The role of satellite remote sensing in detecting anthropogenic land-cover change

Brian Salmon and Dr Waldo Kleynhans

The wellbeing of the environment is one of the major factors that contributes to sustainability. The United Nations General Assembly's discussion on sustainable human settlements concluded that countries' local governments need to plan, implement, develop and manage human settlements. It was further stated that the local government needs to manage existing settlements and prevent the establishment of any new unplanned settlements.

The ability to determine where new settlements are formed, ties directly with the United Nations Millennium Development Goals. The United Nations proposes a systematic development of sustainable cities for newly formed settlements. The South African government incorporated this vision into its local policies by focusing on service delivery to these newly formed settlements, as human settlement expansion is currently the most pervasive form of land-cover change in South Africa.

Anthropogenic changes to natural land cover are being driven by a need to provide water, food and shelter to more than seven billion people. Unfortunately, these changes have a major impact on hydrology, biodiversity, climate, socioeconomic stability and food security. Changes in land use contribute to human impact on the climate as we are changing the natural rate of exchange of carbon dioxide between the atmosphere and the terrestrial biosphere, for example, huge stocks of carbon are released as a result of deforestation.

Remote sensing is the science of obtaining information on an object or area without being in contact with the object or area under investigation. Remote sensing imagery has proven to be a valuable tool in the effort to monitor land cover globally.

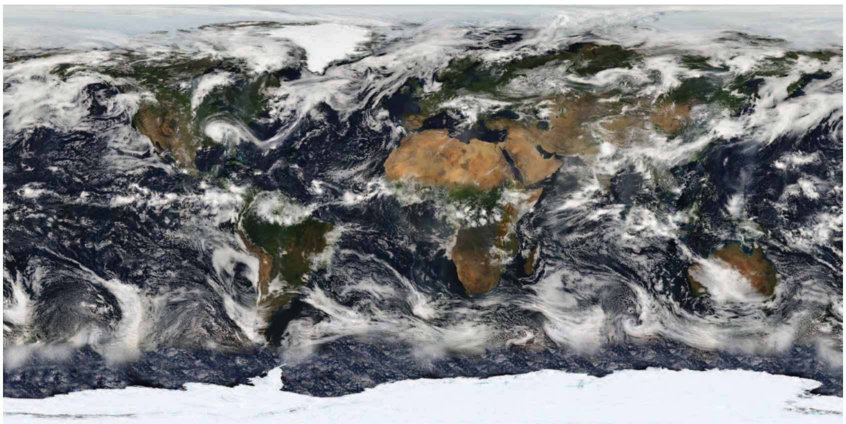
The most pervasive form of land-cover change in South Africa is human settlement expansion, which commonly occurs in areas that are covered by natural vegetation. Determining where and when new settlement areas are developed is beneficial not only from an environmental, but also from a socioeconomic point of view.

Determining when and where these types of changes occur has historically been done on an ad hoc basis by means of the visual interpretation of aerial and satellite imagery. Coarse resolution satellite data provide frequent observations (daily or multi-day composites) of land surface conditions at regional to global scales and are thus an attractive option for regional-scale change detection. When considering current change detection methods in literature, the majority of methods are based on multi-date high resolution data (in most cases only two images are used) for change detection that fails to exploit the valuable temporal components (for example, phase or frequency modulation) of the signal that is driven by seasonal changes in land surface phenology.

For South Africa, two major land cover mapping efforts were made to produce a land-cover database in 1994 and 2000, referred to as the South African National Land Cover (NLC) Database 1994 and NLC 2000 datasets respectively. These datasets were used to determine a change map by comparing the class labels for each pixel. Unfortunately, the 1994 and 2000 versions of the NLC were compiled using very different methods. The NLC 1994 had a minimum mapping unit of 25 ha, and contained 31 land-cover classes, whereas the NLC 2000 had a minimum mapping unit of 2 ha, and contained 45 land-cover classes.

Converting these classes into comparable pixel sizes and land-cover classes was not a trivial task, taking into consideration that the original classification accuracy of the land-cover datasets were 79.4% and 65.8% respectively. The production of a highly accurate land-cover change map using this post-classification change detection approach proved challenging. Both of these maps took several years to complete. Subsequently, it was preferable to map land cover by provincial governments on an ad hoc basis through private companies using a variety of methods.

Since land-cover classification methods have not been standardised, reliable



A map produced by the MODerate-resolution Imaging Spectroradiometer (MODIS), one of the satellites used by the RSRU.

comparison between land-cover maps has not been possible. The Landsat-based land-cover mapping efforts relied on single-date imagery, acquired at a range of different dates for the entire area. This resulted in considerable seasonal variability between images, which hampered multi-spectral land-cover classification. It follows that a need exists for automated change detection to reduce operator dependence and enable large datasets to be processed frequently.

Since 2008, a team of researchers at the Meraka Institute's Remote Sensing Research Unit (RSRU) at the Council for Scientific and Industrial Research (CSIR), in collaboration with the University of Pretoria, has been actively doing research on how satellite-based remote sensing data could be used for automated land-cover change detection using machine learning and signal processing methods.

The hypertemporal time-series analysis approaches used by the RSRU explore the time domain of satellite images and capitalise on seasonal dynamics to characterise land cover and land-cover change using repeatable and standardised methods that can be applied over large areas. It proved to be very effective in detecting anthropogenic land-cover change, and numerous algorithms have been developed, published and presented internationally.

A recent paper presented at the flagship Institute of Electrical and Electronics Engineers (IEEE) Geoscience and Remote Sensing Symposium 2011 conference was awarded best paper and the team was presented with the award at the IEEE Geoscience and Remote Sensing Society 2012 conference held in Munich, Germany, in July 2012.

Quickbird images taken in 2002 (left) and 2007 (right). (Courtesy of Google™ Earth)

***Brian Salmon** received the BEng degree in Computer Engineering and the MEng degree in Electronic Engineering (Signal Processing) from the University of Pretoria in 2004 and 2008 respectively. He is currently associated with the Remote Sensing Research Unit at the CSIR. He is working towards a PhD in Electronic Engineering. His research interests are machine learning and graph theory.*

***Dr Waldo Kleynhans** received the BEng, MEng and PhD (Electronic Engineering) degrees from the University of Pretoria in 2004, 2008 and 2011 respectively. He is currently a senior researcher with the Remote Sensing Research Unit at the CSIR. His research interests include remote sensing, time-series analysis, wireless communications, statistical detection and estimation theory, and machine learning.*