Comprehensive Satellite Constellation for Land Administration Assessment and Monitoring

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Abstract

1. Introduction

Africa as continent offers some of the richest natural resources in the world. It is recognised by its pristine beauty of wild animals, wide undisturbed natural environments and indefinite potential for development and economic growth. It is also true that the Africa continent face various harsh challenges primarily caused by the humans that occupy it. Addressing basic principles for prosperity such as education, leadership, political stability, health, population growth management, infrastructure, management of all resources, industrialisation of products, attracting investment, etc. is all stepping stones to establish a sustainable economy for any country.

Suitable land administration as a key principle to assess and monitoring progress within any country is a foundation block to measure progress. If land is not managed in a sustainable way to optimise prosperity, then the logic is the depletion of wealth and value of such a country. During this article a few examples will be illustrated using the unique constellation of radar and optical earth observation satellites operated by Airbus Defence & Space to practically demonstrate the value of geo-monitoring as well as the spatial information that can be derived from it. When such spatial information are analysed in a time series method, then evidence of the *status quo* on the ground becomes factual. Satellites such as SPOT 6, Pléiades, TerraSAR-X and Deimos-1 is key in this exercise and application areas such as agriculture, mining, and infrastructure will be illustrated.

2. Space based observing systems

In this section the author would like to introduce a unique satellite constellation that can offer a wide range of temporal, spatial and spectral diversity to address various geo-information requirements.

2.1 Optical assets

2.1.1 SPOT 6 & SPOT 7

The SPOT systems can provide target specific information to detect and identify objects larger than 4.5m. The system has a capability to take 60km wide strips up to 1 000km in length, or even to cover areas such as 300km x 330km in one satellite pass. The SPOT 7 satellite is due for launch in mid-2014 and is forecasted to be operational a few months later. These satellites will be an excellent resource to establish national baseline information for topographical maps and resource

management. The orbital path of the satellites enables a nadir revisit of every 26 days, yet also capable to do an off-nadir acquisition that exceeds 30 degrees. The latter enables a 2 to 3 day revisit per target opportunity – down to 1 day revisit capacity using wider acquisition angles.

In addition, SPOT 6 and SPOT 7 agility allows for targeting of any point within a 1500km-wide across track corridor (45° viewing angle). This also opens the way to various acquisition scenarios matching different applications, e.g. the strip mapping mode to collect wide areas in a single pass. When nominal acquisition scheme for the SPOT 6 and SPOT 7 satellites is north to south, they may also be tasked to follow linear targets such as communication lines, rivers or coastlines. The SPOT 6 and SPOT 7 system also incorporates native tasking modes for stereo or tri-stereo acquisition, for accurate 3D extraction purposes.

Pansharpened and orthorectified images are standard. The orthorectification process relies on Airbus Defence & Space worldwide elevation layer (Reference3D). The registration of SPOT 6 and SPOT 7 images on Reference3D enables a perfect overlay for applications implying multi-source or multi-date data in a GIS environment, facilitating change detection processing, map revision, or complex projects.

To summarize its strengths, SPOT 6 and SPOT 7 maintain key characteristics (both in terms of satellite performances and service) which guarantee the continuity of a High Resolution (HR) offer fitted for medium scale cartographic projects.

Table 1: Satellite specifications for SPOT 6 & SPOT 7

Sensors	
One camera	1 panchromatic 4 multispectral channels
12 bits	Native dynamic range per pixel at acquisition for meaningful information
PAN Colour	Simultaneous acquisition
Geolocation	• <20m CE90@30° without GCP • <10m CE90@30° with Reference3D

Products	
1.5 m	Panchromatic Pan-sharpened
6 m	Multispectral
Ortho rectified	As a standard Fully automatic processing thanks to location reset performed mostly on Ref3D products Monopass mosaics when contiguous segments are acquired during the same orbit pass
Per sq.km	Pricing model / Multi-Government

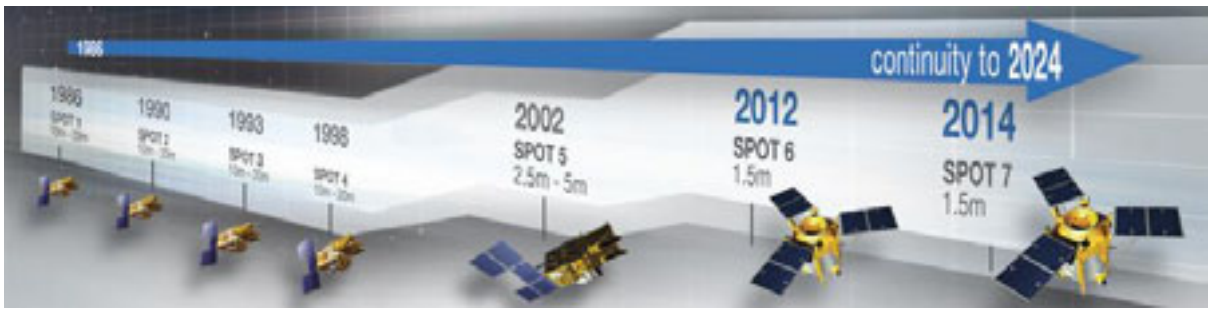

Figure 1: The SPOT satellite series continuity roadmap since 1986

Figure 2: SPOT 6 1.5m pansharpened
(source: © Astrium Services 2013. All rights reserved)

2.1.2 Pléiades 1A & 1B

The Pléiades system provides very high resolution imagery. The product includes a processed 0.5m panchromatic and 2m 4 band multispectral image. The highly agile system can target up to 20 targets within a 1 000k x 1 000km block with a 20km x 20km scene swath. This is the ideal system to collect very high resolution images over a specific target. The system provides for inner-daily revisit over a specific target (persistent tasking) or excellent periodic monitoring (up to daily). The identification of objects greater than 1.5m is achievable with this system complimented by its 12 bit spectral data (4096 values), enabling to distinguish objects in the darkness of the shadow more easily. It is an accurate, reactive and available system.

Table 2: Satellite specifications for Pléiades 1A & 1B

Sensors		Products	
One camera	1 panchromatic 4 multispectral channels	50 cm	Panchromatic Pan-sharpened
12 bits	Native dynamic range per pixel at acquisition for meaningful information	2 m	Multispectral
PAN Colour	Simultaneous acquisition	Ortho rectified	As a standard Fully automatic processing thanks to location reset performed mostly on Ref3D products Monopass mosaics when contiguous segments are acquired during the same orbit pass
Geolocation	8.5m CE 90 at nadir exc. specifications	Per sq.km	Pricing model

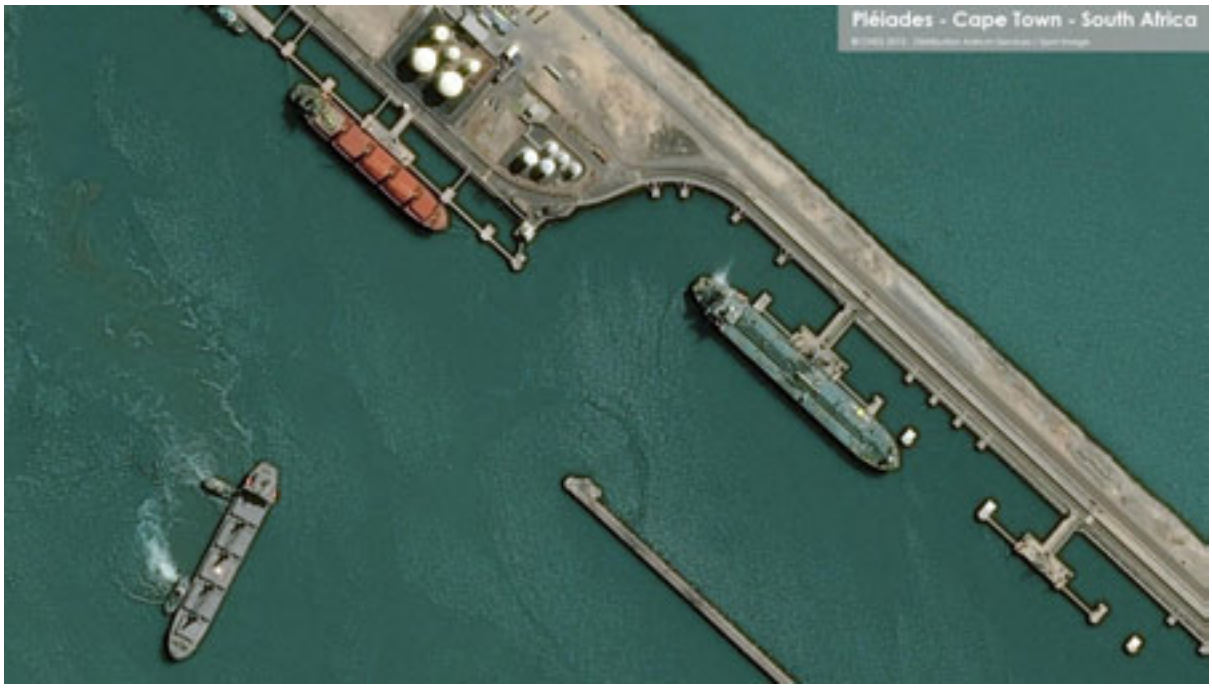

Figure 3: Pléiades pansharpened image (source: © CNES 2013. Distribution Astrium Services/ SPOT Image S.A, France. All rights reserved)

2.1.3 DEIMOS-1

Medium resolution satellites refer to a wide swath system with moderate spatial resolution of 20m+ ground sampling distribution (GSD). These systems can acquire a scene size of up to 900 000 sq.km as a single collection with a high revisit frequency rate. These systems are ideal to monitor large areas for example the monitoring of seasonal agricultural crops.

Table 3: Satellite specifications for Deimos-1

Mode and resolution	Multispectral (NIR, Red, Green): 22 m
Spectral bands	NIR: 0,77 – 0,90 µm RED : 0.63 – 0.69 µm GREEN : 0.52 – 0.60 µm
AOIs Size	Minimum size 6000 sq/km Up to 900.000 sq/km AOIs in 8bits mode
Revisit interval	2 days
Viewing angles	Nadir Acquisitions (up to 12°)
Satellite tasking	Yes, standard or priority programming modes (see feasibility study)
Image dynamics	8 bits/pixel or 10 bits/pixel

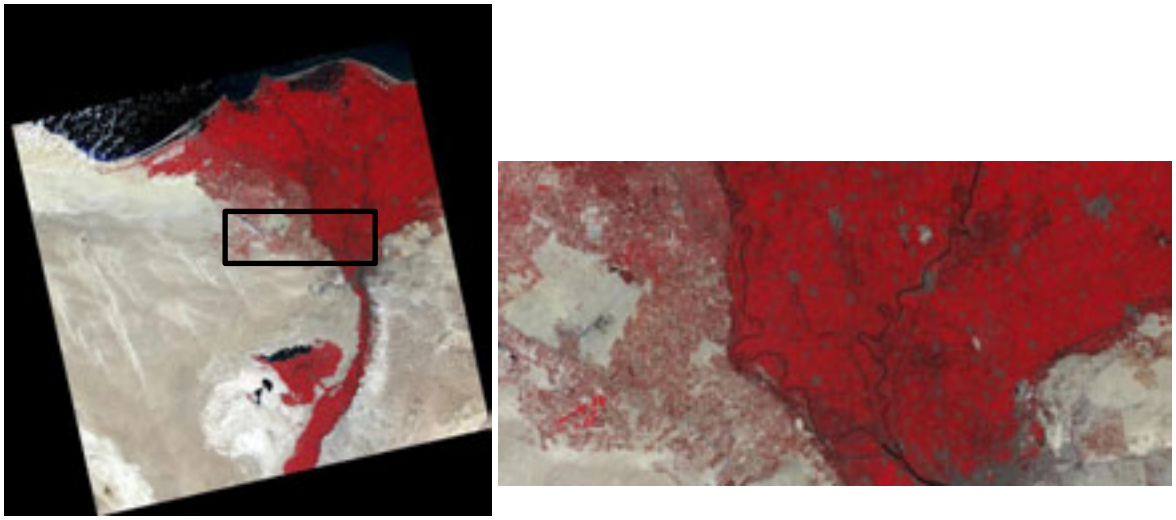

Figure 4: Deimos-1 image

(Source: DEIMOS IMAGING 2013. Distribution SPOT Image S.A. All rights reserved)

2.2 Radar Assets

2.2.1 TerraSAR-X

This synthetic aperture radar (SAR) satellite based system is a world leading X-band radar technology within its class with an excellent pointing accuracy. The satellite consists of several beam modes and can provide 0.25m to 40m spatial resolution data. The higher the resolution is the smaller the swath. The maritime monitoring beam in the form of WIDE ScanSAR (200km x 270km @ 40m GSD) and ScanSAR (100km x 150km @18m GSD) can offer large area specific ship detection. The StripMap and SpotLight mode is excellent for high precision monitoring of surface substance changes, up to 2mm - 4mm measurement accuracies. Time Series Interferometric Analysis (including techniques such as Persistent Scatter Interferometry and Small Baselines

Subset) is applied to derive the movement measurement over the area of interest (see figures 5 & 13).

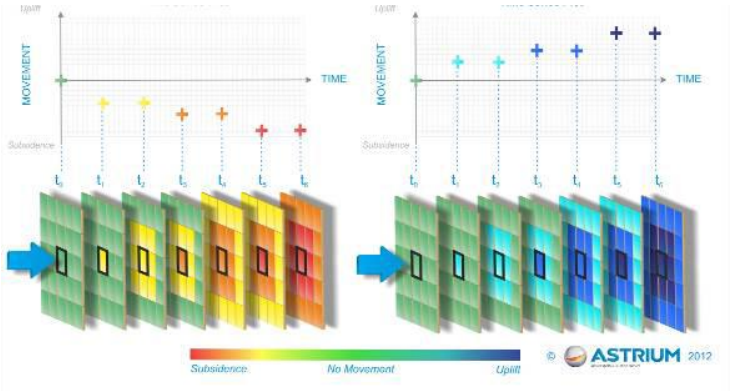

Figure 5: Time series analysis using multiple acquisitions. A time series will be available for every measurement pixel.

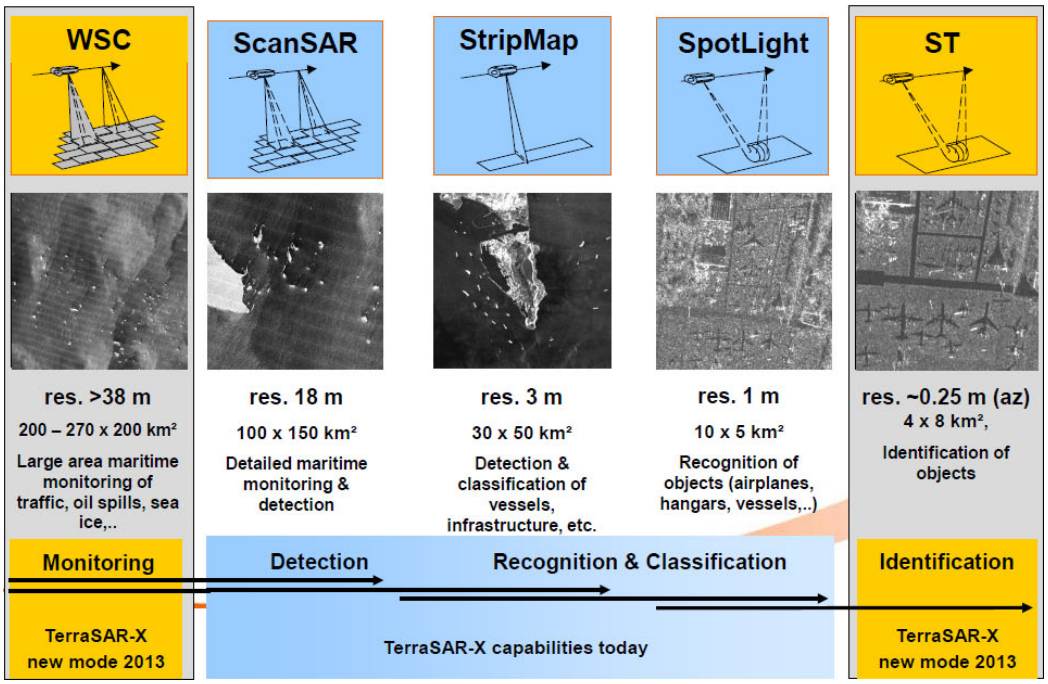

Figure 6: TerraSAR-X data product range

2.2.2 PAZ

The PAZ satellite will be the 3rd SAR satellite available within the Airbus Defence & Space constellation. It is a replica of the TerraSAR-X and TandDEM-X satellite series. The launching schedule for PAZ is set for 2014. This additional system will increase the monitoring frequency: global mean revisit time is predicted to at least increase from 43 h today to ~21 h in 2014 (see figure 6). This increase in data availability is ideal for maritime monitoring. The leading innovation to include AIS (Automatic Identification System) information at same time as SAR image acquisition due to PAZ's Sat-AIS receiver will leap-frog the surveillance ability for maritime from satellite.

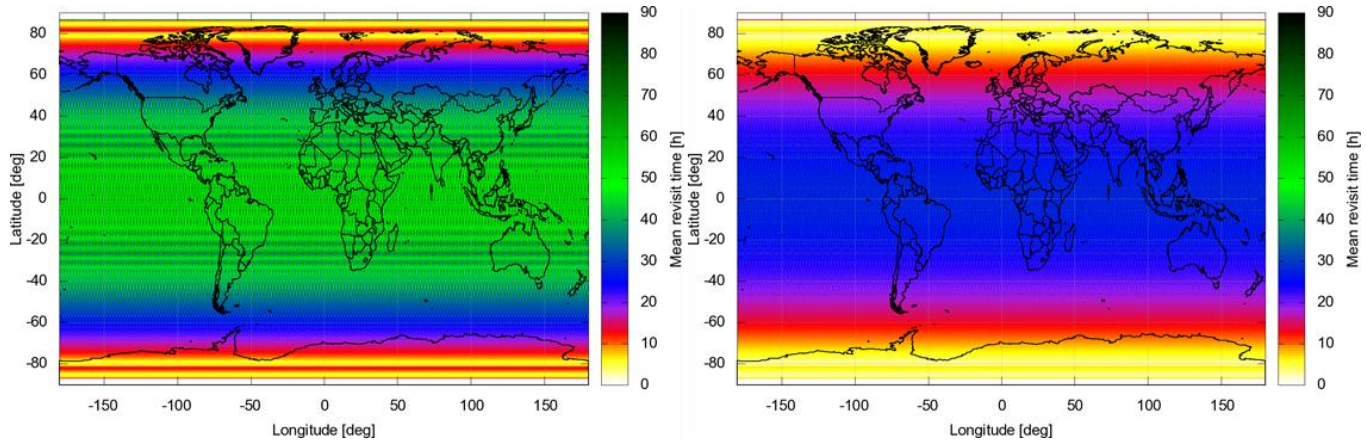

Figure 7: Global mean revisit will improve with PAZ

2.3 Elevation Models

Leading technology from Airbus Defence & Space is its diverse geo-elevation offerings, applying its satellite constellation to offer high quality digital surface models (DSM) and digital terrain models (DTM). From off the shelf available elevation models such as the Elevation 30 to newly tri-stereo/stereo collections to create a DSM/DTM over any area in the world is a certain unique offer.

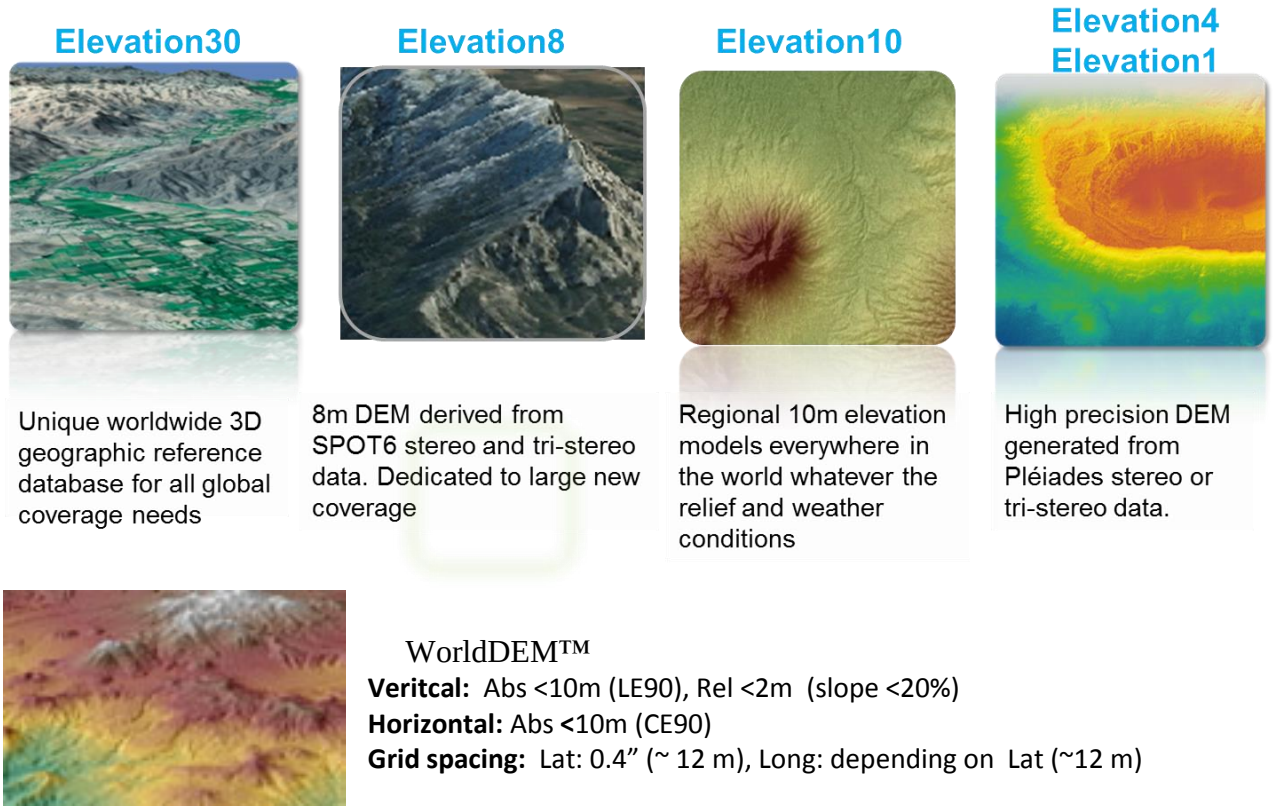

Figure 8: Geo-Elevation product suite available from Airbus Defence & Space

3. Geo-applications for land administration

Land administration in the current discussion is not only referred to as system to manage cadastre or the integration to a property taxation solution. Land administration in this article refers

to the efficient en effective management and control over a country's resources. The ability to identify suitable land capability for commercial agriculture as well as the managing of the fine balance between environmental protection and mining activities is *inter alia* relevant examples.

The mining investment into Africa during 2012 by foreign investors was estimated at USD 50 milliard, creating more than 106 000 sustainable job opportunities. The challenge is to manage these resources to the best of Africa and to ensure good governance to fight corruption as the rational for the establishment of the "Extractive Industries Transparency Initiative (EITI)".

3.1 Agriculture

The Africa continent is blessed with high agricultural potential in terms of land availability, soil and water, with specific emphasis to the central regions of Africa. The demand for food and food security solutions at country, regional and global level is a prominent worldwide discussion. If Africa can manage to commercialise its agricultural potential fully, it can certainly become one of the largest producers for a rich variety of food products. Fundamental pillars to achieve the latter are education, infrastructure, establishment funding, political stability etc. The contribution of remote sensing for agriculture is its ability to assist with spatial planning, land suitability indices, crop yield calculations, monitoring and precision farming. Applying a multi-sensor approach to analyse from macro (national) to micro level (small field) do provide for a rich platform for spatial information for agronomic applications.

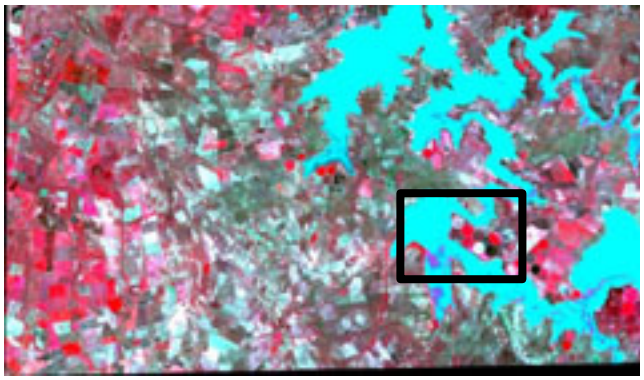

Figure 9: False colour Spot 6
(Source: ©Astrium Services 2013. All rights reserved)

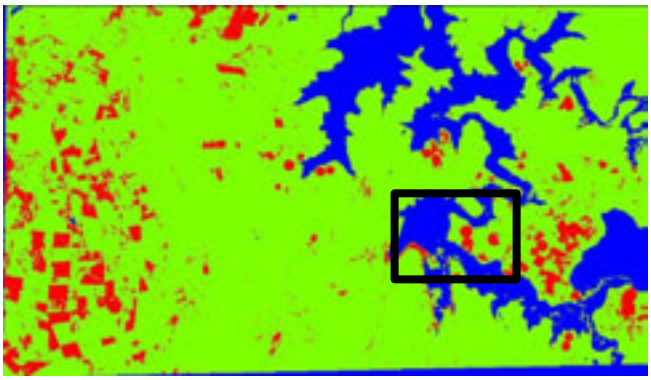

Figure 10: Spot 6 NDVI colour coded index

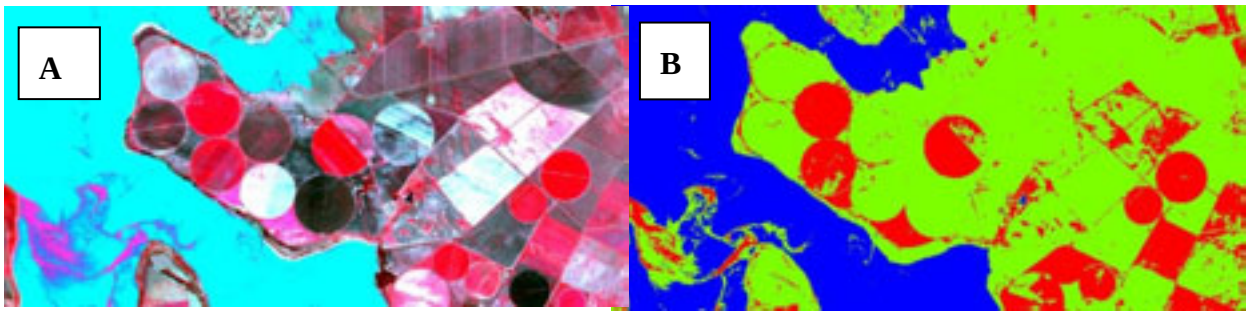

Figure 11: (A) False colour Spot 6 (B) Spot 6 NDVI colour coded index
(Source: ©Astrium Services 2013. All rights reserved)

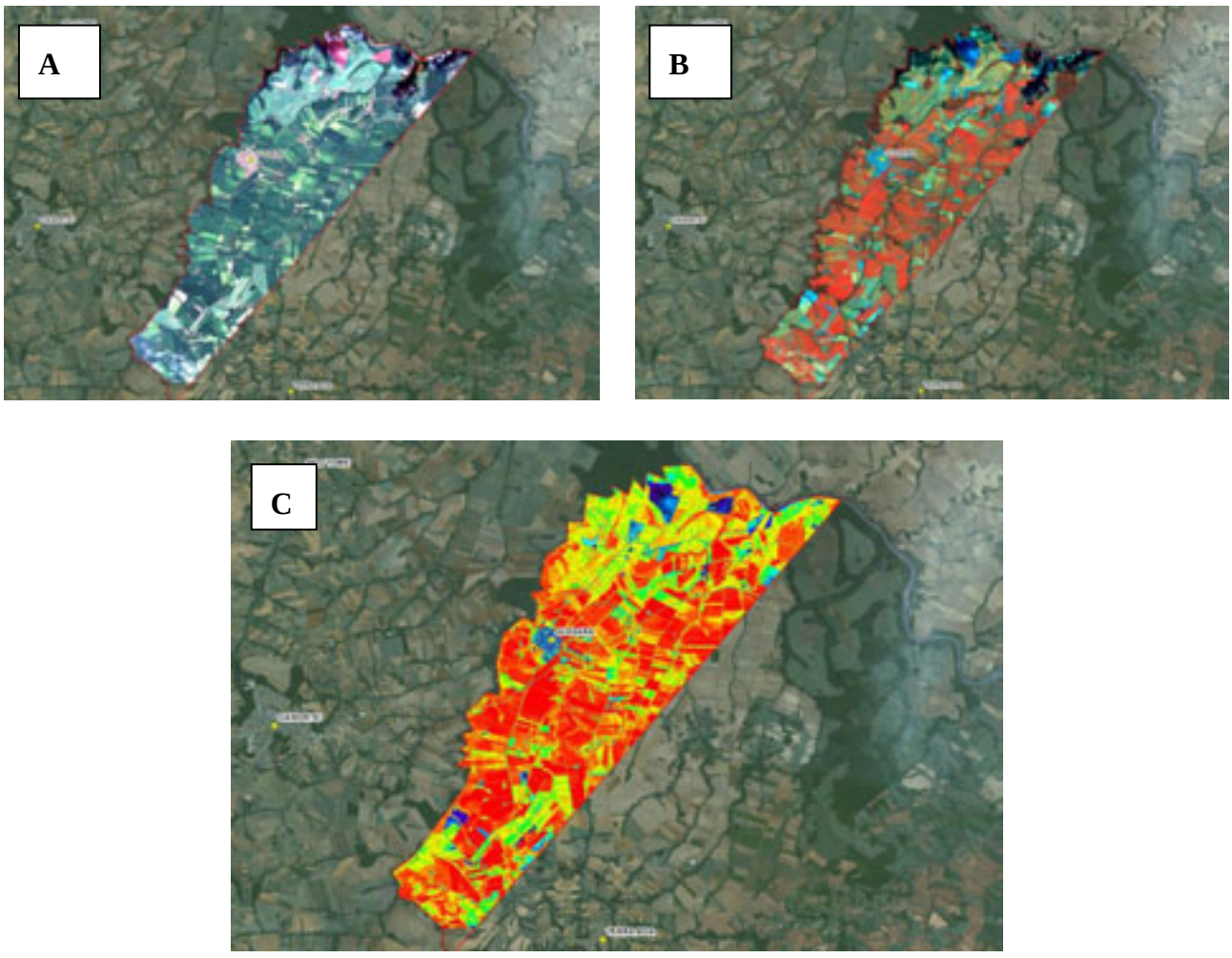

Figure 12: SPOT 6 satellite image, (A) natural colour composite, (B) False colour composite and (C) NDVI indices over agricultural fields. (Source: © Astrium Services 2013, All rights reserved.)

3.2 Mining

The geological diversity on the Africa continent provide for rich mineral fields that includes gold, diamonds, coal, copper, platinum, titanium, etc. The existence of many oil and gas fields further excels the interest in the Africa content from various developed nations. Mine exploration activities is distributed all over the Africa continent. Open surface mines have especially create long term devastation on the environment. Years of sub-surface mining such as deep gold mines created acid water and if it surface create serious environmental threats, for example the East Rand region in South Africa. Therefore, it is critically important to balance the economic value of mines versus the impact it has on the environment. This can be achieved through good spatial monitoring and management principles. The TerraSAR-X satellite is the ideal technology to monitor any change in slopes stability (subsidence, stability and uplift). Various mines make use of "tailing dams", which contains highly polluted mine water. If such a tailing dam breaks or the water filter through to non-toxic ground water tables or natural rivers then disaster is evident. Optical satellites such as SPOT 6 and Pléiades are ideal for monitoring any contamination in the surrounding vegetation around mine activities. The NDVI indices is a well-known remote sensing algorithm that can monitor vegetation health over a period of time, using especially the near-infrared (NIR) multispectral band of the satellite.

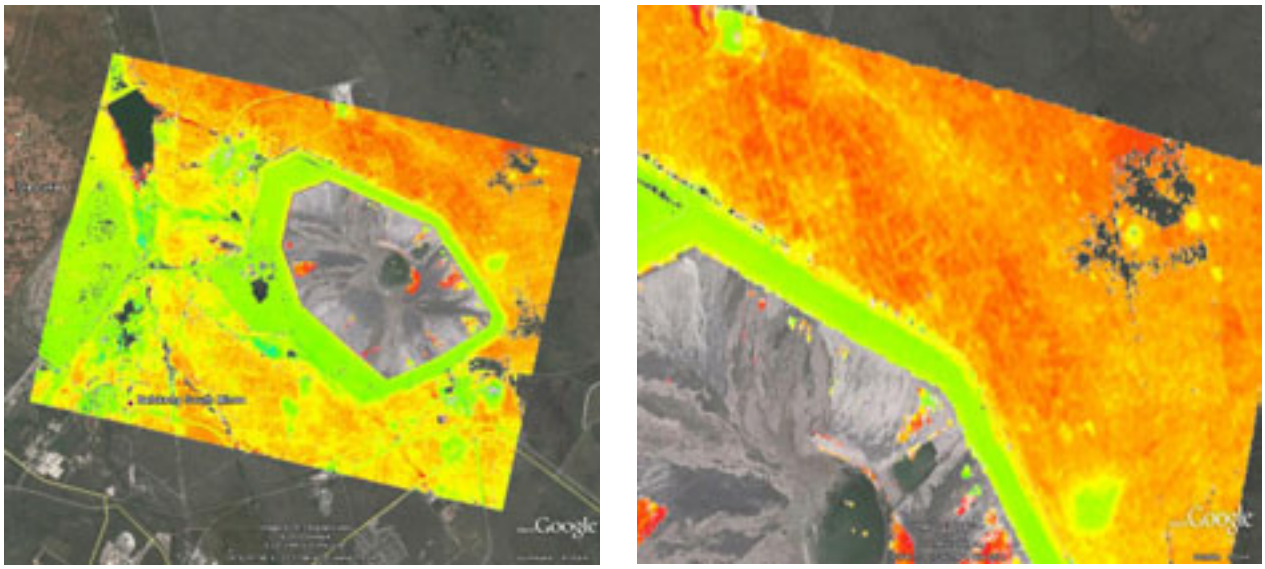

Figure 13: Slope stability measurement using TerraSAR-X

(Source: © DLR 2013. Distribution Astrium Services/ Infoterra GmbH. All rights reserved.)

Figure 14: Open surface mine examples (A) Péiades (B) SPOT 6
(Source: (A) © CNES 2013, Distribution Astrium Service/SPOT Image S.A., France. All rights reserved (B) ©Astrium Services 2013. All rights reserved.)

3.3 Infrastructure

Large capital investments in infrastructure such as roads, power plants, bridges, industrial and housing developments do place an extra responsibility on a country's government to manage and control these projects. Continues monitoring of these projects during the project lifecycle is critical to ensure that these projects are on schedule and that payments are done according to measurable achievements. The constellation of satellites offered by Airbus Defence & Space provides exactly this service. The frequent monitoring and reporting on any changes that occur during a project provides for factual spatial information. Spatial information contributes to the visual interpretation of an area, the measurement of physical changes, area measurement, linear measurements, etc.

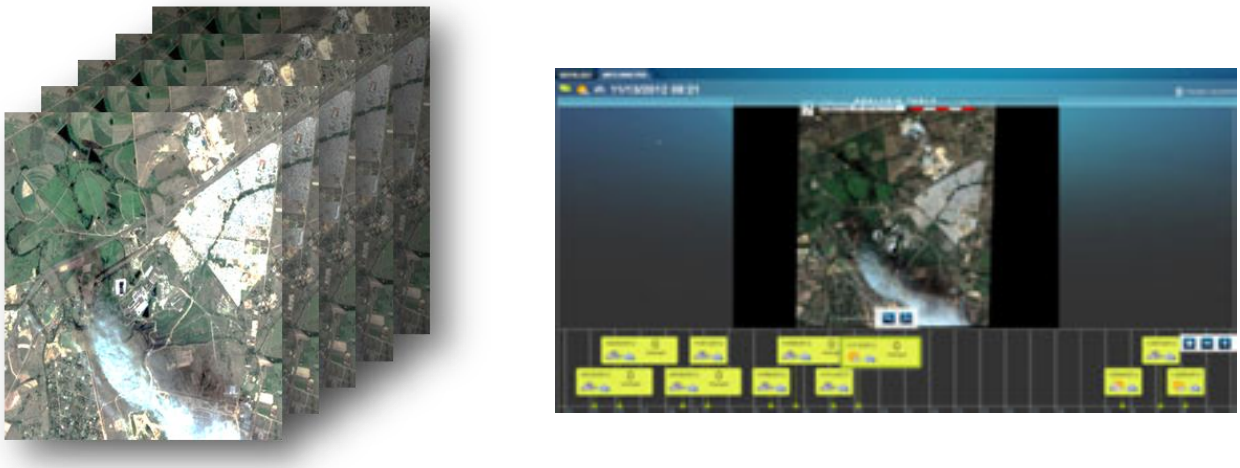

Figure 15: Multiple Pléiades acquisitions over a specific target monthly to identify newly constructed houses

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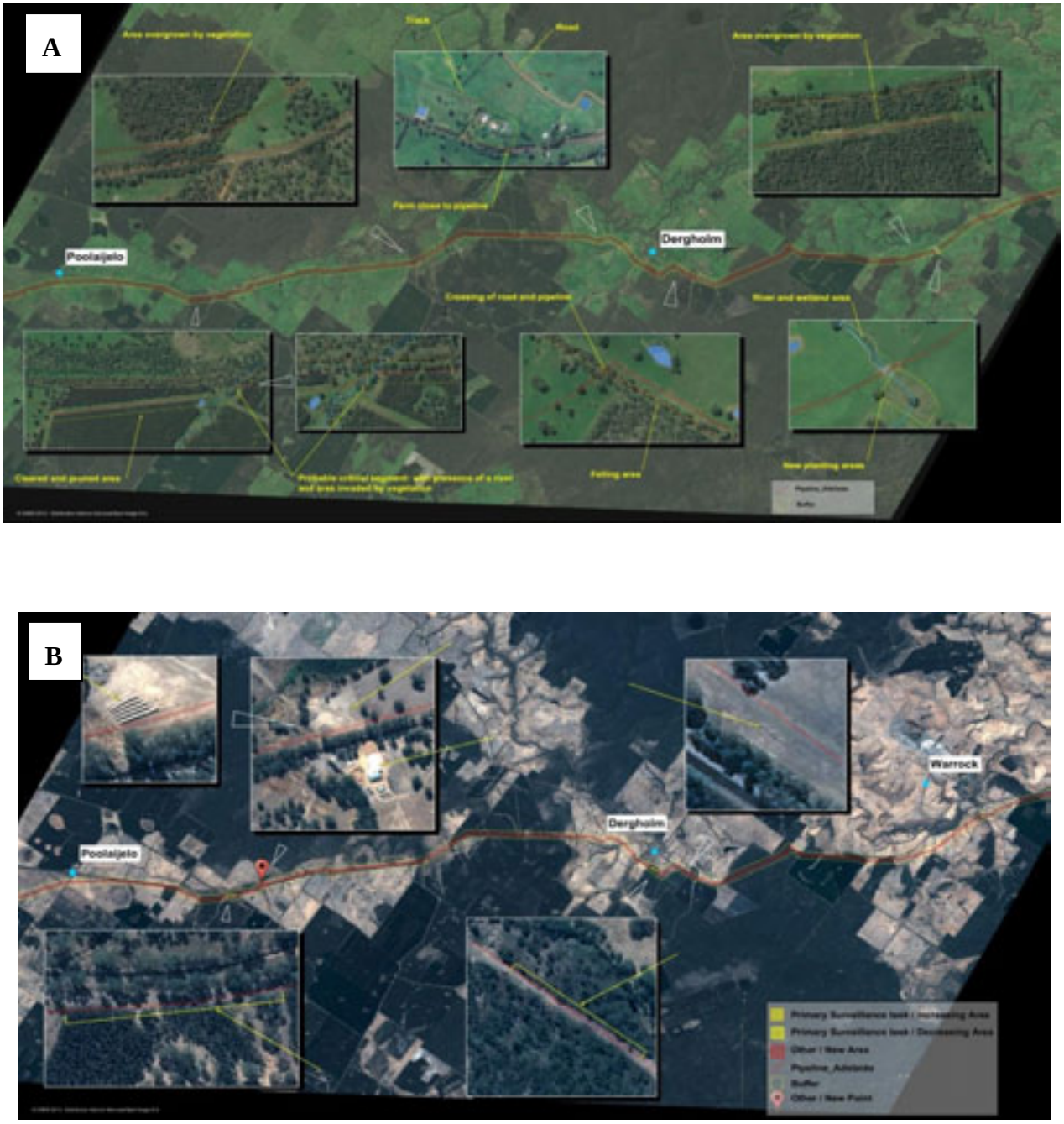

Figure 16: (A) & (B) Pléiades monthly monitoring over a pipeline corridor
(Source: © CNES 2013, Distribution Astrium Service/SPOT Image S.A., France. All rights reserved)

Figure 17: (A) (B) (C) (D)Pléiades time series analysis over a construction site, Arena Corinthians Soccer Stadium, Brazil (Source: © CNES 2013, Distribution Astrium Service/SPOT Image S.A., France. All rights reserved)

3.4 Land administration

Land administration in the sense of managing cadastre, deeds and property information is a domain that needs to be highlighted. A country that manage and control its property information correctly can ensure consistent property tax income and good governance.

The Land Administration, Valuation and Information Management System (LAVIMS) project was an initiative by the Government of Mauritius designed to modernise land administration by greatly improving access to information between different departments and creating a complete and up-to-date national valuation roll. LAVIMS is really four sub-projects in one including: development of the Cadastre; implementation of a digital Deeds Management System; Valuation of properties; and Information Management. At the highest and strategic level, it is the objective of the authorities to establish a beneficial LAVIMS that will lead to, amongst other things:

- Improved urban planning and infrastructure development; and
- Enhanced environmental management improved production of national statistical data.

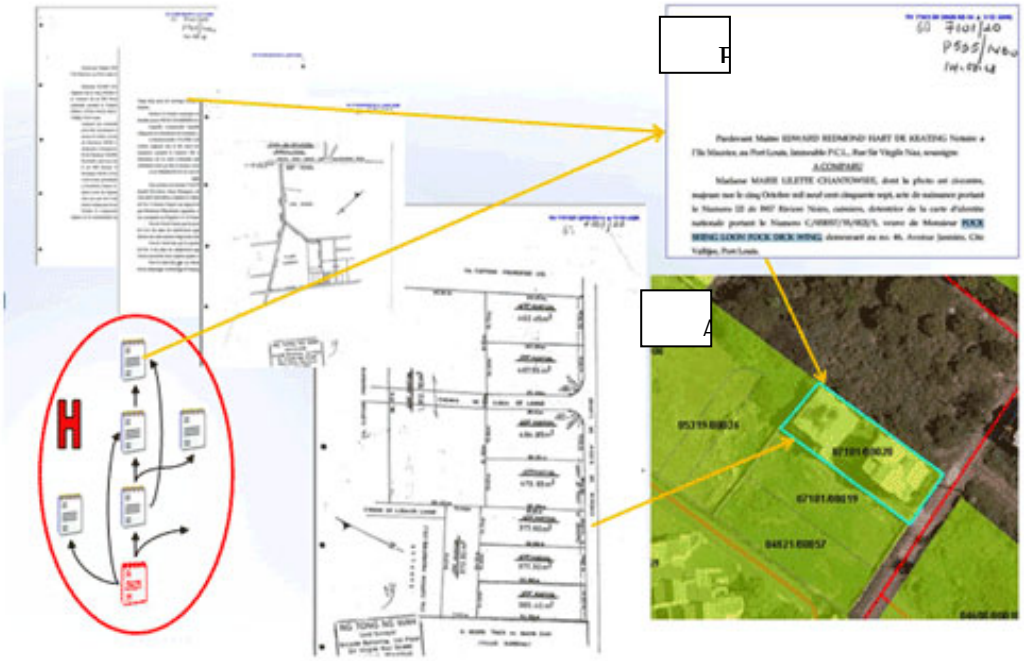

Figure 18: Extraction from the LAVIMS system, illustrating the vectorised cadastre (A) that is linked with the original property deeds (B) ownership document

4. Conclusion

Satellite observation systems can contribute to detect change, identify structures or measure surface substance changes in a frequent monitoring schedule. The constellation of satellites available from Airbus Defence & Space can collect geo-spatial information over very large geographical areas or target specific. The availability of optical as well as radar satellites can contribute to collect information even in challenging weather conditions. The orbital positions of

the constellation of satellites enable a scope for various monitoring options. Applying this earth observation technology effectively can contribute to the management of various land administration activities in Africa. It is a technology that can objectively and factually provide information for the public as well as private sector to monitor progress, improve resource management and ensure sustainable implementation of socio-economic projects. It is the ideal spatial information partner to ensure informative planning and monitoring as a contributor to the sustainable prosperity for Africa.

5. References

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