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

sansa
SOUTH AFRICAN NATIONAL
SPACE AGENCY

REPORT:
ASSESSMENT AND ANALYSIS OF THE FIRE NEAR MOSSEL BAY

PREPARED FOR:

Kerryn Smith

February 2017

Compiled By:

Willem Vorster

Earth Observation

SANSA

South African National Space Agency
Tel +27 12 844 0393
Fax +27 12 844 0397
Email wvorster@sansa.org.za
Physical Address The Innovation Hub
Pretoria
Postal Address PO Box 484, Silverton 0127,
Gauteng, South Africa

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CSIR	Council for Scientific and Industrial Research
GSD	Ground Sample Distribution
SPOT	French owned earth observation satellite constellation
AOI	Area of interest
EOSC	Earth Observation Service Centre
WBS	Work Breakdown Structure
MSG	Meteosat Second Generation
GMT	Greenwich Mean Time (to convert to local time, add 2 hours)

AFIS	Advanced Fire Information System
MODIS	Moderate Resolution Imaging Spectro-radiometer
SANSA	South African National Space Agency

1. Introduction

1.1 The South African National Space Agency (SANSA) as represented by Willem Adriaan Vorster (RS Production & VAP Technologist, with specific field of expertise in satellite image processing) was requested to assist in a fire investigation by means of using available satellite imagery and satellite data.

1.2 The incident which is the subject-matter of this fire investigation is a fire which occurred on 23 December 2016 in the Mossel Bay area of the Western Cape, and the specific request was to establish with the aid of satellite imagery the probable area where the fire started, the probable time when the fire started, the progression of the fire and the eventual fire scar.

2. Methodology for fire analysis

2.1 Remote sensing can be used to detect and monitor disasters and hazards such as wildfires. Deploying an aircraft for every fire is very expensive and also impractical. Satellite remote sensing is more economical and reliable than aerial photography, especially in post-fire analysis. Characteristics of satellite images such as spatial, temporal and spectral resolution play an important part in the forensic capabilities.

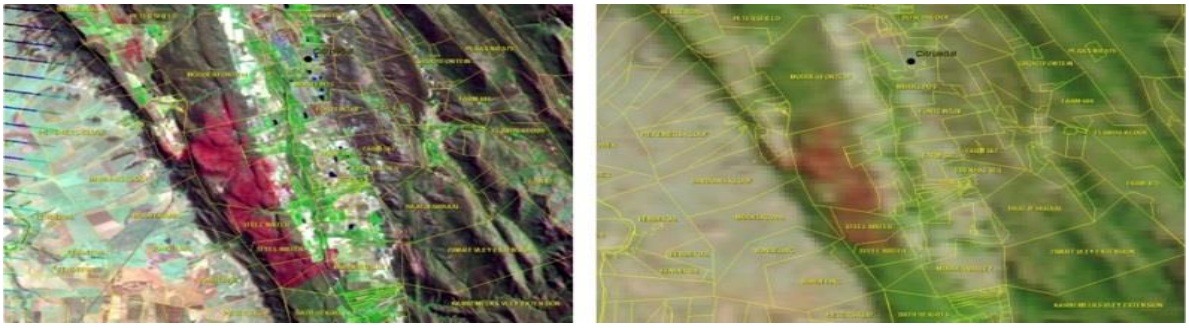
2.2 **Temporal resolution**

Earth observation satellites revisit the same area on a regular basis and therefore have a good temporal resolution, resulting in the area destroyed by the fire being scanned within a day to thirty days after the event.

Temporal resolution plays a vital role in terms of detecting a fire as it burns. Satellite sensors with low spatial resolution (e.g. MODIS) but with a high temporal resolution, can detect wildfires, but the analysis thereof is constrained.

2.3 **Spatial resolution**

Apart from temporal resolution, spatial resolution also has an important role in the analysis of wildfires. The example illustrates the difference in resolution. Higher spatial resolutions (e.g. Landsat 30m), will result in a better analysis of the wildfire event. The Landsat image on the left covers the same area as MODIS on the right and indicates a clearly visible fire scar in the centre of the image (the scar is the area with a reddish colour).



Example: A subset of Landsat on 10 March 2012 (left) with the high resolution and a subset of a MODIS image of 13 December 2012 (right) with the low resolution.

2.4 All satellite data are ortho-rectified so that the different datasets can be compared (Mather, 2004) and be used in a geographic information system (GIS). The accuracy of the position of the data is crucial to determine on which side of a fence a fire started.

2.5 **Spectral resolution**

The spectral bands of the satellite sensor determine which indices can be calculated for the fire analysis. The following indices can be useful in interpreting a fire event: the normalized differential vegetation index (NDVI), which consists of the red band and the near-infrared band (NIR); the normalized burn ratio (NBR), which consists of NIR and short-wave infrared bands ($SWIR_{2.2}$) (Brewer, *et al*, 2005; Carla, *et al*, 2016; Henry, 2008; Lentile, *et al*, 2006) and the normalized differential infrared index (NDII), which consists of NIR and $SWIR_{1.6}$ bands (Carla, *et al*, 2016). The results of the different indices are added to the original bands of the sensor used. This increased dimensionality enables a supervised classification to determine the extent of a fire scar more accurately.

2.6 Image analysis

The higher resolution data is classified through supervised classification with the use of samples from the classes of a known identity (Campbell &Wynne, 2016). With supervised classification and change detection, old fire scars can be separated from newer scars to eliminate the older scars through image subtraction. The final classification is then vectorized in a GIS to be able to calculate the area that has been destroyed by the fire. Using a combination of a fire scar vectors and the farm boundaries, the burnt area per farm can then be calculated and the starting-point of the fire identified.

2.7 AFIS system

The Advanced Fire Information System (AFIS) monitors all active fires on a daily basis. Information obtained from AFIS (point data) was used in the GIS to keep track of the dates and times of the fires. The AFIS system is based on MODIS data that is obtained from sensors on-board the two satellite platforms, Aqua and Terra. AFIS also obtains information from the Meteosat Second Generation (MSG) satellite, a geo-stationary metrological satellite that provides weather information over Africa and Europe. The image acquisition frequency of MSG is every fifteen minutes, which makes it ideal to track the spread of fires, even though it has a very low spatial resolution of 3km. The AFIS system detects the active flames of a fire, using bands from the mid-infrared range (Frost, 2012). The spatial resolution of the mid-infrared bands and the thermal infrared bands, which are used in the AFIS system, is approximately 1km. The smallest flaming unit (single fire) that can be detected is 50m x 50m (Frost, 2012). In the case of MSG, the smallest flaming unit is 500m x 500m.

2.8 The satellite images used in this report were the following:

2.8.1 MODIS images of 22 December 2016 at 10:25 and 14:40,
2.8.2 MODIS images of 23 December 2016 at 11:10 and 13:45,
2.8.3 MODIS images of 24 December 2016 at 10:15 and 14:30,
2.8.4 MODIS images of 25 December 2016 at 10:55,
2.8.5 MODIS images of 26 December 2016 at 10:00 and 14:15,
2.8.6 MODIS images of 27 December 2016 at 10:45,
2.8.7 MODIS images of 28 December 2016 at 14:05,

2.8.8 MODIS images of 29 December 2016 at 14:50,

2.8.9 Sentinel 2 image 29 November 2016,

2.8.10 Sentinel 2 image 29 December 2016.

2.9 To extract information from the digital photographic satellite source images, use was made of advanced and reliable image processing techniques, including NDVI for biomass indication and other image classification techniques, all regularly used and applied by similar experts in the field, SANSA, NASA and similar institutions and organisations internationally.

2.10 The digital photographic satellite image data referred to below in this report was identified and sourced from the USGS catalogue, which catalogue is available to SANSA. The MSG satellite image data was sourced from the EumetSat Earth Observation Portal.

2.11 To obtain true comparison quality, the core methodology was to align all the image data and the boundary data from the Chief Directorate: National Geo-spatial Information (CG-NGI) database to the same referencing system.

2.12 There is no reason to doubt the accuracy of the working method or the reliability of image- weather- or time and data obtained from any satellite, the databases of SANSA or the databases of the CG-NGI. The date used, and the working methods applied in this report, are accepted and relied upon internationally by governments and space agencies of all developed countries including NASA, the USA Federal Government and European countries such as Germany, France and the United Kingdom and by military, private and governmental agencies across the globe on a daily basis for a variety of purposes ranging from wildlife protection, wildlife management and nature conservation, veld and forest fire protection and the management of traffic flow for purposes of town and city planning and military intelligence gathering.

3. Results of image interpretation

3.1 General locality:

The picture in Figure 1 represents the study area.

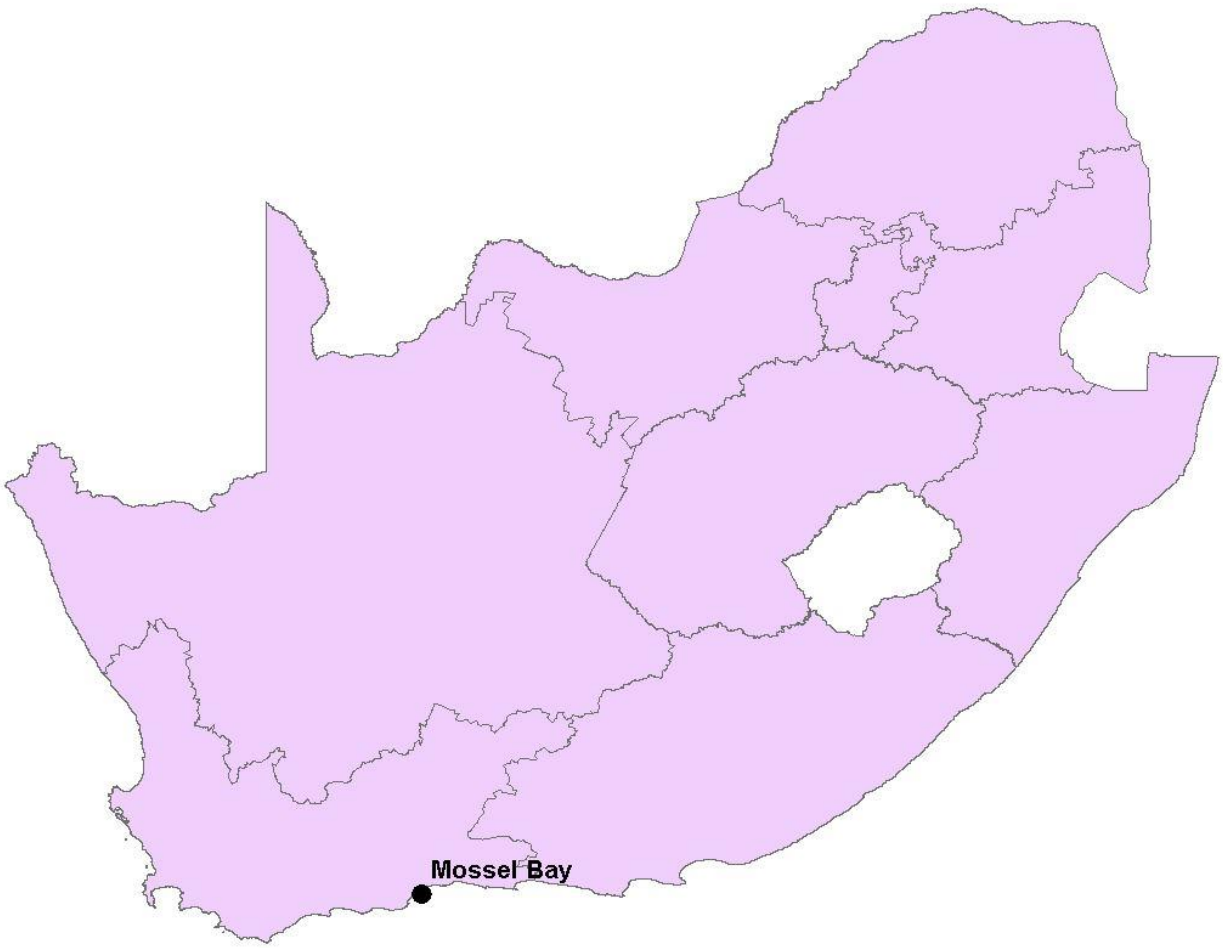


Figure 1 - The geographical location of Mossel Bay

Figure 2 gives an indication of the locality of Mossel Bay in relation to the farms which are the subject-matter of this fire investigation. The image in Figure 2 is from Sentinel 2 image of 29 November 2016, with the band combination 4, 3, 2 as red, green and blue (true color). Mossel Bay is at the bottom right of the image.

Figure 2 - A geographical location of Mossel Bay with the farm boundaries in yellow.

3.2 AFIS data interpretation (MODIS and MSG images)

3.2.1 To establish the fire scar and progression of the fire, MODIS information was firstly used and then MSG data. MODIS has a pixel resolution of 250 m. For the AFIS system to detect a fire with MODIS, the size of a fire must be about 50 m^2. For the AFIS system to detect a fire with MSG (pixel resolution of 3 km), the size of the fire must be about 500 m^2.

3.2.2 In Figure 3 below, a MODIS image of 22 December 2016 at 10:25 shows no active fire.

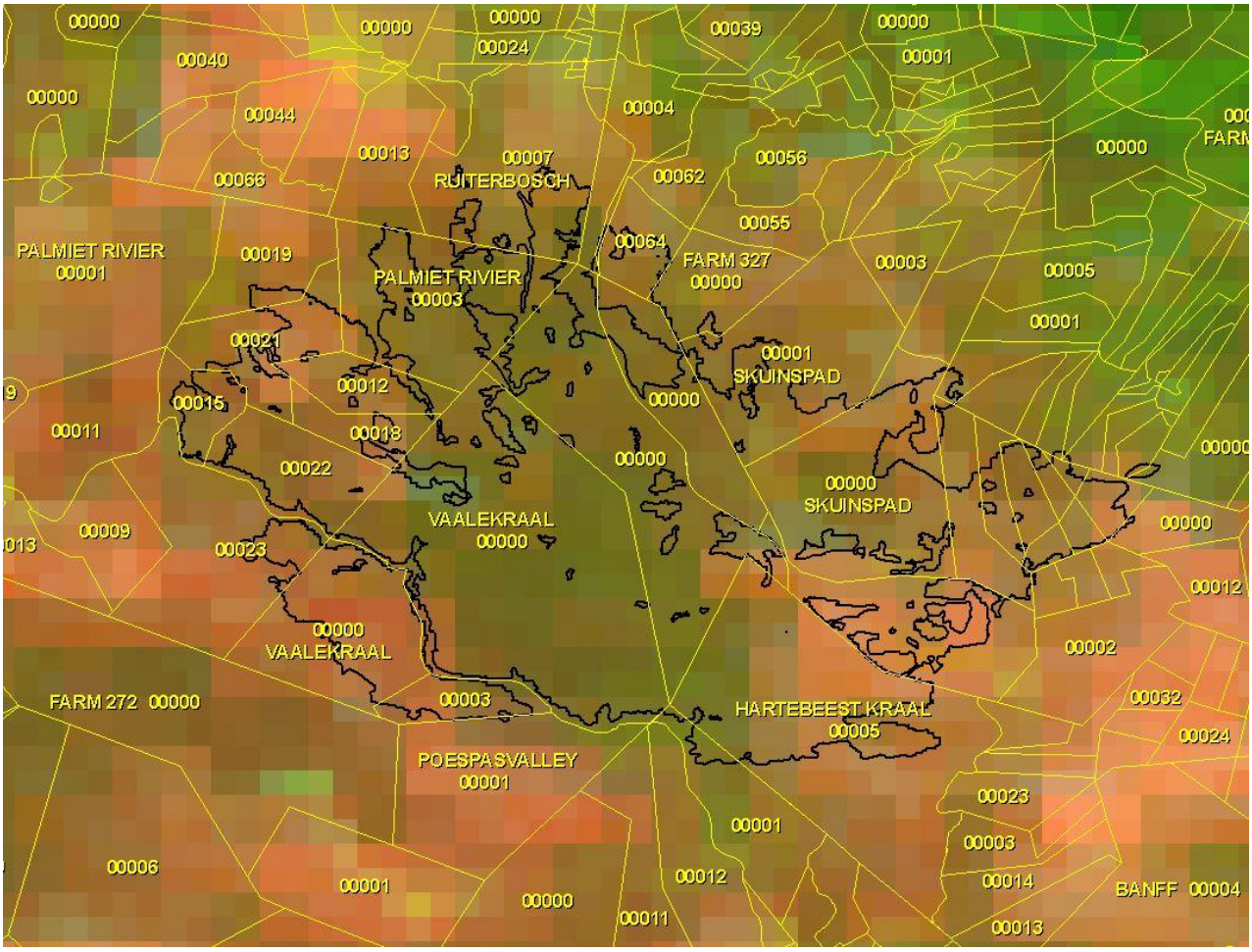


Figure 3 - MODIS Image of 22 December 2016 at 10:25. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar of 23 December 2016 which has been superimposed on the MODIS image.

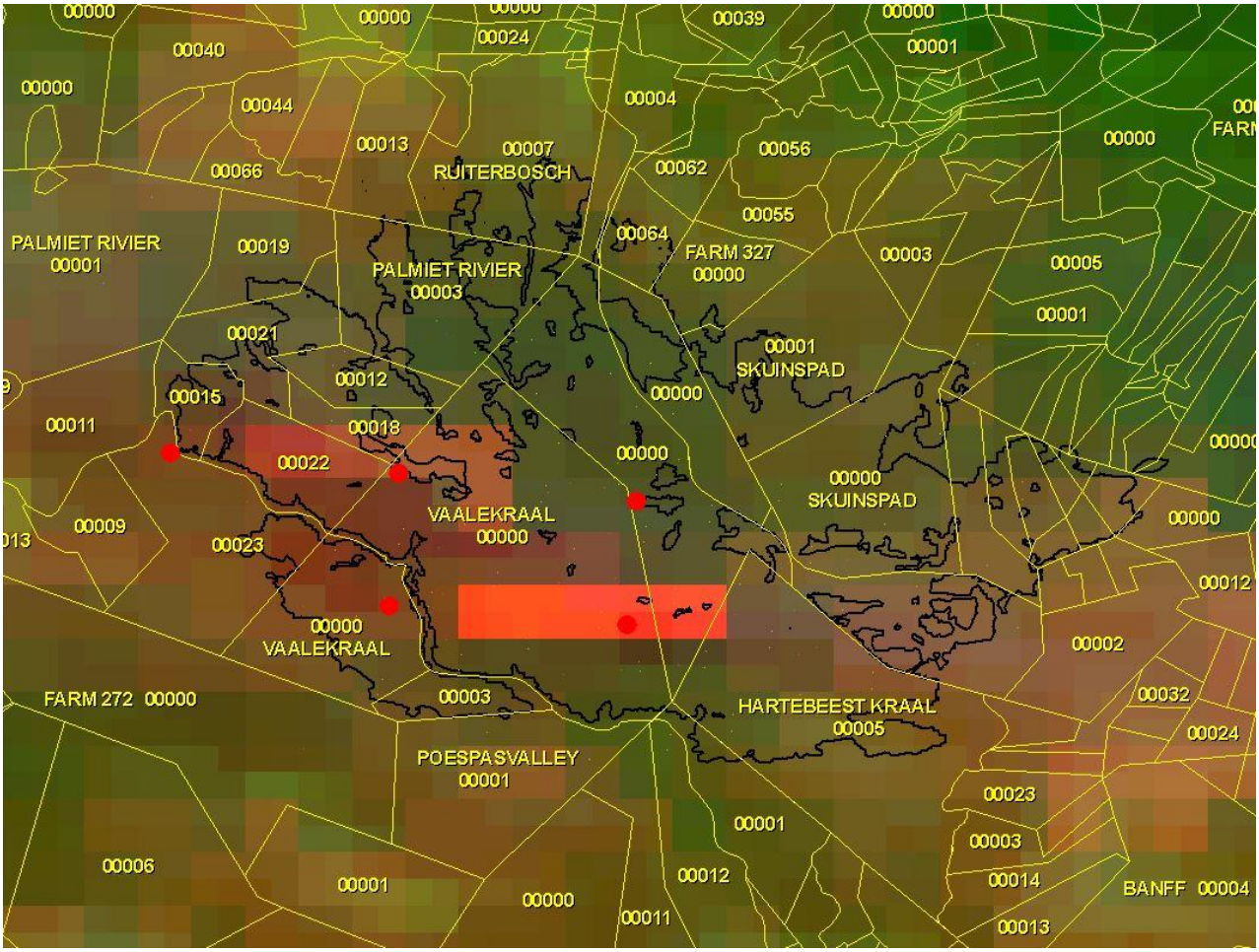


Figure 4 - MODIS Image of 23 December 2016 at 11:10. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar.

3.2.3 In figure 4 above, a fire is visible on the farm Vaalekraal and west thereof at 11:10 on 23 December 2016. The red dots, obtained from AFIS, indicate fire detected at 11:10 on 23 December 2016. A fire scar is also visible on the western side of Vaalekraal.

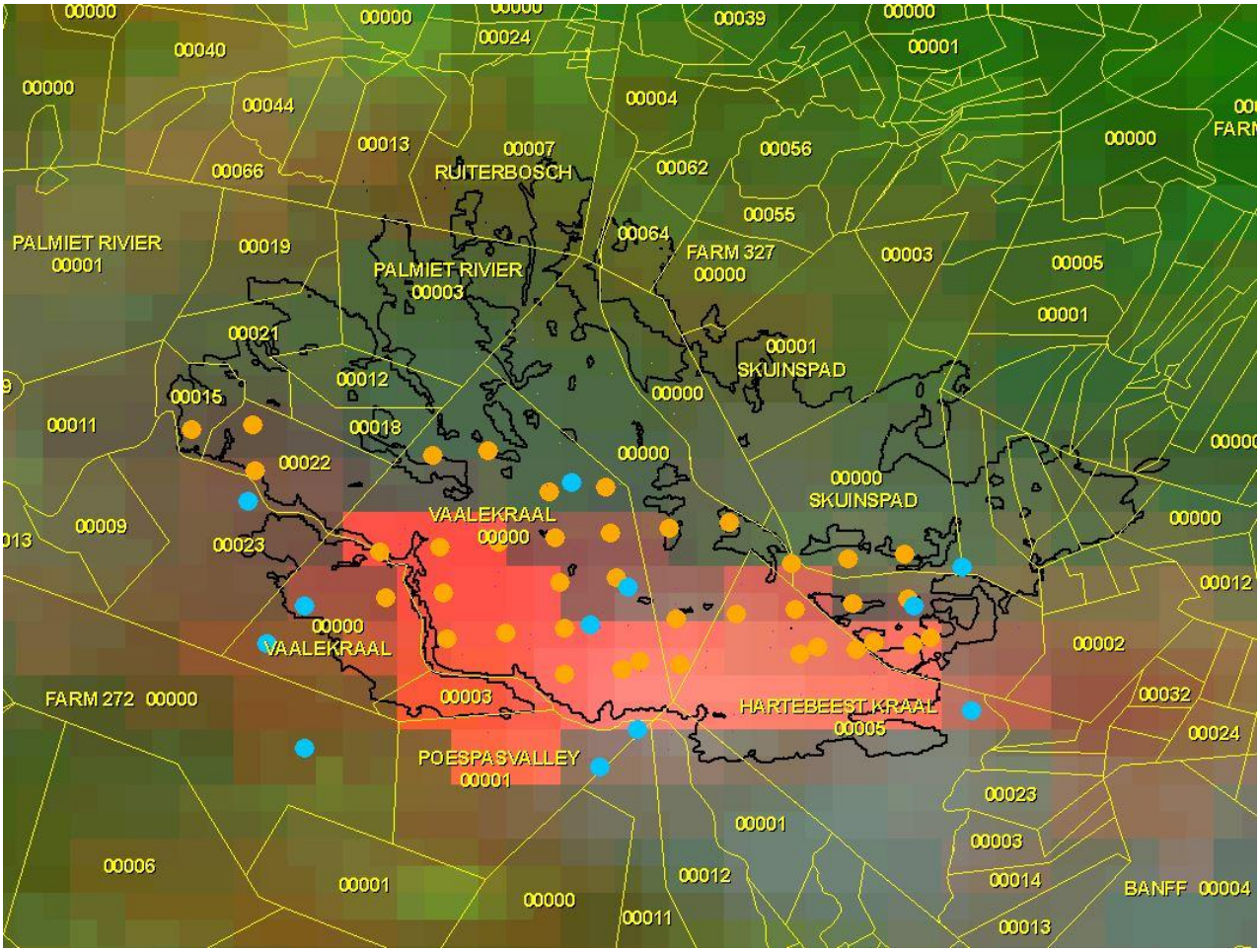


Figure 5 - MODIS Image of 23 December 2016 at 13:45. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar.

3.2.4 In figure 5 a large fire is visible at 13:45 on 23 December 2016. The colour dots of AFIS were taken at the same time from two different satellites, the blue from MODIS and the orange from NPS-VIIRS.

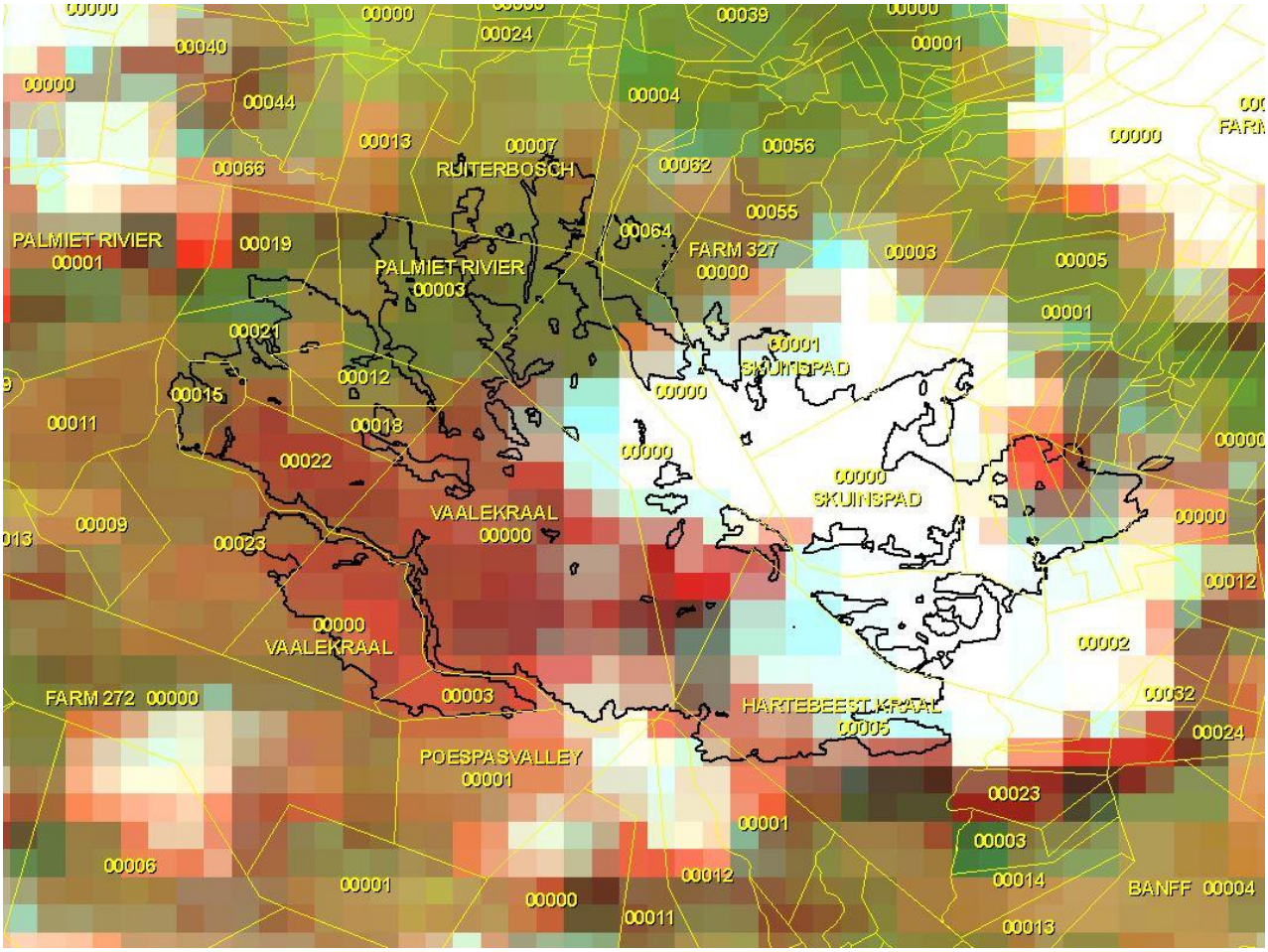


Figure 6 - MODIS Image of 24 December 2016 at 10:15. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar.

3.2.5 In figure 6, no fire was detected due to cloud cover.

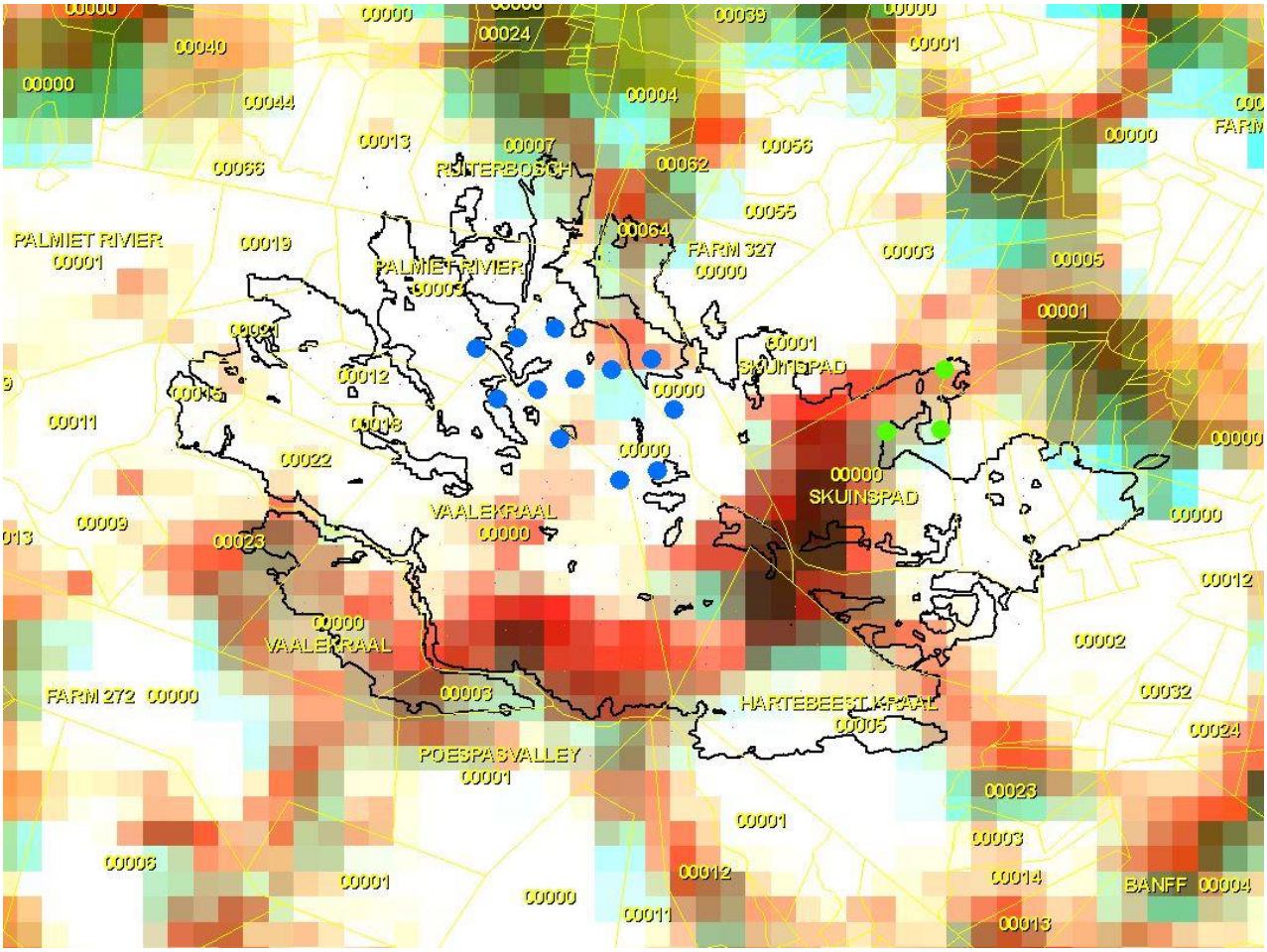


Figure 7 - MODIS Image of 24 December 2016 at 14:30. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar.

3.2.6 In figure 7, the fire was only detected with AFIS, green dots in the east at 13:22 and the blue dots in the centre (indicates fire) at 15:03 on 24 December 2016.

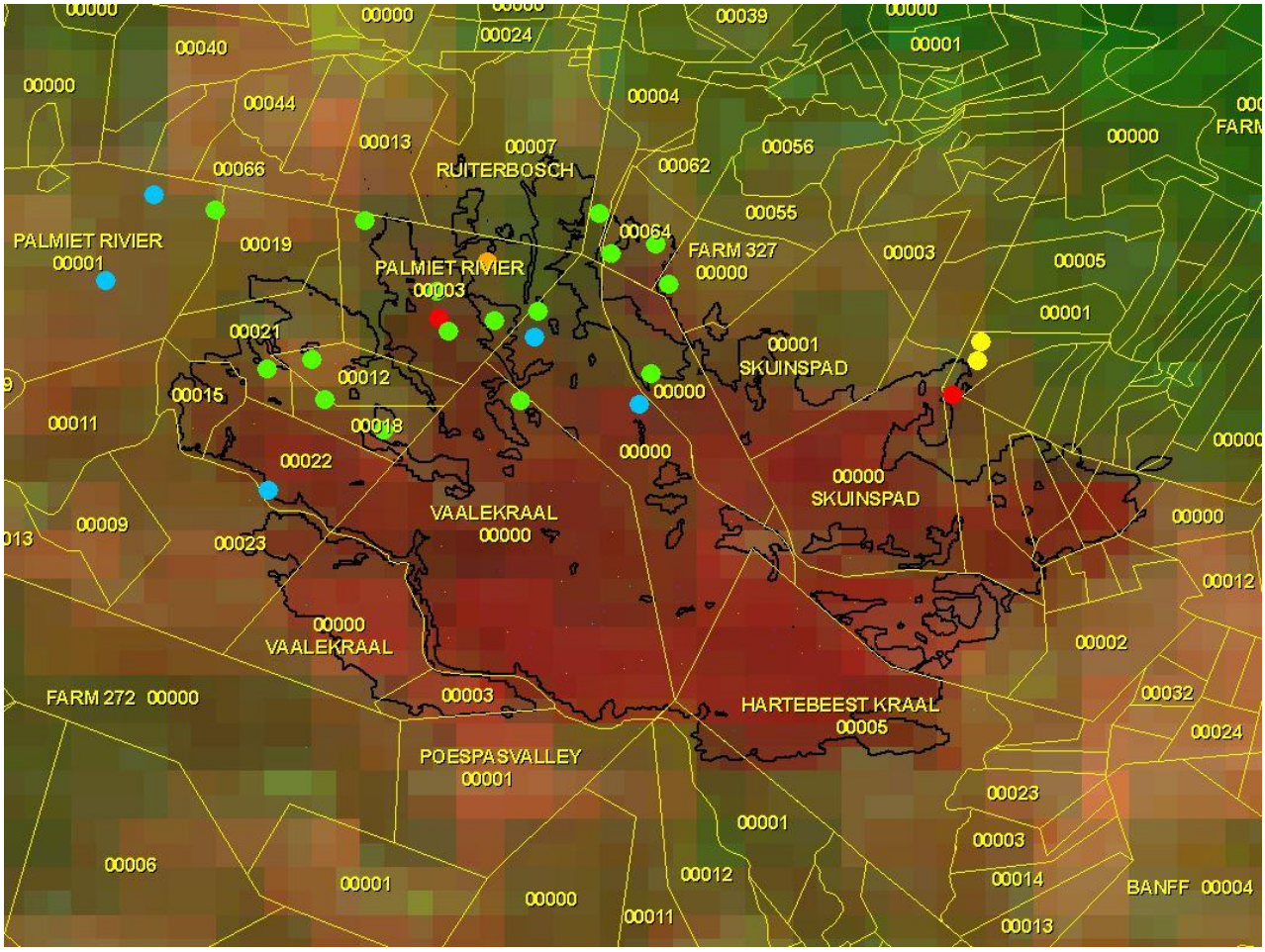


Figure 8 - MODIS Image of 25 December 2016 at 10:55. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar.

3.2.7 In figure 8, the fire was detected with AFIS only on 25 December 2016 at 00:37 (red dots), 1:25 (orange dot), 2:18 (yellow dots), 14:48 (green dots) and at 15:12 with the blue dots.

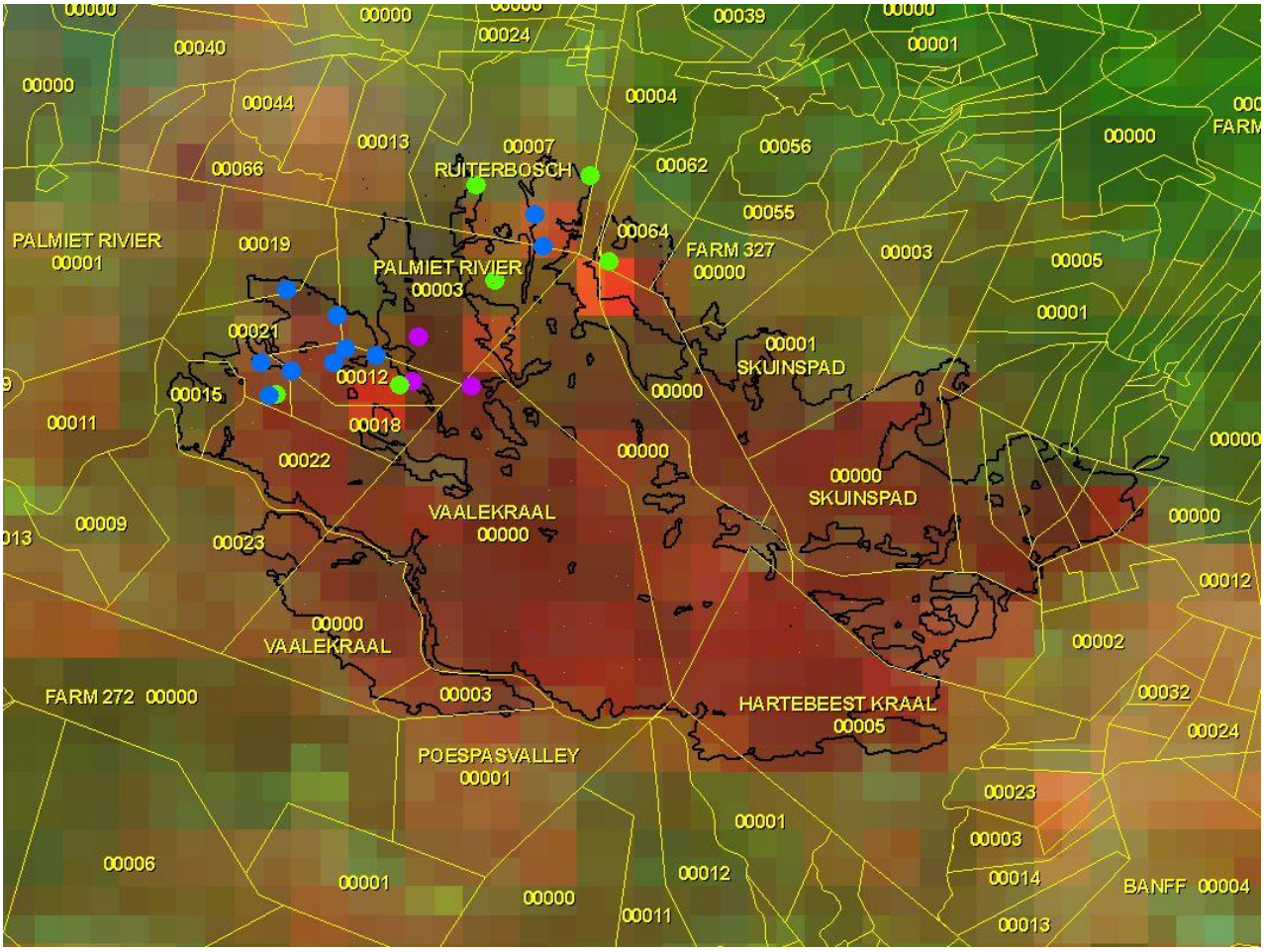


Figure 9 - MODIS Image of 26 December 2016 at 14:15. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar.

3.2.8 In figure 9, the fire was detected at 14:15 on 26 December 2016 and was indicated with the green dots of AFIS. The purple dots indicate fire detected at 2:00 and the blue dots fire at 14:25.

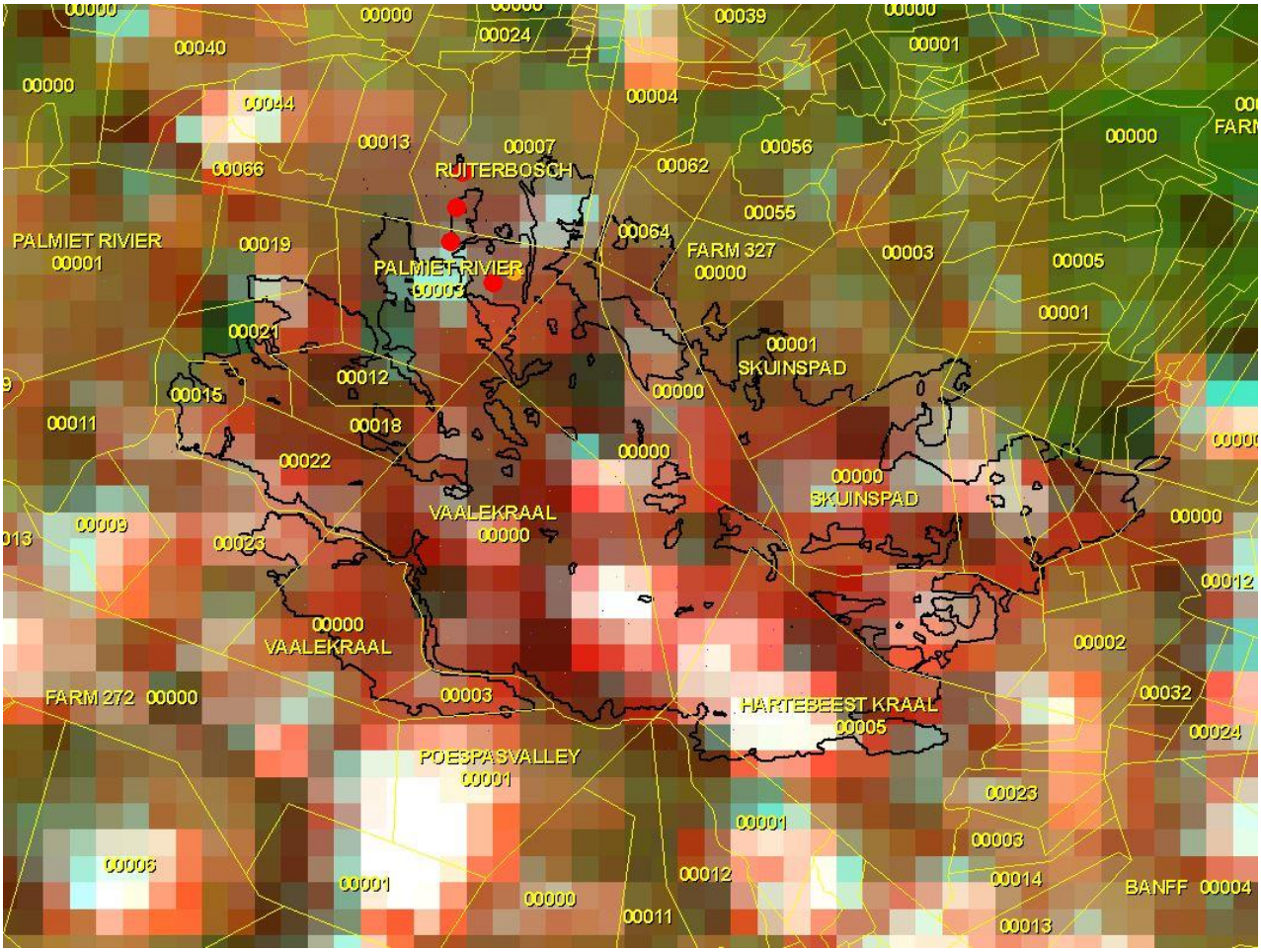


Figure 10 - MODIS Image of 27 December 2016 at 10:45. The farm boundaries are in the yellow lines, and the black lines indicate the new fire scar.

3.2.9 In figure 9, fire was detected at 10:45 on 27 December 2016 by AFIS (orange dot). AFIS detected fire at 1:40 (red dots).

3.3 Sentinel 2 data interpretation

3.3.1 With Sentinel 2 with a ground resolution of 20 m a more thorough investigation was done. The satellite imagery enabled the researcher to calculate the actual burned areas. Further, areas smaller than one hectare was not considered during the calculation. In Sentinel 2, the following band combination was used: 12, 7, 2 as red, green, blue. In this case the fire scars are red patches and the vegetation green.

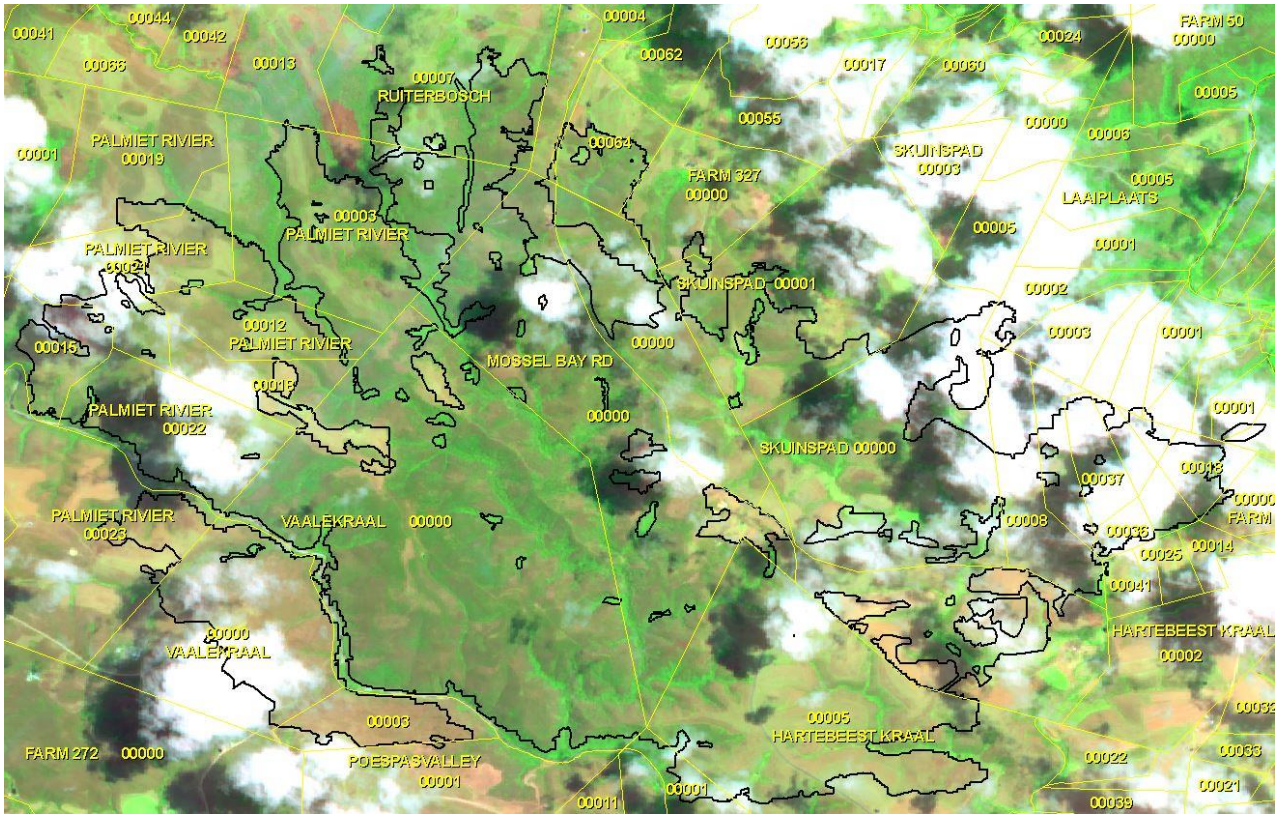


Figure 11 – Sentinel 2 data of 29 November 2016 with the farm boundaries in yellow and total fire scar in red.

3.3.2 Old fire scar is visible in the vicinity of the farms Ruiterbosch and Palmietrivier at the top of the image.

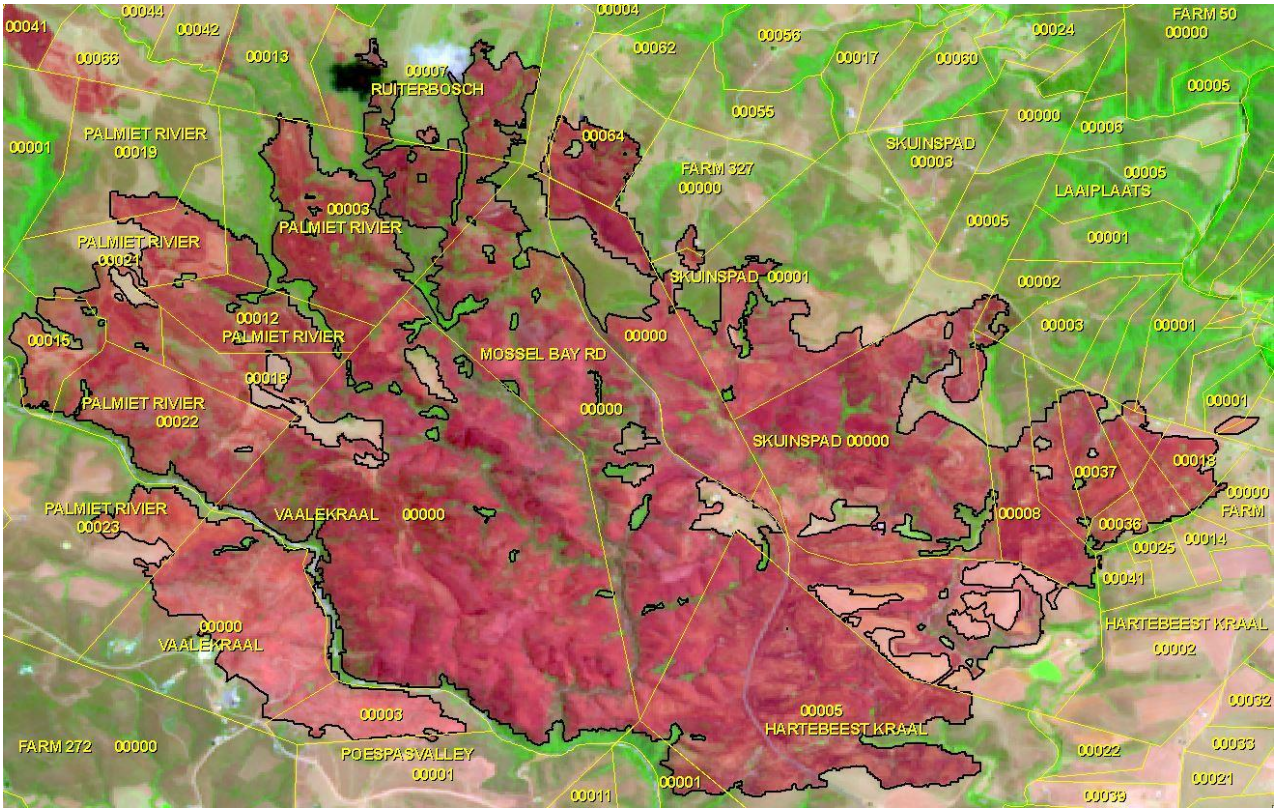


Figure 12 – Sentinel 2 data of 29 December 2016 with the farm boundaries in yellow and total fire scar in red.

3.3.3 A fire scar is visible on 29 December 2016.

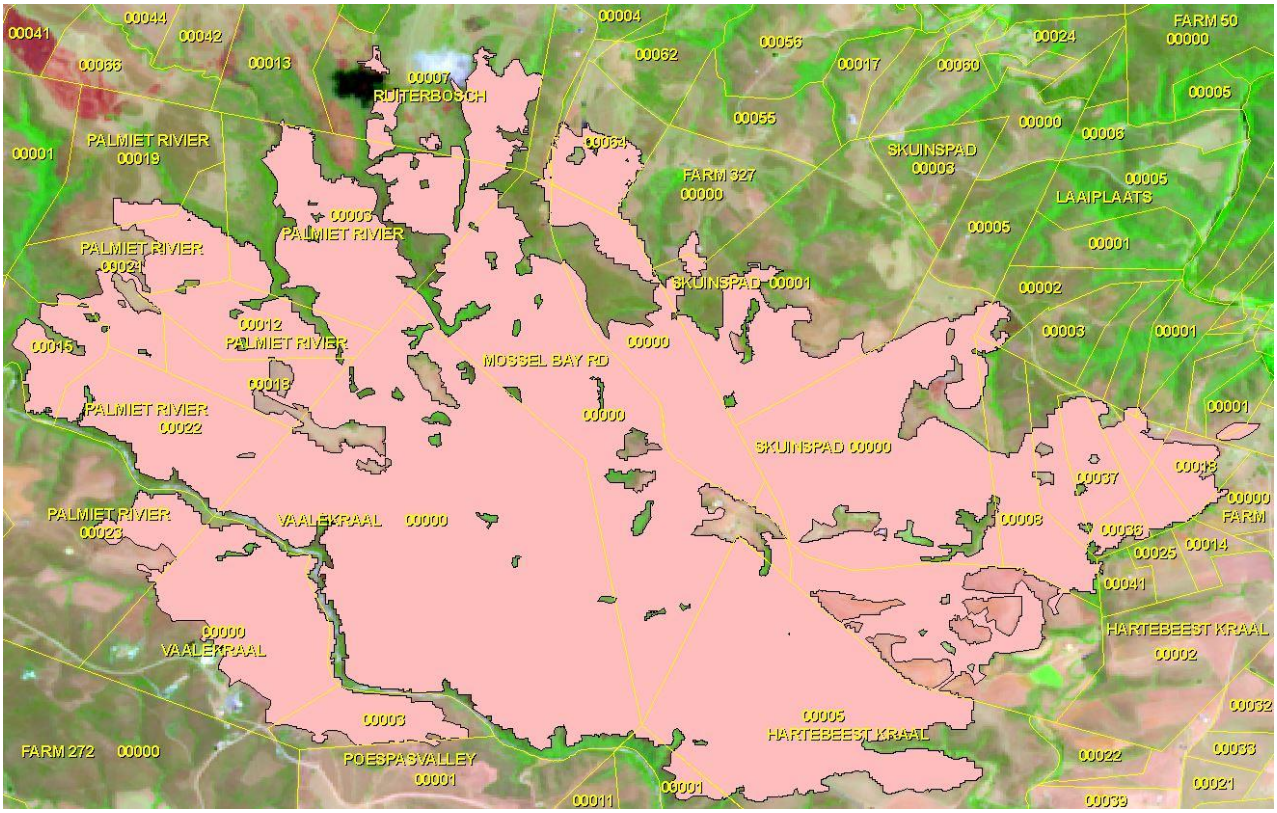


Figure 13 - The mapped fire scar.

3.3.5 The total area of this fire scar was approximately 3 174.5 hectares. The total area is mapped into different areas and the areas are calculated (indicated in figure 13). The fire scar was mapped with taking into account all the data.

In figure 14 and 15, the final fire scar (figure 13) was divided into the different portions of the farms. The areas are given in hectares. The areas given are the total area per farm – all potions calculated together.

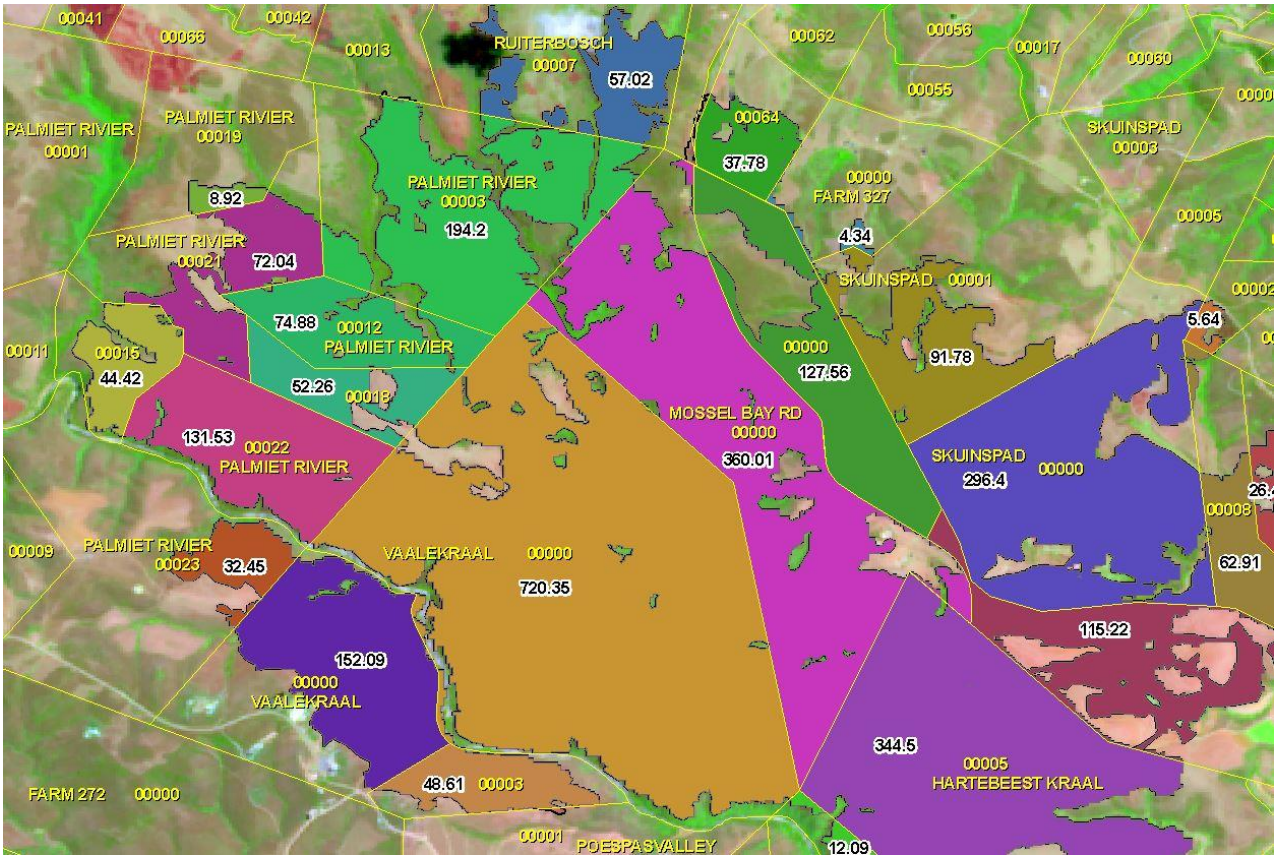


Figure 14 - Fire scar in the portions per farm in different colours.

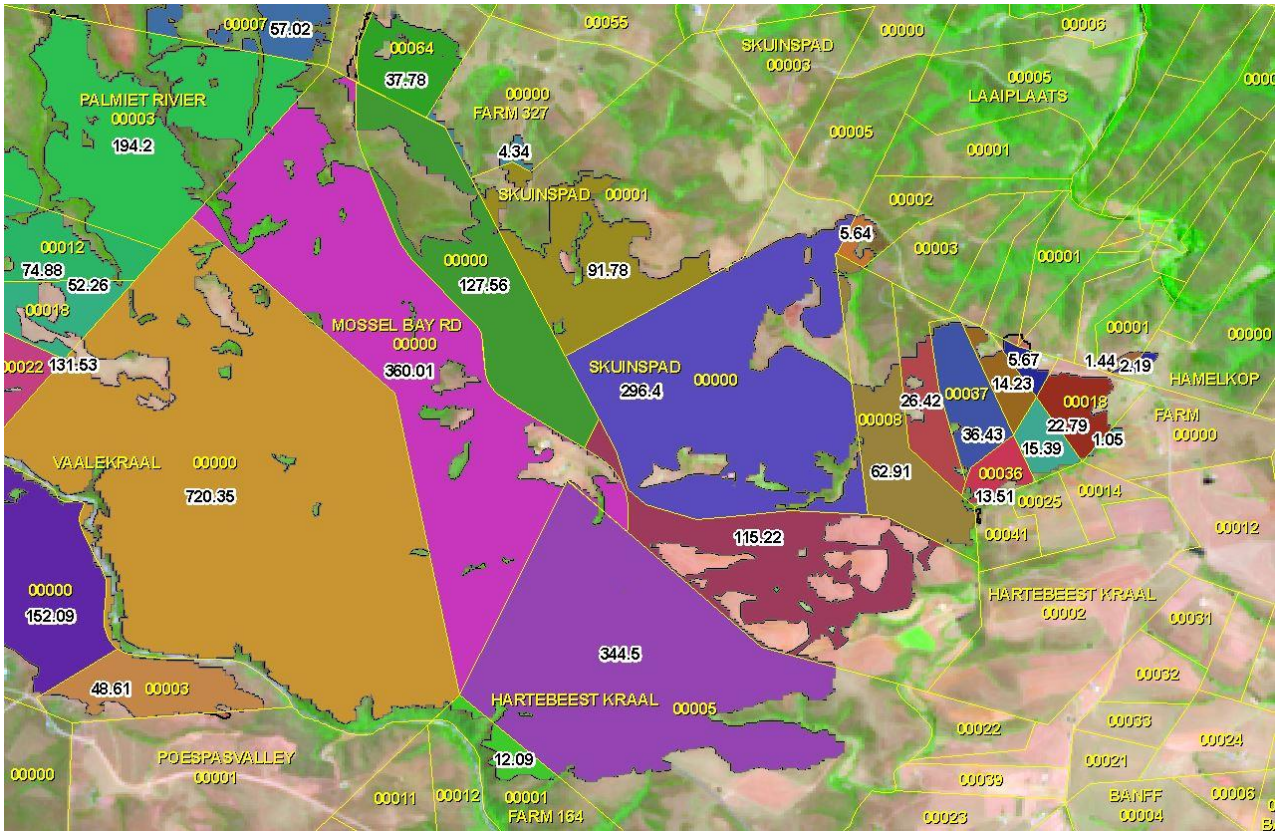


Figure 15 - Fire scar in the portions per farm in different colours.

4. Conclusion

It is the expert's opinion, based on his knowledge and experience as an experienced satellite image processing specialist, and based on his research and interpretation of the available satellite images that the following can be stated with a reasonable degree of confidence:

4.1 The relevant fire which is the subject-matter of this case probably started on 23 December 2016 on Portion 015 of the Farm Palmiet Rivier at the approximate time to the orbit of the relevant MODIS satellite before 11:03 (figure 4). That fire rapidly spread to the farms Vaalekraal and Hartebeestkraal on 23 December 2016.

4.2 On the days after 23 December 2016, the fire spread mainly to the north.

5. References

5.1 CNES, (2014): SPOT., http://www.cnes.fr/web/CNES-en/1415-spot.php, [Access: 4 November 2014]

5.2 NASA (a), (2014): Landsat Then and Now., http://landsat.gsfc.nasa.gov/about/L5_td.html [Access: 4 November 2014]

5.3 NASA (b), (2014): MODIS., http://modis.gsfc.nasa.gov/about/, [Access: 4 November 2014]

5.4 Assessment and analysis of wildfires with the aid of remote sensing and GIS, Willem A Vorster and Martin Jordaan, addressed at the proceedings of the Tenth International Conference of AARSE, October 2014

5.5 EUMETSAT Earth Obserbation Portal.