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Application of Unmanned Aerial Vehicles in Improving Land Registration in Kenya

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ABSTRACT : This paper explains why and how Unmanned Aerial vehicles (UAVs), also known as drones, can be used to improve land registration in Kenya. According to a World Bank report that was released in 2003, only about ten percent of land in Sub-Sahara Africa has been formally registered. A more optimistic figure for developing countries in the whole World was released in 2013, which shows that only about thirty percent of land is registered. Thus, a majority of the people are unable to gain from the benefits of registration. An effective land registration system can contribute towards improving: tenure security, real estate markets, access to credit, taxation, dispute resolutions and urban planning among others. A key requirement for improving the extent of registration is to map property boundaries. A means of rapidly mapping the boundaries is to use UAVs. However, it is not clear how UAVs can be used in a county like Kenya. This paper employs case study methodology to explain why and how the UAVs can be used in Kenya. The results section explains different types of UAVs that may be used, legal regulations for using the UAVs and techniques that are required for land registration. The hope of this paper is that it might contribute towards the use of UAVs for improving land registration not only in Kenya but also in other developing countries.

Keywords : Unmanned Aerial Vehicles, Land Registration, Kenya

I. INTRODUCTION

This paper explains why and how Unmanned Aerial Vehicles (UAVs), also known as drones, can be used for improving land registration in Kenya. According to a World Bank report that was released in the year 2003, only about ten percent of land in Sub-Sahara Africa has been formally registered [1]. In the year, 2013, a more optimistic value was given for all developing countries in the World, in which only about thirty percent of the land has been formally registered [2]. Despite the possible increase in the extent of registration, a majority of the people are unable to gain from the benefits of land registration. In general, an effective land registration system can contribute towards improving: land tenure security, real estate markets, access to credit, taxation, dispute resolution and urban planning among others [3]. In order for people in developing countries to gain from the benefits, there is a need to increase the extent of formal land registration.

There are many requirements for increasing the extent of formal land registration in developing countries. The requirements can be categorized as technical, legal, organizational and financial. In terms of technical aspects, there is a need to improve on the methods of conducting surveys for registration and how the data is managed. For example, there is a need for African countries to adopt a uniform reference frame for mapping [4]. There is also a need to develop computerized systems for better management of land records. In this regard, a Land Administration Domain Model (LADM) has been developed as a means of enabling computerization of land records [5] In terms of legal aspects, there is a need to develop more "pro-poor" systems that are compatible with informal and customary practices in developing countries [2]. The "pro-poor" systems have also been referred to as "fit-for-purpose" systems [6]. In terms of organizational aspects, there is a need to determine which government agencies are in charge of registration. In terms of finances it is important to clarify where the funding for registration will come from and how the money obtained from the system will be utilized. Despite the many requirements for land registration, the scope of this paper is limited to the technical aspects, in particular, on the use of UAVs for land registration.

Unmanned Aerial Vehicles (UAVs) can be used to improve land registration in developing countries. In a country like Kenya, most of the existing land registration was introduced using aerial photographs [7]. During the colonial era by the British, aerial photographs were used to map planted hedges, which represented parcel boundaries [8]. Based on the aerial photographs, Registry Index Maps (RIMS) were developed for most parts of the country [7]. To-date, most of the land registration in Kenya is based on the RIMS. In a similar manner, UAVs can be flown to map planted hedges and other features, as a means of enhancing land registration [9]. The problem statement for this paper is that it is not clear how the UAVs can be used for improving land registration in Kenya, particularly in terms of regulations required and technical procedures.

There are not many projects that have attempted to use UAVs for land registration in Kenya. According to a literature search, only one project seems to be trying to show how the UAVs may be used for registration. The project is entitled "its4land" and is a European Commission Horizon 2020 funded project. The main aim of the project is to show the use of geospatial technology innovations for improving land tenure security in Eastern Africa countries [10]. The main partners in the project are: WestfaelischeWilhelms-UniversitätMünster (Germany), KU Leuven (Belgium), HansaLuftbild AG (Germany), Institutd'EnseignementSuperieur de Ruhengeri (Rwanda), Bahir Dar University (Ethiopia), The Technical University of Kenya (Kenya) and Esri Rwanda Ltd. Despite the presence of the project, it is still not clear how UAVs can be used in Kenya, particularly as regards the regulations and technical procedures. The next section of this paper describes the methodology that was used to explain how the UAVs may be used for improving land registration in Kenya.

The remaining parts of this paper are arranged as follows. Section two will explain the methodology that was used in this paper. The subsequent sections will provide results on the use of UAVs in Kenya, after which a conclusion will be provided.

II. METHODOLOGY

Case study methodology was selected as the main form of inquiry for this paper. This methodology was selected because it is a social science method that can be used to develop sound theories about a phenomenon under investigation [11]. The methodology was also selected because it allows the use of multiple sources of data, such as books, journal articles, newspaper articles, interviews and observation among others [12]. Case study methodology is also a recommended method of inquiry for research in cadastral and land registration systems [13].

Based on this methodology, the Republic of Kenya was selected as the case. In this regard, focus was on how UAVs can be used for land registration. Data was obtained by conducting telephone interviews with staff members from the Kenya Civil Aviation Authority (KCAA), from existing literature and practical use of drones. The next sections provide the results, which are categorized into (i) types of drones/ UAVs that can be used, (ii) regulations concerning the use of UAVs in Kenya and (iii) technical aspects on the use of drones for land registration.

III. TYPES OF UAVS/DRONES

This chapter provides an explanation of the different types of drones that may be used for improving land registration in Kenya. Drones can be classified according to their weight, functionality [14] and propulsion [15]. An elaboration of each category is shown in table 1:

Table 1: Classifications of drones with descriptions in each category

Category	Description
Weight	
Micro air vehicle (MAV)	Weigh less than 1gramme and is the smallest UAV
Miniature UAV (also called SUAS)	Weigh less than 25 kg
Heavier UAVs	Weigh more than 25 kg
Functionality	
Target and decoys	These are targets that simulate enemy missiles
Reconnaissance	Provide intelligence in the battlefield
Combat	In high- risk missions they have attack capability
Logistics	Provide cargo delivery services
Research and development	provides a framework on improving technologies in UAVs
Civil and commercial UAVs	These include aerial photography, data collection, agriculture, wildlife as well as other uses
Propulsion	
Single-rotor	Used in aerial LiDAR laser scanning  Figure 1: HCP-M Copter (Image courtesy of NM Group) [16]

Multi-rotor	Used for sight-seeing and photography  Figure 2: DJ1 Phantom 3 (Image courtesy of DJI Professional) [17]
Fixed-wing	Used for aerial mapping  Figure 3: DT 18 UAV (Image courtesy of Delairtech) [18]
Fixed-wing hybrid	Used for delivery services e.g medicine, food  Figure 4: Wingcopter hybrid drone (Image courtesy of Geozone Geomatics) [19]

IV. REGULATIONS ON THE USE OF UAVS/ DRONES IN KENYA

This section outlines the regulations for using UAVs in Kenya. In February 2017, Kenya approved the regulations for the use of drones, making it the second country, after Rwanda in the Eastern African region to approve the use of drones [20]. In January 2015, Kenya placed restrictions on the use of drones such that one needed authorization from the Ministry of Defense and the Kenya Civil Aviation Authority (KCAA) to operate one. The Kenya Civil Aviation Authority (KCAA) had prepared draft regulations that would guide users of remotely piloted aircraft systems (RPAS), commonly known as drones, in Kenya [21]. The final regulations, which were approved by the Security Council, are yet to be published which will provide proper guidelines on the use of drones [20].

According to the draft regulations, KCAA has categorized drones as recreational, private and commercial, with those weighing less than 5kg to be used for recreation or sports only, those between 5-25kg for private activities [22]. In Africa, Kenya will be among the few countries to prepare regulations for remotely piloted aircrafts. Highlights of the draft RPAS regulations published by KCAA [21] are:

- KCAA shall establish and implement a system for registration and identification of RPAS in Kenya.
- Kenyan citizens above the age of 18 and resident in Kenya are eligible to own RPAS.
- RPAS operators to obtain RPAS Operating Certificates to be issued by KCAA.
- RPAS operators must have adequate third party insurance cover.
- RPAS operators are responsible for the safety and security of RPAS operations including associated facilities, personnel and equipment.
- The regulations provide for fines and jail terms for those who violate the rules.
- RPAS for private, recreational or sports use will not be allowed to fly higher than 400 feet above ground level. Commercial RPAS will be flown at heights specified by the Authority.
- No RPAS operations at night or in conditions of poor visibility.
- RPAS operators shall ensure that all incidents and accidents are reported to KCAA.
- RPAS flights from Kenya to another country must be authorized by the state of destination. Similary, RPAS flights originating from outside Kenya must have authorization from KCAA.
- RPAS shall not be flown within 10 kilometers of an aerodrome from the aerodrome reference point for code C, D, E and F aerodromes except with the written permission of the owner or operator of the aerodrome and approval from the Authority.
- RPAS pilots shall ensure that air traffic control is made aware of any operations that shall take place in areas which are likely to affect manned and controlled air traffic.

1. Challenges with use of drones

Some of the challenges cited by KCAA [23] include:

- Drones can pose a danger as they can stray into air traffic lanes leading to collisions. As they are remotely piloted, the drone operator has no visual to other air traffic within the drone's vicinity.
- Most civilian drones do not have radar systems, do not have links to air traffic control systems nor do they have collision avoidance systems.
- The ground based pilot controls the aircraft using radio frequencies. Therefore, a portion of the radio spectrum should be allocated for use by drone aircraft.
- Training of pilots-In countries where drones are normally used such as US, UK, Australia, they specify that drones above a certain size must be operated by a trained pilot. Smaller sizes do not require a pilot license as they are considered model aircraft, though one still requires training.

2. Authorization Process of Kenyan Drones

Institutions, entities or individuals intending to test, procure or operate Remotely Piloted Aircraft must seek authorization from the following [24]:

- Approval to operate your drone must first come from the Ministry of Defense;
- After receiving an approval from the Ministry of Defense, an application should be made to the Kenya Civil Aviation Authority to fly one's drone. Authorizations will only be considered after an approval from the Ministry of Defense.

V. USE OF UAVS FOR LAND REGISTRATION

This section describes technical aspects on the use of UAVs for land registration in Kenya. Explanations are provided on (i) flying the drone, (ii) data processing and (iii) possible products for land registration.

(i) Flying the drone

As explained in the previous section, there are different types of UAVs. In general, the UAVs can be put into two main categories (a) quad-copters, which take off vertically like a helicopter and (b) fixed wing, which take off like a normal airplane. This section provides a brief description on how to fly either the quad-copter or the fixed wing. In this regards, the procedures are generalized because the two machines are different. Nonetheless, the two types of UAVs share some common aspects on flying. The descriptions below are based on the first authors experience in flying a quod-copter from agribotix and a fixed wing drone from delair-tech.

The first step in flying a UAV can be described as flight preparation. The preparation includes: charging batteries, developing a flight plan, checking the drone and its payload and checking weather conditions. In most cases, UAVs fly using lithium ion batteries which can be difficult and sensitive to charge. In order to avoid damage to the batteries and to ensure proper charging takes place, the user should follow a strictly developed sequence of charging the batteries [25]. The flight plan can be developed in the office using a laptop or device which has high resolution imagery. In this case, the device could be a mobile phone or a computer tablet. Based on the high resolution image on the device, the user can delineate waypoints (coordinates) on the main parts of the area to be surveyed [26]. Based on the waypoints, the user can use software to automatically generate a flight plan. The flight plan will appear as shown in Figure 5.The flight plan can be subsequently modified to fit with the field conditions.

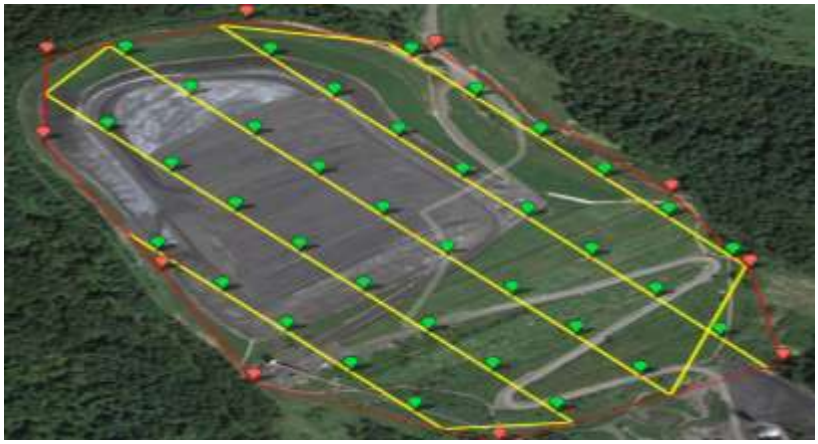

Figure 5 shows a sample UAV flight path with waypoints. Image obtained fromhttp://9threesolutions.com/portfolio/stockpile-volume-estimation/

The next step in the flight preparation is to check the drone itself and its peripheral devices. The user needs to ensure that all parts of the aircraft are functioning and connected to each other. In this regard, most UAVs come with a manual that has techniques of checking that the craft is working. Finally, the user needs to ensure that the payload is working. In this case, in order to map property boundaries, the operator needs to have camera which operates in the visible portion of the electromagnetic spectrum (i.e. Red Green and Blue) as the payload. If necessary, a video camera can also be included. However, the main aim is to be able to capture high resolution images of property boundaries. The user should also ensure that a memory card is available for storage of the captured data [26].

The next portion of the work is to conduct the flight itself. After going through all the pre-flight preparations, the user can take the equipment out to the field, into the area which is to be mapped for registration. Considering that the take-off and landing are the most sensitive parts of using the UAV, the operator is advised to strictly follow the sequence provided by the manufacturer. In the field, the user is required to connect the laptop to the drone and antennae to ensure proper communication between the devices. After confirming that the system is working properly, and a lock is obtained with a sufficient number of Global Navigation Satellite Systems (GNSS), the user can launch the UAV and start data collection. At this point, one pilot/ operator observes the laptop to ensure all configurations are correct, while another pilot observes the drone to ensure all is well in the air. After the data capture is accomplished, the drone is brought back and landed from a selected area of the mapping area. In some cases, the pilot is advised to take control of the drone using a handheld joy-stick, to make sure the craft lands safely. The next step is data processing.

(ii) Data processing

The data obtained from the UAV should then be processed to develop products that can be used for land registration. In general, when the UAV is in flight, it captures overlapping photographs of the area being mapped. The obtained photographs can have a forward overlap of 60 percent and a side overlaps of 30 percent. The size of the overlaps can also be determined by the user. According to photogrammetry principles, the overlaps can be used to develop a mosaic of the area [27] as shown in figure 6.

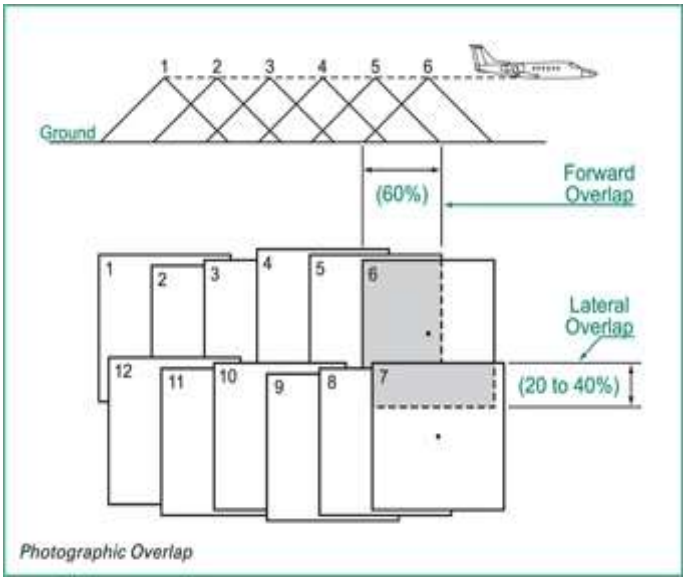

Figure 6 Example of overlapping photographs. Image obtained from **http://www.photogrammetrynews.com/2015/12/planning-of-aerial-photography-overlaps.html**

There are multiple software for processing the aerial photographs obtained from the UAV. In most cases, different companies that manufacture UAVs have their own software for data processing. In addition, other commercial companies that deal with phogrammetry and Geographic Information Systems (GIS) have developed software for manipulating the photographs. As an example, Delair-Tech in France has their own "DLTool" for processing images obtained using their drones. One of the most common drone mapping software is known as "Pix4D" and can be used for mosaicing the photographs [28]. A company such as ESRI, which is one of the leading GIS companies in the World, has also developed a software product known as "Drone2Map" [29]. In essence, "Drone2Map" is product for ArcGIS software, for creating professional imagery from photohraphs captured using drones. A company known as Hexagon geospatial also produces software that can be used for manipulating drone imagery.

(iii) Products for land registration

After processing the data, there should be some form of legal recognition of the product to be used for land registration. In Kenya, there are three main types of maps that are used for land registration, namely, deed plans, Registry Index Maps (RIMs) and Sectional Property Maps. In general, the deed plans are developed after an accurate survey has been carried out for a parcel of land. In this regard, using ground survey methods, a surveyor measures bearings and distances from a known geodetic control point, to determine the extents of the parcel [8]. Thus, deed plans may not be the appropriate method of recognizing data from UAVs. The second type of data is sectional plans that are used for registering apartment units or commercial units within an office block. The sectional plans may also not be the best way of legally recognizing the UAV data for land registration.

The Registry Index Maps (RIMs) provide the best method of legally recognizing the UAV data for registration. As described earlier, most of the land registration, especially in rural parts of the country, is based on RIMs. Majority of the RIMs, were produced using aerial photographs by the colonial and post-independence governments [8]. The products from the mosaic of UAV derived imagery can be used to develop a category of RIMs that is legally recognized as a means of registration. Thus, using appropriate software, the outline of parcel boundaries can be derived from the aerial images to develop a product which can be known as "UAV based-RIM" or any other name that may be seen to be appropriate. The use of the UAV based data can enhance the speed with which Kenya and other developing countries increase the extent of land registration.

VI. CONCLUSION

This paper has provided some explanations on why and how UAVs can be used to improve land registration in Kenya. The advent of UAVs provides an ideal opportunity for developing countries to accelerate the process of land registration, so that more people can gain from the systems. The main advantage of this paper is that it provides key aspects on the use of UAVs for land registration. In particular, it explains different types of UAVs, regulations in Kenya and some of the technical aspects of the application. The main limitation of this paper is that it is still conceptual. Thus, there is a need for practical research on the advantages or

disadvantages of using drones for land registration. This paper has provided some directions on how the practical might be done. The hope of the authors is that this paper might contribute towards improving land registration not only in Kenya, but also in other developing countries.

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