A Quantitative Comparison of Completely Visible Cadastral Parcels Using Satellite Images: A Step towards Automation

Divyani KOHLI, Netherlands, Rohan BENNETT, Australia, Christiaan LEMMEN, Kwabena ASIAMA, Andres MORALES, Netherlands, Andre PINHEIRO, Mozambique, Robert WAYUMBA, Kenya, Jaap ZEVENBERGEN, Netherlands

Key words: Cadastre, Land Administration, Visual Interpretation, Parcel, Boundary, Satellite Image

SUMMARY

Estimates suggest that 70 percent of the world's population has little or no access to formal land administration systems and hence their rights are often neither recognized nor secured by governments. A system of organized land rights information, embedded in a broader land administration system, is argued as a key pillar for underpinning any sustainable economy and equitable economic development. Cadastres are a core ingredient of any land administration system. Traditional methods for cadastral surveying and mapping are however, often lengthy and labor intensive. In response, remote sensing based techniques have great potential and are being increasingly employed for rapid creation and upgrading of cadastral maps: the Global Land Tool Network (GLTN)'s fit-for-purpose (FFP) land administration guidelines provide ample evidence in this regard. Furthermore, (semi)-automatic methods for detecting cadastral boundaries are currently under development. These methods seek to make use of very high resolution (VHR) satellite images or sensors capable of similar resolutions. Creating approaches that are both highly automated and transferable between contexts remain a challenge owing to diverse morphologies of parcel boundaries found across contexts. Anyhow, object-based image analysis methods appear highly promising as they mimic the human interpretation process to identify features from an image.

A pre-step to utilizing any of these methods should be determining the quantity of the boundaries that are actually identifiable through visual interpretation. Therefore, in this paper, we assess the quantity of visible/non-visible boundaries in different contexts with the aim of determining the percentage of known cadastral parcels that are completely visible via VHR satellite images. For this purpose, we selected subsets from case locations in the contexts of Ethiopia, Ghana, Kenya, Mozambique, Rwanda, Guatemala and Nepal. To cover different landscapes, a combination of rural, peri-urban and urban areas were included. In each case, control cadastral data (i.e. vector files or existing cadastral maps) served as a reference for the assessment. Results show significant difference between visual identification for the samples from seven contexts. The percentage of completely visible cadastral parcels ranged from zero to 71 percent when compared to the reference cadastral map. These were parcels for which all boundaries were fully visible, i.e. a closed polygon.

Considering the result of the study, it appears that (semi)-automated cadastral boundary extraction methods using VHR imagery will have high utility in specific contexts (e.g. smallholder and rural), whereas their use in complex urban environments may be challenging and require other methods or data. Nonetheless, an approach like this will greatly enhance the application of FFP approach in Land Administration for cadastral mapping in areas where no relaible data exists, for e.g. even if a small amount of boundaries could be automatically generated (e.g. 30 percent), potentially large cost reductions in cadastral surveying and mapping could be achieved.

A Quantitative Comparison of Completely Visible Cadastral Parcels Using Satellite Images: A Step towards Automation

Divyani KOHLI, Netherlands, Rohan BENNETT, Australia, Christiaan LEMMEN, Kwabena ASIAMA, Andres MORALES, Netherlands, Andre PINHEIRO, Mozambique, Robert WAYUMBA, Kenya, Jaap ZEVENBERGEN, Netherlands

1. INTRODUCTION

Estimates suggest that 70% percent of the world's population has little or no access to formal land administration systems and hence their rights are often neither recognized nor secured by governments. A system of organized land rights information, embedded in a broader land administration system, is argued as a key pillar for underpinning any sustainable economy and equitable economic development. Cadastres are a core ingredient of any land administration system. In the broader purpose of implementing land management policies, cadastre acts as the data infrastructure which is used as the basis for recording and changing the ownership, value and use of land. With detailed information on the land records along with the spatial location and geometry, cadastre is indispensable to plan land-related policies and laws. With many countries in the global South either completely lacking or having outdated cadastral maps, there seems to be a huge gap between the countries that have effective land administrative systems and the others that do not, referred to as '*cadastral divide*' (Bennett, 2012).

Traditionally, field–based methods have been used to collect data to create cadastres. Cadastral surveys were completed using theodolites and plane-table methods. Though accurate, in terms of recording the boundaries, these methods often prove lengthy and labor intensive. Moreover, the repetition of such surveys to update maps and to capture the dynamics of boundaries can prove to be challenging considering the resources required. Advanced remote sensing based methods offer great potential for detecting visible cadastral boundaries and hence be used for rapid creation and upgrading of records. With the availability of very high resolution (VHR) satellite images at regular temporal frequency, multiple avenues and possibilities can be explored in the field of land administration where digital solutions and automation are lately being sought (Wassie, Koeva, & Bennett, 2016). Remote sensing based techniques are already being increasingly employed for rapid creation and upgrading of cadastral maps: the Global Land Tool Network (GLTN)'s fit-for-purpose land administration guidelines provide ample evidence in this regard. The fit-for-purpose (FFP) approach calls for flexible and affordable spatial information recording system in combination with flexible legal frameworks that accommodates these changes. FFP solutions can also be achieved when digital cadastral data and simple GIS tools are available. Though recent studies utilize such methods and are substantiating the importance of techniques that could expedite cadastral mapping, the work so far is still very limited and needs more attention (Luo, Bennett, Koeva, & Quadros, 2016; Wassie et al., 2016).

Previous studies have specifically used visual interpretation, in a participatory setting in the field, to map cadastral boundaries (Ali, Tuladhar, & Zevenbergen, 2012). Use of digital pen for cadastral survey by storing data directly into geo-referenced digital format has also been explored, utilizing the benefits of participatory mapping (Lemmen, Zevenbergen, Lengoiboni, Deininger, & Burns, 2009; Rugema, Verplanke, & Lemmen, 2015). Another study used colonial cadastral maps and satellite imageries as a basis to create seamless digital cadastre (Sengupta, Lemmen, Devos, Bandyopadhyay, & van der Veen, 2016). On-screen visual interpretation seems to be a straight forward approach to map anything from an imagery but can also be time-intensive, difficult to repeat and highly variable in terms of accuracy. Automatic methods that could mimic the visual interpretation capabilities of the human mind and produce similar results, are thus sought. This can result in objective and speedy detection of object of interest and easy to replicate in a similar setting. However, creating approaches that are both highly automated and transferable between contexts remain a challenge owing to diverse morphologies of cadastral parcel boundaries found across contexts. Anyhow, object-based image analysis methods appear highly promising as these have the ability to mimic the human interpretation process to identify features from an image.

As a pre-step for any image-based approach to work well, it is important to first conceptualize the feature of interest. For the identification of cadastral boundaries, it is thus important to understand the boundary morphologies and to find out if they are completely visible on an image. To explore this, a pre-step to utilizing any of the automated methods should be determining the quantity of the boundaries that are may be identifiable through visual interpretation (Luo et al., 2016). Therefore, in this paper, we assess the quantity of visible/non-visible boundaries in subsets of different contexts with the aim of determining cadastral boundaries or more specifically, full parcels that are visible via VHR satellite images. The objective of this paper is to find out the percentage of completely visible cadastral parcels using very high resolution (VHR) satellite images in a broad variety, although clearly not universal, set of contexts.

In this paper, after the above rational of the study, we continue with the method section where we describe the procedure of visual boundaries assessment. We considered samples from seven different case locations for this study to cover as many diverse locations as possible. Results for each sample are presented in terms of percentage of completely visible cadastral parcels. Further, the results are discussed based on the observations made from the various contexts, focusing on the opportunities and limitations of the study.

2. METHOD

2.1 Data collection

In this study, we used a combination of VHR satellite images, ESRI basemaps available via ArcGIS online or Google Earth images as a basis to carry out desktop visual interpretation. Small portions of cadastral data, in the form of vector files or scanned maps were accessed to act as control: these authoritative datasets enabled the quantification of identified parcels from the cadastral map. A network of experts and data providers were approached to support the work and provide the cadastral data.

2.2 Rational for selecting the case locations

The case locations were selected mainly from Sub-Saharan Africa: many countries in this region lack complete and/or reliable cadastral data and an automated approach may prove to be of highest utility in these contexts. An important factor for selection was also the availability of reference data from the case locations. Different areas with diverse landscapes and attached livelihoods were sought. These included contexts that were urban, rural, peri-urban and undulating. The selected sample image-subsets belonged to Ethiopia, Ghana, Kenya, Mozambique, Rwanda, Guatemala and Nepal.

2.3 Datasets

The description of the datasets used as the basis of visual interpretation are provided in Table 1. For Ghana and Kenya, VHR images were already available and were used to quantify the visible parcels. Due to the lack of images for the other areas, ESRI base maps in ArcGIS or Google Earth were used as the contextualizing background images.

Table 1 Details of the images and reference datasets used in the study.

Country	Image	Landscape	Cadastral data format
Ethiopia	Google Earth	Rural	Shapefile
Ghana	Digital Globe	Rural	Shapefile
Kenya	GeoEye	Peri-urban (informal)	Scanned map
Mozambique	ESRI basemap	Urban	Scanned map
Rwanda	ESRI basemap	Rural	Shapefile
Guatemala	ESRI basemap	Urban	Shapefile
Nepal	ESRI basemap	Rural- hilly	Shapefile

2.4 Visual interpretation of cadastral parcels

For each case area, a subset of image was selected depending on availability of corresponding cadastral data. The lowest number of parcels available for an area were 128 for Ethiopia. To stay consistent for all the case locations, a maximum of 200 parcels per context were selected from the reference map – regardless of the average parcel or farm size. After overlaying the cadastral map on the image, visual interpretation was completed to identify the nominal parcel boundaries. Only those parcels were selected for which all boundaries were fully visible on the image, i.e. a closed polygon. The rest were either fully or partially invisible, and thus were left unselected. This analysis was carried out in ArcGIS: the layer of selected features was saved and stored. The selected land parcels were thus saved in a separate layer and the number of parcels was considered as the final output.

For case locations where shapefiles were not available, such as Mozambique and Kenya, scanned copies of cadastral paper maps were accessed. For Mozambique, cadastral boundaries overlaid on satellite image were available in the form of a scanned map along with the .kml file showing the location of the map. On-screen digitizing was done on Google Earth to map the cadastral boundaries and the output was then converted to shapefile from .kml. The above process of identifying visible parcels was then performed.

For Nepal, shapefiles of cadastral boundaries without spatial reference could be obtained along with the .kml file showing the location on Google Earth. It was also possible to get the geo-referenced shapefile with the outer-boundary of area. Using the spatial adjustment tool in ArcGIS, the land parcel boundaries were first projected and then aligned with the boundary of the area. With ArcGIS, it is possible to use Google images as a base map. The cadastral map was overlaid on this base map to visually check the accuracy. Visual interpretation was then done to identify the completely visible parcels.

For Kenya, a scanned map of cadastral boundaries from an informal area of Kisumu city was made available from the field. This map was geo-referenced using the available Geo-Eye imagery of the area. Rubber-sheeting and edge-matching were used to match the boundaries with the visible features on the image. Roads, fences and hedges were specifically helpful in matching the boundaries. Though some discrepancies were also observed, for e.g. many roads visible on the reference map could not be located on the image.

2.5 Limitations

Recent studies show a much-needed inclination towards exploration of alternative approaches using satellite images for cadastral mapping. This research explores the potential benefits but also identify several limitations of the method as discussed in this section.

The visual interpretation was done by one person (first author) of this study. This approach can introduce systematic errors or bias in terms identifying boundaries/parcels. We also recognize that if the analysis was done by a different person it might result in a different analysis results. That said, the problem is an inherent challenge related to remote-sensing based studies, where image classification results may also differ if performed by different operators (Belgiu, Drăguţ, & Strobl, 2014). Considering the limited research on this issue so far, we consider this study a step towards understanding the potential of automatic methods.

The procured cadastral boundary maps which were used as reference, whilst needing to be considered authoritative and accurate could not always be fully ascribed with these characteristics. Some digitizing errors in the cadastral boundaries could be seen in terms, of shifted polygons or unmatched borders. In cases where there was not a large offset, some of these errors were ignored while interpreting and selecting visible parcels. Whereas such an approach can also introduce bias, considering the data were procured in some cases from data-poor environments, the method was found as a suitable for the purpose of this study.

For Mozambique and Kenya, only scanned cadastral maps could be obtained. Because of the relatively organized urban layout, it was easier to digitize boundaries in Mozambique compared to Kenya. In Kenya, the map was available for an informal, peri-urban area. While geo-referencing the map, features such as roads, hedges did not always match with similar features on the image. Specifically, the well-defined roads on the map did not overlap with the informal/irregular access lanes on the image and thus, many edges did not match well. This mismatch may have influenced the identification of cadastral boundaries/parcels in this context.

Finally, a low percentage of identification can also be attributed to the fact that only polygons with all visible boundaries, i.e. full and completely visible parcels were considered in this research. A higher percentage may be achieved if incomplete parcels or individual boundaries (e.g. 3 visible boundaries out of a total of 4) were also considered.

3. RESULTS

Figure 1 shows the maps with the visual interpretation results and Table 2 shows the respective identification percentages for sample subsets from Ethiopia, Nepal, Ghana and Rwanda. These case locations are from rural areas, with Nepal particularly from a hilly terrain. There is a noticeable difference in number of fully and complete visible parcels in the four areas, with the range of identification percentage from zero to 71 %, the latter being the highest amongst the seven contexts. For Ghana, the identification is 12.5 % which is lower than the overall average of identification i.e. 22 % which is coincidently also the percentage of visible parcels in Rwanda.

Figure 2 shows the maps for Kenya, Mozambique and Guatemala. While the Kenyan case location comprises of an informal, peri-urban area, the latter two represent formal and organized urban

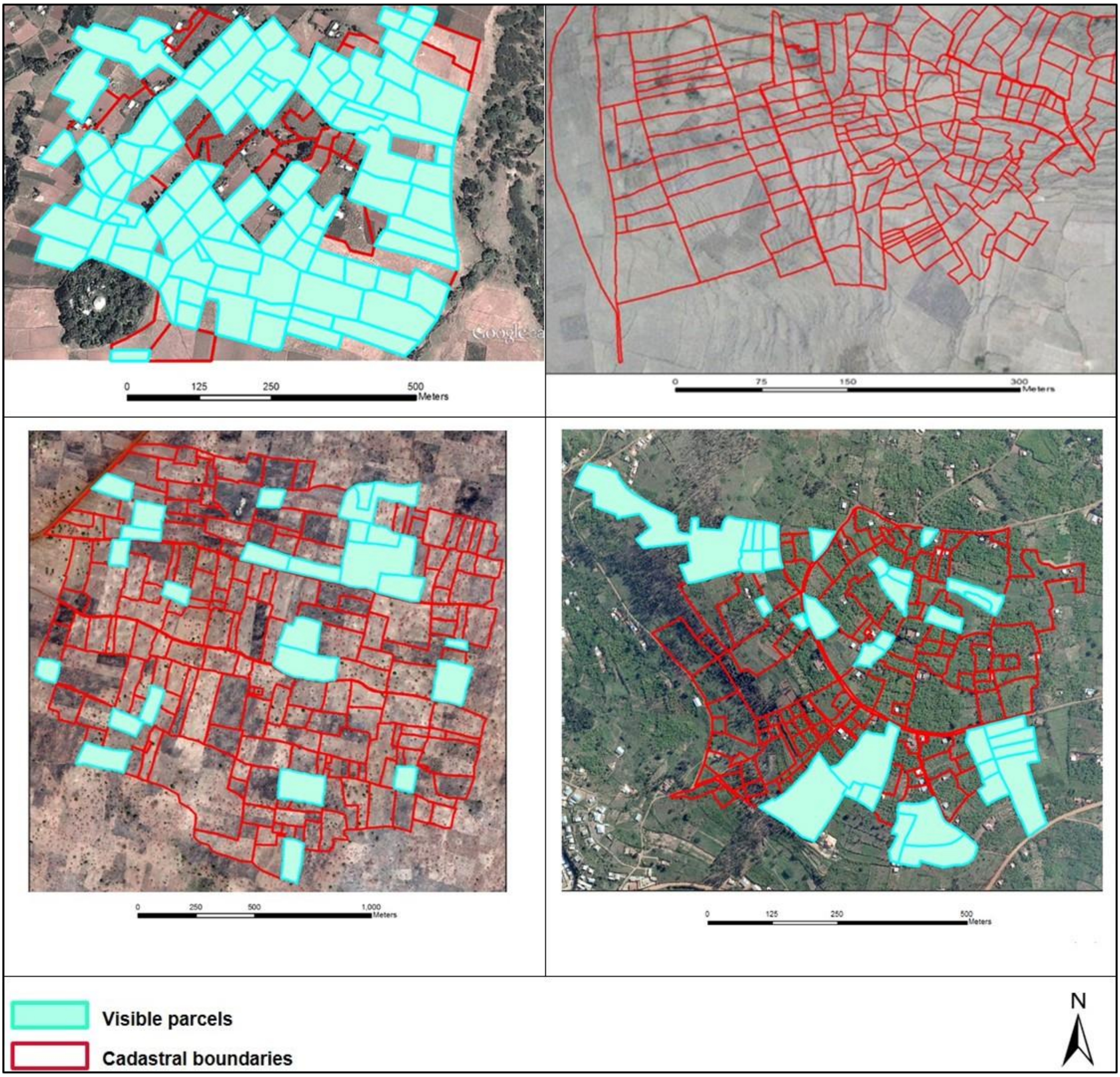

Figure 1 Visual interpretation of complete cadastral parcels in Ethiopia, Nepal, Rwanda and Ghana (clockwise from top-left). Source for Ethiopia image-subset: Google Earth; Source for Nepal and Rwanda image-subsets: ESRI basemaps in ArcGIS Online.

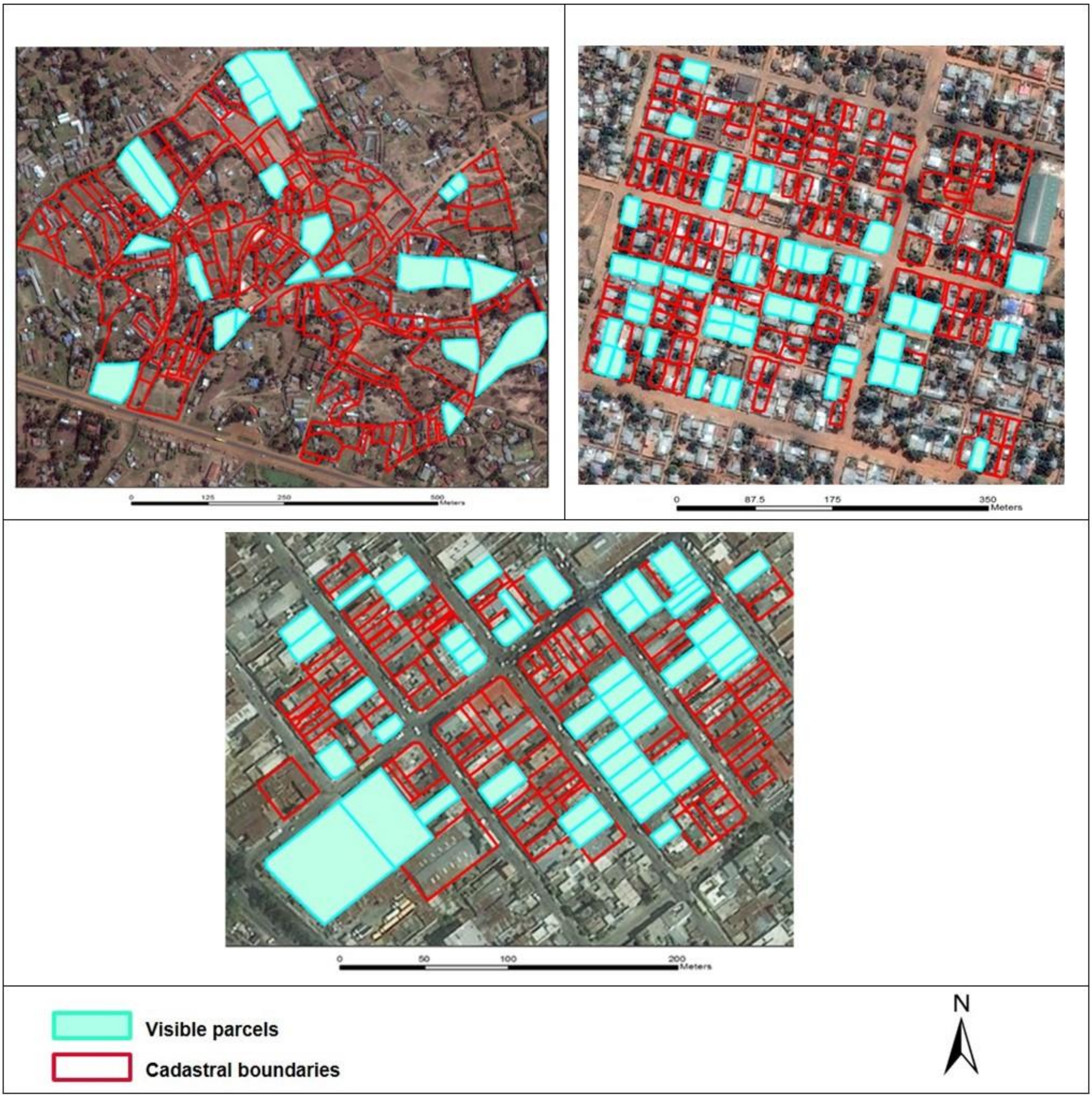

Figure 2 Visual interpretation of complete cadastral parcels in Kenya, Mozambique and Guatemala (clockwise from top-left). Source for Mozambique and Guatemala image-subsets: ESRI basemaps in ArcGIS Online.

areas. Guatemala and Mozambique were easier cases than Kenya, though the identification of parcel boundaries was restricted by the spatial resolution of the base images.

Table 2 The total number of parcels considered per case location and the corresponding visible parcels for each context.

Place	Total	Fully visible		Landscape
		Number	Percentage	
Ethiopia	128	92	71%	Rural
Rwanda	151	33	22%	Rural
Guatemala	172	47	27%	Urban
Ghana	200	25	12.5%	Rural
Mozambique	190	47	24.7%	Urban
Nepal	164	0	0	Rural-hilly
Kenya	179	23	12.8%	Peri-urban/informal

4. DISCUSSION

With the availability of very high resolution remote sensing images and the remarkable development of automated methods for different application fields, there seems to be potential in the area of land administration as well. Going a step further from the previous field-based methods, using visual interpretation or (semi)-automatizing the visible cadastral boundaries could be useful for contexts where no reliable cadastral data exists and hence greatly enhance the application of FFP approach in Land Administration for cadastral mapping. In this research, we study the potential of using remote sensing based methods by exploring and quantifying the visible cadastral parcels across image subsets from different contexts. We focus mainly on Sub-Saharan Africa but also explore other contexts to get an understanding of the diversity. Though considering seven different samples with different landscapes does give an overview of opportunities and limitations, the results are in no way representative of any region. Nonetheless, our study does make a step towards understanding morphological diversities and could be used as a basis for further analysis where image-based methods could prove to be extremely useful.

Cadastral boundaries are not just physical entities, they are social and legal constructs. The identification of parcels through desktop visual interpretation alone, without actual context/field knowledge, may depend a lot on the landscape morphology. The results of this study show that the percentage of visible parcel identification ranges from zero to 71%. These results reflect upon the fact that some landscapes are much easier as compared to others. The Ethiopian case seems to be the easiest with 71% identification which could be attributed to the clearly visible small holder farms. The farm boundaries in this case coincide with the parcel boundaries. This seems to be very promising for the use of satellite images for cadastral mapping in Ethiopia. Ghana, on the other hand, seemed to have clear farm boundaries but these rarely match with the reference layer and thus resulting in a much lower identification of 12.5%. Large farms, comprising of multiple parcels were challenging to image-based identification in the case of Ghana. In Nepal, the hilly terrain shows terrace farming patterns but none of the farm-boundaries coincides with the cadastral boundaries.

Further research to access the quality of existing cadastral maps may provide more insight on the reasons of low identification percentages in such areas.

In the case of Rwanda, with the identification of 22%, vegetation was a major hurdle in identification. Many boundaries were completely hidden under vegetation. Crop/vegetation pattern, thus may play an important role in identification of visible boundaries. Visual identification for the same regions may be enhanced significantly with an image from a different season. This observation opens avenues for the use of multi-temporal images which may potentially enhance the identification percentages.

Small holder farms (e.g. Ethiopia) seem to be easier than other areas. In these area, land use corresponds to cadastral boundaries and hence easy to visually identify. On the other hand, it was difficult to identify boundaries in complex and dense urban areas where boundaries may not be always visible. Especially, in cases where multiple parcels exist within a visible cadastral block or building. Detailed knowledge on the context or urban form in terms of housing typologies may improve the identification in such cases.

Guatemala and Mozambique were relatively easy and with better identification percentage of 27% and 24.7% respectively. This can be attributed to an organized road layout and clear boundaries between adjoining blocks. In both the cases, the spatial resolution of the available images, could be seen as a major hindrance resulting in comparatively low identification percentages. The spatial resolution often seemed inadequate for identifying boundaries between dwellings in both the cases. Therefore, whilst the resulting percentages are not high, it may be easy to fill the gaps due to the regular nature of the boundaries and street layout. Aerial or satellite images with better spatial resolution could improve the identification percentage substantially in these cases. The use of aerial or UAV images could be potentially explored in future for similar work.

5. CONCLUSION

In this paper, we quantify and compare the visible cadastral parcels across samples from seven contexts using satellite images. The analysis was useful to get understanding of the diversity in boundary morphologies and their visibility across different areas. Our results show significant difference between visual identification of complete parcels for the seven contexts with the percentage of complete visible boundaries of parcels ranging from zero to 71 percent when compared to the reference cadastral maps for respective locations. Small-holder farms and organized urban areas have significant potential in terms of visual boundary/parcel identification when compared to large farms or hilly terrains. We expect that this research gives an understanding on potential of using remote-sensing based methods for large-scale application and provide fit-for-purpose solutions in land administration by cost-effective and speedy cadastral mapping.

ACKNOWLEDGEMENTS

We are extremely grateful to Ganesh Prasad Bhatta and Susheel Dangol from the Survey Department, Nepal for providing the reference data. We are also thankful to Mireille Biraro from INES-Ruhengeri for providing data for Rwanda.

REFERENCES

Ali, Z., Tuladhar, A. M., & Zevenbergen, J. A. (2012). integrated approach for updating cadastral maps in Pakistan using satellite remote sensing data. *International Journal of Applied Earth Observation and Geoinformation : JAG, 18*, 386-398.

Belgiu, M., Drăguţ, L., & Strobl, J. (2014). Quantitative evaluation of variations in rule-based classifications of land cover in urban neighbourhoods using WorldView-2 imagery. *ISPRS Journal of Photogrammetry and Remote Sensing, 87*, 205-215.

Bennett, R. M. (2012). cadastral divide : a view from the bridge. *Geospatial World, 2*(11), 42-45.

Lemmen, C. H. J., Zevenbergen, J. A., Lengoiboni, M., Deininger, K., & Burns, T. R. (2009, 9-10 March, 2009). *First experiences with high resolution imagery based adjudication approach for social tenure domain models in Ethiopia.* Paper presented at the FIG - World Bank Conference : Land governance in support of the Millennium development goals, responding to new challenges, Washington, D.C.

Luo, X., Bennett, R. M., Koeva, M. N., & Quadros, N. (2016). Cadastral boundaries from point clouds? : Towards semi-automated cadastral boundary extraction from ALS data. *GIM International, 30*(12), 16-17.

Rugema, D. M., Verplanke, J. J., & Lemmen, C. H. J. (2015). Digital pen method. *In: Advances in responsible land administration / edited by J.A. Zevenbergen, W.T. de Vries and R.M. Bennett. Boca Raton: CRC Press, 2015. ISBN: 978-1-4987-1961-2. pp. 131-144*.

Sengupta, A., Lemmen, C. H. J., Devos, W., Bandyopadhyay, D., & van der Veen, A. (2016). Constructing a seamless digital cadastral database using colonial cadastral maps and VHR imagery : an Indian perspective. *Survey review, 48*(349), 258-268.

Wassie, Y. A., Koeva, M. N., & Bennett, R. M. (2016). Towards automated detection of visual cadastral boundaries : initial investigation of imagery, algorithms and perceptions. *GIM International, 30*(8), 23-25.

BIOGRAPHICAL NOTES

Divyani Kohli is currently working as a Post-doctorate researcher at the Faculty of Geo-information Science and Earth Observation (ITC), University of Twente, The Netherlands. She completed her doctorate from the same university in 2015. Her past assignments have included a range of topics such as the use of GIS/Remote sensing in urban mapping, automated feature extraction, spatial analysis, spatial metrics, uncertainty analysis and advanced image processing techniques. Currently, her research focuses on exploring the use of Remote Sensing based methods, specifically object-based image analysis, for cadastral boundaries extraction from very high resolution satellite images.The methods being developed for this research are aimed at expediting and supporting cadastral mapping of areas where no reliable data exists.

Rohan Bennett is an Associate Professor of Information Systems at the Swinburne University of Technology, Australia. He holds a PhD from the University of Melbourne and also degree in Engineering (Geomatics) Science. His recent research investigates the utility of UAVs, automatic feature extraction, and mobile apps in supporting urban and rural land governance, food security, and land tenure security. Rohan was also project coordinator of its4land, a multidisciplinary European Commission Horizon 2020 project, running from 2016-2020, involving 8 academic and private-sector partners, and 6 countries in Europe and Africa. In 2015, he was listed by XYHT Magazine as a Top 40-under-40 Remarkable Geospatial Professional.

Christiaan Lemmen holds a PhD from Delft University, The Netherlands. He is geodetic advisor at Kadaster International and visiting scientist at University of Twente/ITC, The Netherlands. He is director of the FIG Bureau OICRF and Chair of the Working Group 'Fit-For-Purpose Land Administration' in FIG Commission 7. He is contributing editor of GIM International and editor of ISO 19152 Land Administration Domain Model.

Kwabena Asiama is an AiO Researcher/PhD candidate at the University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), Department of Urban and Region Planning and Geo-information Management in Enschede, The Netherlands. He obtained MSc degree in Geo-Information Science and Earth Observation for Land Administration from the same university in 2015. His research interest focuses on land management and administration, and presently he is doing research on Responsible Land Consolidation on Customary Lands.

Andres Morales was born in Guatemala City, Guatemala. He graduated as a bachelor in architecture with honors in 2009. From that year until 2011 he worked at the Guatemala City Office as subordinator of urban projects. This role involved various tasks in urban analysis to support territorial policies, urban interventions and to work with various city stakeholders. From 2011 until 2013 he completed his MSc in Geo-information and Earth Observation with application in Urban and Regional Planning at ITC Faculty, Twente University, The Netherlands. Institutions where he is currently completing his PhD research. His research interest are on urban land value modelling, urban accessibility, Space Syntax, geostatistics, and collaborative planning.

Andre Pinheiro graduated in Geomatic Engineering in Lisbon, Portugal, in 2005, and started to work right after in a research group in remote sensing sciences. In 2007, he concluded a master degree in Geographic Information Systems and started the international experience. Currently, he works as team leader of a Land Cadaster project in Cape Verde, funded by Millenium Challenge Corporation. André also has 6 years of experience in Mozambique in land administration projects.

Robert Nilson Wayumba is a Lecturer at the Technical University of Kenya. He holds a PhD from the University of Otago in New Zealand. He also holds a Master of Science in Land Management from the Royal Institute of Technology in Sweden and a Bachelor of Science in Surveying from the University of Nairobi. Robert has worked in various organizations in Eastern Africa as a Land Surveyor and GIS Expert. He is also an Associate Member of the Institution of Surveyors of Kenya.

Jaap Zevenbergen is a full professor of land administration and management at the ITC faculty, Univeristy of Twente, Enschede, The Netherlands. He has extensive expereince with design and evaluation of recording or registration of land tenure rights, legal restrictions ad other land information in the Netherlands, Eastern Europe and numerous developing countries. Currently, his main focus is on innovative land tools, especialy to expand tenure security to the legitimate, previously unrecorded rights of the poor and underprivileged. In addtion to teaching, supervision and research, he is a member of the International Advisory Board of Global Land Tool Netwrok (GLTN) and the Advisory Board of LANDac, the Dutch Academy for Land Governance.

CONTACTS

Divyani Kohli
University of Twente (ITC)
Hengelosestraat 99
7514 AE Enschede
The Netherlands
Tel. + 31534898095
Email: d.kohli@utwente.nl
Website: https://www.itc.nl/

Rohan Bennett
Swinburne Business School
Department of Business Technology and Entrepreneurship
Swinburne University of Technology
P O Box 218 Hawthorn
Victoria 3122, Australia
Tel. +61 3 9214 4991
Email: rohanbennett@swin.edu.au

Christiaan Lemmen
Kadaster International
Hofstraat 110
7311 KZ Apeldoorn
The Netherlands
Email: Chrit.Lemmen@kadaster.nl

Kwabena Asiama
University of Twente (ITC)
Hengelosestraat 99
7514 AE Enschede
The Netherlands
Tel. +31534896183
Email: k.o.asiama@utwente.nl

Jose Andres Morales
University of Twente (ITC)
Hengelosestraat 99
7514 AE Enschede
The Netherlands
Telephone: +31534874564
E-mail : j.a.morales@utwente.nl

Andre Pinheiro
Zeneti
Boa vista, Cabo Verde
Sal Rei
Cabo Verde
Tel. +238-9976422
Email: abcpinheiro@gmail.com

Robert Nilson Wayumba.
Technical University of Kenya, School of Surveying and Geospatial Sciences
P.O.Box 53387 - 00200
Nairobi
Tel. +254 705 104 295
Email: rwayumba@gmail.com

Jaap Zevenbergen
University of Twente (ITC)
Hengelosestraat 99
7514 AE Enschede
The Netherlands
Tel. +31534874351
Email: j.a.zevenbergen@utwente.nl
Website:
https://www.itc.nl/resumes/Zevenbergen