Implementation of an automated burned area mapping system using historical Landsat TM and ETM+ time series data in South Africa

Karen Steenkmap, Derick Swanepoel, Riaan Stegmann, Konrad Wessels, Linda Kleyn, Lufuno Vhemani, Frans van den Bergh, Prince Sibanda, Philip Frost, Melissa Hankel

CSIR Meraka Institute

and

Lisa Collett, Dan Tindall, Neil Flood, Nicholas Goodwin

Remote Sensing Centre, Queensland Government, Australia
• Fires occur frequently due to prolonged dry season and rapid fuel accumulation,
• Fire is a major determinant of tree-grass dynamics and woody vegetation structure in the savanna and grassland biomes,
• Socioeconomic impacts such as damage to property, infrastructure, livestock, and loss of life occur.

Cape Town, January 2017
Burned area in South Africa

South Africa burned area per year (ha)

Data source: Modis Terra & Aqua
Importance of Burned area data set

- Long term fire history reflect dominant fire regimes, and provide insight into the interactions of vegetation, climate, land use and management practices.
- New legislation (National Greenhouse Gas Emission Reporting Regulations Act) requires the calculation of greenhouse gas emission statistics.
Objectives

• Local implementation of Remote Sensing Centre (RSC) code for automated burned area mapping,
• Testing and validation in fire prone biomes in South Africa,
• Development of ‘days since last burn / veld age’ product for SA National Fire Danger Rating System.
Automated Burned area mapping by the Remote Sensing Centre, Queensland Government, Australia

System

• Automated burned area mapping system utilizing temporal, spectral and contextual information in hierarchical framework
  – processes entire time series of Landsat 30m resolution data acquired since the mid 1980’s
  – Accommodates TM/ETM sensors on board Landsat 4,5,7,8 platforms
• System produces atmospherically, BRDF and terrain corrected surface reflectance data
• Cloud + cloud shadow, topographic shadow - masking

Implemented

• Repeatable burned area maps for entire archive of Landsat for Queensland, Australia (> 60 000 images)
• Over 80% of burned area were detected with less than 30% commission error in savanna dominated area
Remote Sensing Centre’s system

- System specifically developed for savannas
- Time series of Landsat TM band 4 (B4) and sum of reflectance band 4 + band 5 (B45)
- 3 key processing stages
  - Detection of time series outliers
  - Region growing of change clusters
  - Attribution of change objects

Detection of time series outliers

- Identification of post-fire declines in reflectance as outliers to their observed reflectance over time is achieved by
  - Defining reference of ‘no change’ ($B_{45\text{ref}}$)
  - Performing multi date change detection
- Reference of ‘no change’ is obtained by choosing one of 2 median filters depending on temporal curve
  - Preceding mean for long-term non seasonal trends
  - Seasonal mean for highly periodic seasonal trends
- Calculating Difference image ($\text{Resid}_{B_{45t}}$ and $\text{Resid}_{B_{4t}}$) for each image in Path/Row stack
Detection of time series outliers

So what is change (burned)?

- Large change in B45 and small change in B4
- \((\text{Resid}_{B45t} > \text{Th}_s) \text{AND} (\text{Resid}_{B4t} > \text{Th}_{B4})\)

- Thresholds were obtained through optimization using 16,000 training points and experimental determination of ranges
Watershed region growing

- Clustering and watershed region growing used to obtain change objects,
- negative outliers used as ‘seeds’ and set as local minima with unburned ‘seeds’ set as elevated points in watershed,
- Filter samples valid pixels in rectangular window around change object centre with 10 pixel increments in each direction.
Attribution of change objects

Fig. 4. Part classification tree used for attributing change objects.

Implementation of automated system in South Africa

- Path/Row selection based on high fire risk area, biomes, available ground truth data and high income land use
Number of Landsat scenes

- Maximum number of scenes per year 41 with number of scenes per path / row between 439 and 465
Burned area mapped: Savanna

Landsat 8
27 June 2014
Burned area mapped: Grassland

Landsat 7 SLC off
10 August 2007
Burned area mapped: Fynbos

Landsat 5
15 February 1989
Validation

- Validation on 10 randomly selected images per Path/Row,
- 1000 stratified random samples per scene, 500 within burned area and 500 in unburned,
- 3 operators identifying burned vs unburned points
Validation: Savanna & Grassland

- User’s accuracy for Savanna and Grassland more than 80% with less than 18% commission error

<table>
<thead>
<tr>
<th>Biome</th>
<th>Path/Row</th>
<th>Commission (%)</th>
<th>Omission (%)</th>
<th>User's accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savanna</td>
<td>168077</td>
<td>12.9</td>
<td>3.7</td>
<td>87.1</td>
</tr>
<tr>
<td>Grassland 1</td>
<td>169079</td>
<td>17.8</td>
<td>3.9</td>
<td>82.2</td>
</tr>
<tr>
<td>Grassland 2</td>
<td>169080</td>
<td>17.0</td>
<td>11.9</td>
<td>83.0</td>
</tr>
<tr>
<td>Fynbos</td>
<td>175083</td>
<td>42.1</td>
<td>2.0</td>
<td>57.9</td>
</tr>
</tbody>
</table>
Validation: Fynbos

- User’s accuracy for Fynbos is low at 58% and commission error high at 42%

<table>
<thead>
<tr>
<th>Biome</th>
<th>Path/Row</th>
<th>Commission (%)</th>
<th>Omission (%)</th>
<th>User's accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savanna</td>
<td>168077</td>
<td>12.9</td>
<td>3.7</td>
<td>87.1</td>
</tr>
<tr>
<td>Grassland 1</td>
<td>169079</td>
<td>17.8</td>
<td>3.9</td>
<td>82.2</td>
</tr>
<tr>
<td>Grassland 2</td>
<td>169080</td>
<td>17.0</td>
<td>11.9</td>
<td>83.0</td>
</tr>
<tr>
<td>Fynbos</td>
<td>175083</td>
<td><strong>42.1</strong></td>
<td><strong>2.0</strong></td>
<td><strong>57.9</strong></td>
</tr>
</tbody>
</table>
Exclusion of Agriculture

- Agriculture (ploughed fields, dark wet soils) may show similar spectral and temporal behaviour as burned area,
- Both grassland sites improved with 9% in user’s accuracy and commission reduced with 9%,
- Limited agriculture occurs in savanna path/row,
- User’s accuracy for Fynbos does not improve with exclusion of agriculture.

<table>
<thead>
<tr>
<th>Biome</th>
<th>Commission (%) excl. agric</th>
<th>Omission (%) excl. agric</th>
<th>User's accuracy (%) excl. agric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savanna</td>
<td>12.9</td>
<td>3.7</td>
<td>87.1</td>
</tr>
<tr>
<td>Grassland 1</td>
<td>17.8</td>
<td>3.9</td>
<td>82.2</td>
</tr>
<tr>
<td>Grassland 2</td>
<td>17.0</td>
<td>11.9</td>
<td>83.0</td>
</tr>
<tr>
<td>Fynbos</td>
<td>42.1</td>
<td>2.0</td>
<td>57.9</td>
</tr>
</tbody>
</table>
Fynbos false positives
Fynbos false positives
Conclusion

• Savanna and Grassland are mapped satisfactorily with high accuracies
• The exclusion of agriculture improves accuracies in the Grassland biome by 9%
• Fynbos show low burned area accuracies which might be related to vegetation structure and spectral/temporal characteristics of burned area in Fynbos
• RSC’s system is developed for savannas which are characterized by dry vegetation and post fire decline in reflectance. Fynbos remains green during dry season and characterized by change in spectral shape rather than decline in both bands 4 and band 4+5
Further work

- Continue with validation of 2 additional Path/rows
- Acquire outstanding Landsat scenes from SANSA / USGS
- Process entire fire prone region of South Africa for Years 1984 to 2016
- Determine the influence of data gaps in time series on burned area accuracy and possible bias
- Temporal aggregation of mapping products to annual composites for the calculation of veld age (days since last burn)
Thank you

(ksteenkamp@csir.co.za)