Catalyzing Innovation
ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY
WASHINGTON DC, MARCH 25-29, 2019

EVALUATION OF UAV-BASED TECHNOLOGY TO CAPTURE LAND RIGHTS IN KENYA: DISPLAYING STAKEHOLDER PERSPECTIVES THROUGH INTERACTIVE GAMING

CLAUDIA STÖCKER[1*], MILA KOEVA[1], ROHAN BENNETT[2,3], JAAP ZEVENBERGEN[1]
[1] Faculty of Geo-Information and Earth Observation, University of Twente, The Netherlands
[2] Swinburne Business School, Australia
[3] Kadaster International, Netherlands
* e.c.stocker@utwente.nl

Paper prepared for presentation at the
"2019 WORLD BANK CONFERENCE ON LAND AND POVERTY"
The World Bank - Washington DC, March 25-29, 2019

Abstract

Limitations of western-oriented land administration systems and traditional surveying approaches have indisputably contributed to a reality where approximately 70% of the world's land rights are not recorded. Amongst others, unmanned aerial vehicles (UAVs) are evolving as a remote sensing tool for alternative data acquisition. However, so far UAVs have only been tested and rarely been implemented in the context of land tenure mapping. To investigate technology uptake and to unlock the potential of UAV-based remote sensing, this paper introduces an interactive workshop approach. Key stakeholders are asked to rank four different means of data acquisition, namely satellite images, aerial images, UAV images, and ground surveying according to six predefined parameters. The results of the board game visually unveiled opportunities and drawbacks of each data acquisition technology from the perspective of the stakeholder while the group discussion provided valuable insights into existing workflows and different perceptions. Results reveal that on average, UAV-based images have the potential to compete with the currently most prevalent data collection technology - field surveying - as UAV-based images mostly ranked similar, except in terms of time efficiency (UAV images outperform field surveying) and accuracy (field surveying outperforms UAV images).

Key Words: Land administration, UAV, surveying techniques, qualitative data, gamification

1. INTRODUCTION

The livelihoods of many, especially the poorest and vulnerable, are based on access and control over land. In this context, land tenure security enables economic growth and is a key factor for facing eradication of poverty and hunger, promotion of peace, and the sustainable use of the environment. Accordingly, equal access to basic services, ownership, and control over land and other forms of property is a crucial target of the first Sustainable Development Goal aiming to end poverty in all its forms and everywhere by 2030. Notwithstanding political motives and power imbalances contributing to the problem, the limitations of western-oriented land administration systems and traditional surveying approaches, and a substantial lack of capacity to undertake those surveying activities have indisputably contributed to a reality where approximately 70% of the world's land rights are still not formally documented.

This immense global challenge is transferred to the national level, and Kenya serves as a case study for this paper. Kenya faces major land tenure problems associated with community land, especially in urban areas where this tenure dominates. Lack of legal certainty over land, poor quality land information and informal land markets have led to widespread land-related conflicts. Regarding data, Kenya's cadastre remains largely incomplete due to multiple land laws, a history of voluntary registration, and disconnected land administration functions. Mismanagement and politics of land distribution in both colonial and post-colonial governments have left Kenya contending with a multitude of land issues. Land policies and innovative technological applications are seeking appropriate concepts and tools which can address these challenges (Bennett and Zevenbergen, 2013; Koeva *et al.*, 2017; Mwanyungu *et al.*, 2017).

Amongst others, unmanned aerial vehicles (UAVs) also known as Remotely Piloted Aerial Systems (RPAS) or drones are evolving as a remote sensing tool for alternative data acquisition. The advent of these low cost, user-friendly and lightweight platforms and recent developments in digital photogrammetry and computer vision have created new opportunities for collecting timely, tailored, detailed and high-quality geospatial information. Evidence of numerous UAV-based data acquisition missions across the globe prove the capabilities of this innovative technique (Nex and Remondino, 2014; Pajares, 2015). However, so far UAVs have only been tested and rarely been implemented in the context of land tenure mapping. Preliminary studies among Kenyan stakeholders revealed a recognized need for improved cadastral and better quality non-cadastral data. This paper introduces and reports on the results of an interactive stakeholder workshop to investigate technology uptake and the perception of UAV-based remote sensing for capturing spatial data and how UAV technology compared to ground surveying, traditional aerial images, and satellite images. The workshop was undertaken in Kenya in October 2018.

After elaborating on the method of the workshop, each data acquisition technology, as well as each parameter, is explained separately before discussing perspectives of and perceptions on opportunities for UAV-based images in the context of Kenya. This research is associated with the European Commission funded Horizon2020 project “its4land” that aims to develop an innovative suite of land tenure recording tools (www.its4land.com).

2. BACKGROUND KENYA

Kenya is a medium-sized East-African country characterized by arid and semi-arid landscapes. Land in Kenya is dominated by two main categories: statutory tenure (30%) and customary tenure (70%) (Lengoiboni, Bregt and van der Molen, 2010; Ochori and Achola, 2015). Formally registered land includes individual/group tenure and public tenure whereas customary tenure is not formally registered but governed by the community according to their customary practices. In 2017, estimates suggested that 30% of the land in Kenya is formally registered in cadastral maps (Mburu, 2017). In this context, two main types of boundaries prevail fixed boundaries and general boundaries (Wayumba, 2013). Whereas fixed boundaries are surveyed predominantly in urban areas using highly accurate field surveying techniques, most of the rural and peri-urban areas are registered using general boundaries (Ochori and Achola, 2015). The latter is represented by physical features such as hedges or shrubs which were subsequently demarcated on aerial images taken by the colonial and post-independence governments in the 1960s. Based on this, cadastral boundaries were created and formalized in Registry Index Maps representing the spatial extent of the paper-based land titles. However, the poor orthorectification of the aerial images caused geometrical and topological inconsistencies in the base data, which are still leading to conflicts as the Registry Index Map does not represent the reality on the ground. In 2012, the Land Registration Act was passed into law aiming to harmonize the multitude of land laws, some of which date back to early post-colonial times. Besides the new Land Registration Act, former laws are still in a phase of transition as no timeline for full implementation was given (Mburu, 2017). Adding to this problem, the paper-based system and lengthy bureaucratic procedures are well-known issues hindering efficient maintenance of the land registration system.

3. METHODS

The data was collected during a workshop event organized by the its4land project team. Stakeholders from Kenya national government, local government from Kajiado County, the private sector, academia, and NGOs were invited to attend an interactive boardgame dealing with different data acquisition techniques for cadastral surveying. In total eight groups were formed acknowledging a similar background and affiliation to ensure that people can speak openly. The data collected during this workshop provided the baseline to evaluate the potential of UAV-based technology to capture land rights in Kenya from the perspective of key stakeholders.

The set-up of this workshop was intuitive and easy. A blanc radar chart with six axes served as a board game and is presented at the centre of the table (see Figure 1). During the workshop, stakeholders were asked to rank four different methods of data acquisition, namely satellite images, aerial images, UAV images and ground surveying according to six parameters derived from state-of-the-art frameworks for selecting fit-for-purpose data collection methods in land administration (Rahmazitadeh 2018). Both, the different data acquisition technologies as well as the chosen parameters are sufficiently explained to the participants before the group discussion started. Once a consensus was found, the group placed the chip on the board game with each data collection technology being represented with one colour — the closer the chip was positioned towards the centre, the better the ranking. The conversational process to reach consensus facilitated the group members to engage in a constructive dialogue and share experiences with other practitioners. Hence, the workshop served not only as a means for the collection of qualitative and quantitative data but also to exchange information and generate knowledge among the group members. Results of this paper were obtained from a survey about the familiarity of the workshop participants with the data collection methods, the outcomes of the board game (i.e. placement of the chips), as well as voice recordings during the group conversation. The workshop was completed under ethically sound conditions, and informed consent was obtained beforehand.

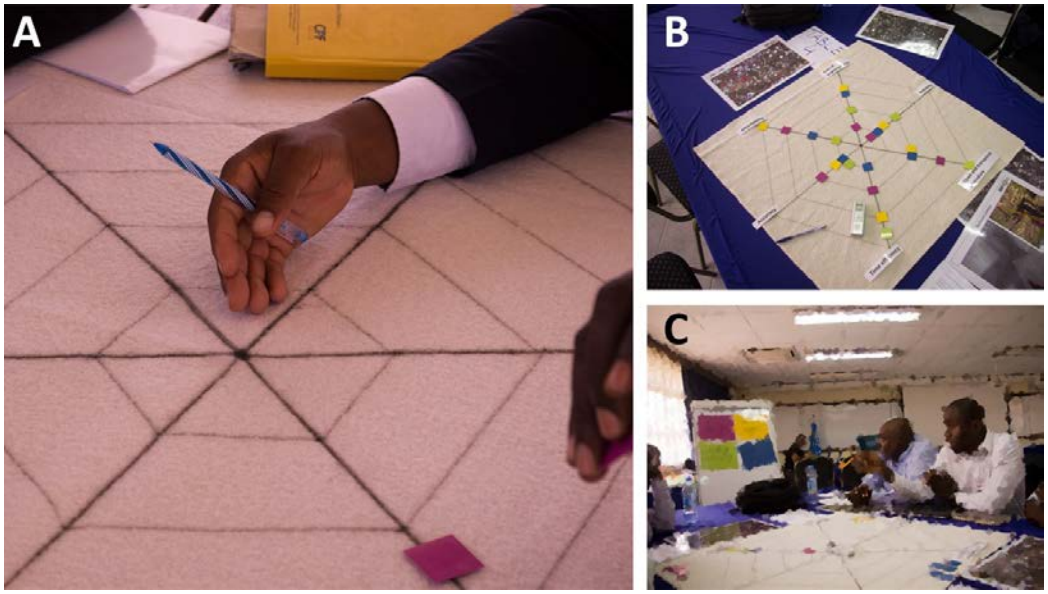

Figure 1: Impressions from the interactive workshop. A) Starting the game with a blanc radar chart; B) Final result of the board game; C) Active discussion to find consensus among the group members

3.1 Surveying techniques

According to the employed method, data acquisition techniques are commonly distinguished as direct and indirect techniques (Fig. 2 and Fig. 3). Direct techniques measure the physical location of boundary points directly on the ground. Remotely sensed observations based on space- or air-borne images are seen as the medium which allows for imagery based boundary delineation and subsequent cadastral mapping.

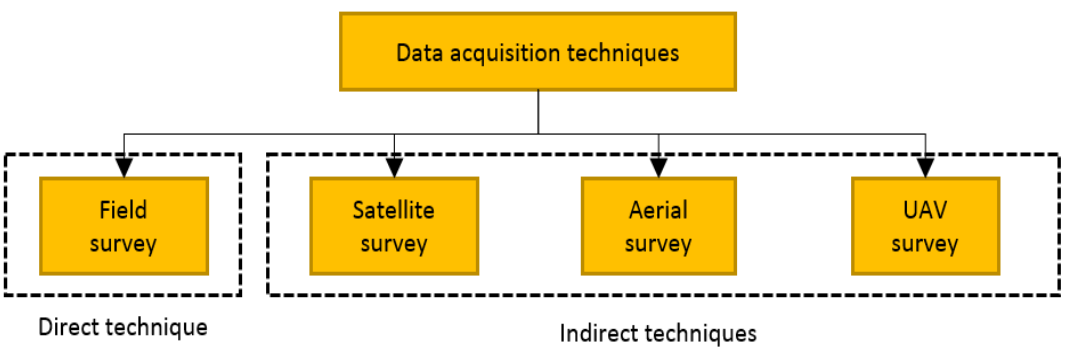

Figure 2: Overview of data acquisition techniques that were covered during the workshop

Field Survey

Field surveying is the most traditional approach to land administration and surveying. Historically, simple plane table measurements were replaced by coordinate-based point distance measurements on the ground. Here, every corner point needs to be measured to allow the determination of distances and line-vectors. Depending on which accuracy is needed, either simple measuring instruments such as tapes and compass or professional equipment such as a tachometer, theodolite, total station or real-time kinematic (RTK) GNSS are employed.

Satellite-based images

Satellite images have become a potent data source as they provide freely/commercially available high-resolution imagery[1]. This allows identification of physical features which either represent a boundary such as roads and paths or are related to a parcel such as a building. Various studies prove that visual boundaries can be identified on plotted satellite images and either be demarcated by local stakeholders in a participatory manner (Asiama, Bennett and Zevenbergen, 2017) or delineated using manual or automatic feature extraction approaches (Kohli, Unger and Lemmen, 2018). Satellites operate 365 days of a year and often have frequent revisit times. However, clouds and occlusions from trees and houses may hinder accurate surveys.

Aerial-based images

Aerial photogrammetry allows generating planimetric precise true orthoimages. The spatial resolution highly depends on the flight height and is typically in the range of 10cm to 50cm. Data results are corrected for tilt and relief displacement (Paine and Kiser, 2003). Hence, direct measurements and accurate definition of point coordinates are applicable for parcel boundary delineation. One prominent current example is the Land Tenure Regularization Programme in Rwanda where 99% of the whole nation were covered by high-resolution aerial photography (Ngoga, 2018).

UAV-based images

Due to their flexible operational setups, UAVs can bridge the gap between time-consuming but high accurate field surveys and the timeless fashion of classical aerial surveys. A range of different sensors and types of platforms accommodates almost all environmental and physical constraints such as limited space for taking off and landing, steep terrain, or poor weather conditions. Advancements in automized flight

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[1] 10m ground sampling distance for images of the Sentinel mission (ESA) – freely available, 41cm ground sampling distance for RGB images GeoEye Mission (DigitalGlobe) – commercial product

control and intuitive flight manager software allow multiple stakeholders to capture, process, and use the data. This includes orthoimages, digital elevation models and 3D point clouds which can all serve as a basis for cadastral mapping applications (Mumbone *et al.*, 2015; Meha *et al.*, 2016).

Figure 3: Examples of data derived from different data acquisition techniques. These examples were printed on A3 paper and used during the workshop

3.2 Parameters

Parameters were derived from state-of-the-art frameworks for selecting fit-for-purpose data collection methods in land administration (Rahmazidadeh 2018). The framework is based on a representative Delphi study among land administration experts. Due to time constraints and a required simplicity of the interactive workshop in this paper, the authors chose six of the most important parameters. This number had proven to allow enough room for discussion in the given time frame of one hour and fitted nicely to the layout and design of the board game. Four out of six parameters characterize the data collection method, namely *time efficiency, affordability, ease of implementation,* as well as *open and transparent procedure*. The remaining two parameters *accuracy* and *reliability* mainly refer to the data quality itself (see Table 1).

Table 1: Definition of parameters for the board game

Parameter	**Definition**
Accuracy	Geometric accuracy of the data product
Time efficiency	Time aspect of data collection
Affordability	The available budget for the data collection
Reliability	Trustworthiness and reproducibility of data product
Open and transparent procedure	Extend to which the procedure of data collection is transparent
Ease of implementation	Ease of access and availability of the data collection method

RESULTS

A total number of 36 people attended the workshops. The results of the survey prevail that most of the participants were profoundly acquainted with field surveying, satellite and aerial images. This can be explained by the fact, that these techniques were or are currently used for surveying/mapping tasks in Kenya. Figure 4 shows that satellite images and aerial images reveal similar distributions of the responses. All persons were familiar with these data acquisition technique; a majority (more than 70%) has already worked with this kind of data. In contrast, the distribution of responses for UAV images looks slightly different. Here, 22% of all participants were not familiar with UAV data. The remaining 78% indicated a certain familiarity with this data acquisition technique, but only 21% of them have worked with UAV data already. Most stakeholders were highly familiar with field surveying and only three persons (8%) were not.

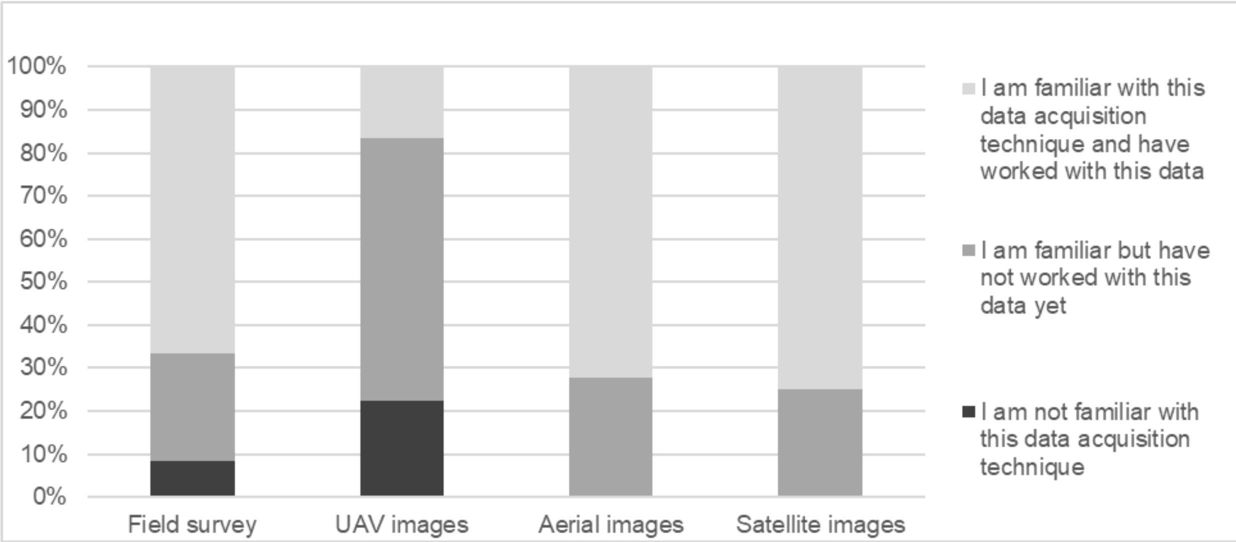

Figure 4: Familiarity of workshop participants with surveying techniques (n=36)

The results of the board game visually unveiled opportunities and drawbacks of each data acquisition technology from the perspective of the stakeholder group while the continuous group discussion provided valuable insights into existing workflows and different perceptions. Although the interactive workshop equally weights all four data acquisition technologies, results were derived with a focus on UAV-based images. The parameters accuracy and time efficiency show lowest variances among the statistical analysis as shown in Figure 5. This means that all eight stakeholder groups have ranked the various data acquisition technologies similarly. In contrast, the other parameters *open and transparent procedure*, *ease of implementation*, and *reliability* show high variances in their rankings and thus reveal different perspectives, especially between data provider (i.e. practitioners) and data user (i.e. national and local government and NGOs). The following subsections will provide more insights into the group discussions and driving arguments for the individual ranking.

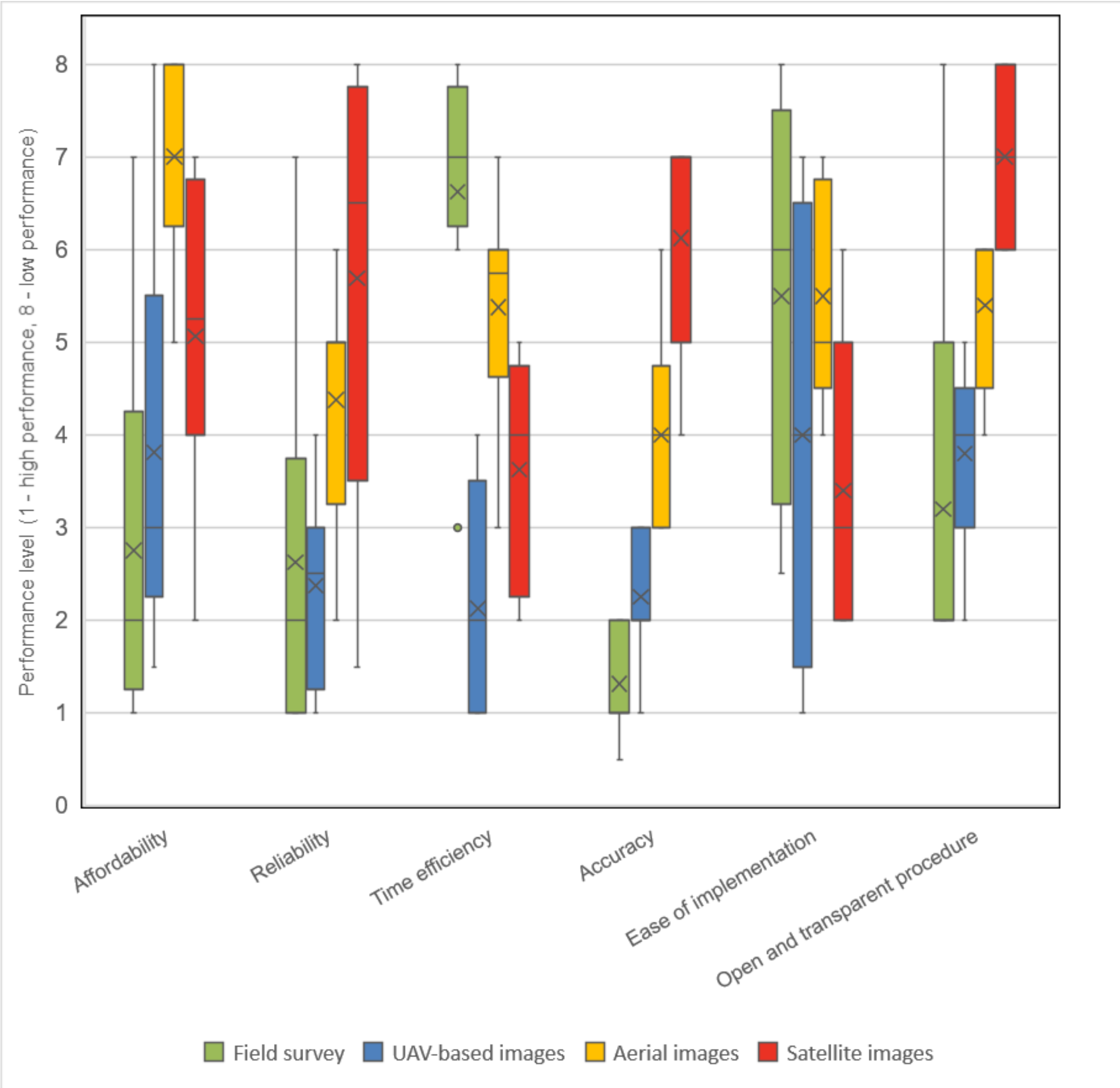

Figure 5: Statistical distribution of responses presented in a Box-Whisker plot (n=8 groups)

Affordability

Although the parameter *affordability* was ranked differently among the various stakeholder groups, a general trend can be observed. On average aerial images were ranked with the lowest performance, followed by satellite images. The respondents identified that recurring costs for each data request characterize both data collection methods, i.e. hiring a company to capture aerial images or requesting satellite images. In contrast, field surveying and UAV data collection involve only one-time purchases of the professional equipment and recurring staff rates. The highest variance in the ranking of the performance level can be observed with UAV-based images, ranging from 1.5 to 8, a result of the broad range of purchasing costs. Moreover, costs for airworthiness certification and legal registration were perceived to have a large share of the total costs as well. Field surveys perform the best, especially when using general boundaries where measurement accuracies of a few meters are acceptable. Besides the costs of the data itself, the majority of the groups raised the economies of scale about the indirect surveying techniques. The more parcels are captured in one orthoimage; the cheaper and more cost-effective the image-based data collection will become.

Reliability

Two different discourses emerged during the discussion of *reliability*. The first discourse referred to the *reliability* of the data collection technique itself and the second to the *reliability* of the person who collects and processes the data. In this aspect, we observed a large variance in the responses for field surveying and satellite images. Although a professional GNSS device can determine cm-accurate boundary coordinates, the majority of groups raised concerns regarding the trustworthiness of the surveyor.

Furthermore, beacons or monuments of geodetic reference points can be found as demolished, moved or even removed. Looking at satellite images, most doubts were mentioned about post-processing (i.e. correct rectification) and image quality (i.e. cloud cover).

In contrast, post-processing of UAV and aerial images was considered reliable among the groups with the only drawback of weather-dependency setting its operational limitations (i.e. cloud-free sky, no strong wind and decent lighting conditions). The highest performance was achieved by UAV images which can be captured in post-processing kinematic or a real-time kinematic mode and thus do not necessitate the collection of ground control points which was perceived as a processing step which could lower the performance of UAV images. Some groups indicated the problem of vegetation cover which can obstruct the view from above and hinder the correct identification of parcel boundaries and thus have an adverse effect on the *reliability* of the data.

Time efficiency

All groups reached a consensus that the parameter of *time efficiency* highly depends on the scale. However, the results on average suggest a general trend with UAV images showing the best performance, followed by satellite images, aerial images, and field survey with the lowest performance. A critical point which caused the low ranking of UAV images refers to the legislation and flight authorization, a component which was found unpredictable as it can range from a few days to a few months. However, compared to to the timely processes of tendering and procuring a flight mission with a regular airplane, the immediate realisation of UAV missions – with given authorization – was identified as most promising about time efficiency. Next, to this, the opportunity to directly download satellite images enthused the workshop participants. However, it was observed that this argument provoked an intense discussion as most satellite data providers restrict access to up-to-date pictures or charge additional fees for this service. Another weak aspect of satellite images was the fact that satellite data can hardly be tailored to the requirements as the satellite usually has a fixed orbit with determined revisit times. The parameter *time efficiency* showed the only statistical outlier from this study. Here, one group ranked field surveying with a high performance whereas all other groups decided to rank it with low performance.

Accuracy

Similar to the parameter of *time efficiency, accuracy* shows a clear ranking and consensus among the groups. According to the statistical analysis, field surveying demonstrates the best performance followed by UAV images, aerial images, and satellite images. This parameter was found to be easy to rank as it highly correlates with the spatial resolution for indirect surveying techniques and the measurement accuracy for field surveying. The group discussions revealed that for both aerial and UAV image-based techniques ground measurements are still required to achieve geometric accuracies below 0.5m.

Ease of implementation

The assessment of this parameter showed the most substantial variance in group responses among the six parameters. Responses for UAV images have a range of 1 – 7, field surveying 2.5 – 8, and satellite images 2 – 6. Only aerial images showed more consensus with a range of only three performance levels. On average, satellite images were ranked with the highest performance due to the simplicity of downloading and using the images right away. Main reasons to rank UAV images with a high performance were identified in the little amount of training for UAV mapping as many processes such as flight planning, image capture, and processing are automated.

In contrast, rectification of aerial images, as well as field surveying with GNSS equipment, requires a high level of training which lowers the ease of implementation as the staff has to be trained. At the same time, responses revealed that field surveying is the only data acquisition technique which is defined in a standard (Act of Surveying) and thus the only legally accepted surveying method. Current UAV legislation in Kenya was identified as a hindering factor with a negative impact on the ease of implementation. However, most groups found that the fast deployment and data collection in the field can compensate for this aspect.

Open and transparent procedure

The ranking of this parameter was quite clear for the indirect surveying methods but showed a large variance in the responses for field surveying. Main reasons to rank UAV images better than aerial or satellite images are that the data collection takes place on the ground and people can participate in this process. Furthermore, delineation on top of a UAV/aerial/satellite image scores better in terms of transparency compared to field surveying where the surveyor collects measurements while people are present but processes the data when he/she is back in the office. With an overlay of cadastral boundaries on top of an orthomosaic, people can prove that the cadastral boundary corresponds to the real situation on the ground. However, some groups also indicated that local people are mainly used to “traditional” surveying maps and might not accept orthoimages as a source for the delineation of their parcel boundaries.

DISCUSSION

The interactive workshop was designed to assess the potential of direct and indirect surveying methods from the perspective of various stakeholders in Kenya. In some instances, perceptions differed widely which can be explained by the different levels of familiarity but also different interpretations of the parameters. Further difficulties were observed in the singular ranking of parameters as most of them show interdependences among each other, such as *reliability* and *accuracy* or *affordability* and *time efficiency*.

Overall, the most obvious finding to emerge from this study is the compatibility of UAV images with field surveying. Particularly about *open and transparent procedures*, a parameter which was considered as most important for choosing a fit-for-purpose data collection method (Rahmazitadeh 2018), UAV images were perceived to outperform the other techniques. It was somewhat surprising to see how much emphasis was drawn on the opportunity of public participation during the data collection whereas aerial and satellite images were ranked with a low-performance level as they are captured without the awareness of the people. One reason for the low average performance of aerial images can be seen in the experiences in Kenya with poorly rectified aerial images from the 1960s.

Furthermore, a big potential was identified in the independence of the UAV data capture; independence from a long training program and large companies or donors who can afford satellite images or aerial flight missions. Local authorities, private companies as well as government agencies saw UAV technology capable of providing long desired up-to-date raw data at a medium scale such as towns or municipalities where cadastral plans can be updated using accurate and reliable UAV images. This procedure reflects the expressed wish of local authorities to opt for time-efficient and modern geospatial technologies which could potentially support Kenya's endeavours to digitize the current land registration system (Mburu, 2017). Looking at future developments, the results suggest that most stakeholders already perceive UAV technology as a viable method for land data capture. Given that legal issues will UAV regulations will be cleared in the near future, this study clearly shows the benefits of UAV technology compared to other surveying techniques and can be considered as a starting point for a successful technology uptake.

Reflecting on the workshop design, it was observed that the immediate visualization of the ranking through the placement of the chips on the boardgame had the positive consequence that the chip was only placed once the group came up with a consensus. This approach strongly encouraged workshop attendees to contribute to the co-production of information through the exchange of practical experiences. Furthermore, the gamification of the discussion accelerated the social interaction and allowed to break silos and think out of the box. The strategy to discuss one parameter with regard to all four technologies instead of all parameters for one technology minimized a potential bias of ranking one technology per se with high performance. However, the presence of high-level politicians or professionals introduced bias as those attendees have tended to take over as a team leader with a notion of pushing their perspectives and perceptions in the ranking. Nevertheless, based on this experience it was found that the approach of this interactive workshop can facilitate a constructive discussion to rank various (technological) solutions according to a set of parameters that should be considered in the process of tackling a real-world problem. In this regards, it can be said that the method of this interactive workshop can be transferred to various domains to supports decision making processes, especially if different stakeholder groups are involved.

CONCLUSION

The results show that different stakeholder groups have different perceptions of the performance of the four surveying techniques examined in this interactive workshop. The setup of the interactive workshop was intentionally chosen to initiate lively debates to find consensus in the group. The open discussion round engaged stakeholders to exchange their experiences and perceptions and finally come up with a group consensus. Results reveal that on average, UAV-based images have the potential to compete with the currently most prevalent data collection technology - field surveying - as UAV-based images were on mostly ranked similar, except in terms of time efficiency (UAV images outperform field surveying) and accuracy (field surveying outperforms UAV images).

Additionally, stakeholders identified that the high resolution and quality of information of a UAV-based image could significantly increase the transparency and openness of the boundary delineation procedure as physical features are clearly visible and identifiable by local stakeholders. However, during the group discussions, the lack of legislation and adequate capacity were identified as significant constraints that are currently impeding scaled implementation of UAV technology. At this point, satellite and aerial images were considered more straightforward to implement. Nevertheless, the fact that existing surveying standards do not acknowledge remotely sensed data as a qualified means to define boundaries was deliberately debated as a hindering factor.

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