property registration. Land administration (LA) incorporates the concepts of cadastre and land registration. This includes processes such as recording, securing, storing, and disseminating data related to land tenure, value, use, and development [2]. Delivering tenure security is essential for LA systems that aim to reduce poverty and ensure food security by promoting land investments [3]. Conventionally, cadastral data has been collected by high precision ground-based methods, which are often time-consuming, demand high levels of expertise, and therefore unaffordable for many countries. With the technological development, and the aim to speed up the land recordation process, many countries have adopted the so-called fit-for-purpose LA (FFP-LA) approach [4]. It promotes multisensory data collection and an interdisciplinary approach providing outputs that serve the purpose of the concrete country case [5].

The FFP-LA approach is being actively supported by international organizations such as the International Federation of Surveyors (FIG) and Global Land Tool Network (GLTN). The crucial concept of FFP-LA also includes the use of remote sensing data acquisition techniques such as satellite, aerial, LiDAR, RADAR, or UAV data. In addition, related

cutting-edge innovative analytical technologies such as machine learning [6] for data processing and automatic feature extraction based on imagery data are used to accelerate the cadastral mapping process [7]. Geo-cloud services are also playing big part in data storage, management, dissemination, and e-service delivery [8].

The abovementioned approaches are the focus of the current Special Issue as a continuation of the "Remote Sensing for Land Administration" first edition [9]. Starting with a broad review paper, focusing on the developments of photogrammetric methods and remote sensing applied to the LA domain, the Special Issue provides an overview of diverse experiments, demonstrations and implementations in a range of case contexts. This includes papers related to (i) design and testing of the flight configurations of UAVs; (ii) quantitative and qualitative methods for assessment and comparison of different remotely sensed techniques for valuation and taxation; (iii) innovative machine learning methods development and integration for cadastral data extraction, including also a social-economic parameters; and (iv) usage of LiDAR data and analysis techniques for building extraction and agricultural land delineation.

The Special Issue consists of nine (9) individual works; developed by multi-disciplined research by researchers from Europe, Asia, Oceania, and Africa. The works use a variety of qualitative and quantitative research methods applied to diverse social and remotely sensed data types, in support of lend tenure recordation, land valuation, and land use planning (Table 1). The next section outlines each work and synthesizes the overarching contribution of the Special Issue.

Table 1. Remote sensing applications for LA presented in this issue.

Source	Title	Geographic Focus	Applications	Techniques	Data
Rohan Mark Bennett et al.	Review of Remote Sensing for Land Administration: Origins, Debates, and Selected Cases	Global and historic	Land tenure, photogrammetry and remote sensing	Review paper	LiDAR, Aerial, UAV, topographic and cadastral maps among many other
Claudia Stöcker et al.	High-Quality UAV-Based Orthophotos for Cadastral Mapping: Guidance for Optimal Flight Configurations	Europe and Africa	Land Tenure from UAV images	Comparative analysis	UAV imagery
Koeva et al.	Remote Sensing for Property Valuation: A Data Source Comparison in Support of Fair Land Taxation in Rwanda	Rwanda	Land valuation and taxation	GNSS survey, semi structured interviews, focus group discussion	Satellite digital aerial and UAV imagery, cadastral data
Cheonjae Lee et al. Damian Wierzbicki et al.	Testing and Validating the Suitability of Geospatially Informed Proxies on Land Tenure in North Korea for Korean (Re-)Unification	North Korea	Land Tenure; cadastral mapping	Geospatially informed analysis, questionnaire	Google Earth images
Bujar Fetai et al.	Deep Learning for Detection of Visible Land Boundaries from UAV Imagery	Slovenia	Multi-purpose cadastre; Map creation and updating	U-Net ENVINet5	UAV imagery, cadastral boundaries

Table 1. *Cont.*

Source	Title	Geographic Focus	Applications	Techniques	Data
Shih-Hong Chio et al	Application of a Hand-Held LiDAR Scanner for the Urban Cadastral Detail Survey in Digitized Cadastral Area of Taiwan	Taiwan	Land tenure; cadastral mapping	Pointcloud filtering, RANSAC	Handheld LiDAR, cadastral data
Natalia Borowiec et al.	Using LiDAR System as a Data Source for Agricultural Land Boundaries	Poland	Land Tenure; cadastral mapping of agricultural lands	Edge detectors, Hough-Transform	LiDAR, cadastral data
Damian Wierzbicki, et al.	Polish Cadastre Modernization with Remotely Extracted Buildings from High-Resolution Aerial Orthoimagery and Airborne LiDAR	Poland	Cadastral map creation, verification and updating	Fully convolutional network U-Shape Network (U-Net)	LiDAR, cadastral data high resolution aerial orthoimagery
Dušan Jovanović et al	Building Change Detection Method to Support Register of Identified Changes on Buildings	Serbia	Cadastral updating, building change detection	Pixel-based and object-based analysis	VHR imagery with RGB and NIR bands

2. Overview of the Contributions

- Paper 1

Rohan Mark Bennett et al. present a systematic review paper that enriched a complete synthesis of the developments of photogrammetric methods and remote sensing applied to the domain of LA. It incorporates developments from early phototopography and aerial surveys through to analytical photogrammetric methods, the emergence of satellite remote sensing, digital cameras, and latterly lidar surveys, UAVs, and feature extraction. The synthesis illustrates the debates over the benefits of the techniques. Various comparative analyses on criteria relating to time, cost, coverage, and quality are presented. Apart from providing this more holistic view and a timely reminder of previous works, this paper brings contemporary practical value in further demonstrating to LA practitioners that remote sensing for data capture, and subsequent map production, are an entirely legitimate, if not essential, part of the domain.

- Paper 2

Claudia Stöcker et al. provide a detailed investigation of different flight configurations to guide efficient and reliable UAV data acquisition in support of cadastral map creation and updating. Imagery from six study areas across Europe and Africa provide the basis for an integrated quality assessment, including three main aspects: (1) the impact of land cover on the number of tie-points as an indication of how well bundle block adjustment can be performed, (2) the impact of the number of ground control points (GCPs) on the final geometric accuracy, and (3) the impact of different flight plans on the extractability of cadastral features. The results suggest that scene context, flight configuration, and GCP setup significantly impact the final data quality and subsequent automatic delineation of visual cadastral boundaries. This study reveals large discrepancies in the accuracy and the completeness of automatically detected cadastral features for orthophotos generated from different flight plans. With its unique combination of methods and integration of various study sites, the results and recommendations presented in this paper can help land

professionals and bottom-up initiatives alike to optimize existing and future UAV data collection workflows.

- Paper 3

Koeva et al. in their study, assess different remote sensing data in support of developing a new approach for property valuation for taxation in Rwanda. Three different remote sensing technologies, (i) aerial images acquired with a digital camera, (ii) WorldView2 satellite images, and (iii) unmanned aerial vehicle (UAV) images obtained with a DJI Phantom 2 Vision Plus quadcopter, are compared and analyzed in terms of their fitness to fulfill the requirements for valuation for taxation purposes. Quantitative and qualitative methods are applied for the comparative analysis. Primary data is collected via semi-structured interviews and focus group discussions. The results show that UAVs have the highest potential for collecting data to support property valuation for taxation. The main reasons are the prime need for accurate-enough and up-to-date information.

- Paper 4

Cheonjae Lee et al. investigate in their research the role of remote sensing data in detecting, estimating, and monitoring socio-economic status (SES) such as quality of life dimensions and sustainable development prospects. In the context of Korea, the main challenge is the lack of complete and adequate information when it comes to clarifying unknown land tenure relations and land governance arrangements. Deriving informative land tenure relations from geospatial data in line with socio-economic land attributes is currently the most innovative approach. Therefore, the authors provide empirical evidence of whether the proposed proxies are scientifically valid, policy-relevant, and socially robust. They revealed differences in the distributions of agreements relating to land ownership and land transfer rights identification among scientists, bureaucrats, and stakeholders. Moreover, the authors measured intrinsic, contextual, representational, and accessibility attributes of information quality regarding the associations between earth observation (EO) data and land tenure relations in North Korea from several different viewpoints.

- Paper 5

Bujar Fetai et al. with their research, aim to accelerate cadastral mapping through innovative and automated approaches for the creation and updating of cadastral maps. Using deep learning, they explored algorithms to automatically detect visible land boundaries from unmanned aerial vehicle (UAV) imagery. In addition, the authors evaluated the advantages and disadvantages of programming-based deep learning compared to commercial software-based deep learning. They used the convolutional neural network U-Net, implemented in Keras, written in Python using the TensorFlow library. For commercial software-based deep learning, they used ENVINet5. The results showed that both models achieved an overall accuracy of over 95%. The high accuracy is due to the problem of unbalanced classes, which is usually present in boundary detection tasks. U-Net provided a recall of 0.35 and a precision of 0.68 when the threshold was set to 0.5. A threshold can be viewed as a tool for filtering predicted boundary maps and balancing recall and precision. The authors concluded that programming-based deep learning provides a more flexible yet complex approach to boundary mapping than software-based, which is rigid and does not require programming.

- Paper 6

Shih-Hong Chio and Kai-Wen Hou present a study that investigates the feasibility of a handheld LiDAR scanner to collect 3D point clouds in an efficient way for a detail survey in urban environments with narrow and winding streets. After point cloud filtering and the ranging systematic error correction that was determined by a plane-based calibration method, the collected point clouds are transformed to the local cadastral coordinate system using control points. Using the detail points surveyed by a total station to verify the detail line data digitized from the corrected handheld LiDAR point cloud, 97% error of the digitized detail data was less than 15 cm The results demonstrated the feasibility of

using a handheld LiDAR scanner to perform an urban cadastral detail survey in digitized graphic areas.

- Paper 7

Natalia Borowiec and Urszula Marmol explore LiDAR sensor data to identify agricultural land boundaries. Their study focuses on accurately determining the edges of parcels using only the point cloud, which is an original approach because the point cloud is a scattered set, which may complicate finding those points that define the course of a straight line defining the parcel boundary. To detect automatically the edges of parcels, the author's first step is to do classification then use edge detectors to define land use boundaries. The obtained boundaries are compared with the boundaries from the Polish land registry database. The proposed algorithm allowed the detection of inconsistencies in farmers' declarations. These mainly concerned areas of field roads that farmers misclassified as subsidized land when in fact, they should be excluded from subsidies.

- Paper 8

Damian Wierzbicki et al. dived into automatic building extraction from remote sensing data for cadastre verification, modernization and updating. They explored deep learning algorithms, particularly fully convolutional network U-Shape Network (U-Net), for high resolution aerial orthoimagery segmentation and dense LiDAR data to extract building outlines automatically. They reached 89.5% overall accuracy and an 80.7% completeness compared to the reference data, which made it very promising for cadastre modernization in Poland. In addition to the numerical achievements, the authors discuss the possibilities and limitations of the automated approaches that could help local authorities decide on the use of remote sensing data in LA.

- Paper 9

Dušan Jovanović et al. based on satellite imagery and existing cadastral data proposed a method based on a comparison of object-based and pixel-based image analysis approaches to automatically detect newly built, changed, or demolished buildings and import these data into extended cadastral records. Using only VHR images containing only RGB and NIR bands, the results showed object identification accuracy ranging from 84% to 88%, with kappa statistics from 89% to 96%. The accuracy of obtained results is satisfactory for the purpose of developing a register of changes on buildings to keep cadastral records up to date and to support activities related to the legalization of illegal buildings, etc.

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