The Development of the South African National Land Cover Mapping Program: Progress and Challenges

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Abstract

The Chief Directorate: National Geo-spatial Information (CD: NGI) as South Africa's National Mapping organisation is mandated, amongst others, to provide and maintain national mapping coverage of the Republic. As an extension to its current product offering, it has recently embarked on a program of national land cover mapping.

The demand for land cover mapping that is current, meets requirements and provides for an accurate reflection of the landscape, is reaching unparalleled proportions within the South African user community. In order to address this need, the CD: NGI used a phased-in approach in its attempt to achieve national coverage.

The paper will provide an overview of the various phases of development of the national land cover mapping program. The first phase was a pilot project over a number of small areas, where the process included both a desktop and independent field verification exercise. The second phase was to move to a more programmatic strategy whereby the entire province is mapped. Refinements of the pilot projects were introduced to improve on the quality of the dataset. A brief description of the problems experienced will be discussed. The paper will further reflect on the development of an accurate field dataset that can provide a basis for an accuracy assessment of the products.

Constant refinement of the methodology is underway. The need for automated classification, against the very labour intensive manual methods currently being used, is driving the process within the CD: NGI to revisit such methodologies and to further develop capacity within the industry to better serve the user community.

The conclusion will reflect on the lack of cohesion and disparate programs amongst the major role players in the South African public sector, coupled with factors such as financial constraints, capacity of the industry and quality of underlying data that are impeding significant progress in this field.

1. Introduction

Land cover, as defined by the Food and Agricultural Organisation (FAO) is *the observed physical cover, as seen from the ground or through remote sensing, including the vegetation (natural or planted) and human constructions (buildings, roads, etc.) which cover the earth's surface*. The process of producing land cover data involves classifying the landscape into a set of predefined classes, as defined by the creator. This is usually done using specialised software, whereby remote sensing techniques are used to group similar pixels based on their spectral value, shape, size and texture.

Land cover allows users to observe the physical cover, vegetation and human development, of an area of interest without having to have advanced image interpretation skills. The specific colours assigned to each class allows the user to, very quickly and accurately, interpret the nature of the landscape. Further information such as tree height or permanence of water can be derived.

The land cover user community includes both public and private sector organisations. The public sector user community is found across all three tiers of government, each fulfilling their respective legislative mandates. It is disturbing however that in light of the great need for a credible standardised land cover dataset across the entire country, there is very little co-operative efforts between the various parties, including a pooling of resources, both financial and human capital in order to address the need.

2. Availability of Land Cover in South Africa prior to 2012

Prior to 2012, there have been two attempts at creating a national land cover product in South Africa. The first dataset, known as NLC94, was produced at a nominal mapping scale of 1:250 000 using Landsat imagery from the 1994 and 1995 epochs. Thirty-one classes were classified at a minimum mapping unit of 25 hectares. Although this dataset provided a sound basis for land cover in South Africa, the number of rapid changes occurring in the country resulted in the product quickly becoming outdated.

The entire country underwent an update of the NLC94 in 2000, using Landsat-7 satellite imagery, and mapped to a minimum mapping unit of two hectares. A total of 45 land cover classes were captured. A latency of five years before the final dataset was publicised resulted in it being already outdated at the time of publication.

Exploring the availability of other datasets, it must be noted that there are various provincial initiatives that have produced a land cover over, for example Gauteng, KwaZulu-Natal, Limpopo and the North West Province. Attempts to combine these land covers in order to create a more recent national coverage have been unsuccessful, due to the varying legends, scale and classification systems.

Strategically, for South Africa there is an urgent need for a standardised, highly accurate land cover dataset that provides a national coverage on a programmatic level at an acceptable refresh rate. It is from this need that the CD: NGI Land Cover program was borne.

3. The CD: NGI Land Cover Program

3.1. Consultative Process & the development of the Field guide

In 2008, the CD: NGI, known then as the Chief Directorate: Surveys and Mapping (CDSM) held several workshops for all stakeholders in land cover. These workshops were designed in order to establish user requirements with respect to the legend, methodology, update frequencies etc, and were represented by an extensive number of stakeholders including all of the users listed above.
The consultations lead to the development of the Land Cover Field Guide in 2010. This document was intended not only for the CD: NGI, but also to provide guidance for all land cover initiatives within South Africa. It proposed the 32 class legend, which is compatible with the Land Cover Classification System (LCCS).

The LCCS is an international standard, which is designed to correlate with existing land cover legends, and also to allow the user to create their own legend for any land cover requirements, independent of scale or methodology.

The CD: NGI legend consists of eight super classes and 32 sub-classes. It includes both land cover and a few land uses in its classes. The legend can be seen in appendix A.

Emanating from this consultative process was a general consensus for a raster pixel size of 10m by 10m and a minimum mapping unit (MMU) of one hectare. The purpose of a minimum mapping unit provides for a more generalised effect on the dataset, thereby minimising unnecessary noise. Over time, this has been revised to address the generalisation of certain smaller classes, such as rivers and roads.

Included in the land cover process is a thorough field verification and accuracy assessment. The accuracy assessment initially looked at only the user's accuracy, but has since been extended to include the producer's accuracy and Kappa Index of Agreement (KIA).

3.2. Mapping of the pilot sites

In 2012, the CD: NGI embarked on the land cover of a number of pilot sites, the main aim being to test the existing methodology and commence with the process of land cover mapping on a national level. The selection of the areas was done to meet the departmental initiatives for the Comprehensive Rural Development Program (CRDP). Eight pilot sites were selected for the generation of a land cover dataset, using on a desktop approach. The land cover was mapped from a combination of 2009 SPOT-5 satellite imagery and 2009 Colour Infrared (CIR) CD: NGI aerial photography.

A separate, independent accuracy assessment was undertaken using data generated from a field inspection. The methodology for the accuracy assessment proved difficult to define. Initially, a field visit required for a verification of ten instances per class in an area of 10km^2. Each instance required a geo-tagged photograph to be supplied in support of the classification. In instances where there were less than ten samples per class, every sample within that class had to be verified. A minimum of 80% accuracy was required. Following the completion of these pilot sites, a number of shortcomings that were identified led to a refinement of the methodology.

The first major shortcoming was a lack of a colour scheme associated with the classes. Because the land cover is a raster product, colour plays a vital role in identifying the class type, especially if the product is presented in hard copy format. This lack of a colour scheme resulted in it being difficult to compare adjacent areas (completed by different contractors) or for one to become familiar with a particular class associated to a particular colour. This problem was solved by creating a uniform colour chart which would accompany all land cover bids. The colour chart was designed such that the shades of a various colour would be similar for each one of the eight super-classes mentioned above. For example, the super-class, *Cultivated and Managed Terrestrial Primary Vegetated Areas,* is green in nature, and the seven sub-classes are all varying shades of green.

A second shortcoming which was identified during the pilot test phase was the MMU. While an MMU effectively reduces noise in an image, it can also cause a loss of significant information. Important (but often geographically small) features such as rivers and rural dwellings would be correctly classified but then removed when the MMU was incorporated. This issue was resolved by removing the MMU for most classes and only retaining it for a specific few. Currently all of the vegetation classes, with the exception of urban vegetation, have a 1ha MMU, while the remaining classes do not have an MMU.

A few minor amendments were made to the wording of the definitions of the classes.

3.3. Programmatic coverage of the country

After the success of the eight pilot areas for land cover, the CD: NGI moved towards a programmatic coverage of the country on a provincial basis. The North West province was selected as the first province to be classified. This was based on a request from the provincial government in that province. The province was divided into five areas which were similar in size, and was mapped by external contractors from 2010 SPOT-5 satellite imagery. During this stage another serious shortcoming in the methodology was detected. The contract required a field verification of ten samples per class in order to complete the accuracy assessment. This would amount to a maximum of 320 samples in the whole job. In the pilot areas, where the scenes were small, this was not a problem. However the jobs for the North West Province were significantly larger (1/5th of the province, which is approximately 20 000km^2) and ten samples were insufficient. The contracts were

amended to include a further random sample of five to ten samples per 100km^2. Unfortunately this was only done after the North West was completed. This increase in sample points will result in a comprehensive coverage of the area of interest with geo-tagged photographs, which can be used to assist the CD: NGI with other mapping initiatives, like the 1:50 000 topographic compilations.

Once the accuracy had been assessed, the five areas making up the North West Province were mosaiced together and cookie-cut into 1:100 000 quarter degree squares. This product is now available from the CD: NGI along with the associated metadata. The CD: NGI is currently mapping the Eastern Cape Province, and has already completed the coastal and northern regions of the province.

Due to financial constraints, the CD: NGI is managing to only complete a land cover classification over one province per year. So, the way forward would be to pool resources across government in order to hasten delivery on land cover in South Africa.

4. Future of land cover mapping

The CD: NGI has had discussions with major role players such as Eskom, KwaZulu-Natal Ezemvelo Wildlife, Cape Nature, Western Cape Provincial Government and the Department of Environmental Affairs. These discussions are ongoing, but negotiations are often very slow. This is mainly due to bureaucratic procedures, and does not provide any indication that a national land cover will be completed soon.

In addition to financial constraints, a lack of capacity within industry has been identified as a reason for the slow production rate. The CD: NGI's national production program should hopefully encourage skills development within this area. The need for an automated and sustainable methodology for producing land cover is evident. Current classification techniques are largely manual and labour intensive, and are not practical for the amount of work required. Continued research exploring alternate approaches such as the use of Object Based Image Analysis (OBIA) or different satellite imagery is necessary.

Furthermore, the development of a best practise guideline, which is an objective of the Land Cover Community of Practise (CoP), coupled with the creation of a CD: NGI land cover standard will go a long way to assist both users and producers of land cover within the industry.

Mention must also be made of the efforts from the Meraka Institute of the CSIR, to provide a service of updating land cover on a regular basis using automated classification techniques. However, this is dependent on two things, namely adequate funding from government and the existence of a highly accurate, standardised base land cover layer across the entire country upon which the update can be done.

5. References

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Appendix 1: The CD: NGI 32-class land cover legend with associated colour scheme