

USE OF REMOTE SENSING IN SUPPORT OF CROP AREA ESTIMATES IN SOUTH AFRICA

S. L. Ferreira a, *, T. Newby b, E du Preez c

^a GeoTerraImage, 53 de Havilland Crescent, Persekor Technopark, Pretoria, South Africa -
fanie.ferreira@geoterraimage.com

^b Agricultural Research Council Private Bag X79, Pretoria, 0001 South Africa - Terry@arc.agric.za

^c SiQ, 53 de Havilland Crescent, Persekor Technopark, Pretoria, South Africa - Eugene.duPreez@siq.co.za

Commission VIII, WG VIII/10

KEY WORDS: Satellite Imagery, Crop Area Estimates, Aerial Survey, Point Frame, Crop Type Classification & Spatial Analysis

EXTENDED ABSTRACT:

In South Africa the National Department of Agriculture (DoA) is the custodian of the Crop Estimates Committee (CEC) that is responsible for the grain crop production estimates, published monthly. The CEC meets monthly to review and debate the current status of cropped area and conditions, to determine crop production estimates for grain crops. Grain crops in South Africa consist of two groups of which crops such as maize, sunflower, Soya beans, and sorghum, are cultivated during summer. The second group of crops are grown during the winter and include wheat, barley, oats and canola. Information about crops was previously only supplied by provincial and industry representatives along with qualitative reports on weather patterns and crop conditions that resulted in subjective calculations.

In 1994 South Africa entered a new political dispensation, which also saw the abandonment of governmental control and subsidies for agricultural crops. This left the South African grain farmers exposed to the free market and global supply and demand trends, which necessitated the requirement for objective and statistically reliable crop production information. The DoA realised the importance of conducting independent scientific production estimates in 2001 and awarded a tender to the National Crop Statistics Consortium (NCSC). The mandate of the NCSC was to develop and implement a system to estimate planted areas and forecast yields based on a geographic point sampling frame that is stratified according to cultivation density, while also continuously improving the system.

A system was designed and implemented whereby satellite imagery was used as a first step to stratify the country by separating all non-agricultural areas from agricultural areas. The agricultural areas were stratified for rangeland and cultivation areas, and subsequently the cultivation areas were further classified into three cultivation intensity classes: high (>65%), med (30%-65%) and low (<30%). A point grid with 225m intervals was generated across the cultivation intensity areas, which was used for a geographic systematic random selection of points, with an increased sampling rate in higher density cultivation areas. These selected points are surveyed by field staff (predominantly farmers) that conducts an interview

with the farmer to complete a questionnaire to gather information on crop types, area planted and expected yields. Information is captured into a digital questionnaire with checks and balances to reduce errors, and downloaded daily through internet connections to a central database, where statistical processing takes place to calculate a crop area estimate for each crop type per province. As this system is dependant on information gathered directly from the farmer, it is essential to have the co-operation of farmers. Over the last three seasons the response rate to interviews has decreased to such an extent that it has prompted the NCSC to look for alternatives, while at the same time retaining the confidence of a Coefficient of Variation of below 5% at national level.

In combining and integrating satellite imagery, remote sensing, point frame statistical platforms, GIS and aerial observations, a Producer Independent Crop Estimate System (PICES) was developed in a pilot project over the Gauteng province to demonstrate the feasibility of such a method. As a first step satellite imagery (Landsat 5) over three seasons was used to capture field boundaries for all cultivated fields in the province. The field boundaries that were mapped, replaced the cultivation density stratum, and were used as a frame for a random geographic systematic selection of sample points across each province. These selected points were sampled to determine the crop type for each field/point by aerial observations using an Very Light Aircraft (VLA). For the aerial survey trained observers (predominantly farmers), that could identify different crop types, were employed to record crop information for selected points on a digital tablet PC with a touch screen in combination with a GPS navigation instrument. The observers also recorded additional information while in transit between selected points, for fields clearly visible with identifiable crops, from the aircraft.

Information gathered during the aerial survey was firstly used to calculate a statistical area for each crop type per province. Secondly it was used as training sets for satellite imagery during classification procedures to generate a crop type for each individual field. During the growing season both Landsat 5 and Spot 2 and 4 images were recorded and used to perform a crop type classification. From the classified satellite imagery, the

* Corresponding author

crop type was assigned to individual field boundary polygons to provide a complete set of classified fields for each province.

Subsequently the methodology has been expanded and implemented in the four major summer grain producing provinces on an operational level that is functional in providing reliable crop area estimates. These provinces are Northwest, Mpumalanga, FreeState and Gauteng where the grain crops are predominantly cultivated under rain fed conditions, relying on summer rainfall. The same procedure as explained above was followed to digitise field boundaries for 280 000 fields, covering 6,5 million hectares across all four provinces. These provinces represent approximately 90% of the total area in South Africa under summer grain production. For the satellite image classification, images were recorded within the growing season, by Landsat 5 as well as Spot 2 and 4, but due to rainfall and associated clouds many images recorded were not suitable because of high cloud cover. Suitable images with the least cloud cover were selected for the months of February and March, which coincide with maximum vegetative development of the summer grain crops. All clouds were mapped for each individual image in a shape file, and the fields intersecting with cloud polygons were removed before further processing. Field boundaries were used as masks, in order to retain only the spectral information within the fields, thereby enhancing the image histogram for crop type discrimination.

Information on crop types captured during the aerial survey was used as input to the image training procedure. The additional information on crop type captured in between selected points was used as training for the signature files, while the selected points with crop type information was retained for accuracy assessment. Fields in all four provinces planted with maize covered 80% of the summer grain fields, while sunflower covered only 10% and Soya beans 5% with other crops less than 2%, according to the ratio of crop types generated from the aerial field surveys. This ratio of very few points for crops with a low representation had the effect that there were no field verification samples available on certain images. To overcome this problem, satellite images recorded on the same day were all mosaiced together, which resulted in long strips of imagery to allow field verification across a larger area that had a better chance of all the crops being represented. This approach improved the possibility to generate signature classes for all crops on all images, although on certain individual scenes it was still not always possible.

Signature files were generated for each field masked image, considering the crop phenology stages for each crop type. Crop types such as sunflower and maize had substantial overlap in the signature files, and maize was split into six classes of more specific spectral types. Another factor contributing to overlap between classes is the less than 100% canopy cover that causes a high proportion of soil reflectance to be included in each of the crop type signature classes. This is due to the arid conditions with high summer temperatures and average rainfall of only 700 mm per season. Crops are therefore planted at a low density, which results in a less than 100% canopy cover. With crops not growing at optimal conditions, the heterogeneity within crops fields are emphasized and subsequently limit the possibility of having pure signatures for specific crop types.

Signature sets were evaluated for separability for each image using the Jefferson-Matusita analysis and each signature class in a set was refined to reduce overlap between classes. Before classification, the different bands in each image were also evaluated to determine the best combination to discriminate between different crop types, and it was found that generally the red band along with the infrared bands provided the best separation. Images were classified using the Erdas supervised classification approach and selecting the maximum likelihood combined with the parallel-piped functions. Crops such as Soya beans and sunflower have typically shorter crop phenology cycles, compared to that of maize. It should therefore have been potentially possible to discriminate on this basis. This did not realise in practice. Farmers generally stagger planting dates for all crops from October until December to spread the risk of erratic rainfall across the season, which makes it impossible to fix the crop calendar for specific crops according to planting dates or times of harvest.

After the supervised classification procedure, a zonal majority function was used to assign a crop type to each field boundary polygon based on the raster classification. This step generated an ArcView shape file with a crop type for each field during a specific season for an entire province, providing a basis for various queries and analysis.

Through integrating and combining technology it was possible to calculate statistical area estimates for each province through aerial surveys, while also generating a map showing the spatial distribution of crop type patterns. It is now possible to extract information on sub provincial level such as agro-climatic zones or district level, or any polygon boundary of importance. This provides decision makers with spatial analysis possibilities not previously available.

REFERENCES

- Allen, R., Hanuschak, G., and Craig, M., May, 2002. History of Remote Sensing for Crop Acreage, Washington, USA. <http://www.nass.usda.gov/research/Cropland/Method/>
- Allen, R., Hanuschak, G., and Craig, M., May, 2002. History of Remote Sensing for Crop Acreage, Washington, USA. <http://www.usda.gov/nass/nassinfo/remotehistory.htm#3>
- De Wit, A.J.W, 2004. Efficiency and accuracy of per field classification for operational crop mapping. *International Journal of Remote Sensing*, 25(20), pp. 4091-4112.
- Epiphano, J. C. N., Luiz, A. J. B. and Formaggio, A. R., 2002. Crop area estimates using simple sampling scheme on satellite images. *Bragantia*, vol.61, no.2, p.187-197. ISSN 0006-8705.
- Lemoine, G. and De Groof, H., 2001. Monitoring land use preparation for early season crop area estimates using ERS-1 SAR data for the Great Driffield site. 3rd ERS Symposium, Florence 97.
- Gallego, F.J., 1999. Crop area estimation in the Mars Project. Conference on ten years of the MARS Project, Brussels.