

# **Advantages of a Digital Cadastre Using an Unmanned Aerial Vehicle (UAV) Tool to Support Better Governance and Land Administration in Cameroon: An Exploratory Study**

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**Key words:** Cadastre, Master Plan, Multipurpose Cadastre, Urban Development, Land Administration.

## **1- INTRODUCTION**

African countries such as Cameroon have a colonial planning legacy that needs to be altered to fit the reality of urban areas in the national territory of Cameroon. With an urbanization rate of 52% in 2010 (BUCREP, 2010), there is enormous pressure on land resources which requires good governance and better management in order to ensure sustainable urban development (FAO, 2011). The informal settlements of the city of Yaoundé occupy almost 35% of the urbanized area and shelter more than 70% of its population (Ngnikam, 2011), as in the majority of the cities of the south Sahara African countries (Augustinus, 2010). Most Cameroonian cities thrive in anarchy without an appropriate urban planning tool and, in the absence of a cadastral plan to register and secure the land rights of their populations (adapted from: Augustinus, 2010; Enemark, McLaren & Van der Molen, 2009; Lemmen, 2010).

Only 16.70% of the occupants have an official document guaranteeing their settlement in this study area and 21% have a plot plan. Cameroon in general and the city of Yaoundé in particular thus find themselves on the list of developing countries where less than 30% of the land is covered by a cadastral plan (Lemmen, Augustinus, Haile, and Van Oosterom, 2009). That is to say, more than 70% of the land in these countries is not included in a formal registration system (Lemmen & Augustinus, 2009; Augustinus, 2010; Lemmen, 2010; Zevenbergen et al., 2013) to better manage the occupation of land (UN-FIG, 1999). In recent years, the cadastral concept has developed considerably and now plays a multi-purpose role in meeting the needs of society, whether for the land market or for property taxation (FIG, 1999; Lisa &

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Williamson, 2012; Francis & Alain, 2008). In Cameroon there is massive rural to urban movement by people seeking decent employment and better living conditions. The lack of urban planning results in illegal and anarchic settlements in unbuildable areas. This confluence of factors is an important source of land conflicts. The Municipality does not have an effective policy of access to housing. With limited resources, local authorities cannot offer living conditions favorable for harmonious urban development and access to basic services (Ngnikam,2011).

The aim of this paper is to propose the development of a new type of multi-purpose municipal cadastre which employs low altitude Unmanned Aerial Vehicles (UAVs) as a geospatial data collection tool.

Such a municipal cadastral approach has numerous advantages: 1) it can be easily updated and; 2) it would therefore be immediately beneficial to diverse actors of the land and cadastral administration as well as municipal town planners and land managers. Traditional methods of cadastral surveying have been shown to be expensive, time consuming and unsuitable to the needs of most of the populations (Enemark et al., 2014; Nathan, 2013; Norzailawati, 2018; Mukendwa, 2015; Barnes et al., 2013; Manyoky et al., 2011; Kelm, 2014). The development of a new type of multi-purpose municipal and digital cadastral plan is based on a participative approach where all stakeholders are included.

This exploratory study was conducted in Yaoundé to justified the need to reduce the development of informal settlements within the city and the resulting land conflicts. The implementation of a new tool used by urban actors at municipal level seeks to ensure economic, social, cultural and environmental development. As far as we know, no previous research in this domain has been investigated in Yaoundé. For the researcher, this study also contributes to the improvement of his theoretical knowledge in the field of cadastral surveying. In practical terms, this study seeks to prove that cadastral-surveying based UAVs imagery is a profitable technical solution to be used by the multiple actors intervening in the domain of land administration / management and land use planning on the whole national territory (Edita et al., 2018, Manyoky et al. 2011; Mukendwa, 2015, Volkman & Barnes, 2014; El Meouche & al., 2016). A multipurpose cadastral map used in land management supports sustainable urban development and improves the mobilization of revenues by property taxation and valua-

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tion, poverty alleviation and enables proactive urban expansion management (Norzailawati & Nur, 2017; Quanlong, 2015; Volkman, & Grenville, 2014).

## **2-MATERIALS AND METHODS**

The studies carried out in the field of the cadastral surveying use the information systems methodology (Barry, 1999; Fourrie & Van Gysen, 1995; Bittner et al., 2000; Castanyer & Canet, 1990; Williamson & Fourie, 1998; Williamson & Ting, 2001; Zevenbergen, 2002). Other studies in this area have highlighted the use of several research methodologies encountered in the social sciences. For this exploratory study, the qualitative approach is appropriate (Creswell, 2007) and makes it possible to collect data from several sources (Bonoma, 1985; Stake, 1995; Yin, 2003; Zahir, 2013). In this study, the author explains how the lack of urban planning impacts sustainable urban development. The benefit of cadastre in land management, administration and land use planning is discussed. The advantages of UVA over satellite imagery data and other special collection techniques are analyzed. These advantages are further evidenced through two different primary data collection approaches: 1) Administration of survey questionnaires to Cameroonian officials responsible for land management and administration and using the Computer Assisted Personal Interviewing (CAPI) and Paper and Pencil Interviewing (PAPI) methods; 2) Geospatial data was collected using geo-referenced imagery from UAV DJI Mavic Pro. In addition, secondary data have been consulted: 1) Satellite imagery provided by the Yaoundé (Cameroon) City Council and 2) archives from the Cameroonian Ministries of Land Affairs (MINDCAF); Housing and Urban Development (MINHDU) and the National Institute of Cartography (NIC). This paper concludes with a recapitulation of the advantages of a digital cadastre based on an UAV tool. The processing of this data was achieved using software such as Microsoft Word, Excel, ArcGIS 10.3.1, 3D Survey, Pix4Dmapper and Autodesk architectural desktop. The 3D Survey and Pix4Dmapper software was used to process the images collected by the UAV, while Microsoft Excel helped to build the attribute table inserted in ArcGIS for the preparation and display of the maps. The IBM version 21 SPSS program helped with the statistical analysis.

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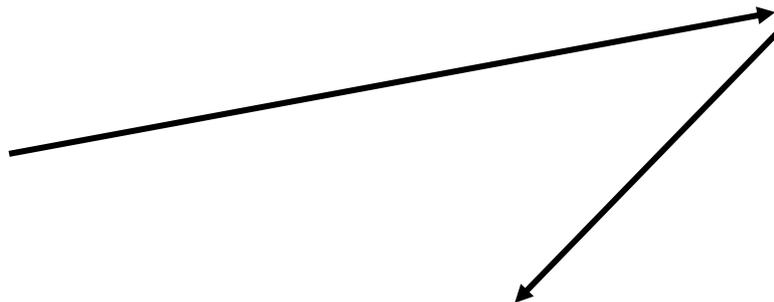
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### **3- PRESENTATION AND SPATIAL DELIMITATION OF THE STUDY AREA:**

Cameroon is a central African country located at the bottom of the Gulf of Guinea. Its territory covers an area of 475,650 km<sup>2</sup>. At the administrative level, Cameroon has 10 regions, 360 sub-divisions, 360 councils and 14 city councils. According to the National Institute of Statistics (INS/ECAM 4), the survey carried out in 2014, the population of Cameroon is estimated at 21.6 million inhabitants of which 51% are women and 49% are men. Forty-four percent of this population are youths (INS, 2016).

The study (see figure 1) was carried out in a part of the city of Yaoundé, the political capital of Cameroon. Yaoundé, capital of the Center Region and the Mfoundi Division, is located at 300 km from the Atlantic coast, between 3 ° 5'N latitude and 11 ° 31'E longitude (YOGO.S, 2005). It is also called the city of seven hills which accounts for its particular climate. Its geographical limits cover the administrative territory of the City Council of Yaoundé (CUY) and includes an area of 28,798 hectares divided into seven sub-divisions. The city is located in a rugged terrain, with plateaux between 700 and 800 m above sea level and mountain ranges reaching up to 1200 m above sea level (PDU, 2008). In 2010, the urbanized part of the city was approximately 20,000 hectares, including a real density of 117 inhabitants per hectare



(Ngnikam, 2011) This low density leads to longer travel distances for the popula-

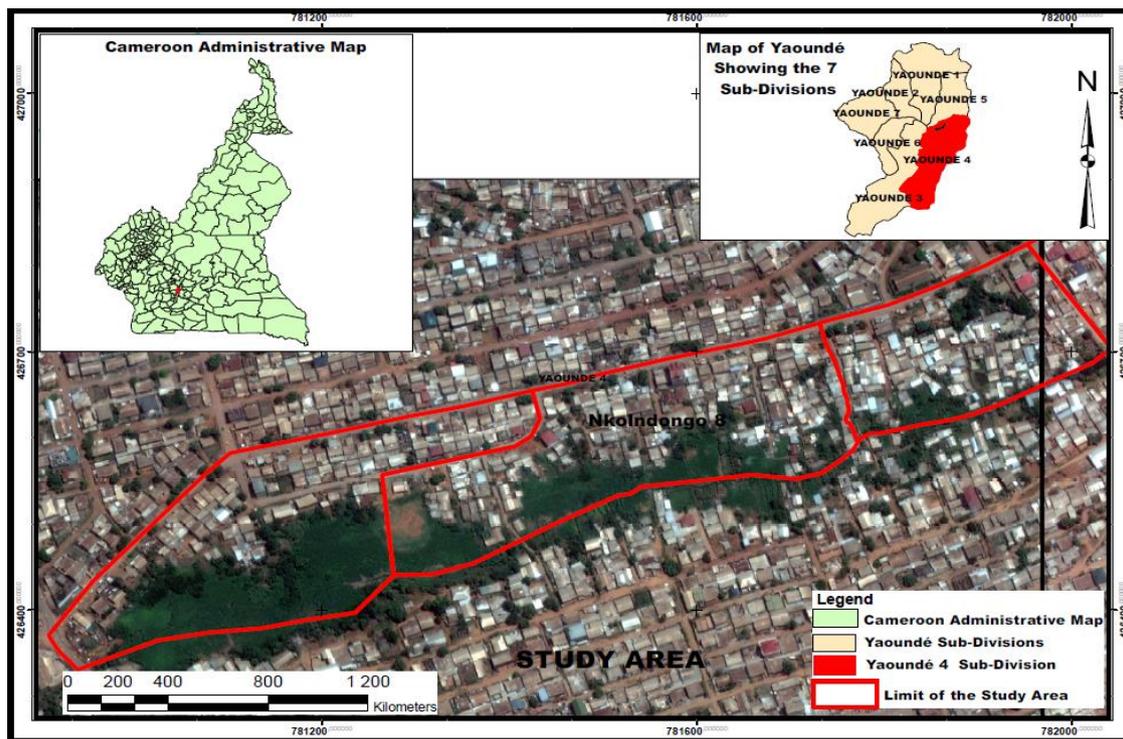


Figure 1 : Study Area

Source :Mbarga Mbarga 2019

#### 4- HOW THE LACK OF URBAN PLANNING IMPACTS SUSTAINABLE URBAN DEVELOPMENT

Informal settlement development is common in Yaoundé and in the study area. These informal settlements with high-density housing and population increase pressure on basic infrastructures necessitated good urban planning (Ting, 2002). Urban planning needs land data to be able to regularize existing buildings and plots so that the new urban plans passed by the government can be implemented.

The rapid urban population growth and environmental change experienced by developing countries are factors that affect land use in urban and peri-urban areas (Wu, Zhang, & Shen, 2011). The urban plan is a tool that allows the regulation of access to land, economic development activities and urban population growth (Ge & Li, 2017; Gasore, 2019). Urban planning in Cameroon is marked by several stages which have not always contributed to the harmonious development of these cities. Some laws regulating land use were implemented

~~around 1966 and those promulgated in 1972 after reunification resulted in the development of~~  
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In order to ensure sustainable urban development, the law n°2004/003 of 21<sup>st</sup> April 2004 governing town planning in Cameroon provides four tools to support land use planning. These tools are:

- **Urban Master Plan (PDU):** considered as the main pillar of planning and urban development policy, the destination of land and the construction of urban equipment in the long term. It is accompanied by graphic documents produced on a scale between 1/20000 to 1/25000.
- **Land Occupancy Plan (POS):** It sets the land allocation, the rules for restriction, easements of land use in the medium term (10 to 15 years). The accompanying graphic documents are drawn up on a scale of between 1/5000 and 1/10000. The law specifies that all urban centers and all urban district municipalities must have a land use plan.
- **Summary Town Planning Plan (PSU):** In the absence of the land use plan, mandatory to each urban center, the municipalities can have a summary planning document playing the role of the POS drawn up, the graphic documents of which are drawn up at the POS scale, 1/5000 to 1/10000.
- **Sector Plan (PS):** It is drawn up for part of a locality covered by a land use plan. It specifies in detail the technical methods of land use, the equipment to be built, their locations as well as the technical and financial characteristics of the urban infrastructure to be built. Its graphic documents are produced on a scale between 1/500 and 1/1000.

The use of a Multi-purpose cadastre proposed in this study is a tool for facilitating orderly urban land use planning. This process is based on the design of land use and the development of infrastructures such as communications, transportation, and distribution networks that efficiently meet the citizen needs. The multi-purpose municipal cadastre implemented here, supports effective urban planning. Multipurpose municipal cadastre as the record information on land parcels is a usefull alternative tool for city planning that fits the technical needs of various urban actors working for sustainable urban development.

## **5- BENEFIT OF THE MULTI-PURPOSE MUNICIPAL CADASTRE IN LAND MANAGEMENT AND ADMINISTRATION IN URBAN AREAS**

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This section discusses the benefit of a multi-purpose municipal cadastre in the process of recording and disseminating information about land ownership and security of rights.

Beyond recalling the traditional geometrical characteristics of the plots and its historical roles, (the identification of a parcel of land, the registration of rights to landed properties, the property assessment, the drawing up of plans, property taxation, security land titles as well as current and future land use (Law 76/25 of December 14, 1976; Enemark, S., 2005)). This definition adds new purposes related to land management and land use (planning of development, exercise of administrative powers), prevention of natural risks, development of natural resources, protection of the environment and implementation of sustainable development (Francis Roy, 2007), which gives it a versatile character. The enrichment of its functions through technological improvements offered by geomatics makes the cadastre a Land Information System (LIS) based on the plot and regularly updated with the statements of work (building permits, demolition permits ...) and acts of sale (Francis Roy, 2007).

The cadastral system allows land reforms undertaken by states around the world to unequivocally promote access to land and land use, to secure land rights as well as access to credit (Payne, 2002; Deininger, 2003). The cadastral system also focuses more on the activities carried out by other public or private actors intervening in various fields. These fields are: town planning, land management, environmental monitoring, land use control, natural risk prevention and sustainable urban development (FIG, 1995; Williamson & Ting, 2011, Tan & Looi, 2013; Francis & Alain, 2008). Through technological evolution and the need for permanent updating, cadastral systems have evolved towards modern, digital and multi-purpose cadastres (Molen, 2003; Tan & Looi, 2013), thus replacing paper plans and registers easily usable digital versions. The cadastre of Cameroon has to be modernized and adapted to current trends around the world.

The multi-purpose cadastral system became important and fundamental in the context where most Cameroonian cities faced a lack of urban planning and cadastral plans to support sustainable urban development (adapted from: Dawidowicz, Żróbek, 2017). The figure 5 below is an example of poor land administration where few stakeholders own the land titles.

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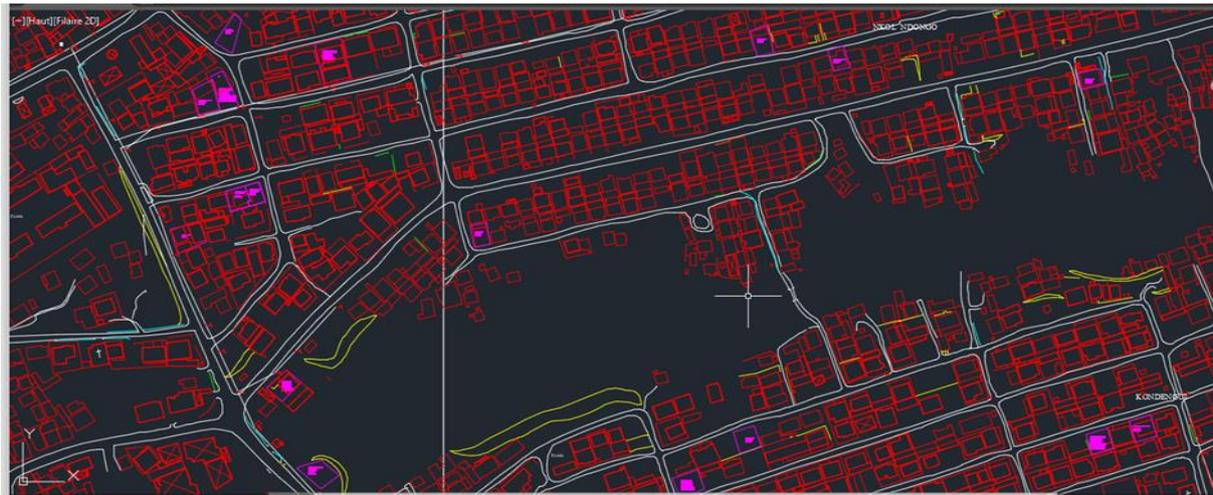


Figure 5: Example of multipurpose cadastral plan in Yaoundé

Source: MINDCAF 2019

- Red lines indicates buildings;
- Parcels up-to-date

Cameroon does not have a modern cadastral system to provide statistical data on land management and maintain up-to-date information about land parcels. Consequently, it cannot provide security of property rights, appropriate land administration and sustainable urban development (UN-Habitat, 2010). Finally, the multi-purpose cadastre is a source that integrates all the legal, tax and technical information for a plot. It therefore takes on the character of a land information system useful to the various actors in sustainable urban development.

Thus, for land management to be effective, complete information on the land parcels must be recorded and managed in an efficient and secure system. This system allows better availability, being kept and rapid decision-making. “Land information is an essential condition for decisions making regarding land investments, development and management.” (Kaufmann & Steudler, 1998 cited by Nnam et al., 2014). The implementation of this new tool will not only improve the quality of geographic data management, but will also limit the many land conflicts inherent in the absence and unavailability of quality land information. Multi-purpose municipal cadastre as Cameroonian Cadastral Information System (CCIS) should be saved in the form of a database on the various areas. Innovations such as the conservation of digital property titles, administrative documents related to land ownership and recordation of geospatial data should be integrated (Adapted from: Bryan & Fitzpatrick, 2016; Lukitasari, 2017).

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As a decision-making support tool, the CCIS or multipurpose municipal cadaster based on the GIS technology will include, on the one hand, a geographic database. It relates to land allowing better investment planning, judicious occupation of space in urban area. On the other hand, the multi-purpose municipal cadastre will include procedures and techniques relating to an efficient, easy and flexible management of geospatial information. This will be based on a systematic collection, analysis, permanent updating and geospatial data dissemination (Nichols, 1993; Dawidowicz, Żróbek, 2017).

Figure 6 below is an example of plots plan giving information about the parcel ownership. This plan is useful for various urban actors. It shows a well organize space based on a digital plan that gives information related to land parcels and is easy to update.



Figure 6: Example of needed organized parcels, Where **a** and **f** are spaces provide for housing facilities; **b** is a space allocating for school equipment; **c** space setting for leisure purpose; **d** space provide for urban developers; **e** allocating for health facilities. Source: MAETUR Nkondom Layout.

The advantages of computerized resource management no longer need to be demonstrated. The MINDCAF in charge of the management and the maintenance of the cadastral plans, continues to handle it in a paper form. Paper documents are difficult to keep or store. On the technical level, these paper documents make the data management extremely difficult for the public agents of the ministry in charge of land affairs (adapted from: Steudler & Kaufmann, 2002). It is therefore easier to lose data that the acquisition of which is expensive for the State. It is for these reasons that we propose in this study to set up and gradually create, a multi-purpose municipal cadastre plan/ Cameroonian cadastral information system (CCIS). This research has pointed out that, Cameroon does not have a national paper cadastral

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plan. It is partially covered by what is called “in MINDCAF” multipurpose mapping (Figure 5), equivalent to the Multi-purpose Cadastre in some countries like in neighboring Nigeria (Nnam et al., 2014). In Nigeria, a project to set up a multipurpose cadastral plan has been carried out in part of the metropolitan area of Enugu State. This project shows decision-makers, the need and the usefulness of putting in place such a system which contribute to an efficient management of land resources in this State. Cameroon through our exploratory study, can draw inspiration from this example to develop its multi-purpose municipal cadastre plan.

The description of Cameroon’s current land administration system demonstrates why there are problems in urban planning that need to be addressed as it is not possible to have sound urban planning with good land records. Instead Cameroon needs to learn lessons from (Zahir, Tuladhar and zevenberger, 2010; Enemark, 2010; McLaughlin & Nichols, 1987) to create a framework for improving the quality of land administration system and the management of human settlement and to make land parcels data available for a maximum use.

## **6-THE ADVANTAGES OF UNMANNED AERIAL VEHICLE (UAV) OVER SATELLITE IMAGERY DATA AND OTHER SPATIAL DATA COLLECTION TECHNIQUES**

The cadastral plans corresponding to the situation of the place can be produce easily at low cost. Administration in charge of the security of land rights can benefit of the evolution of new geospatial information technologies and data processing techniques. Drones or Unmanned Aerial Vehicle (UAVs) provide new data collection method fit to this purpose.

The cadastral plans produced by these new geospatial data acquisition techniques have the advantage of being current and up to date. UAVs use GPS techniques which offers an easy and fast method of producing maps. The UAVs utilized in the study produced very high-resolution images of areas to be surveyed (Barnes et al., 2013, Barnes et al., 2014). These images with very high-resolution and accuracy allow the establishment of orthophotographs necessary for participatory mapping. Each stakeholder is able to recognize his land area, the boundaries of his parcel of land and neighborhood elements in this image. In 2014, the World Bank team tested the use of UAVs as a tool to accelerate the production of fit-for-purpose geospatial data and the up-to-date and accurate data for multi-purposes cadastral plans. The test was conducted in Albania due to the need for new and improved cadastral

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maps in this area. This test showed that, UAV technology is a promising new tool with significant advantages. It improves project design and during implementation geospatial data can be captured in a short time at a low cost due to its rapid and ease deployment characteristics.

In 2017, (Norzailawati & Nur, 2017) another study was conducted on the evolution of UAVs application from the urban planning perspectives. With the rapidly evolving technology, UAVs provide potential uses in many aspects of urban life, including urban planning fields. Remote sensing UAVs applications provide a superior low cost, adaptable and accurate data gathering tool for planners (Nathan, 2015; Colomina & Molina, 2014). The use of UAVs in urban areas presents excellent options for accuracy assessment by providing a real-time, and higher resolution imagery of remote areas. They conclude that, the utilization of UAVs in urban planning provides one of the most cost-efficient data collection and transport task utility tools of our time.

The implementation of UAV based photogrammetry (El Meouche R. et al., 2016) enhances land surveying, comparisons and possibilities. The study was conducted to compare two cadastral plans and evaluate the accuracy of the UAVs technique to the classical method using total station instrument. The evaluation showed that, the main potential problems associated with using a UAVs are were the level of precision and the visualization of the whole area. However, he results indicated that the precision is quite satisfactory with a maximum error of 1.0 cm on ground control points, and 4 cm for the rest of the model. A study was conducted by (Tahar, 2012) titled, Aerial Terrain Mapping using UAV approach. The accurate and very high geospatial resolution images of UAVs are an alternative to replacing satellite imagery and to enable the development of plans and maps at lower cost. These plans and maps will serve as a basis for urban planning and the implementation of a precise cadastral system. UAV technology presents recent advances in highly automated mapping techniques and offers a new methodology for producing faster and cheaper geospatial data that can benefit the land administration and management sectors (Kelm, 2014, Norzailawati, 2018 ; Manyoky, Theiler, Steudler & Eisenbeiss, 2011).

In cadastral application, (Manyoky et al., 2011) presents the investigation of UAVs for use in cadastral survey. The scope of a pilot study UAVs was tested for capturing geodata and compared with conventional data acquisition methods for cadastral survey. Two study sites

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were therefore surveyed with a tachymeter-GNSS combination as well as a UAV system. Their result show that the UAV image orientation is the limiting factor for the obtained accuracy due to the low-cost camera including camera calibration, image quality, and definition of the ground control points. However, the required level of accuracy for cadastral survey was reached. The use of UAV images in cadastral application provide new opportunities and further information such as orthoimages, elevation models and 3D objects can easily be obtained (Manyoky, Theiler, Steudler & Eisenbeiss, 2011; Lukitasari, 2017). For urban or land use land cover (LULC) mapping and flood monitoring, UAVs can provide high-resolution images with fast and accurate detection of inundated areas in complex urban landscapes (Quanlong, 2015). The canadian urban planner Robert Vogt developed a drone program with his planning team. The use of UAVs allowed them to take low altitude aerial photography for development sites, street corridors, natural areas, and the urban form of the communities that they were working with. This gave an urban design perspective and access to sites that ws unprecedented (Vogt, 2014; Nathan, 2013; Norzailawati, 2017; David, 2016; Caroline, 2018).The figures below show the difference of resolutions between UAV image (fig. 2) and satellite image (fig.3). These two images (Figure 2 and 3) showing the same area are a proof of our choice of high-resolution UAVs imagery for this work. Satellite image (fig. 3) is expensive and difficult-to-access for municipalities whose financial resources remain modest. It's cannot allow the same spatial resolution as low altitude UAV imagery.



Figure 2: UAV Imagery showing a part of the study area A=A'

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Figure 3 : Satellite imagery of the same study area A'=A

The high resolution UAV (Figure 2) embryonic technology in Cameroon is an alternative solution to be used instead of satellite image. This is to surmount the negative implications caused by ground-based surveying methods. Data collection by drones is affordable and easy to acquire. This makes it possible to develop a multi-purpose municipal cadastre and to implement urban plans, as demonstrated by the previous studies.

## 7- RESULTS AND ANALYSES:

The exploratory study of the multi-purpose municipal cadastre and the elaboration of master planning for sustainable urban development for Cameroonian cities produced several observations: Cameroon does not have a national cadastral plan. In cities where it exists, it does not cover its total area. The realization of cadastral maps at local level can be based on the use of very high-resolution images of UAVs. This method of collecting geospatial data has advantages in terms of cost, accessibility, volume and quality of data collected in a relatively short time.

The lack of urban land use planning leads to the proliferation of illegal settlements. It negatively affects harmonious sustainable urban development. While it is true that the master plan for the city of Yaoundé was approved in 2008, the fact remains that, not all cities in Cameroon have an urban planning tool. The land use plan for the Yaoundé IV council where this study was carried out is being prepared and is in the process of being approved.

At the level of the study area, out of a hundred households interviewed, 16.70% have a

~~provisional attribution certificate provide by the (Yaoundé) city council in this municipal lay-~~  
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out. 29.20% hold certificates of sales and 50% have a deed of conveyance, proof of the interference of the traditional land rights holders in land management in this municipal layout. 4.20% of households have no official document. Similarly, 72% households have a land sketch instead of parcel plan, 21% have a plot plan and 7% have a location plan. The inconsistency observed in the results presented above is proof of the urgency of setting up a multi-purpose municipal cadastre. This CCIS will contribute to improving the performance of the land administration at the local level. With the implementation of decentralization processes, each municipality could increase the establishment of land titles. They will therefore raise funds in order to effectively improve the living conditions of its populations and ensure the economic development of the territory.

In terms of urban planning, 81.70% of households in the study area do not have a building permit, proof of the informality of the occupancy that exist. 8.3% of occupants claim to be in the process of obtaining this authorization to build.

The table below shows the activity of national land conservation over the past fifteen years.

**Table n°1 : National data statistics in land titles production**

Stakeholder status	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Men	4873	8614	9692	8526	10769	11322	9307	10410	10142	9298	9091	8268	8884	9035	6817	135048
Women	935	1819	2023	2033	2405	2846	2469	2430	2922	2965	2962	2798	2762	3505	2395	37269
Collectivities	88	131	117	120	256	260	355	570	1629	1816	1889	2577	3252	3452	2579	19091
<b>Total</b>	<b>5896</b>	<b>10564</b>	<b>11832</b>	<b>10679</b>	<b>13430</b>	<b>14428</b>	<b>12131</b>	<b>13410</b>	<b>14693</b>	<b>14079</b>	<b>13942</b>	<b>13643</b>	<b>14898</b>	<b>15992</b>	<b>11791</b>	<b>191408</b>

Source : MINDCAF

In view of the above, 191,408 Land titles were established in Cameroon between 2005 and 2019. That is, 13,5048 (70.56%) for men, 37,269 (19.47%) for women and 19,091 (9.97%) for communities which represents an average of 12,761 land titles per year over the past 15 years. As per the previous period.

The multi-purpose municipal cadastre plan produced, based on very high-resolution UAVs imagery, is an alternative to the use of satellite images which are expensive and difficult to access by the municipalities. The multi-purpose municipal cadastre thus obtained, is a reliable tool for management of geographic data, which could also boost security of land rights and ensures availability up-to-date information on land parcels.

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## **8- CONCLUSION**

The study of the Cameroonian cadastral system remains a vast field open for research. This exploratory study can serve as a base for future researchers. The establishment of tools such as a geodetic network and a basic mapping are a prerequisite for setting up a digital, modern multi-purpose municipal cadastre. The need to use a multi-purpose, digital cadastre produced based in very high-resolution UAV imagery has the advantage of being easy to update and accessible. The pooling of all these geospatial infrastructures is a solid basis for the development of a modern cadastral information system. This system is capable of supporting land governance and land administration for the benefit of all. It is able to ensure poverty alleviation, supporting environmental protection, reducing informal settlements and thereby ensuring sustainable economic and urban development in Cameroon.

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