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Woody Vegetation Cover Monitoring with Landsat Data in Southern African Savannahs

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Rationale
- The only viable method of mapping and monitoring woody vegetation cover over large areas is via Earth Observation (EO) technologies
- Landsat programme: unparalleled achievement of free, radiometrically corrected, high-resolution data that date back to 1970s
- Although pixel-based Bayesian approaches were the most commonly applied land cover classification techniques, recently, majority of studies employ machine learning algorithms, such as random forests, support vector machines, etc., which have been shown to be more accurate
- Aim: to employ random forests to map and monitor woody vegetation cover in the Northwest Province of South Africa
- Specific objectives include:
  - Mapping of woody cover, other vegetated areas, and non-vegetated areas every 4 to 5 years over the last 25 years
  - Identification of areas where woody cover is increasing over time so that mitigation measures can be prioritised & effectiveness of existing control measures assessed

Area of study
Northwest Province (NWP), South Africa:
- Covers an area >100,000 km²
- 11 Landsat scenes required for mosaic (Figure 1)
- Temperatures:
  - 17° to 31 °C summer
  - 3° to 21 °C winter
- Annual rainfall:
  - ~360 mm, -all in summer months, (October to April)

Datasets: Landsat
- Landsat imagery employed for mosaics shown in Table 1
  - Where ETM+ SLC-off data had to be used, gaps were filled in using the Gapfill plug-in for ENVI 5.2

Datasets: Sampling
- 0.5m-pixel colour aerial photography [free for 2008 onwards by South African National Geospatial Information (NGI) mapping agency]

Methods: Sampling
- > 15,000 point samples of three land cover types were selected:
  - woody vegetation cover (VC)
  - other VC (including grasses and crops)
  - no VC (urban areas and bare areas)
- Samples were considered appropriate for 2007 and 2011
- For the years before 2007 and for 2015, the samples were checked superimposed on the Landsat imagery

Methods: Classification
Random forest (RF) regressions carried out using R
- Accuracy statistics reviewed and training samples modified to achieve optimum predictive models

Results in Figure 3
Overall, the spatial extent of the land cover types in question are in agreement with the 1:250,000 land cover map developed by a consortium between the Agricultural Research Council (ARC) and the Council for Scientific and Industrial Research (CSIR) for 1994, 2000, 2005 and 2013 using Landsat data (Ngicole and Thompson, 2013).
- However, the mapped changes in the extent of woody cover cannot be directly linked with land degradation, as Bahlidge et al. (2011) and Wassell et al. (2007) point out.

Results 1 Spatial extent of land cover
Sample of accuracy statistics estimated by random forest regressions for the seven time slots are summarised in Table 2.

<table>
<thead>
<tr>
<th>Year</th>
<th>Overall Accuracy</th>
<th>Balanced Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>0.76</td>
<td>0.74</td>
</tr>
<tr>
<td>1974</td>
<td>0.74</td>
<td>0.72</td>
</tr>
<tr>
<td>1990</td>
<td>0.81</td>
<td>0.81</td>
</tr>
<tr>
<td>2002</td>
<td>0.83</td>
<td>0.82</td>
</tr>
<tr>
<td>2007</td>
<td>0.80</td>
<td>0.79</td>
</tr>
<tr>
<td>2011</td>
<td>0.82</td>
<td>0.79</td>
</tr>
<tr>
<td>2015</td>
<td>0.81</td>
<td>0.79</td>
</tr>
</tbody>
</table>

- Woody = quarter of the area (increasing trend; Figure 2)
- Other vegetation cover types: ~65% of area (on the decrease)
- Urban areas and bare land: expanding - together they cover ~10% of the Province

Figure 2. Area covered by each cover class as % of total area

Figure 4. Changes in the three land cover types (i.e. woody, other vegetation and no vegetation cover) that occurred in the last 25 years in the Northwest Province

Conclusions
- The NWP has been experiencing problems of bush encroachment that greatly affects grazing capacities and food production
- It is important for accurate, high resolution and low cost monitoring mechanisms to be devised for woody cover thickening and expansion
- Our study that maps and monitors woody cover in the Province using multi-temporal Landsat data and open source modelling tools is a positive step towards this objective.

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