



# Land Governance in an Interconnected World

ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY  
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## **SATELLITE IMAGE ANALYSIS FOR OPERATIONAL MAINTENANCE OF A PROPERTY DATABASE FOR DAKAR CITY**

**GRAHAM DEANE, TIM PATTISON, ROBERT OWEN**  
**Airbus Defence and Space, United Kingdom**

Tim.pattison@airbus.com

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## **Abstract**

The city government of Dakar, Senegal, has a requirement to generate revenues for developing and maintaining city infrastructure and services. The legal framework for property taxation is already in place, but the city lacks resources to collect and maintain the information needed to calculate the tax due. Using very high resolution satellite data the land parcels and building extents (including heights) can be monitored through a combination of 3D image analysis and field data collection. This project is designed to develop an operational system for creating and maintaining a parcel reference map, whose accuracy can be further improved through GPS-based field survey, and, mapping new buildings and changed building heights. This will provide the framework for field teams to collect and maintain an accurate database of property characteristics, thereby enabling tax calculations to be made in order to support sustainable and transparent revenue generation for the City.

## **Key Words:**

Land Administration, Senegal, Change Detection, Satellite Imagery, Revenue



## 1. INTRODUCTION

Many cities in Africa are growing rapidly. According to the United Nations, by 2030 almost 60 per cent of the world's population will live in urban areas and 95 per cent of urban expansion in the next decades is expected to take place in the developing world. This presents several challenges on how to manage large populations and also provide appropriate, efficient and cost-effective services to citizens. Property-based revenue generation is seen as a way of helping to finance the provision and maintenance of such city services:

*“Efficient and effective revenue collection .... is a must if we have to fast track our development agenda.”* (Hon. Dr W.K. Ottichilo, Governor, Vihiga County, Kenya, 19<sup>th</sup> September, 2017)

Revenue generation not only requires accurate property information, it must also be based on up-to-date data in order to ensure that the system is fair to all; fairness and objectivity will help to maximise the buy-in by citizens. This study in Dakar, Senegal, is designed to demonstrate that a combination of change analysis using very high resolution satellite imagery and targeted field data collection can provide a cost-effective means of ensuring that property databases can be fully maintained and fit-for-purpose as the basis for a city-wide property revenue system.

The project is being undertaken by the Intelligence programme line of Airbus Defence and Space Limited (Airbus DS) which has considerable experience in building and delivering land information management systems, the capture of data to ingest into them and the change management needed to ensure their operational deployment. Airbus DS is also well-known for the provision of a range of satellite image products and services across a wide range of applications. In Dakar, Airbus DS is working in partnership with New Africa Consulting (NAC), a locally-based development consultancy, geospatial and technical training company whose aim is to optimise the application of new technologies in Senegal. The Dakar change-monitoring project is one of twenty-two projects currently supported by grant funding within the UK Space Agency's International Partnership Programme (IPP):

[www.gov.uk/government/collections/international-partnership-programme](http://www.gov.uk/government/collections/international-partnership-programme).

The IPP is a five-year programme that utilises the UK space sector's research and innovation strengths, in partnership with local organisations, with the primary aim of delivering sustainable economic or societal benefits to emerging and developing economies around the world. The Programme, which also encompasses forestry, land use, agriculture, marine environments, disaster resilience, health and education, and, renewable energy, is being delivered in alignment with UK aid strategy and the United Nations' (UN) Sustainable Development Goals (SDGs).



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ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY  
WASHINGTON DC, MARCH 19-23, 2018



The Dakar project involves an automated analysis of stereo satellite imagery to determine building development and height increases within the city area to identify areas of change. These locations of change (and not the entire city land and building stock) are then visited on the ground to provide detailed information on the nature of change so that the property valuation database can be updated. The project aims to demonstrate that this is both an efficient and affordable method for property database maintenance compared with alternative approaches and an appropriate foundation for a city-wide revenue system based on property.

## 2. BACKGROUND

In Dakar, a metropolitan area of around 2.5 million people, representing over 17% of Senegal's total population, urban expansion is restricted by its peninsular location and so development is often upwards, involving building additional levels on top of existing buildings, and not always with planning consent or knowledge of the authorities. The population growth rate of Senegal also makes it one of the 25 fastest growing nations (Source: CIA World Factbook), adding further pressure on land and resources in the city area.

As a result of these rapid and extensive changes, the city government lacks up-to-date information on land and property development in the city. Maintenance of a property database is therefore a major issue, with any existing data quickly rendered obsolete. Indeed the maintenance of such records is a significant issue in many parts of the developing world and one that is not always fully addressed in project briefs or in the implementation of sustainability and capacity building plans.

Airbus DS has been in discussion for some time with the *Direction Générale des Impôts et des Domaines* (DGID) the national tax authority of Senegal, and the City Authorities (the *Mairie*) to find ways of implementing a property monitoring service, as part of a revenue generation capability based on existing property tax legislation. We undertook a small pilot study in collaboration with DGID, in 2016, to demonstrate an efficient method of field data capture, using mobile technology. We subsequently designed a study, within the UKSA's IPP programme, to demonstrate how satellite data could be used to keep a property database fully up-to-date on an annual basis as part of an operational property revenue generation system. This IPP project commenced in January 2107 and is due to be completed by the end of 2018.

The current project has developed both a system for creating a land parcel reference map (which is currently not available for the whole of Dakar), whose accuracy can be later improved through GPS-based field survey, and, a means of monitoring new buildings and changes in building heights through a 3D



# Land Governance in an Interconnected World

ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY  
WASHINGTON DC, MARCH 19-23, 2018



monitoring system. Using very high resolution (0.5 metre resolution) stereo Pleiades satellite data, this project is designed to demonstrate that individual land parcels and building extents can be effectively monitored for changes in area, height and volume using automatic image analysis software combined with field data collection to verify the results.

Success for this project will mean that rather than a complete field survey exercise over entire areas of the city, to decide where changes have occurred, the changes are quickly identified on imagery and the field work is specifically directed to those areas; thereby saving significant time both in the field and in the office analysis because of the automatic techniques used. The project therefore has captured data that maps parcel boundaries to create an initial database (because the currently available information is out of date to start with); the method detects changes to parcels in a timely and efficient manner (with six-monthly image analysis) and then determines the accuracy of the assessment by field verification to ensure that no significant changes are omitted from the database.

At a technical level, the initial project outputs are designed to confirm that property developments and building changes can be identified quickly and that an up-to-date and a sustainable property database can be maintained with the assistance of very high resolution satellite imagery.

The change detection processes and software application have been developed in the first year (2017) of the project. The second year (2018) will focus on development and testing to reduce errors of omission and commission as well as significant knowledge transfer and development with local partners, and, the implementation of a cost-effectiveness analysis.

There will be three primary phases of data capture:

- The initial land parcel reference map;
- First change detection; and,
- Second change detection testing.

The second change detection testing will primarily be conducted by trained local technical staff, thereby contributing to long-term sustainability, to test whether local operational capacity is substantial enough to replicate the same quality of results. To ensure sufficient capacity in Dakar to operate and maintain the solution, the organisations involved have implemented a 'train the trainer' approach to knowledge transfer and capacity building. This includes training sessions and workshops for both office and field operations, as well as the provision of comprehensive work instructions and technical manuals.



### 3. DATA CAPTURE

The method uses ortho-rectified satellite imagery to map land parcels, if they do not already exist, and image to image comparison to identify areas of change. These areas of change are then visited in the field in order to capture detailed information about each property. In the following paragraphs we describe the methods used in more detail followed by the analysis of the results in order to confirm that the process is working satisfactorily.

#### a) Imagery

The change detection analysis is undertaken using Very High Resolution (VHR) satellite imagery. The imagery used in Dakar is from the Pleiades satellite constellation, acquired in a tri-stereo format, which enables the imagery to be processed into the standard Elevation1TM product, which contains the following data layers:

- Ortho-photograph (50cm resolution)
- Digital Surface Model (DSM) (1m resolution)
- Digital Terrain Model (DTM) (1m resolution)
- Contour lines (not used in this analysis)

To ensure the best possible accuracy for the creation of these products, Ground Control Points (GCPs) are needed. In order to obtain GCPs a successful cooperation with DTGC (*Direction des Travaux Géographiques et Cartographiques*) the Senegalese mapping agency, which is a part of ANAT (*Agence Nationale de l'Aménagement du Territoire*), was initiated. DTGC are in the process of densifying the ground control network for their own mapping activities and successfully collected an additional six points to Airbus specifications, in order to enable the Elevation1 product to be generated.

With any change detection process, at least two epochs of data are required. The following dates have been used in the first analyses (the January 2017 image is illustrated in Figure 1):

- Images from 7th November 2015 and 28th January 2017 were used in the development of the change detection tool; and,
- A composite image from 25th August and 6th September 2017 was used for subsequent testing of the change detection software. The 'composite' image was generated to ensure cloud-free imagery over the entire city area.



## b) Land Parcel Data Capture

The change detection analysis needs a land parcel reference map (Cadastral map) and as such a reference dataset was not available to the study, the parcel boundaries had to be created by interpretation of the ortho-imagery; the January 2017 image was used for this purpose. In order to create this layer, GIS data capture was required, and a local team was employed to do this at the premises of our international partner New Africa Consulting (NAC). Part of the knowledge transfer component was to set up the production facility and train the NAC team to undertake this work.

The production office in Dakar consisted of a server and five workstations, each operating Quantum GIS (QGIS) Open Source Software. A simple bespoke digitising toolkit was created within QGIS and deployed on the five workstations. A cadastral data model was established to collect baseline cadastral data and survey attribute data across the project. This data model implements the existing schema supplied by DGID and meets industry best practice for cadastral data. In the data model, the cadastral parcel data is collected as a polygon feature class.

Airbus staff mobilised to Dakar to train the local team, both in the use of the digitising toolkit and in the interpretation of the imagery to facilitate land parcel identification and capture. A set of work instructions was produced and used as the basis of the training; Figures 2 and 3 illustrate the training programme for the local team.

Following the initial training, the digitising team, captured small areas themselves and then went into the field with together with a hardcopy printout of their initial interpretation, for verification. This enabled the team to gain a much better understanding of the way the physical landscape appears on the imagery and, therefore, enabling a significantly improved interpretation going forward. Once the training mission had been completed the NAC team captured land parcels across a set of 15 test sites with differing urban landscapes and then across the whole of the Dakar peninsula, In total approximately 90,000 parcels were captured, far in excess of the original target of 15 test sites.

Quality assurance of the captured parcels was carried out in two stages; both within the NAC team and by Airbus GIS specialists based in the UK. The QA undertaken was primarily to detect geometry/topology errors (Airbus having provided specific software tools to the NAC team for this purpose), and, errors of interpretation.

The geometrical and topological integrity (removal of overlaps/slivers/kick-backs, etc.) is vital for the correct operation of the change detection software. The interpretational accuracy, whilst still important



was less critical as the parcels were chiefly being used to create entities to be monitored for change, rather than being used for more highly developed Land Administration information and processes.

## c) Field Data Collection

The principal activity was to undertake the collection of baseline property attributes for a sample of the land parcels captured. The property information was to be captured for two main reasons:

- To provide a baseline of detailed property information that the change detection processes can be tested against; and,
- To provide the attributes to enable property valuation calculations to be made (and therefore enabling a city-wide assessment of the potential tax revenue that could be realised).

It was decided that the same local team that undertook the land parcel capture should also be involved with the field data collection, given the experience they had already developed in the understanding of the urban landscape and capturing information about it. It would also be important for any future roll-out of the methodology to a team of experienced individuals, familiar with all stages of the process, employed by NAC as part of the commitment to long-term sustainability which is a key outcome for projects supported under the International Partnership Programme.

Prior to commencing the field data collection, the necessary tools, training materials, user manuals and production controls were prepared. The project deployed a customised version of ESRI Arc Collector on to five Android tablets (7-inch screen versions). The tool was designed to enable attributes to be collected against each land parcel, as well as one or more linked photographs. Data collected on the tablets could then be synchronised with the central database to enable NAC QA/Supervisors to review the completeness of the collected data in the project office.

A training mission of two weeks was undertaken by UK-based staff. The training initially focussed on use of the tablet and the data capture application, before quickly moving on to actual property data collection. For logistical reasons the initial in-field training was carried out on properties close to the NAC offices, allowing regular drop-ins to the office to synchronise the collected data with the central database, as well as receive support and advice to help them to get fully up-to-speed with the full data capture process.

Following the training programme, staff collected data in specified areas, selected for their property characteristics and proximity to the base office; and, where we had support from local authorities by providing a letter of authorisation to permit the field staff to collect personal information from residents.



# Land Governance in an Interconnected World

ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY  
WASHINGTON DC, MARCH 19-23, 2018



Each tablet was loaded with a working block of approximately 100 land parcels; and it was expected that each block could be collected in a week. To maximise the efficiency of data collection, the staff worked on a shift basis meaning that no person had to spend a full day working outside in the hot conditions.

On a regular basis the tablets were required to be synchronised with the server, once done, this allowed QA checking to take place. The Airbus QA team could not review the data compared to the reality in the field, but could provide feedback on completeness of data, which is essential for ensuring sufficient attributes for valuation calculations.

## d) Data Model & Valuation

The data model for the fieldwork collection was based on DGID's '*Methode Cadastrale*' but simplified to make it easier and quicker to collect. The original '*Methode Cadastrale*' specification requires internal property measurements and a number of attributes to be collected for every room in a property; potentially exceeding 200 individual attributes for a large family home. This approach would be very laborious to carry out and, for a project of this nature, would be difficult to get agreement from occupiers for such an invasive survey.

Instead, the project employed a model that requires only external measurements derived from GIS data (land parcel and building areas), and floor level assessment of room types, that would enable a usable area (*Surface Utile*) to be approximated within minutes rather than the very labour intensive room by room approach of the '*Methode Cadastrale*'. Once the usable area was approximated, the remainder of the attribute collection was closely aligned to those that are required by the *Methode Cadastrale*. Specifically on a property-wide basis collecting attributes on:

- Condition and upkeep
- Neighbourhood and location
- Age
- Building grade

Where all these attributes are collected successfully then valuations based on the building can be calculated. In addition a small number of attributes covering courtyards, boundaries and outbuilding were also put into the data model but these were rarely populated due to the nature of the areas being surveyed. Some administrative details and photographs of the property were also required during the field data collection.



After two months of field survey work, notification was received from DGID that they intended to change the detailed *Methode Cadastrale* to a much simpler one, and requested that the project use this going forward and, specifically, to employ this in the Grand Dakar pilot area illustrated in Figure 4.

The new model employed a much simpler method for determining the usable area, by merely calculating the gross area (building footprint x number of storeys) x 0.78 plus any balcony area not included. This approach was even simpler than the simplified method that Airbus had been working on and was seen as a very positive development and an important potential impact of the IPP project in Dakar and confirmation of the successful cooperation between the stakeholders involved.

Following the agreement to capture the data for Grand Dakar, DGID and the *Mairie* provided the field teams with the necessary letters of authorisation to allow the field data collectors to work in the area. Small modifications were also required to the data model to align with DGID's new and simplified *Methode Cadastrale*, but this did not require any re-engineering of the application, merely adjustment to the attribute structure. The field teams were therefore able to be deployed in the area to collect the data within three weeks of the notification of the new model.

#### 4. SOFTWARE DEVELOPMENT AND CHANGE DETECTION

The aim of the software development component of the project, was to develop a software application that could analyse two epochs of imagery (Pleiades Elevation1<sup>TM</sup> products), each containing an ortho-image, Digital Terrain Model (DTM) and Digital Surface Model (DSM) layers, and, to identify urban changes including building height growth, and then apply the output of this analysis onto a land parcel layer to indicate which parcel had shown change (and the type of change) between the two image dates.

The software was built in Python 3.6 running under Windows 7. In addition to the core Python installation a number of additional Python packages were utilised, including, for example the Open source Python library for scientific and technical computing (SciPy). The code was developed in the Integrated Development Environment (IDE) Eclipse. The development also built upon existing Airbus technology that had been used for comparing raster images with vectors for large scale databases.



## a) Height Change Detection

The software records the statistics of raster DSM pixels that intersect each input polygon, across multi-temporal data sources. The system stores multiple epochs by appending  $T_n$  to the database field name. For example 'MEAN\_HEIGHT\_ $T_n$ ' would be written as 'MEAN\_HEIGHT\_2015' for 2015 data.

For each epoch, for each input polygon the following height statistics are stored in the database:

- the minimum height value of non-masked pixels within the building footprint;
- the maximum height value of non-masked pixels within the building footprint;
- the mean height value of non-masked pixels within the building footprint;
- the ' $n^{th}$ ' percentile height value of non-masked pixels within the building footprint.  $n =$  PERCENTILE\_VALUE, currently set at 90;
- the number of non-masked pixels within the building footprint;
- the number of 'no\_data' pixels within the building footprint.

For a given epoch image pair, for each input polygon the following height change statistics are stored:

- the difference in the minimum height values between  $T_0$  and  $T_1$ ;
- the difference in the maximum height values between  $T_0$  and  $T_1$ ;
- the difference in the mean height values between  $T_0$  and  $T_1$ ;
- the difference in the  $n^{th}$  percentile values between  $T_0$  and  $T_1$ ;
- the difference in the cell counts between  $T_0$  and  $T_1$ ;
- the difference in the 'no\_data' counts between  $T_0$  and  $T_1$ .

An illustration of mean height difference is shown in Figure 5.

Moving beyond a simple comparison of polygon height statistics, the DSM layers and satellite imagery are classified to give a more informative result with reduced noise. Specifically the height change classification achieves three key things:

- Informs the end user as to the nature of the change. Height change is labelled based on its polarity, context and interaction with tree canopy cover. For example, an elevated building can be separated from a felled tree;
- Gives area wide change detection. The per polygon height change statistics are limited by the coverage of digitised land parcels. The height change classification is generated to cover the



entire satellite data coverage area. Therefore end users are informed of changes outside of the land parcel database;

- Noise reduction. Raw satellite change detection results are prone to significant noise from edge effects, spurious values, and shadows. The height change classification is prepared to suppress these effects.

For each epoch pair of satellite data, a classified, thematic raster map is produced describing eight classes:

- Unclassified, raster value 0
- Elevated Growth, raster value 1
- Elevated Shrink, raster value 2
- Ground Growth (Isolated), raster value 3
- Ground Growth (Extension), raster value 4
- Ground Shrink, raster value 5
- Vegetation Growth, raster value 6
- Vegetation Shrink, raster value 7

## b) Image Change Detection

In addition to height changes, the system also reports changes in the imagery; specifically, where the local structure of the image has fundamentally changed. The image based change detection is executed and reported for each input land parcel polygon. This brings two levels of additional value:

- Compounds height change. Those parcels with a reported height change may have their confidence increased if a strong image change is also reported;
- Identify changes with little or no height change. For example, ongoing construction may not exhibit significant changes in height, but may be reported as strong image change.

The image change algorithm works by first extracting a bi-temporal pair of images covering the extent of each land parcel. The image pair is then compared in terms of image brightness, colour, texture and spatial pattern. The degree of image change is then reported as a continuous value from 0 to 255, where 0 is 'no perceived image change' and 255 is 'a very strong image change'.



## c) Parallax Correction

One of the most significant challenges in high resolution urban change detection with satellite images is the effect of sensor viewing geometry. Specifically, images acquired over the same areas at different times will more than likely view the surface from different angles. This will have the effect that buildings and trees will ‘lean’ in different directions and by varying degrees, creating potential errors in the change detection process.

Within the change detection software this impact is suppressed through modelling and a parallax correction at the land parcel level. Specifically, the following workflow is implemented:

1. Using the height above ground level of the land parcel and the satellite sensor position, calculate the parallax shift for each image;
2. Prior to image change detection for each land parcel, remove the parallax shift, aligning the imaged rooftop with the land parcel ground location.

This shifting of the image to remove the parallax effect is therefore carried out on a parcel by parcel basis, with the image segments for each parcel being shifted prior to the change detection analysis.

## d) Shadow Masking

Shadows are also a considerable challenge to change detection, as the two images are likely to have been acquired with different sun-angles. This would result in varying shadow patterns triggering false alarms. Furthermore, deep shadows also induce spurious DSM values (as the DSM is generated from image matching within a co-temporal set of three images), so managing them is of concern to both image and height change detection. The software was enhanced to include bi-temporal shadow mapping and masking to reduce the likelihood of shadow based false alarms. A methodology was developed that used the DSM data to model the scene illumination and the imagery itself to provide the detail, and exact shadow extent.

## 5. CHANGE DETECTION RESULTS AND ANALYSIS

The initial software development work was undertaken using the November 2015 and January 2017 images as the two epochs. However, whilst this enabled the software to be tested and refined as a result of interpretation of the ortho-imagery, there was no field data from 2015 so only a partial test of the efficacy of the software was possible with these images. In order to test the software outputs fully, a



subsequent epoch of imagery was required so that field data collected at a similar date could be used to help verify the software outputs.

Prior to the start of the IPP project, Airbus had been undertaking some initial fieldwork in the Grand Dakar pilot area with the approval of DGID. This meant that there was a set of field data (although not complete) for this area, which was captured reasonably close to the January 2017 imagery acquisition. The request by DGID to capture data for this pilot area according to the new valuation model meant that in doing so the new field data could be used in conjunction with the August/September imagery to help assess the accuracy of the software change results.

The new imagery acquired in August/September was processed with the January data to generate a new raster change map covering the whole city, as illustrated in Figure 6.

To assess the accuracy of this change detection, a comparison of the field data collected in Grand Dakar in late 2016 and in November 2017 was undertaken. This first comparison analysis is restricted to properties with sufficient data from 2016 to be able to be compared with the later data. Clearly, whilst it was possible to carry out recollection of the 2017 field data, this could not be done for the 2016 data. The most useful attribute for the comparison is the photograph, as this provides an accurate picture of the specific building at that point in time; however, this does mean that an entirely manual approach to this first analysis is required. A count of building storeys had been captured in the 2016 field survey, but as this attribute had been pre-populated based on photogrammetrically captured building heights, there could be an error in the conversion of the building height to storey count.

This analysis is ongoing and uses those properties that are identified as having sufficient 2016 data to carry out the comparison with the 2017 data. The analysis will classify the properties that were identified as having:

- no change;
- change reflected in the raster change map;
- change that was not reflected in the raster change map;
- change in the raster change map that is not reflected in the field data.

For the Grand Dakar pilot area (image 6) the change detection algorithm identified the following statistics of change between January and August/September 2017 have been observed:

- 3.5% of the properties exhibited a height increase greater than 1m, averaged over the whole parcel;



# Land Governance in an Interconnected World

ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY  
WASHINGTON DC, MARCH 19-23, 2018



- Of those, the mean height increase was 2.42m, equivalent to one storey;
- 5.6% of the properties exhibited height change that occupied more than 10% of the area of the parcel;
- 2.1% of the properties have increased in height, with extensions covering more than 10% of the area of the parcel. One of these properties is illustrated in Figure 7;
- 0.6% of the properties have decreased in height, with modifications covering more than 10% of the area of the parcel.
- 0.5% of the parcels have had new buildings constructed from the ground up, accounting for more than 10% of the area of the parcel.

These preliminary results indicate that the image analysis is capable of identifying change at the level of detail needed to direct the field teams to the areas where detailed information needs to be collected on the ground. However, further analysis is required in order to quantify the confidence levels at which the change detection process is operating.

In order to achieve this, the agreements and mismatches between the raster change maps are being reviewed and statistically analysed at the time of writing but a number of anecdotal observations have already been made:

- a) Fieldwork for both epochs is not at the exact date of the imagery. Therefore change that had happened between the fieldwork dates (approximately 12 months apart), that did not happen between the imagery dates (only 8 months apart) can be misclassified;
- b) Change in building height reflected by outer walls, but for a partially completed storey with no roof, the DSM height did not change;
- c) Incorrect photo being attached to 2016 data (adjacent parcel captured instead);
- d) Potential noise from vegetation changes;
- e) Edge effects from neighbouring parcels.

To date the assessment is still ongoing on the change results, which are still to be applied to the land parcels. This work will allow a more comprehensive analysis which will also take into account shadow masking and parallax adjustment. Once this has been completed a thorough assessment of the accuracy of the change analysis can be established.



# Land Governance in an Interconnected World

ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY  
WASHINGTON DC, MARCH 19-23, 2018



However, the main objective of the method is to identify the areas of change in a systematic and unbiased way so that the detailed field work can be targeted at those areas where change has been identified. The importance is that the satellite imagery alone is not considered as the provider of detailed information; it is a pointer to change, as illustrated in Figure 7, and, in the case of increased building height or volume, is an indicator of the extent of change.

As the purpose is to maintain the accuracy and integrity of the database over the long term, the process will be enhanced and improved through time, based on the results from previous change analyses. For example the seasonal impacts of vegetation possibly leading to spurious change results (such as vegetation with and without leaf cover) will gradually be reduced as the database of information about the individual land parcels is built up over time.

## 6. LONG TERM SUSTAINABILITY

In the operational system, the change detection system will operate on pairs of bi-temporal 3D satellite images and cadastral land parcels. In turn it will report, for each land parcel, indicators of change identified in the satellite imagery that may assist in the city's land administration process and in particular to enable the Operational Maintenance of a Property Database for Dakar City, Senegal. The identified change detection, and the resulting improved and increased property database, can be a major factor in enabling the generation of increased tax revenues which can in turn be used to enhance and improve city wide services, with overall benefits to the wider stakeholder community and citizens. This information is particularly important due to a rapidly changing land and property environment in Dakar with significant increases in new land parcels and buildings being developed.

The IPP Dakar project operates on the basis of identifying change to land and property which can then be used in many different ways. A key description of this is the maintenance of land and property data (through computer databases) which can be used as the basis for a multitude of services – revenue generation, property ownership and property markets, street addressing and property numbers, services provision (health, education, social benefits) land planning, energy provision, etc. The key terminology/activity is “data maintenance” which is an essential component of a fair and sustainable property revenue system. Planning the field data collection on the basis of a fully independent view from satellite will also help to ensure that data are collected in an unbiased way, thereby also ensuring transparency for the benefit of all citizens.



For maintenance to be fully effective, the starting point in Senegal must be, firstly, the existence of a National Database of Land and Property and, secondly, a comprehensive and robust Land Management System which manages and updates it – and into which the IPP change detection will ultimately transfer data. Note that this IPP project will create base land and property data for demonstrating the change detection concept and procedures. Neither of these two major infrastructure systems currently exists but there are now plans in Senegal to develop them.

## 7. APPLICABILITY IN OTHER AREAS

Such is the dearth and inaccuracy of current property information it is estimated that future land tax collections in Dakar could be improved five-fold through the implementation of a property information system and the application of such space-based solutions for data collection and update. Through the Monitoring and Evaluation component of the this project, the potential impact of such a system has also been assessed by identifying that the wider use of a city-wide property based revenue generation system will:

- Support city activities (infrastructure development and maintenance) through providing financial resources for capital project funding and recurrent expenditure (such as infrastructure maintenance) that are independent of the central exchequer;
- Increase employment in local government, both in building and maintaining infrastructure within the city and developing a permanent team to collect city data;
- Develop a capability to have an operational revenue collection system paid for from tax revenues thereby ensuring long-term sustainability of city finances;
- Provide a technology and model for application to other Senegalese, African and developing world cities.

The project, with its ultimate focus on providing trained staff and an implemented methodology to ensure the maintenance of a land and property database, will complement the current national strategies in the sector; both to provide national cadastral information and an associated information management system. These recently launched national strategies acknowledge the need to develop a fully digital national database of land and property; a cornerstone being the ability to ensure that the database can be maintained cost-effectively.



A further outcome will be a methodology that can be rolled out to similar cities, across Africa and the wider developing world, where city infrastructures and services, always under pressure, could be improved and enhanced by raising local revenues based upon an up-to-date property database and a fully implemented property-based tax system.

## 8. CONCLUSIONS AND ROAD MAP

The project is due to be completed in late 2018. The next steps are to continue the review of the first change detection and to provide statistical evidence of the accuracy of the change detection. The results achieved to date look promising but the detailed analysis will underpin confidence in the operational capabilities of the methodology.

This review will be followed by a second change detection analysis based on changes between the August/September satellite imagery and a new acquisition in the first quarter of 2018. In this second change detection it is planned that that process will be undertaken, as far as possible, in a pre-operational mode with maximum participation by the local team in Dakar.

In parallel there will also be a continuing monitoring and evaluation activity designed to determine the impacts of the methodology on the availability of property-related information for Dakar. This is complementary to the sustainability of the IPP-related activities to be achieved by the transfer of technical skills, the use of the software tools developed, the concepts of maintenance and the inculcation of the value of a rigorous accurate and complete database which can be used as the basis for government self-funding revenue generation and the provision of other services.

The IPP Dakar Change project is a key element in data maintenance and can form a crucial role in the future by contributing to the sustainability of land-related initiatives of Government policy. It is hoped that an operational change detection process will help to engender a culture where data maintenance is recognised as an important element in all operations and services connected with land.



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Figure 1 Pleiades imagery from January 2017

(Source: Satellite Image Analysis for Operational Maintenance of a Property Database for Dakar City, Senegal, Milestone Report, Airbus, 2017)



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Figure 2 and Figure 3 Technical Training for the Data Collection Team

(Source: Satellite Image Analysis for Operational Maintenance of a Property Database for Dakar City, Senegal, Milestone Report, Airbus, 2017)



Figure 4 Grand Dakar Pilot Area

(Source: Satellite Image Analysis for Operational Maintenance of a Property Database for Dakar City, Senegal, Milestone Report, Airbus, 2017)



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Figure 5 Observed Mean Height Difference between November 2015 and January 2017  
(Source: Satellite Image Analysis for Operational Maintenance of a Property Database for Dakar City, Senegal, Milestone Report, Airbus, 2017)

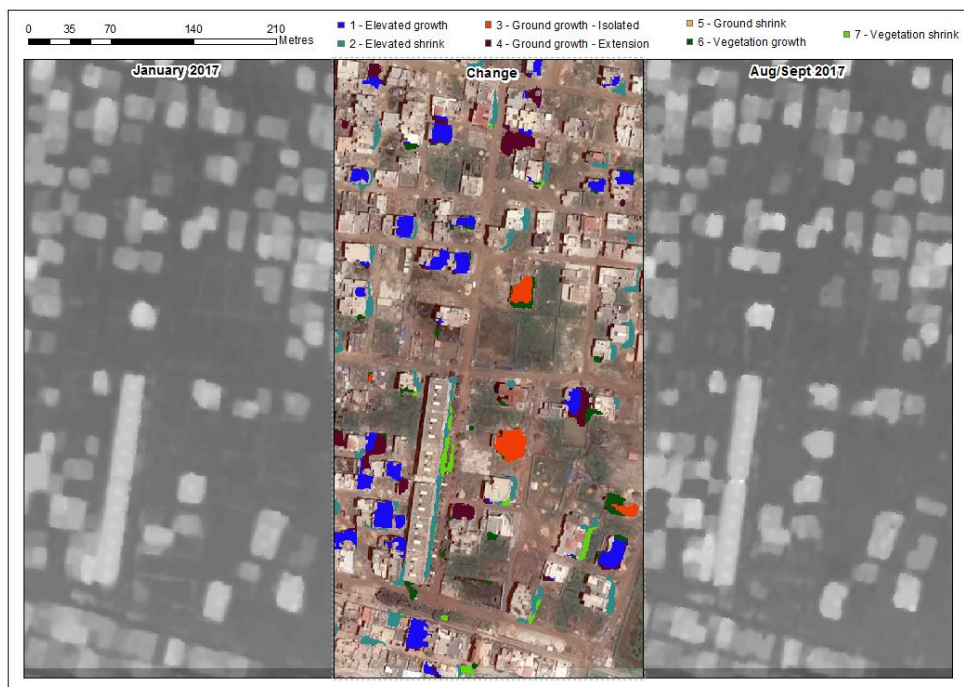


Figure 6 Observed Change Results



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(Source: Satellite Image Analysis for Operational Maintenance of a Property Database for Dakar City, Senegal, Milestone Report, Airbus, 2017)

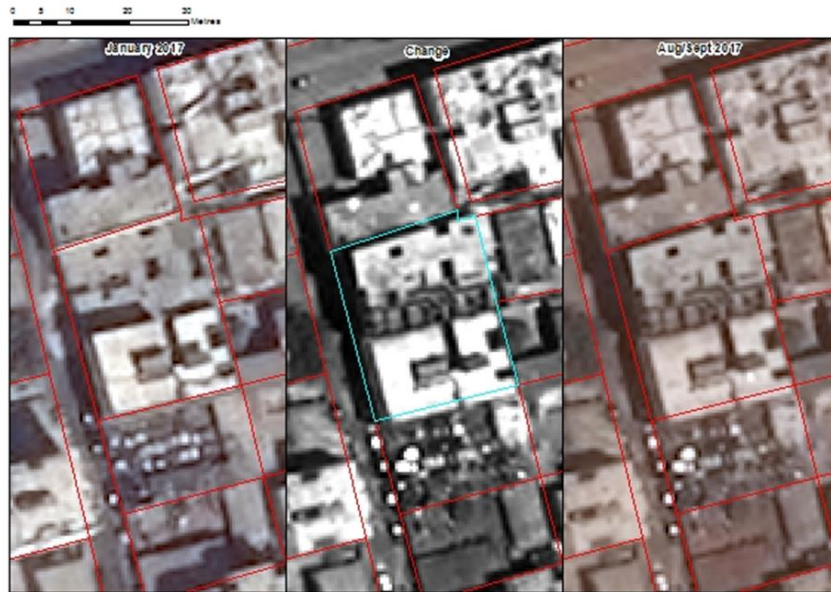


Figure 7 Building increase in height. The southern half of the highlighted property remains unchanged but the northern half has increased in height by several stories.

(Source: Satellite Image Analysis for Operational Maintenance of a Property Database for Dakar City, Senegal, Milestone Report, Airbus, 2017)