SANSA Policy Brief

The role of satellite-based remote sensing technologies in support of urban spatial planning

Executive Summary

South Africa is rapidly urbanising and that puts pressure on adequate and effective urban planning. The growth of cities also results in degradation of natural habitats, changes in species composition, cities micro-climate, energy flows and subsequently creating urban heat islands. There is an urgent need for effective and sustainable urban planning and development management, supported by adequate and up-to-date geospatial information base.

The purpose of this policy brief is to demonstrate how remote sensing technologies support urban spatial planning and human settlements development policies. Using several case studies, it has demonstrated that satellite earth observation supports the implementation of key national programmes and policies such as the NDP and SPLUMA. When used in conjunction with other socio-economic and environmental datasets, satellite Earth observation has a potential to improve key national regulations, in particular the Environmental Impacts Assessment (EIA) regulation of the National Environmental Management (NEMA) Act.

The policy brief also provides recommendations to government on the strategic use of satellite-based geospatial information to optimize human settlements and urban spatial planning in the country.

science & technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

sansa
SOUTH AFRICAN NATIONAL SPACE AGENCY

1. Introduction

In the 2016 State of the Province Address (SOPA), the Premier of Gauteng, David Makhura stated that the Gauteng Province is faced with various problems related to rapid urbanisation. The Gauteng Premier estimates that about one million people migrated into Gauteng between 2011 and 2016. Such scenario, he mentioned has major implications on the spatial planning imperatives relating to service delivery, housing, health, education, and pressure on infrastructure. Moreover, in 2015, the United Nations estimated that 71.3% of South Africa's population will live in urban areas by 2030 and almost 80% by 2050. Furthermore, South Africa urban population is growing larger and younger with two-thirds of South African youth living in urban areas. Polokwane, Rustenburg, Vanderbijlpark, Nelspruit and Ekurhuleni are the five fastest-growing urban areas, with average annual population growth rates of between 1.6% and 2.9% over the last decade, compared to Cape Town with a rate of 1.4%. Gauteng province, the country's geographically smallest but economically busiest province, has both the biggest and the fastest growing population, according to census 2011, with 12.2-million people counted in 2011 - a 33.7% increase over 2001 and more than double the national average increase (http://www.southafrica.info/news/urbanisation, (2013).

Recent urbanisation in South Africa isn't unique since the African continent is also rapidly urbanising from 15% in 1960 to 40% in 2010, and the population of urban dwellers is projected to reach approximately 60% in 2050 (UN-Habitat, 2014; African Development Bank, 2012). Whereas these high urban growth rates are associated with rising economic prosperity, urbanisation in Africa has resulted in a proliferation of slums, service delivery problems, and pressure on basic social amenities, poverty and widening levels of inequality. South Africa, widely recognized as one of the emerging economies globally, is confronted with similar problems emanating from urbanisation.

The most important reasons behind rapid urbanising in South Africa are rural-urban migration and natural population growth that result in the proliferation of informal settlements. It is estimated that at least 1.2 million households reside in shacks in at least 2700 shack areas nationwide (SACN, 2011). The proliferation of slums due to urbanization in South African economic hubs such as Cape Town, Johannesburg and eThekwini increasingly present not only a challenge to urban spatial planning but leads to increased poverty and inequality levels in urban centres, as shown by their city Gini coefficients of 0.67, 0.75 and 0.72 respectively.

Rapid urbanisation as seen in South Africa and other regions has placed cities as the most dramatic manifestations of human activities on the surface of the earth (Yigitcanlar & Kamruzzaman, 2015:1). Moreover, cities degrade natural habitats, simplify species composition, disrupt hydrological systems, and modify energy flow and nutrient cycling (2015:1) leading to urban heat islands. Without adequate geospatial information, it is difficult to plan and develop housing or human settlements infrastructure, utilities and services, or to protect and manage the environment, assign appropriate titles and tenure to land and property parcels; or to effectively assess and collect property revenue thereof.

This paper describes how remote sensing technologies support urban spatial planning and human settlements development policies, and demonstrates how the use of satellite-based geospatial information has already improved urban planning and decision making.

1.1. Responding to rapid urbanisation in South Africa

In response to rapid urbanisation, the South African government is progressively developing and implementing new integrated spatial planning and land use management policy aimed at providing sustainable human settlements infrastructure development. Since the introduction of the Integrated Development Planning (IDP) and subsequent sectoral instruments such as the Spatial Development Frameworks (SDF), at least, 5.6 million formal houses were built since 1994 (Department of Human Settlements, 2016). The Spatial Planning and Land Use Management Act 16 of 2013 (SPLUMA) came into effect on 1 July 2015, to provide a fundamental framework for integrated spatial planning and land use management. The act calls for a coherent and planned approach to urban and rural spatial development planning and land use management. In a sense, SPLUMA seeks to regulate urbanization by promoting sustainable land development that limits urban sprawl and protects prime and unique agricultural land from urbanisation through a coherently planned approach.

The role of implementing government programmes is usually cascaded to the provincial government and municipalities. The Gauteng Spatial Development Framework, Gauteng Growth Management Perspective, Gauteng Spatial Perspective (GSP) 2030 Concept Paper and Municipal Spatial Development Frameworks provide valuable insights on how the provinces and municipalities plan to implement the policy directives mandated by SPLUMA and the National Development Plan 2030 (NDP). The latter recognises the value of geospatial information in national spatial development and calls for the establishment of a national observatory for spatial data and analysis.

Among other things, the NDP recognises reconfiguration of towns and cities into more efficient and equitable urban forms including aspects spatial restructuring strategies and the creation of a robust set of indicators as part of a spatial governance evaluation framework. Heeding this clarion call, this paper provides the fundamental role that satellite-based remote sensing has played in supporting urban spatial planning in existing policies and its central role in mapping and monitoring human settlements and urban growth in South Africa.

Key message No. 1: *Satellite Earth Observation is vital in supporting the NDP that identified the need to restructure cities into equitable and efficient spaces by curbing urban sprawl through densification of housing on well-located land parcels in the inner cities and focusing urban development along.*

Moreover, the role that space-based Earth observation technologies should play in providing workable solutions to improve a range of social and economic challenges facing the country was recognised by the Government of South Africa through the SANSA Act (2008) which provides for the "promotion and use of space and co-operation in space-related activities…" The Act provides for satellite-based Earth observation technologies and applications, in support of several applications including urban spatial planning and development in South Africa.

Key message No.2: *Geospatial information provided derived from satellite imagery is critical in planning and identifying suitable locations for human settlements and infrastructure development. The integration of satellite-based information with other socio-economic and field environmental datasets allows city planners to broaden their understanding of urban ecology necessary for them to design smart cities resilient to the impacts of climate change.*

2. Approaches to Mapping Urban Areas

Urban land surfaces are typically arranged in an elaborate complex pictorial designs that are somehow of, unpredictable sizes, shapes, and patterns. Satellite-based remote sensing data has been routinely used (since the 1970s and 1980s) to infer the impact of urban growth on the multiple dimensions of cities, including their physical characteristics and frequently change the pattern at fine scales (Wentz et al. 2014). However, satellite images have traditionally been too coarse to monitor complex and sometimes fine-scale changes in urban land surfaces, so little over the last decade has witnessed the phenomenal growth of high spatial resolution satellite sensors capable of differentiating up to sub-meter urban built-up infrastructure and landscape features. High spatial resolution sensors launched in recent times include SPOT 6/7 (1.5m), Pleiades (0.7m), Worldview,1,2 and 3 (0.46m), Ouickbird 0(0.61m), IKONOS (0.82m), Kompsat 3(0.5m and 0.7m) and Syksat 1 and 2 (0.9m). The emergence of these very high-resolution satellite sensors now

provides new vistas in mapping and monitoring urban landscapes. These sensors are capable of discerning individual buildings and transportation networks making it feasible for urban planners to frequently update cadastral city maps and detect the rapid changes occurring due to urbanisation. Satellite imagery offers an accurate visual portrayal of the physical form and morphology of urban areas that is critical in accurately mapping the complex urban landscape. The repetitive nature of satellite image acquisitions makes it possible to monitor and detect rapid land developments in urban areas.

Key message No. 3: *Satellite Earth Observation sensors are capable of selective individual buildings and transportation networks making it feasible for urban planners to frequently update cadastral city maps and detect the rapid changes occurring due to urbanisation.*

3. Findings

3.1. Spatial distribution of human settlements

Figure 1 shows the spatial arrangement of different land cover types and the condition of the natural environment. Interpretation of urban features from the satellite image show commercial areas, suburban areas, road networks, recreational areas, vegetation and other land use and land cover features around Pretoria. In this case, the understanding of the current spatial orientation of human settlement types is required by planners for site selection, zoning regulation, resource allocation, monitoring the state of the environment and urban growth management. This information is also vital in transforming the apartheid suburban spatial configurations that relegated the black majority from the mainstream urban economy to the urban peripheries.

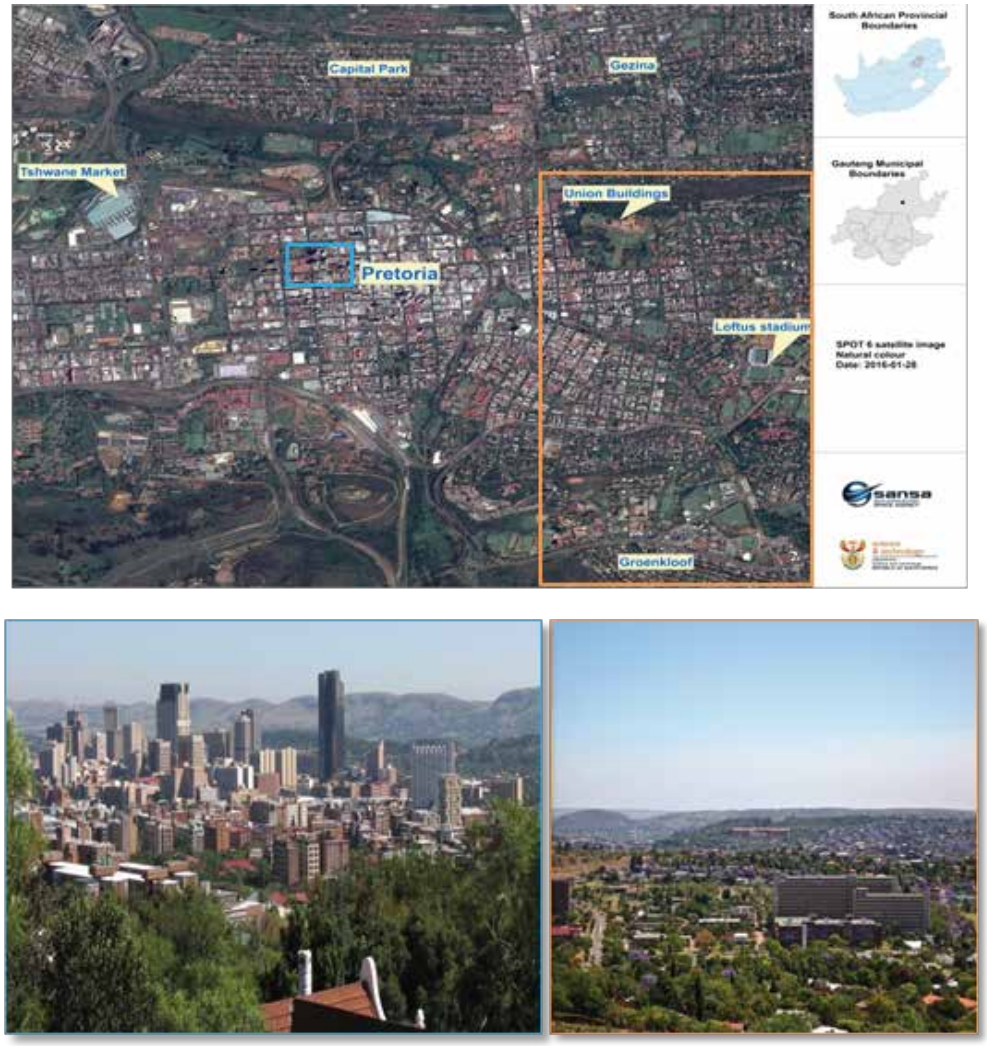

Figure 1: Spatial distribution of human settlement types

Satellite-derived land use information is critical for spatial planning and urban development management. The classification map below (Figure 2) shows the spatial distribution of human settlement types around Johannesburg. The location of townships and informal settlements (Pink) in urban fringes is evident. This information is necessary for improving road network infrastructure, and other services like schools and clinics in areas that are poorly serviced.

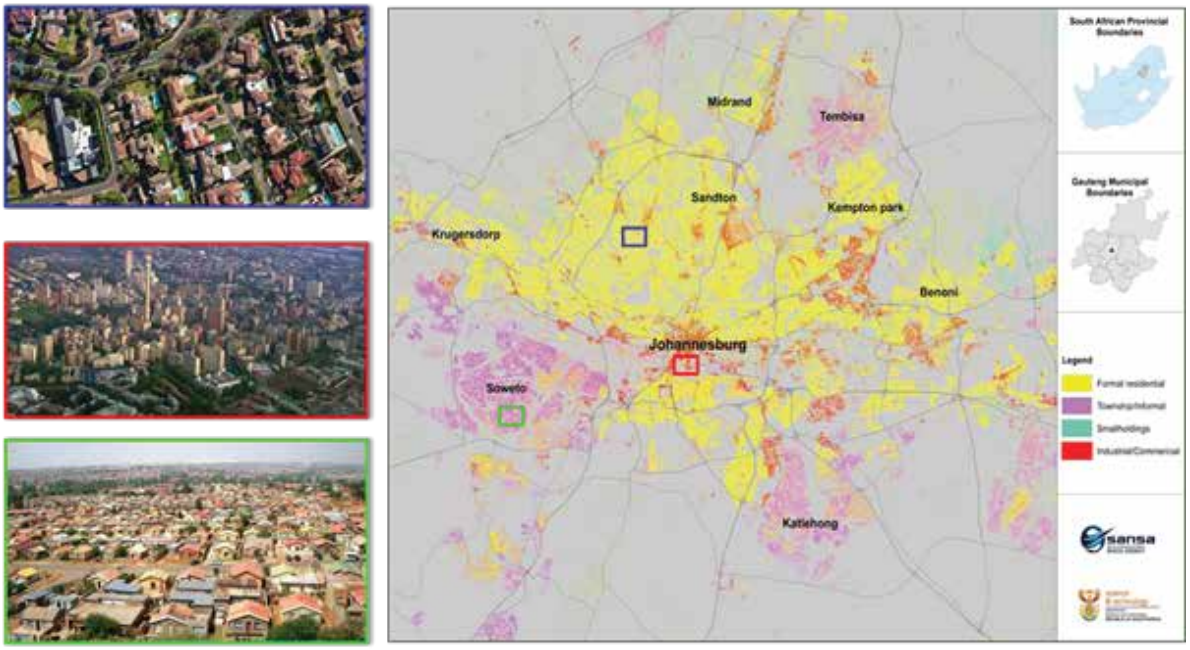

Figure 2: Classification of human settlement

3.2 Urban growth and sprawl

The value of satellite imagery in monitoring and detecting urban growth and transformation is well established and has been demonstrated by this study. Figure 3 shows human settlements expansion around Pretoria between 1990 and 2014. This information is used for planning service delivery to communities and assessing the environmental impacts of human settlement development. It is evident that such urban expansion as shown in Figure 3 requires corresponding capacities to provide basic services such as water, electricity, sanitation, education, health, waste management, transportation infrastructure and recreation facilities and other social amenities.

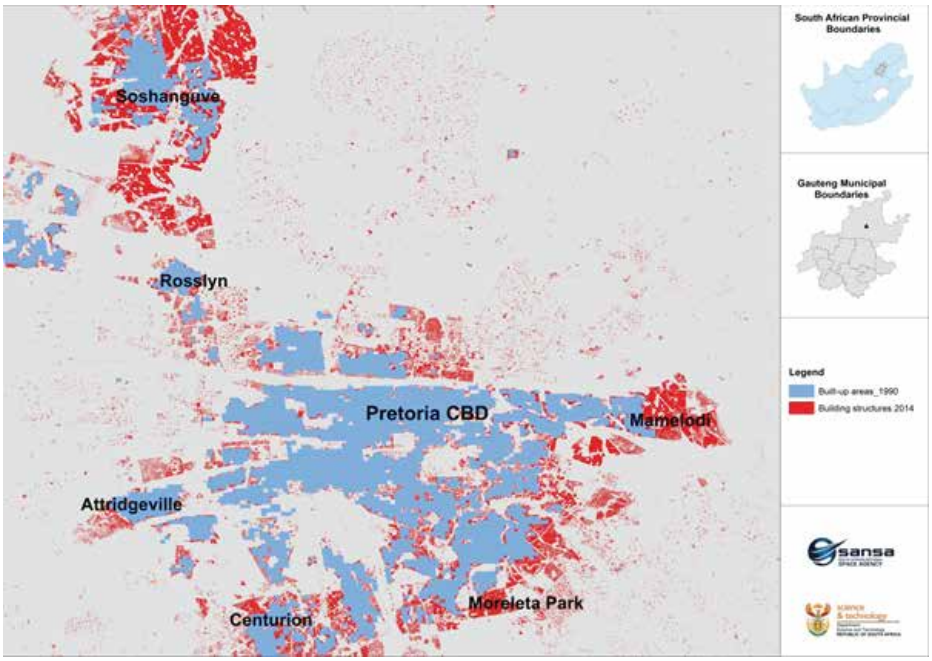

Figure 3: Human settlement growth between 1990 and 2014

Key message No. 4: *Results from this study show that the extent of urban areas in City of Tshwane metro increased by over 80% between 1990 and 2014. Similar satellite image based urban change detection studies reveal comparable trends of 67 % and 57 % in urban expansion in Johannesburg and Ekurhuleni since 1990 (Figure 3).*

Usage of satellite imagery is powerful in demarcating urban extends and its skeletal structure. Municipalities are often confronted with the mammoth task of controlling urban sprawl, which is often exacerbated by the lack of timely spatial information on urban expansion rates. Satellite imagery can be used to provide accurate and timely geospatial information on the spatial structure and boundaries of cities. The image in Figure 4 illustrates the urban footprint of Polokwane city in Limpopo.

Key message No. 5: *Timely information on urban expansion provided by satellite imagery is vital in ensuring integrated spatial planning and land use management as required by the Spatial Planning and Land Use Management Act. Classification of the human settlements is useful in identifying vacant land parcels that are suitable for densification of human settlements as required by the NDP goals on human settlements that are also incorporated in the Gauteng Growth Management Perspective.*

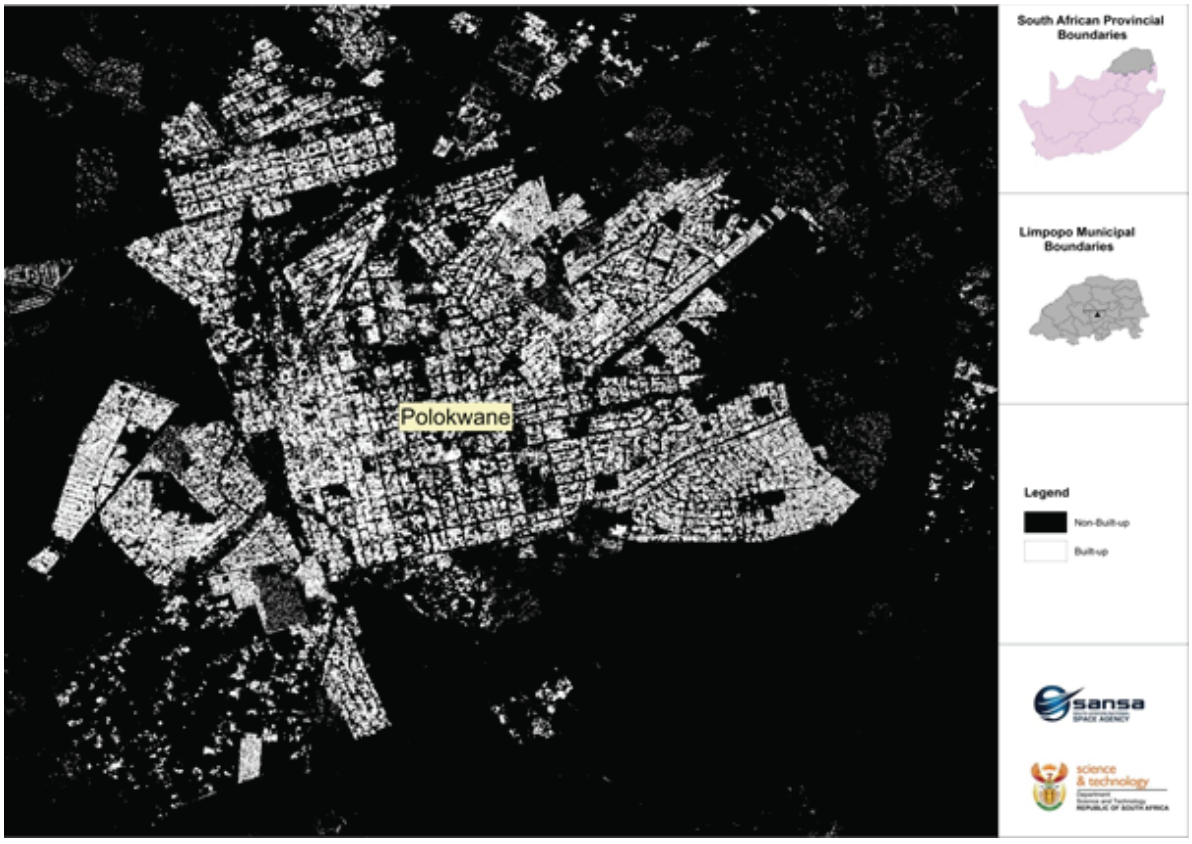

Figure 4: Urban footprint for Polokwane

3.3. Monitoring of informal settlements development

Moreover, very high spatial resolution satellite imagery has been proven to be an indispensable tool in assessing informal settlements development. A collaborative study between SANSA and the Department of Human Settlements in 2013 demonstrated the value of satellite imagery in tracking informal settlement development within 45 municipalities across the country. The study revealed that informal settlements precincts increased by 191 between 2006 and 2011 despite the provision of low-cost housing by the government. It was evident from the study that government required timely and consistent spatial data to track the proliferation of informal settlements. Figure 5 below shows the transformation of informal settlement around Soshanguve, north of Pretoria between 2006 and 2016.

Figure 5: Transformation of informal settlements into

4. Financial Audits

Figure 6: Seraleng Low-cost housing development.

Executing financial audits by municipalities is a challenging task that has to be performed. In 2013, SANSA in partnership with North West Department of Local Government and Human Settlements successfully conducted a satellite image-based study to verify the number of completed houses built during the implementation of the Tranche projects which were implemented between 1996 and 2008. The results of this study were used to support financial audits by municipalities during the implementation of the Tranche projects.

Key Message No. 6: *Very high spatial resolution satellite imagery has been proven to be an indispensable tool in enumerating, tracking and validating low-cost housing units implemented during the Tranche projects in the North-West Province.*

3.5. Provision of services such as water, sewerage, electricity, roads and other social amenities

Provision of services such as water, sewerage, electricity, roads and other social amenities is an integral component of all human settlements programmes in South Africa. Satellite imagery provides urban planners with a visual reference useful in optimizing transmission routes for water, sewerage, telecommunication and electricity. Figure 6 illustrates the value of satellite imagery in the planning of basic services such as underground water pipes to communities. The image also shows encroachment of human settlements on servitudes.

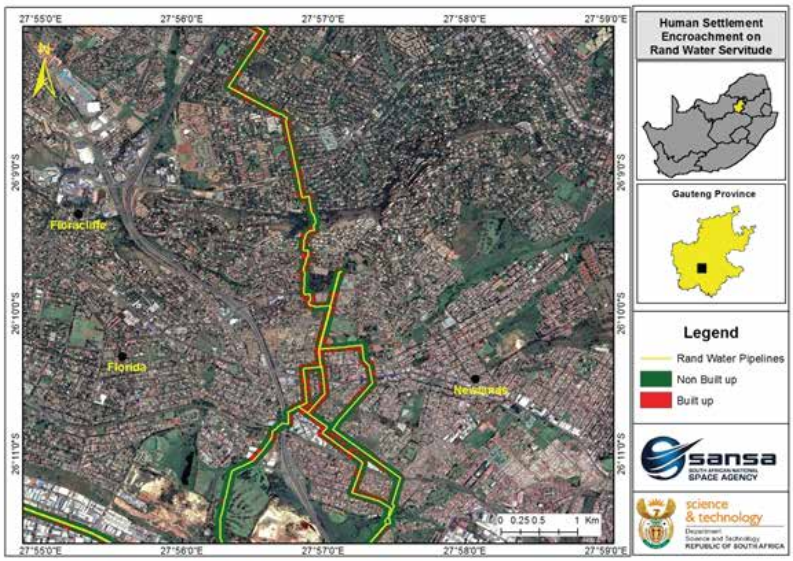

Figure 7: Routing water transmission to communities.

Key message No. 7: *With their superior spatial and temporal parameters that enable satellites to simultaneously assess various parameters, reduce cost, time of data acquisition especially for urban areas; provision of accurate spatial coverage of extended areas, such as rivers and provision of data on a constant basis allowing change detections; calls for an urgent inclusion of satellite data in the national Environmental Impact Assessments (EIAs) regulation.*

4. Conclusion and Recommendations

This brief has provided various policy and legislative interventions enacted by the South African government to guide urban spatial planning and development. In a highly urbanising country, the brief has highlighted the important role that data and geospatial information derived from high resolution satellite-based remote sensing technologies can play to support spatially explicit land use planning and management. Specific remote sensing applications have been presented to highlight the consistency that should be systematically devised in assessing human settlements at the individual city level. The policy brief has provided how remote sensing technology plays a central role in the implementation of the spatial elements of key legislative interventions such as the SPLUMA Act (2013) and its contribution to the NDP.

The brief has shown that Urban planners can monitor urbanization growth rates, identify a suitable site for human settlements, conduct inventory dwelling units, map informal settlements and independently track government investment in the provision of low-cost houses using information derived from remotely sensed satellite imagery.

It is recommended that Urban Planners integrate satellite technologies with other spatially orientated Geographical Information Systems to track land use changes at a scale appropriate enough to enable them, to meet the human settlements and urbanization goals highlighted in the NDP.
It is also strongly recommended that satellite earth observation data should be used in conjunction with other socio-economic and environmental datasets, to improve key national regulations, in particular the Environmental Impacts Assessment (EIA) regulation of the National Environmental Management (NEMA) Act.

Whereas geospatial information forms an integral aspect of urban planning, it is recommended that Government should increasingly place emphasis on the use of remote sensing technology to fully exploit the underlying benefits that can be derived from satellite imaging technologies and spatial intelligence thereof. This calls for a coordinated national programme to increase remote sensing skills and continued investment in high resolution space-borne imaging systems and advanced image processing capability.

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