UAVs FOR LAND TENURE REGULARIZATION

Alexander AYETTEY, Ghana

Key words: UAVs, Urbanization, Fit-For-Purpose Land Administration, Land Regularization; Cadastral Surveying.

SUMMARY

The burgeoning issue of urban land encroachment is palpably evident across many developing nations, with Ghana emerging as a prominent case in point. Rapid urbanization, fueled by a swelling population, has catalyzed the rise of unauthorized land occupations. These lands, though occupied, cannot be registered or used as collateral for capital. While in some cases, they are reclaimed from illegal occupiers, others are subjected to processes of land tenure regularization which aims at bringing these undocumented settlers into the formal system of land administration through adjudication, mapping and registration.

A major drawback to land regularization efforts in most developing countries however is the convoluted process involved which has been exacerbated by the rapid rate of urbanization.

The main objective of this thesis was to conduct a comprehensive evaluation and analysis of encroached urban lands in Baatsonaa, Ghana, by comparatively examining UAV-Based and Conventional Land Tenure Regularization Processes. It further attempted to evaluate the efficiency and reliability of the UAV based land regularization in the context of fit-for-purpose land administration.

To achieve the set objectives, a UAV survey was executed over the project area and subsequently processed based on established Ground Control Points with a mean RMSE of 0.069ft. Parcels with clearly defined boundaries were digitized and their coordinates compared with coordinates derived from the conventional GNSS approach with an RMSE of 0.342ft. To determine the time and cost efficiency, the estimated time and cost for both the UAV and conventional approaches were analyzed, resulting in time and cost efficiency gains of 70.83% and 75.00% respectively for the UAV based approach.

It was concluded that the UAV based approach provides a viable alternative to conventional approaches for rapid and systematic tenure regularization of urban encroachment with an added support for urban planning and development. Furthermore, while it has comparable accuracies to the conventional approach, the UAV approach is more efficient and affordable in the context of Fit-For-Purpose Land Administration.

The study recommended the adoption of the UAV approach for land registration in Ghana and also for further studies in varied urban settings and different interest types.

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1. INTRODUCTION

Land Regularization has been at the fore front of land reforms in most developing countries. The focus has mainly been on improving tenure security for settlers who usually have little or no documentary evidence of their rights to the lands they occupy. The process of land tenure regularization aims at bringing these undocumented settlers into the formal system of land administration through adjudication, mapping and registration, in order to improve security of tenure (title) for settlers (Magigi, 2013; Zakayo et al., 2018).

The United Nations Economic Commission for Europe (UNECE) defines land administration as the process of determining, recording and disseminating information about the ownership, value and use of land when implementing Land Management policies. In this regard, land tenure regularization provides a means of bringing informal settlers and undocumented occupiers into the formal system (acquiring titles) of land administration for effective land management.

Advocates for Land Regularization (e.g De Soto, 2000; Feyertag et al., 2021; Mbilinyi et al., 2022) have argued that in addition to reviving dead capital for investment, the title provided by Land Administration Institutions can also lessen financial exclusion for the poor and increase the likelihood that landowners will be able to obtain loans from formal lending institutions by pledging their titles as collateral.

Developing countries tackling these issues of informal settlements have in recent years had to contend with the counter effect of Urbanization. While Urbanization brings a lot of workforce to cities, the negative effects of haphazard development, urban crime, overcrowding, encroachment on open spaces, sanitation challenges, unemployment (Fernandes, 2011) far outweigh the benefits.

Though considerable efforts have been made by some developing countries to improve tenure security for informal settlers through land tenure regularization, one of the main challenges is the complex and convoluted processes involved (Tellman et al., 2021), exacerbated by the rapid rate of urbanization (Adam, 2020). As Tellman et al., (2021) noted, depending on the nature of land tenure and its location, regularization is a complicated, multi-institutional process that can take anywhere from 5 to 20 years. Due to this drawn-out and complicated procedure, many communities never become regularized. Informal settlements in most cases have outpaced regularization (Tellman et al., 2021).

Modern technological tools such as Geographic Information Systems (GIS), UAVs, Blockchain, and Artificial Intelligence (AI) have the potential to improve land administration by improving efficiency, increasing transparency and ultimately reducing the time taken for land regularization. Researchers have focused on how these technologies can be incorporated into the Land Regularization process to help reduce the time taken for regularization while adhering to existing legal requirements. While these technologies have brought sophistication to data collection and improved the potential of reducing the time required for field work for land regularization, misapplication of these tools may also lead to further delays and additional cost. Land rights advocates have thus recommended fit-for-purpose land administration (Zevenbergen et al., 2013; Enemark et al., 2014) and responsible Land Governance (de Vries et al., 2015) to effectively utilize these tools in reducing turn-around time in land regularization and ultimately improving tenure security.

Though there has been considerable application of fit-for-purpose land administration tools in land tenure security initiative across Africa, most of these applications have focused on pro-poor and customary land rights (Asiama et al., 2017; Nara et al., 2021). The rapid rate of urbanization across Africa and Asia however presents a peculiar situation of increased encroachments on urban state and public lands. Despite the fact that occupation of these lands remain illegal, they ultimately contribute to the size of locked "dead capital" when they remain in the informal sector (De Soto, 2000).

In this paper, an assessment is made on the viability of UAVs for providing an expedited and affordable means of regularization of encroached urban state lands.

2. Methodology

2.1. Study Area – MDPI Acquisition, Baatsonaa

The study area of this research is the Management Development and Productivity Institute acquisition at Baatsonaa in the Greater Accra Region of Ghana. Legislative instrument (LI) 1077 incorporated MDPI as a state agency in 1976. The MDPI acquisition, covering an approximate area of 170 acres (69 hectares) was executed in 1974 by Executive Instrument (EI) 112/1974.

The acquisition is geographically situated between latitudes 5°37'10.8"N and 5°37'54.0"N and longitudes 0°04'59.6"W and 0°04'34.4"W, with a centroid at 5°37'32.6"N, 0°04'44.0"W. Administratively, the acquisition lies within two municipalities, namely, Tema West and Krowor Municipal Assemblies. Spatial planning and development control are therefore the responsibilities of these two municipalities. The Spintex road, which connects parts of Accra to Tema runs through the acquisition and defines the area of each municipality in the acquisition area. The MDPI acquisition is bounded on the south by the Accra-Tema railway line.

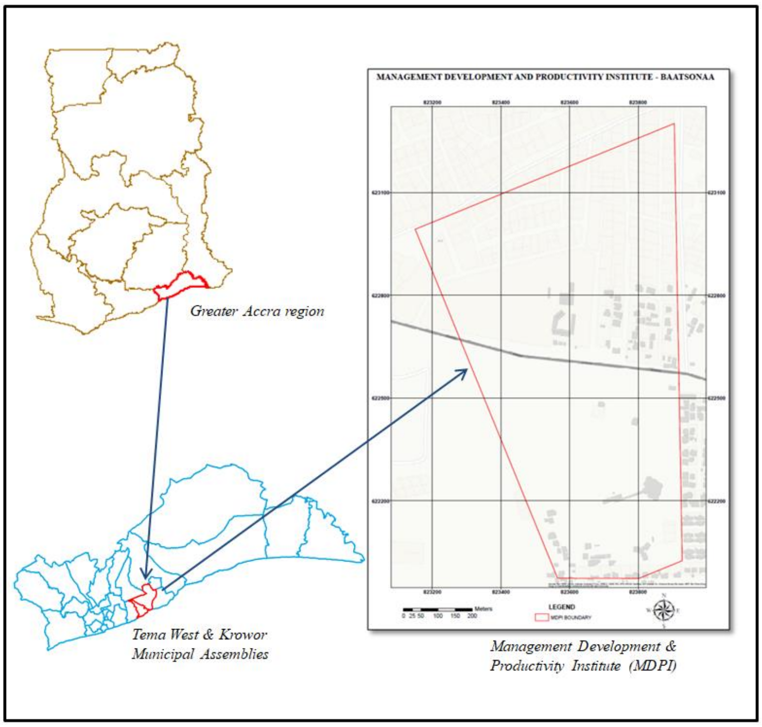

Figure 1: Map of Study Area

2.2. Data Collection

2.2.1. UAV Data Collection

Every successful UAV mission starts with a carefully prepared flight plan that meets both the accuracy requirements of the project and conditions of the terrain being flown. The flight plan for the UAV data collection was designed using the open source Mission Planner software over the acquisition with the following characteristics:

Figure 2: MAP-M4 Quadcopter

- UAV Type: MAP-M4 Quadcopter (Figure 2)
- PPK functionality: Yes

- Camera: Sony Alpha a6000
- Focal Length: 16mm
- Flying Height: 80m
- Forward Overlap: 80%
- Side Overlap: 70%

A total of nine (9) flight blocks covered the acquisition area. Each block overlapped an adjoining block by approximately 30m in order to tie the blocks together. At least four (4) Ground Control Points (GCPs) were placed in each block with at least two (2) within the overlapping region of the blocks.

Post-acquisition, the UAV data underwent a rigorous preprocessing regimen to prepare the data for actual processing. UAV data Processing was then carried out using the observed GCPs in Agisoft Metashape to derive dense point cloud, digital elevation model (DEM) and Orthophoto of the acquisition in the Accra Ghana Grid coordinate system based on the War Office ellipsoid. Independent checks were incorporated to ensure strict adherence to requirements for cadastral mapping in Ghana.

2.2.2. Conventional Data Collection

The study employed geodetic GNSS receivers, Trimble R8s (Figure 3) to survey in static mode, the turning points (40) of selected number of parcels within the acquisition. Appropriate observational procedures as stipulated in the technical guidelines for surveying and Mapping in Ghana (SMD Technical Guidelines, 2008) were followed to ensure that the output derived from the observations meet the minimum requirements for cadastral surveying in Ghana. The duration of the GNSS observations were at least 20 minutes and parcels were carefully selected to minimize canopy effect on GNSS signals.

Figure 3: Trimble R8s GNSS receiver and Data Logger

The GNSS data were subsequently downloaded and converted into the Receiver Independent Exchange (RINEX) Format. GNSS post-processing was performed using Topcon Positioning Systems' Magnet Tools in Accra Ghana Grid coordinate system based on the War Office ellipsoid as was done for the UAV-derived products. Coordinates of the selected points were thereafter exported into excel format (.xlsx) for further analysis.

2.2.3. Local Plan (Layout Scheme)

The local plan covering the acquisition, approved in 1991 was acquired from the Tema West Municipal Assembly. Efforts to obtain similar records from the Krowor municipal assembly proved futile. However, though obtaining these additional data is ideal, the data acquired from the Tema-West municipal assembly proved sufficient to the objectives of the study.

The plan was subsequently scanned and georeferenced to enable comparison with the primary data collected from UAV and GNSS. The nature of the local plan meant that identifying common points to use as GCPs was almost impossible and therefore the existing gridlines on the plan were used to align the scanned map in AutoCAD, into the Accra Ghana Grid coordinate system based on the War Office ellipsoid as was done for the UAV-derived products and GNSS observations.

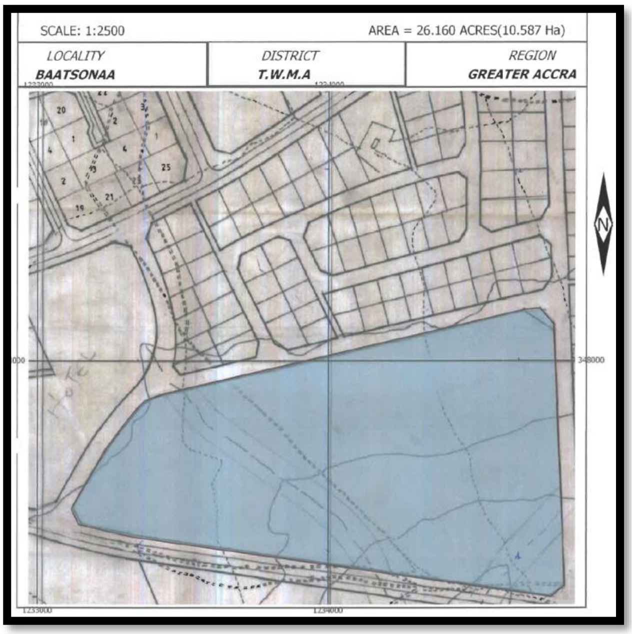

Figure 4: Approved Local Plan

2.2.4. Ground Truthing and Client Information Verification

A very important step in the UAV derived regularization process is ground truthing of the extracted parcels within the acquisition and linkage of these parcels to the rightful occupiers seeking regularization. This is critical because, the UAV derived approach considered a systematic process of regularization rather than the sporadic process which normally accompanies the conventional applications for regularization.

The process of ground truthing and client information verification was simplified using the open source QGIS desktop application and Qfield plugin and Mobile App (Figure 5). Boundaries of the digitized parcels were exported in shapefil format, and together with the outline of the MDPI acquisition boundary and OpenStreetMap, they were synchronized with the Qfield Mobile App using the Qfield plugin in QGIS. The purpose of the synchronization was to enable easy upload of data collected with the Qfield Mobile App. The Mobile App was then used as a collector to capture land-use, client name, photo of parcel and other information that will aid the UAV based regularization process. The ground truthing also involved confirming the dimensions of parcels (Figure 6) as derived from the digitizing of the Orthophoto.

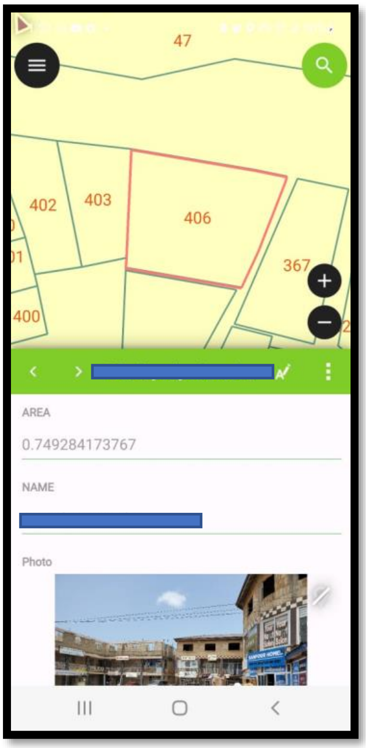

Figure 5: Qfield Mobile App and Client Information Interface

Figure 6: Ground Truthing - Verification of parcel dimensions

2.3.Efficiency and dependability of UAV Data Collection Process

2.3.1. Time and Cost Efficiency Analysis

Time Efficiency Calculation: In addressing the third objective, a meticulous calculation of time efficiency was conducted. The total time taken for UAV data collection was meticulously recorded and compared against the time required for conventional data collection methods. The efficiency gain in time was then calculated using the formula:

$$\text{Efficiency Gain } = \frac{(\text{ Conventional Collection Time } - \text{ UAV Collection Time})}{\text{Conventional Collection Time}} * 100\%$$

$$\text{Efficiency Gain } = \frac{\text{Conventional Collection Time}}{(\text{ Conventional Collection Time } - \text{ UAV Collection Time})} * 100\%$$

This calculation provided a percentage value representing the time saved when opting for UAV-based data collection over conventional methods.

Cost Efficiency Calculation: Similarly, a cost efficiency analysis was performed. The total cost incurred during the UAV data collection procedure was documented and juxtaposed with the expenses associated with conventional data collection. The cost-saving percentage was then calculated using a similar formula to the time efficiency calculation, offering a clear indicator of the economic advantages shown by the UAV-based approach.

2.3.2. Time and Cost Efficiency: UAV vs. Conventional regularization process

Table 1 identifies the various processes that encroachers go through at the lands commission to regularize their unauthorized occupation of state lands in order to obtain legal titles. As this study's focus is on reducing the time taken for cadastral data collection, only those action directly related to the preparation of cadastral plan were considered. The actions marked with "yes" in the related field are those directly related to the collection of cadastral data. Their delays using the conventional approach may prolong the process of regularization. On the other hand, the actions marked "no" are those actions which are not related to the cadastral data collection.

Table 1: The process of regularization at the Greater Accra Regional Office of Lands Commission

S/N	ACTION	RELATED
1	Application for tenure regularization to the Regional Lands Officer in Greater Accra Region accompanied with a site plan (LI 1444 required for registration)	Yes
2	Confirmation of status of encroachment by an internal search from the Lands Commission records	No

3	After confirmation that land falls within a state acquisition, a site inspection is performed to ascertain the nature of encroachment	No
4	The Lands Commission requests for planning comments from the physical planning department of the Municipal Assembly under whose jurisdiction the land falls	No
5	If the site does not conform to planning scheme, the application is rejected. If favorable, an assessment is made of premiums or penalties applicable to the land	Yes
6	Application is sent to the Greater Accra Regional Lands Commission for approval	No
7	If approved, applicant is given an offer letter stipulating requisite premiums and fees	No
8	If the site plan attached to the application is not a LI 1444 complaint plan, the applicant is directed to produce a new LI 1444 plan	Yes
9	Lease is prepared based on LI 1444 complaint plan and executed	Yes
10	Stamp duty assessment and payment	No
11	Plotting and recording is done at the LC records Unit	Yes

While the conventional approach handles applications on a case by case basis, the UAV approach was implemented for systematic regularization of all parcels within the acquisition based on the line map, and client information derived from the ground truth.

Table 2 provides estimates for time and cost it would take for either of the approaches. The conventional data is based on standard estimates of licensed surveyors for preparation of approved plans while the UAV data is from the Photogrammetry Unit of the Survey and Mapping Division of Lands Commission.

Table 2: Time and Cost for Cadastral Data collection from conventional and UAV

S/N	ITEM	CONVENTIONAL	UAV
1	Total Area	169.51 acres	169.51 acres
2	Number of Parcels	275	275
3	Duration for cadastral data collection	28 days (10 parcels per day)	8 days
4	Estimated Cost	GHS 550,000 (GHS 2,000 per parcel)	GHS 137,500 (GHS 500 per parcel)

3. Results and Analysis

This paper has looked at the viability of using UAVs to collect cadastral information to improve turnaround time for land tenure regularization. The results are presented in this section.

3.1 Comparison between UAV-Based Approach and Traditional Cadastral Data Collection

3.1.1 Accuracy

For a thorough comparison between the UAV-based method and the traditional land regularization procedures, data stemming from both techniques were collated and aligned. Both datasets primarily consisted of coordinate information, namely Northings and Eastings of common points from both approaches, forming the foundation for the ensuing comparative evaluation. Table 4.1 shows the coordinates of common points from both approaches.

Table 3: GNSS and UAV derived coordinates of common points

GNSS			Differences		ORTHOPHOTO		
ID	NORTHINGS (ft)	EASTINGS (ft)	ΔN (ft)	ΔE (ft)	NORTHINGS (ft)	EASTINGS (ft)	ID
B1 1	345270.463	1234860.09	0.185	-0.111	345270.2779	1234860.201	B1 1
B1 2	345321.394	1234856.57	-0.028	-0.171	345321.4223	1234856.741	B1 2
B1 3	345326.569	1234926.728	0.280	-1.388	345326.2891	1234928.116	B1 3
B1 4	345276.038	1234931.464	0.424	-0.385	345275.6142	1234931.849	B1 4
B2 1	345856.687	1235028.03	-0.268	0.307	345856.955	1235027.723	B2 1
B2 2	345835.134	1234940.273	0.745	-0.422	345834.389	1234940.695	B2 2
B2 3	345903.395	1234923.654	0.065	-0.124	345903.33	1234923.778	B2 3
B3 1	345969.745	1234497.522	0.423	0.263	345969.3222	1234497.259	B3 1
B3 2	346065.786	1234471.392	-0.120	0.094	346065.9063	1234471.298	B3 2
B3 3	346098.276	1234607.074	-0.297	0.185	346098.573	1234606.889	B3 3
B3 4	346006.421	1234633.644	0.139	0.310	346006.2822	1234633.334	B3 4
B4 1	346124.2	1235191.758	0.382	0.165	346123.8178	1235191.593	B4 1
B4 2	346202.127	1235189.425	-0.351	0.345	346202.4776	1235189.08	B4 2
B4 3	346200.94	1235291.311	-0.181	-0.122	346201.1213	1235291.433	B4 3
B4 4	346129.416	1235291.231	0.078	0.233	346129.3381	1235290.998	B4 4

The tabulated results show a Mean Squared Error (MSE) of 0.117ft and Root Mean Squared Error (RMSE) of 0.342 when comparing the UAV and traditional data. For cadastral plan preparation which forms the basis for regularization, SMD specification requires RMS values for GNSS observations and processing results to be less than 1ft. All error metrics calculated were less than this threshold.

3.2.2 The Regularization Process

The conventional regularization process commences with an application letter from an applicant to the Regional Lands Officer (RLO) of the region in which the land is situate with an intention to regularize the occupation of a parcel within a state acquisition. The process continues with a number of administrative actions (Table 1) until a request is made for the preparation of an LI 1444 compliant plan in case the original plan attached to the initial application wasn't LI 1444 complaint. An LI 1444 complaint plan is simply a plan that meets the basic requirements for plans as stipulated in Survey (Supervision and Approval of Plans) Regulations, 1988 (LI 1444). It simply refers to a plan that is certified by a licensed surveyor and approved by the Director of Surveys of his/her representative. In any case, Section 182 (5) of Land Act, 2020 (Act 1036) requires all plans attached to any instrument for registration to be LI 1444 compliant. The process is sporadic, requiring survey of each parcel with minimal inputs of owners of adjoining parcels. Another major milestone in the process of regularization is the request for planning comments from the Land Use and Spatial Planning Authority to ensure conformity of local plans. As with many unplanned settlements, there is minimal compliance with approved land use plans and thus in most cases these inconsistences leads to delays in the process and ultimately affects the tenure security of settlers.

On the other hand, while the UAV approach employed in this study for regularization also follows the processes outlined in Table 1, it additionally provided a means for systematic regularization of all parcels within the MDPI acquisition. The process began with an announcement of intention to regularize all parcels within the acquisition and a request for applicants to submit all necessary documents relating to their occupied parcels to aid the regularization process. A UAV survey was then conducted over the acquisition and the output Orthophoto Map was digitized into a Line Map of parcels within the acquisition. The line map was thereafter submitted to the Land Use and Spatial Planning Authority to ascertain its consistency with the approved local plan for adoption as the local plan for the area. A joint inspection team of Land Surveyors and Land Administration officers then organized site inspections together with occupiers to collect occupier information (Figures **5** & **6**), for example, Land Use, Name of occupier, Dimensions of Parcel, Photo of Parcel etc. These information reduced the number of site visits, the total cost of survey and preparation of LI1444 compliant plans for each parcel, eliminated the delays arising from inconsistencies of parcels with local plans and ultimately the turnaround time for regularization of each parcel.

3.2.2 Time and Cost Efficiency Analysis

A meticulous analysis was conducted to evaluate the efficiency of the UAV–based data collection process in terms of time and cost. The results are presented in Table 4:

Table 4: Time and Cost Efficiency Analysis Results

Efficiency Metric	UAV Efficiency Gain (%)
Time Efficiency	70.83
Cost Saving	75.00

One of the standout achievements of the UAV-based methodology was its pronounced time-saving prowess. When put side-by-side with traditional data collection techniques, the UAV method demonstrated a time efficiency improvement of a staggering 70.83%. Such a leap in speed is invaluable, especially for projects where time is of the essence, necessitating rapid data acquisition and subsequent evaluation. Beyond the time savings in the actual data collection, the UAV approach also saves time with the process of obtaining planning comments from the physical planning unit of the municipal assembly. As noted by officers of the Lands Commission, the stage of planning is one of the critical bottlenecks in the regularization process because in most cases, applications do not conform to the existing local plan of the area. This might either be due to incorrect layout, site plan or both. Figure 7 shows a typical example of inconsistencies between approved layout and the actual ground situation.

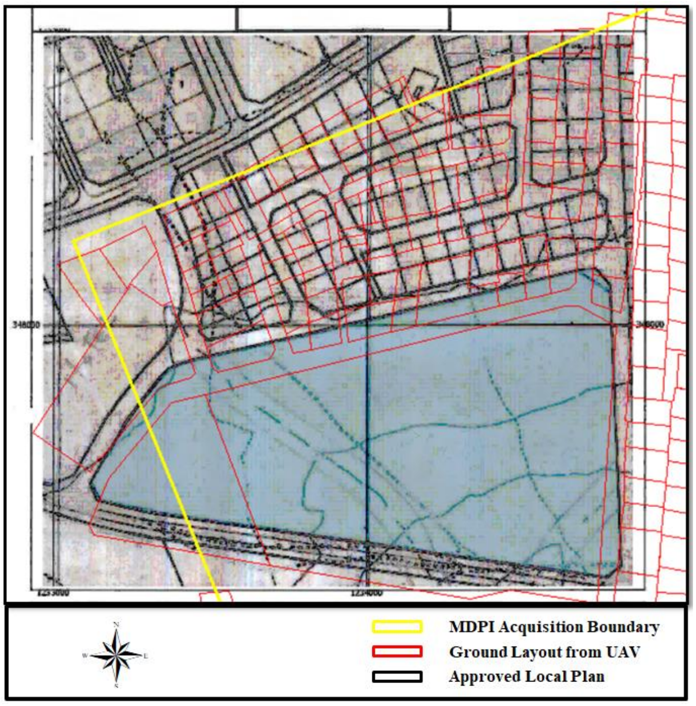

Figure 7: Superimposition of approved local plan and UAV derived line map

The superimposition in Figure 7 shows the extent of shift between the approved layout and the UAV derived line map which shows the actual layout of the area. In the conventional approach, any site plan referenced to the approved layout would be rejected due to inconsistencies. In the UAV approach, the UAV derived line map is submitted to the physical planning unit of the assembly for review and adoption. Once adopted, all subsequent application derived from the UAV line map will be consistent with the new local plan.

Moreover, the request for planning comments may no longer be necessary once the UAV line map is adopted. This saves considerable time in the regularization process.

Furthermore, from an economic perspective, the UAV technique wasn't just about speed – it also presented a compelling case for cost-effectiveness. There was a commendable 75.00% reduction in costs when deploying UAVs, as compared to the conventional approach. Such a significant cutback in expenses emphasizes the fiscal advantages of using UAVs, particularly when operations span large areas or require frequent data gathering exercises.

4. Conclusion

The study demonstrated that UAVs provide an effective means of analyzing encroached urban lands and collecting vital information for an expedited process of land tenure regularization.

While having comparable accuracies to the conventional approach, the UAV approach proved to be faster and more affordable in the context of Fit–For–Purpose Land Administration.

The UAV approach provides a viable alternative for not just systematic regularization of encroached urban state lands in Ghana but also great potential for systematic title registration in Ghana.

Ultimately, the comparative analysis of the two (2) approaches, presents a multi-dimensional portrayal of UAV technology. Its unparalleled precision in delineating encroached terrains makes it an indispensable ally for urban custodians and decision-makers, arming them with granular, actionable insights. And while UAVs are not devoid of challenges, their tangible benefits—in terms of data fidelity and operational efficiency–cast a substantial shadow. Such merits prime UAVs to not just complement but, in certain scenarios, even redefine traditional land administration blueprints, delivering timely and cost-conscious solutions. This exploration is not a mere academic exercise; its ripples extend into the real world. Urban planners and land administrators stand to gain immensely, assimilating these findings into their modus operandi to infuse efficiency and precision. For scholars, this study isn't an end, but a beginning. It beckons deeper dives into UAV's vast potential, urging the academic community to navigate its limitations and also ponder on broader societal, ethical, and legal facets tied to UAV deployments. At the study's horizon, the promise of UAVs in urban land administration becomes palpable. Challenges notwithstanding, their transformative potential is hard to overlook.

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BIOGRAPHICAL NOTES

Alexander Ayettey holds an MSc degree in Photogrammetry and Geoinformatics from University of Applied Sciences, Stuttgart, Germany and a BSc degree in Geomatic Engineering from the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. He is an alumnus of the German Academic Exchange Service (DAAD) and the Carlo–Schmid Programm (CSP). His main interests are Photogrammetry, Cadastral Surveying, UAVs, Urbanization, and Climate Change among others.

Alexander is currently the Head of the Photogrammetry and Remote Sensing Section of the Survey and Mapping Division of Lands Commission, Ghana. He is also the Coordinator of the Young Surveyors Network (YSN) of the Ghana Institution of Surveyors (GhIS).

AKNOWLEDGEMENT

The author wishes to thank the Lands Commission for the support and assistant during the project. Great appreciation also goes to members of the UAV Team of the Lands Commission.
He also wishes to acknowledge the enormous contributions of Dr Kwabena Asiama and Dr Anthony Arko-Adjei in the course of this study.

CONTACTS

Mr. Alexander Ayettey
Lands Commission
P. O. Box CT 5008,
Cantonments – Accra
GHANA
Tel. +233245176148
Email: stlexisaaa@gmail.com / nakutsonbiniiayekwei@daad-alumni.de