COST EFFECTIVE BUILDING CAPTURE AT CONTINENTAL SCALE USING
SATELLITE IMAGERY AND AUTOMATIC FEATURE EXTRACTION

PSMA AUSTRALIA

Dan.Paull@psma.com.au

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Abstract

Many developing countries face land governance issues that are exacerbated by global trends of rapid urbanisation and climate change. The need for an effective and timely response to issues such as population movement can be inhibited by fundamental challenges around the sharing of information, integrating policies and systems, and ensuring data integrity.

Yet recent advances in satellite image processing, machine learning technology and cloud computing have opened new opportunities for data capture at a scale, speed, quality and cost not possible before. These technologies and techniques have been employed to generate data products such as Geoscape in Australia, which is capturing the entire continent’s built environment, and linking data about buildings and land cover to a national geospatial base that includes addresses, cadastral fabric and transportation networks. By linking rich attributes and data types, Geoscape provides a better understanding of what exists at every address to suit geospatial analytics for the whole of Australia.

This top-down technology-driven approach, when combined with bottom-up approaches such as participatory mapping, can establish comprehensive data to support land governance and help address foundational challenges faced by many developing countries – namely to support good decision-making, planning, and ultimately, sustainable development.

Key Words: Cloud Computing, Geospatial Mapping, Land Administration, Participatory Mapping, Satellite Image Processing
Introduction

Advances in satellite image processing, machine learning technology and cloud computing have opened up new opportunities for large-scale capture of data describing the built environment at a quality and cost not possible before.

In Australia, Geoscape, a product developed by PSMA Australia¹ in partnership with global technology partners, provides an example of this technology in practice at a continental scale.

Sophisticated datasets from Geoscape are being used to support Australia’s national, state and local government policy development and service delivery, as well as informing corporate entities in their planning for growth and productivity. This rich decision support information is easily queryable and extractable, having already brought together many different attributes and data types to provide a better understanding of what exists at every address throughout Australia.

Australia’s land administration systems are mature enough to enable the integration of this data into existing land administration policies, functions and infrastructure.

The challenge is to transfer this cost-effective technology to developing countries – most of whom only have 30 per cent national cadastral coverage (FIG/GLTN, 2010) – to build capability that is ‘fit for purpose’ to meet the often informal land tenure and administrative systems, and credibility issues, faced by countries with limited or fragmented land data.

From a land administration point of view and to achieve Sustainable Development Goals, it is expected that details about the built environment be combined with details about the natural environment (Williamson, Grant & Rajabifard, 2005). Sharing this information through a Spatial Data Infrastructure (SDI) “facilitates the sharing, access and utilisation of spatial data across different communities to better achieve their objectives, [and] provides a mechanism to facilitate this integration of cadastral and topographic data to facilitate decision-making” (FIG/GSDI, 2012, p. 15).

¹ PSMA Australia is an independent and self-funded entity owned by all the governments of Australia. Through the creation of national foundational geospatial datasets it enables Australian governments to collaborate on national geospatial matters and provide fundamental infrastructure for a digital world. PSMA aims to maximise the value to the nation of geospatial data by providing access to location datasets on behalf of all the governments of Australia. It is for this reason that our shareholders measure their return not by the size of the dividend but by the value delivered to the nation through the activities of the company.
As the world faces rapid urbanisation and the effects of climate change, developing countries must be able to access useable data in an economically feasible, transparent and reliable way to enable better land management, basic quality of life, and a sustainable approach to growth and change.

The potential value of geospatial information for addressing complex social, environmental, and economic issues is growing, especially if combined with complementary approaches such as community mapping and integration with broader geospatial platforms.

Yet developing nations continue to encounter fundamental challenges around the sharing of information, integrating policies and systems, and ensuring data integrity.

This paper reflects on the potential for Geoscape’s innovative approach to support good land governance in developing nations and underpin the achievement of Sustainable Development Goals, by addressing these questions:

- What aspects of Geoscape technology and methodology could help developing nations?
- How could complementary approaches such as participatory mapping support the technology?
- Could the data be made available through supranational bodies such as the World Bank or United Nations?

**Addressing Land Governance Challenges with Technology**

Land is a primary asset for every country to manage, yet each country and jurisdiction faces challenges in sourcing, updating, disseminating and sharing relevant geospatial information – then linking it to existing systems, policies and processes.

Enemark (2009) argues for land administration systems to be specifically designed as an enabling “infrastructure for implementation of land policies and land management strategies in support of sustainable development” (p. 5), and to take a broader, more integrated view of tenure, value, use and development of land to deliver overall policy objectives.

Detailed spatial information about buildings, and the ability to track changes in the built environment over time, can enable governments to get on the front foot, set policy, and manage tenure, land use, value and development during critical time periods where the imperative is keeping pace with change. An ability to track in ‘real time’ is particularly relevant to enable preparation for natural disasters or monitor population movement into urban areas.
Spatial enablement can support good governance, but “it needs to be regarded as a concept that permeates all levels of society – government, industry and citizens, and its ability to flow through all levels of society will depend primarily on the spatial data infrastructure (SDI) and land administration system” (FIG/GSDI, p. 8).

Within land administration specifically, SDIs need to enable “detailed information and reliable administration of land from the basic foundational level of individual land parcels to the national level of policy implementation” (Enemark, 2012, p. 7).

In the developed world, this ability to effectively manage land is often supported not only by geospatial technology, but by established land administration systems, private sector and government funding, organisational cooperation and alignment with policies.

Yet there are still obstacles facing all countries around outreach and capacity building, with “institutional and political will to publish and therefore share data [being] largely absent in many countries” (Dasgupta, 2009, p. 79). Due to the limited coordination or cooperation around SDIs and data collection, particularly in developing countries, it is difficult to facilitate a digital data exchange, and “there is usually no nationwide SDI and usually no lead agency…to create one” (Dasgupta, 2009, p. 80).

For developing countries, these challenges are significantly multiplied where high levels of informality, inconsistency and reactivity make it difficult to access a reliable evidence base to support decisions across the spectrum of activities involved in land and natural resource management.

Further, there are a range of fundamental and complex land management issues facing many developing countries, such as:

- defining land ownership, legal rights and security
- data ownership and willingness to share data
- over-population or slum living due to rapid urbanisation
- corruption
- poor administrative procedures and systems
- insufficient funding
- lack of foundational cadastral information.

Many developing countries have used cadastral systems and approaches that simply do not meet their needs around informal ownership. As noted by Enemark (2012), when ownership falls outside of the country’s land administration system (which, in some cases, encompass large proportions of land), it can
cause significant issues, “for example in cities, where over one billion people live in slums without proper water, sanitation, community facilities, security of tenure or quality of life” (Enemark, 2012, p. 13).

The UN-HABITAT continuum of land rights proposed under the Social Tenure Domain Model (STDM) (FIG/GLTN, 2010) is a method for capturing informal ownership of land by combining satellite data with on-the-ground agreement about tenure. According to the FIG Report, the continuum:

…provides different sets of rights and degrees of security and responsibility. Each enables different degrees of enforcement. Across a continuum, different tenure systems may operate, and plots or dwellings within a settlement may change in status, for instance if informal settlers are granted titles or leases. Informal and customary tenure systems may retain a sense of legitimacy after being replaced officially by statutory systems, particularly where new systems and laws prove slow to respond to increased or changing needs. (p. 9)

The technologies and techniques employed to generate Geoscape, such as high resolution multispectral satellite imagery and automated feature extraction, could help to establish comprehensive data about buildings as a powerful proxy for cadastre. This approach would in effect help to ‘reverse engineer’ the cadastre without the need for expensive field surveys, helping to address issues like land tenure. When combined with complementary approaches such as participatory or community mapping, this capability offers a relatively quick and cost effective method to capture essential geospatial information that is flexible to the needs of the jurisdiction.

The availability of data is only one (important) factor in the complex range of land issues that today’s global technologies can support. Arguably, creating a spatial framework must combine foundational datasets with community input – ensuring a fit for purpose approach relevant to the area – along with a clear definition of land ownership (using the continuum of land rights).

This high level of integration is required to address multiple social, economic and environmental issues, which are drivers for collecting and understanding population movement data and achieving sustainable development goals.

**Continental Scale Data to Manage Rapid Urbanisation**

Urban cities are hubs of activity and innovation, and their growth is rapid – particularly in developing nations. Cities generate the majority of global GDP, and bringing populations into cities is a significant step towards the achievement of the Millennium Development Goals (MDG), helping to address poverty, and provide access to better amenities and services (World Bank, 2013).
The growth is immense. It is estimated that more than half of the global population lives in cities, with the 3.7 billion urban population set to double by 2050 (Runde, 2015). In Australia, urbanisation has already reached 89 per cent (World Bank, 2015), yet it is the “developing world’s urban centers [that] are expected to burgeon, drawing 96 percent of the additional 1.4 billion people by 2030” (World Bank, 2013).

While cities are viewed as the cornerstone of the world economy, when they form so quickly there is little time for essential planning of resources such as land, water and other amenities. Accordingly, “urbanization can be a positive, but if poorly managed will only amplify existing challenges” (Runde, 2015).

This is a serious reality facing many developing nations, and where today’s newest forms of technology can play a crucial role in the creation of smarter cities. At a 2012 World Bank workshop on embracing smart cities for sustainable growth, it was noted that data is key to any smart city. In fact, “the promise of ‘smart cities’ is their ability to collect, analyze, and channel data in order to make better decisions at the municipal level through the greater use of technology” (World Bank, 2012).

While planning for and creating modern infrastructure for smart urban cities from the ‘top-down’ is the ideal approach, it isn’t the way many developing countries are able to manage land. With the help of continental-scale data that provides analytical, customised results, land administrators can support Enemark’s concept of a flexible and fit for purpose spatial framework in developing nations (Enemark, 2012, p. 14): “When considering the resources and capacities required to build such spatial frameworks in developing countries the western concepts may well be seen as the end target but not as the point of entry.”

**Satellite Imagery to Track and Respond to the Impacts of Climate Change**

The impacts of climate change are being felt globally. Extreme weather events, rising sea levels, food insecurity and availability of water are all examples of the impacts. Yet it is the developing world feeling these impacts more directly and according to the Center for Global Development (CGD), this is “catastrophic for the poor” (Busch, 2014).

As a synopsis of the Intergovernmental Panel on Climate Change (IPCC) report, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, the CGD summarises the regressive impacts for developing nations as:
• extreme weather risks being “amplified for those lacking essential infrastructure and services or living in poor-quality housing and exposed areas”
• the rise of sea levels affecting “low-lying coastal zones and small island developing states and other small islands”
• food insecurity via changes in “food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings”
• an increase in health issues related to temperature change or disease, “especially in developing countries with low income”
• the likely exacerbation of poverty and formation of “new poverty pockets”
• the displacement of populations (Busch, 2014).

To enable adaptation to these changes, governments need to be able to accurately track population movement, predict future movements and plan for natural disasters. Given that the impacts are arguably being felt – and will continue to be felt – more significantly by developing nations, there is no better time to embrace the latest technology and geospatial approaches to support governments in their quest to understand their land and support their people.

The Essential Role of Technology

Based on this current situation analysis for many developing countries, and the range of proposed solutions offered by global experts including the International Federation of Surveyors (FIG), UN-HABITAT, and the Global Land Tool Network (GLTN), technology has an essential role to play.

Utilising recommendations such as the STDM, functional and integrated SDIs (built to be ‘fit for purpose’), greater international, national and jurisdiction collaboration, and the sharing of data, perhaps faster progress can be made to overcoming the developing world’s fundamental land challenges.

The potential value of cost-effective geospatial information to address the complex issues is growing. Relatively low resolution or coarse images can help countries assess population movement, plan for natural disasters, and when combined with other data, have been shown to help local government decision making in countries such as Tanzania (Deininger, 2016). On the other hand, high resolution and accurate satellite images can be essential for determining boundaries and tenure in slum areas near city centres where the land value is very high (FIG/GLTN, 2010).
Never before have we had access to the breadth or capability of technology available today. The rapid advances in satellite imagery and machine learning technology in recent years has opened up a world of possibilities requiring less human intervention. The power of algorithms to extract data from imagery without human involvement significantly reduces costs and error. These competencies are no longer only limited to rich countries – it is feasible to capture continental scale data at a cost that makes economic sense for developing countries.

The techniques being applied to capture and maintain continent scale information efficiently and effectively is attracting significant interest. Many countries are interested in the potential Geoscape has to rapidly and cost-efficiently fill their geospatial information gaps. In particular, this would support the UN’s Sustainable Development Goals by helping to establish important economic infrastructure such as address and land registration systems as well as improving the delivery of humanitarian and natural disaster relief.

Geoscape is complementary to the three key demands of Enemark’s sustainable land governance (Enemark, 2012):

1. When a **spatially enabled** government or society makes their location and spatial information available to people and businesses, this encourages creativity, with potential for proactive economic, societal and environmental decision making. Geoscape is intended to be a high-value data product used by organisations to enable innovation and improve risk management, infrastructure planning, service delivery, environmental conservation and more.

2. The availability of spatial information is limited in many developing countries, where “the cadastral coverage is less than one third of the country and the nationwide spatial framework is merely at a stage of entry” (Enemark, 2012, p. 10). Given this disparity in stages and capability around land administration, Enemark argues that developing countries need to focus on what is fit-for-purpose, as a “flexible approach to accuracy and identification rather than copying the western style of cadastral mapping” (Enemark, 2012, p. 10). Geoscape’s technical capability can provide basic foundational datasets, which, when combined with complementary approaches such as community participation, could form a solid backbone to a spatial framework. Similarly, the Geoscape approach to maintenance can be highly customised to address priority areas for updates, such as urban fringes or environmentally sensitive areas.

3. In support of sustainable development and the Millennium Development Goals, land management is now a global issue. Every country must focus on the impacts of climate change, food security and rapid urbanisation for the greater good. Enemark argues that land professionals play a key role in support of the
global agenda. Geoscape can provide valuable data to governments and business to model urbanisation trends, better prepare for natural disasters, prioritise areas for accuracy upgrades and adapt to the changing needs of their populations.

When taking this fit-for-purpose approach, products like Geoscape can support a spatially enabled society. The role of government is only part of the equation in any country’s approach to land administration or spatial enablement – in fact, embracing private sector and community input will help societies become spatially enabled (FIG/GSDI, 2012).

There are numerous examples of the efforts developing nations are taking to improve their land governance and SDI. At different phases of implementation – from converting analogue to digital, to establishing a solid foundational dataset – Geoscape’s technology could support these processes.

Hypothetically, Geoscape’s technology and techniques could assist with a range of evidence-based land governance challenges, for instance:

- Amhara’s rural land holding registration process (Belay, 2016) by offering a foundational dataset to support their move to digital record-keeping that is actively enhanced by participatory adjudication.
- Determining population hubs via buildings or structures to address spatial misallocation in Nairobi in terms of where land is devoted to slums compared to the desired location of slum residents (Lall, 2016).
- Malawi’s administrative and institutional reforms for land, housing and urban development (Muluzi, 2016) by providing foundational and maintenance data to support their efforts to create a Geographic Information System web portal and share data.
- Brazil’s deforestation monitoring system (Deininger, 2016) by using satellite imagery and algorithms to track trees and support sustainable practices.

**Valuable Input through Participatory Mapping and Crowdsourcing**

With the growth of geographically enabled consumer technologies, especially mobile devices and social media, online communities are increasingly using and creating geospatial data. This has enabled the rise of participatory or community-based mapping. Participatory mapping combines modern cartography tools with collaborative data collection methods to create community based spatial knowledge bases that make use of the expert knowledge of local inhabitants.

The participatory approach to mapping has, for example, supported the collation of data for:
• Albania’s forestry sector to determine land tenure and property rights
• OpenStreetMap.org
• portable navigational systems
• mapping locations of a variety of subjects like lighthouses, webcams and sports facilities through the Google Earth Community (Tulloch, 2007)
• citizen science communities, alliances and projects, which generate valuable research data online.

Community input in the form of explicitly volunteered information or the automated extraction of “probe” data from mobile devices, should now be viewed as a significant data resource for all countries.

In support of multispectral imagery and machine learning, participation from relevant communities can help to build foundational datasets and improve accuracy in less developed SDIs. This additional source of intelligence supports the fit-for-purpose concept recommended for developing countries (Enemark, 2012).

It is also recognised that rich datasets frequently exist at the municipal level (Carrera & Ferreira, 2007), and shouldn’t be disregarded for their contribution to a national SDI. Instead, Carrera and Ferreira propose a combination of top-down ‘standardisation’ and bottom-up data, supported by “technical mechanisms whereby towns will be enabled to accrue and maintain their municipal information in an inexpensive, efficient and sustainable manner” (Carrera & Ferreira, 2007, p. 49). This ultimately could “support higher-level integration for spatial planning and decision-making at the regional, state, national and international scale” (Carrera & Ferreira, 2007, p. 49).

At the Geospatial World Forum Conference in Lisbon, 2015, Fonseca and Gouveia argued that the emergence of volunteered geospatial information invites a new reflection on the role of a bottom-up model in the SDI context. This approach to sourcing data has the potential to broaden the audience, fill gaps, and enhance accessibility (Fonseca & Gouveia, 2015).

Immediacy of data is also a benefit of public participation, notwithstanding the concerns about accuracy. Yet the benefits of a bottom-up approach to creating and maintaining an SDI in developing countries seems to be a better fit for purpose. According to McLaren’s chapter of the Spatially Enabled Society FIG report (FIG/GSDI, 2012):

- Crowd-sourced data are people centric and have strengths in local knowledge, higher currency, a wider range of geospatial data, greater attribution and good vernacular. However, crowd-sourced data are not normally managed in a systematic manner with moderation and therefore tend to
have inconsistent coverage with variable and unknown quality and authenticity. Despite these weaknesses, crowd-sourced geospatial data are being used in an increasing number of professional and social applications where AAA geospatial data are not required. It is delivering significant benefits to developing countries where up-to-date mapping is sparse. (p. 55)

The principles of the UN-HABITAT STDM initiative are based on bringing the people and the land together. Using flexible and sometimes unconventional methods (backed by reliable satellite data), communities can support the mapping of their own data – if they have the right tools (FIG/GLTN, 2010). When data is sourced via cost-effective and reliable geospatial satellite imagery, it can then be clarified by the communities within informal land administration systems. As noted in a FIG report (FIG/GLTN, 2010):

People, living in informal areas in developing countries, who are visited by someone with an enlarged satellite image or aerial photo in his or her hands will give attention to this image or photo. The visitor will be surrounded by many people almost immediately. People really understand what they see on the image. They can identify the place where they live, and where their neighbours live. (p. 5)

Combining the efforts of Geoscape’s cost effective continental scope for forming a foundational dataset, with a bottom-up channel for data gathering, such as participatory mapping, may support a flexible approach to building an SDI in developing countries.

Building Global Linkages for Data Dissemination

In addition to the technical elements of an SDI, there is a strong argument for greater data sharing, transparency, communication and cooperation between organisations to build a robust framework (Dasgupta, 2009).

Already there are global geospatial linkages being made through the World Bank’s Platform for Urban Management and Analysis (PUMA), the UN-HABITAT Global Land Tool Network (GLTN), and the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM).

Similarly, Globalmap, an initiative promoted by the Geographical Survey Institute of Japan, is working to form a Global Spatial Data Infrastructure (GSDI), as a “a key pool of resources for GSDI development to exchange institutional and technological experiences and standards among many countries” (Dasgupta, 2009, p. 84).
Existing supranational platforms can potentially deliver data with impartiality and credibility to enhance the availability of geospatial data to government and private enterprise in developing countries.

Geoscape data could conceivably be delivered to a supranational portal that is centrally managed by one of the recognised global bodies – alleviating concerns about holding power over data, that can lead to corruption or conflicts over ownership, especially in developing nations. As concluded by Dasgupta (2009):

> A fundamental problem underlying data sharing and distribution is the belief that one gains power and influence from withholding information and controlling it. In fact, true power is held by those who distribute the information and whose information is used by senior political levels. Once this leap of faith is taken, as it has been in several countries, data sharing becomes remarkably easy. (p. 81)

Global dissemination of data sourced using Geoscape’s technology and techniques could enable jurisdictions to extract reliable, customised analytics or data for their own database or collection requirements. This central source could also enable ongoing data maintenance for identified priority areas. Plus, the data could be capably linked with existing datasets within these platforms for greater levels of analysis.

The potential opportunities for geospatial capture of entire continents, when linked with supranational platforms, is both exciting and arguably a necessary next step for geospatial mapping and sustainable development.

**How Continental Scale Capture Through Geoscape Works**

Geoscape provides continent scale capture of information about buildings and land use in Australia, one of the world’s largest and most urbanised countries, with a population of more than 24 million people (Australian Bureau of Statistics, 2016).

PSMA Australia is working with technology partners DigitalGlobe² and others to capture Australia’s built environment at scale and link it to a reliable geospatial base. The end product, Geoscape, links together many different attributes and data types, providing a better understanding of what exists at an address to suit geospatial analytics for the whole of Australia. This includes linkages to geocoded address and

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² DigitalGlobe is a leading provider of high-resolution Earth imagery, data and analysis.
property data. The resulting dataset provides easily queryable and extractable information to empower government decision-making, urban and regional planning, risk estimation, and emergency response.

Geoscape’s attribution, scale, scope and innovative approach is unprecedented anywhere in the world. It is enabled through the combined use of various disruptive and emerging technologies (see Figure 1), including:

- high and low resolution multi-spectral satellite imagery
- satellite derived digital surface and terrain models
- SWIR spectral analysis
- high quality national foundation data
- sophisticated geo-integration
- collaborative crowdsourcing
- high performance cloud computing
- machine learning and automated feature extraction
- high quality ground control.

**Figure 1: Integrated Aspects of Geoscape**

Source: PSMA Australia, 2016
Geoscape leverages DigitalGlobe’s WorldView-3 satellite-based sensors, which is a multi-payload, super-spectral, high-resolution commercial satellite sensor platform, providing 31cm panchromatic resolution, 1.24m multispectral resolution and 3.7m short wave infrared (SWIR) resolution. With an average revisit time of less than one day, it is capable of collecting up to 680,000 square kilometres per day.

This continental scale dataset will provide an increased level of knowledge about attributes of a location, particularly in terms of **buildings and feature linkages** (including polygon, roof area, pitch/complexity and roofing material, ground level coordinates for roof vertices, number of roof vertices, ground level building centroid, maximum roof height, solar panel indicator, residential land use indicator, feature level quality information), **vegetation** (including tree coverage and height, grass coverage and unspecified vegetation), **impervious surfaces** (including built up areas, roads and paths, bare earth), **land and water cover**, and related **property information** (such as geocoded address, cadastre boundary, property boundary, and zoning).

These attributes are often used in conjunction with property details, addresses and imagery with an ever-increasing need for 3D representation of both the ground model and surface model (including vegetation and buildings).

The power of machine learning simply enables computer systems to learn without being specifically programmed. In the remote sensing environment, the technique is applied very effectively over vast data stores to discover patterns at scale across varying environments. Rich information can be extracted from large data volumes and used for a variety of applications.

The full capture and production of Australia’s foundational dataset providing location, distribution and physical characteristics for over 20 million structures across 7.6 million square kilometres is expected to take just 18 months, and commenced in July 2016.

Geoscape is also applying collaborative crowdsourcing and machine learning to assist in the identification of features such as swimming pools and solar panels. Tomnod, DigitalGlobe’s crowdsourcing geospatial intelligence technology platform, was used to assess multispectral imagery and identify which properties contained pixels matching the spectral profile of a pool. In this manner, thousands of reliably labelled properties were collected in a matter of days.

This data was used to train DigitalGlobe’s PoolNet, a Convolutional Neural Network (CNN) that contains 16 layers of neurons and runs on a single GPU. CNNs are deep neural networks that are inspired by and
roughly mimic the human visual cortex. They are very effective in ‘learning’ from labelled images, using them as training to automatically infer rules and abstract properties for recognising objects, without explicitly being told what to look for. The input to PoolNet is an array of property pixels, obtained by clipping out the pixels of a pan-sharpened satellite image that correspond to that property. PoolNet is trained by progressively feeding it properties with known labels; it then refines its rules in order to best match the known output.

\textit{Attribution}

Attribution selected for Geoscape was derived through market engagement, the assessment of value to Geoscape as a holistic product, and the capability to deliver at a quality and coverage suitable to satisfy the broad market need. In Australia, market and cost factors led PSMA to define the data attribution differently between urban and rural captures, as listed in Table 1.
Table 1: Overview of the Attributes of Geoscape

<table>
<thead>
<tr>
<th>Class / Attribute</th>
<th>Delivery Category</th>
<th>Urban</th>
<th>Rural Balance</th>
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<tbody>
<tr>
<td><strong>Building Attributes</strong></td>
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<tr>
<td>• Address count</td>
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<td>• Roof shape</td>
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<td>• Roof type</td>
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<td>• Solar panel indicator</td>
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<td><strong>Building Polygon Attributes</strong></td>
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<tr>
<td>• Roof outline polygon</td>
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<tr>
<td>• Ground level Z value for roof outline</td>
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<tr>
<td>• Vertices and centroid</td>
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<td>• Number of roof outline vertices</td>
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<td>• Roof area</td>
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<td>• Maximum roof height</td>
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<td>• Eave height</td>
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<td><strong>PSMA Data linkages:</strong></td>
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<td>• G-NAF</td>
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<td>• Residential land use indicator</td>
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<td>• Swimming pool address indicator</td>
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<td>• Cadastre boundary</td>
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<td>• Property boundary</td>
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<td>• Zoning</td>
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<td><strong>Surface Cover Attributes</strong></td>
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<td>Built up areas</td>
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<td>Road and path</td>
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<td>Bare Earth</td>
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<td>Buildings</td>
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<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Unclassified</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vegetation Height</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree Height</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Source: PSMA Australia, 2016
Coverage

Three categories were developed for Geoscape to cover the Australian mainland and most populated islands (represented in Figure 2):

- **Urban** – centres with a population of more than 200 people and dense industrial areas around populated urban centres covering approximately 90 per cent of the Australian population.
- **Rural** – All other areas of the Australian mainland and significant islands not included in Urban or Remote Communities.
- **Remote Communities** – Urban areas that provide extreme challenges for the collection of suitable ground control to achieve high quality positional accuracy.

Geoscape’s undertaking is to capture the whole of Australia and every building with a roof area greater than 9m² in urban areas and 25m² in rural areas.

Maintenance

Maintenance is a major concern among data users, given the rapid pace of change in most urban environments. The ongoing cost associated with data upkeep is a powerful disincentive even for large organisations to undertake development of their own Geoscape-like product. Maintenance costs are accentuated when using higher resolution imaging from aerial photography or 3D capture methods such as LiDAR, which incur the steep costs of deploying airplanes or unmanned aerial vehicles, and (in the case of LiDAR) require expensive data processing.

For Geoscape we apply a minimum annual maintenance processes to capture all significantly changing regions across Australia, which are generally growth suburbs, whilst also capturing surface cover for urban areas on a 12-month capture cycle.

Identifying significantly changing regions is a challenge in itself. Other land and property related datasets can serve as a useful proxy for change, for instance building approvals data, and testing during the development of Geoscape demonstrated a clear correlation between changes in building approval data and changes to the built environment. Intelligent use of data feeds for roads, cadaster and addresses will also identify areas of potential change with address feeds from the Australian Electoral Commission and Australia Post confirming the likelihood of a building existing at an address.

This customised approach to maintenance means the process can be used to capture areas of particular interest – demonstrating its flexibility to meet specific needs of developing countries.
Figure 2: Mapped Priority Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Area</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>41,723 km$^2$</td>
<td>&gt;90%</td>
</tr>
<tr>
<td>Rural Balance</td>
<td>7,649,262 km$^2$</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Remote Communities</td>
<td>250 km$^2$</td>
<td>&lt;0.1%</td>
</tr>
</tbody>
</table>

Source: PSMA Australia, 2016
PSMA Australia worked closely with DigitalGlobe to define a maintenance arrangement that combines capture requirements based on change indicators. In the context of rapid urbanisation these areas are most often on city fringes. In developing countries where food-price volatility and climate change is accelerating urbanisation, it is these very areas that need to be closely monitored, making cost-effective data refresh an imperative.

**Conclusion**

The advances in technology are powerful to change the way developing countries access reliable data to support their approaches to land governance. This access is helping developing countries make inroads as they strive for greater quality of life, a reduction in poverty and sustainable development.

Deininger (2016) noted in a recent World Bank blog that these significant advances in technology can help nations to observe and track, encourage and enable greater participation, and improve transparency. He surmised, “Advances in earth observation, computing power, and connectivity have tremendous potential to help governments, and us at the World Bank, support better land management, and ultimately reduce poverty and promote shared prosperity” (Deininger, 2016).

Geoscape is the realisation and packaging of this powerful technology, which can enable developing nations to capture their built and natural landscapes at a scale and scope never achieved before. When combined with fit-for-purpose solutions to draw information from local communities, accurate machine learning and powerful cloud storage, the data is more accessible, able to be customised for priority needs, and more reliable. Given these rapid technological advances, this foundational data can now be captured and maintained at an economically feasible price for many developing nations.

With the wealth of knowledge and research into the value of bottom-up approaches to land administration and SDI creation or maintenance in developing countries, it makes sense to involve communities in mapping their land. Geoscape’s methodology actively encourages this approach to participatory mapping and it is working well – albeit in a developed country.

When linked with other datasets on a global scale, this combination of technology and local input has the potential to help developing nations build functional SDIs and support sustainable development goals – for the social, environmental, and economic vitality of their land and people.
References


Tables

Table 1: Overview of the Attributes of Geoscape 18

Figures

Figure 1: Integrated Aspects of Geoscape 15
Figure 2: Mapped Priority Categories 20