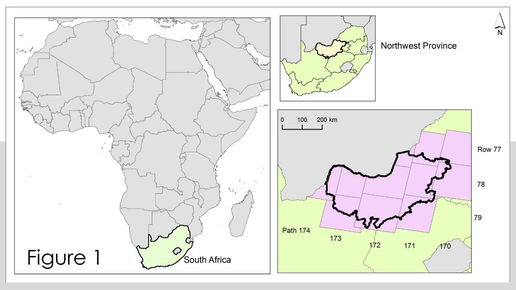
Woody Vegetation Cover Monitoring with Landsat Data in Southern African Savannahs

Elías Symeonakis, K. Petroulaki, T. Higginbottom
School of Science and the Environment, Manchester Metropolitan University, UK
E.Symeonakis@mmu.ac.uk, Kyriaki.Petroulaki@stu.mmu.ac.uk, T.Higginbottom@mmu.ac.uk
esymeonakis.wix.com/landdapp



Rationale

- The only viable method of **mapping and monitoring woody vegetation cover** over large areas is via Earth Observation (EO) technologies
- **Landsat** programme: unparalleled achieve 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 km^2
- **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

- Seven dry-season mosaics were created: **1990, 1994, 2002, 2007, 2011, 2015**
- 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 (Ngcofe and Thompson, 2015).
However, the mapped changes in the extent of woody cover cannot be directly linked with land degradation, as Eldridge et al. (2011) and Wessels 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**:

Year	Overall Statistics		Balanced Accuracy		
	Accuracy	kappa	Woody VC	Other VC	No VC
1990	0.76	0.50	0.76	0.74	0.60
1994	0.74	0.45	0.74	0.72	0.56
1998	0.81	0.60	0.81	0.78	0.65
2002	0.83	0.66	0.84	0.82	0.67
2007	0.80	0.59	0.81	0.79	0.61
2011	0.82	0.63	0.82	0.81	0.69
2015	0.81	0.61	0.82	0.79	0.65

Table 2. Accuracy of random forest regressions

- **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

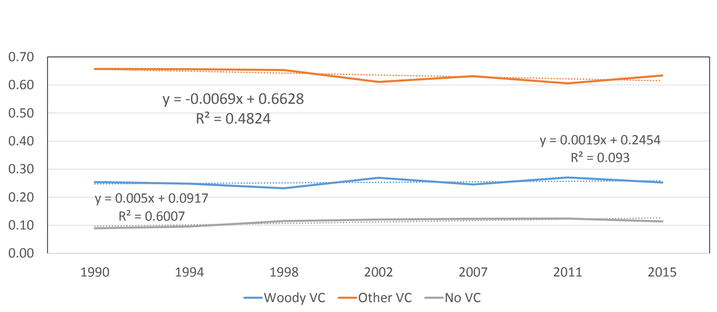


Figure 2. Area covered by each cover class as % of total area

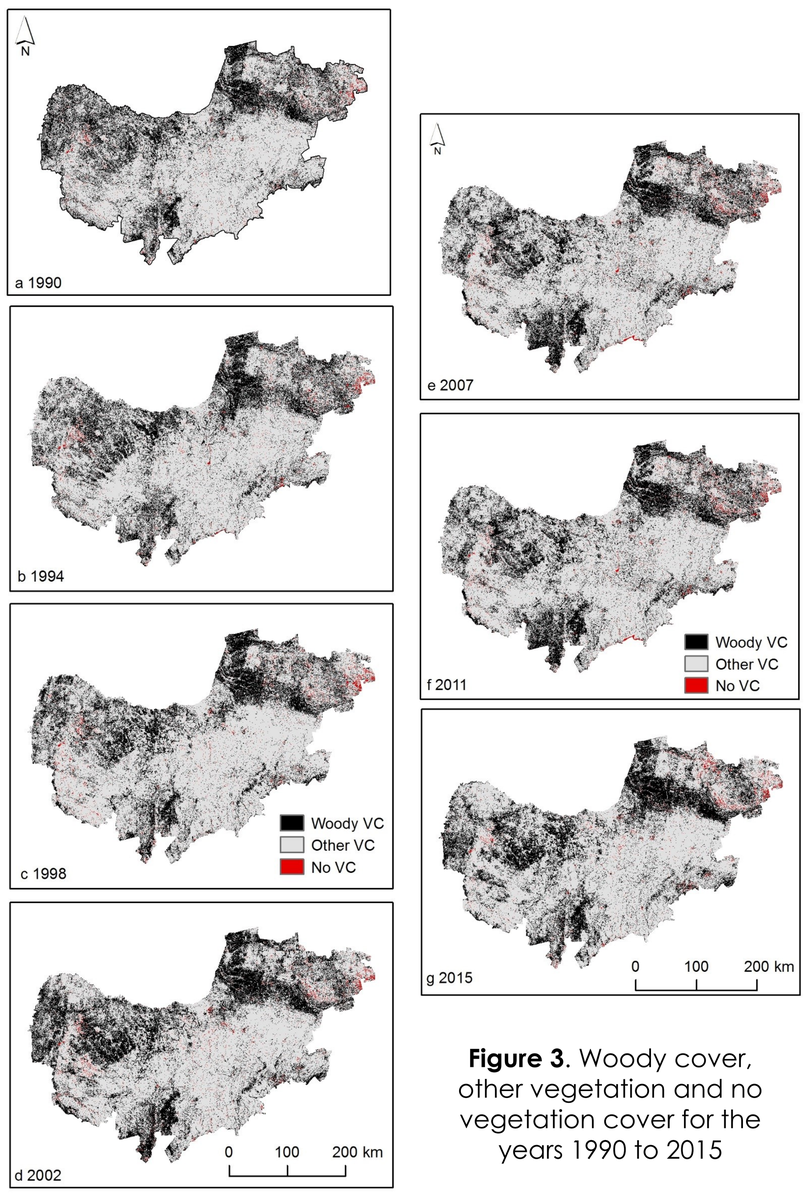


Figure 3. Woody cover, other vegetation and no vegetation cover for the years 1990 to 2015

Results 2
Change in cover

Figure 4 shows spatial distribution of changes that have occurred between the three land cover types in the last 25 years

A**reas in brown** are those that, through the years, have changed from the other two types to woody and are currently, in the year 2015, woody.

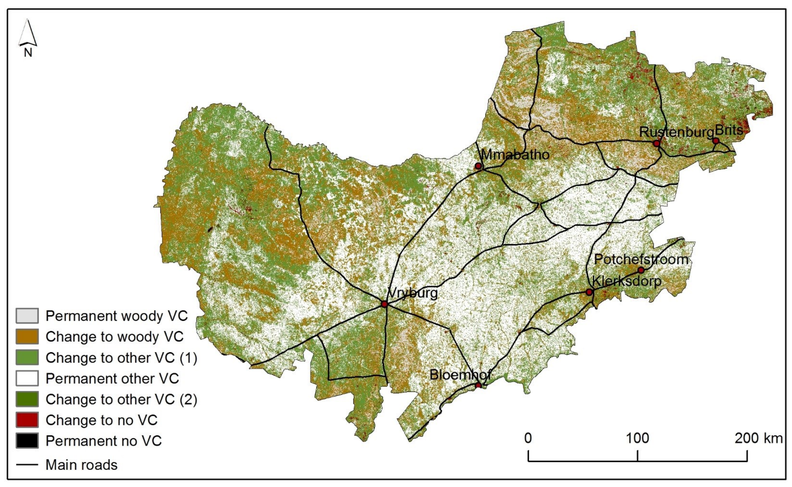


Figure 4. Changes in the three land cover types (i.e. woody, other vegetation and no vegetation cover) that occurred in the last 25 years in the Northwest Province

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 thicketisation 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.

Path/Row	Julian day & Sensor
174/78	234(TM), 245(TM), 192(TM), 227(TM), 182(TM, 2006), 188+236*(ETM+), 223(OLI)
173/78	243(TM), 238(TM), 185 (TM), 204(TM), 191(TM, 2006), 197+213*(ETM+), 216(OLI)
173/79	243(TM), 238(TM), 185(TM), 204(TM), 223 (TM, 2006), 197+213*(ETM+), 232(OLI)
172/77	204(TM), 263(TM), 178(TM), 197(TM), 200 (TM, 2006), 222*+238(ETM+), 225(OLI)
172/78	204 (TM), 263(TM), 178(TM), 197(TM), 184 (TM, 2006), 222*+238(ETM+), 225(OLI)
172/79	204 (TM), 263(TM), 178(TM), 197(TM), 187(TM), 222*+238(ETM+), 225(OLI)
171/77	261(TM), 272(TM), 187, 206, 228, 263+295*(ETM+), 234 (OLI)
171/78	261(TM), 272(TM), 187(TM), 206(TM), 228(TM), 247*+295(ETM+), 234(OLI)
171/79	261(TM), 272(TM), 187(TM), 206(TM), 228(TM), 247*+263(ETM+), 250(OLI)
170/77	206(TM), 265(TM), 196(TM), 215(TM), 173(TM), 224*+256(ETM+), 227(OLI)
170/78	206(TM), 265(TM), 196(TM), 215(TM), 221(TM), 224*+256(ETM+), 227(OLI)

Table 1. Landsat data used in chronological order: 1990, 1994, 1998, 2002, 2007, 2011, 2015. When ETM+ SLC-off data were used: asterisk denotes chosen date, no asterisk = the dates used to fill the gaps with Gapfill plug-in

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