Long-term phenology and variability of South African vegetation

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INTRODUCTION

Satellite-derived phenology allows monitoring of terrestrial vegetation on a global scale and provides an understanding of seasonal phenological patterns. These patterns are essential in (i) the characterisation and classification of vegetation, (ii) for studying the impact of climate change[3], and influence of rainfall variability, (iii) monitoring desertification[1] and (iv) detecting changes in land use/land cover. Furthermore, it provides the opportunity for defining and mapping vegetation zones (e.g. biomes), based on vegetation function.

Objective: Investigate the long-term spatial patterns and inter-annual variability in satellite-derived vegetation phenology in relation to mapped biomes and biophysical parameters in South Africa[4].

METHODS

- Calibrated 1km² AVHRR NDVI 10-day composites (1985-2000) were analysed with the TIMESAT program. A data gap for 1994 exists due to the failure of NOAA-13
- An adaptive Savitsky-Golay filter produced a smoothed curve while capturing rapid phenological changes
- A user-defined threshold of 10% of the seasonal amplitude was set as the start date of the growing season. The process was repeated with a 20% threshold for comparison purposes.

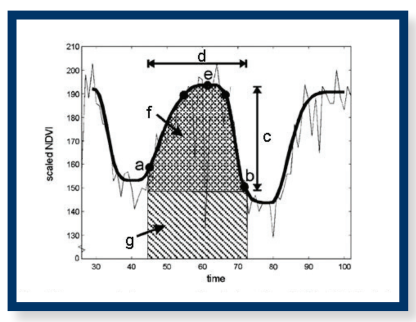


Figure 1: Phenometrics as calculated by TIMESAT (a) start date, (b) end date, (c) amplitude, (d) length of season, (e) middle of season, (f) small integral over growing season, (g) large integral over growing season (After Jönsson and Eklundh, 2004)

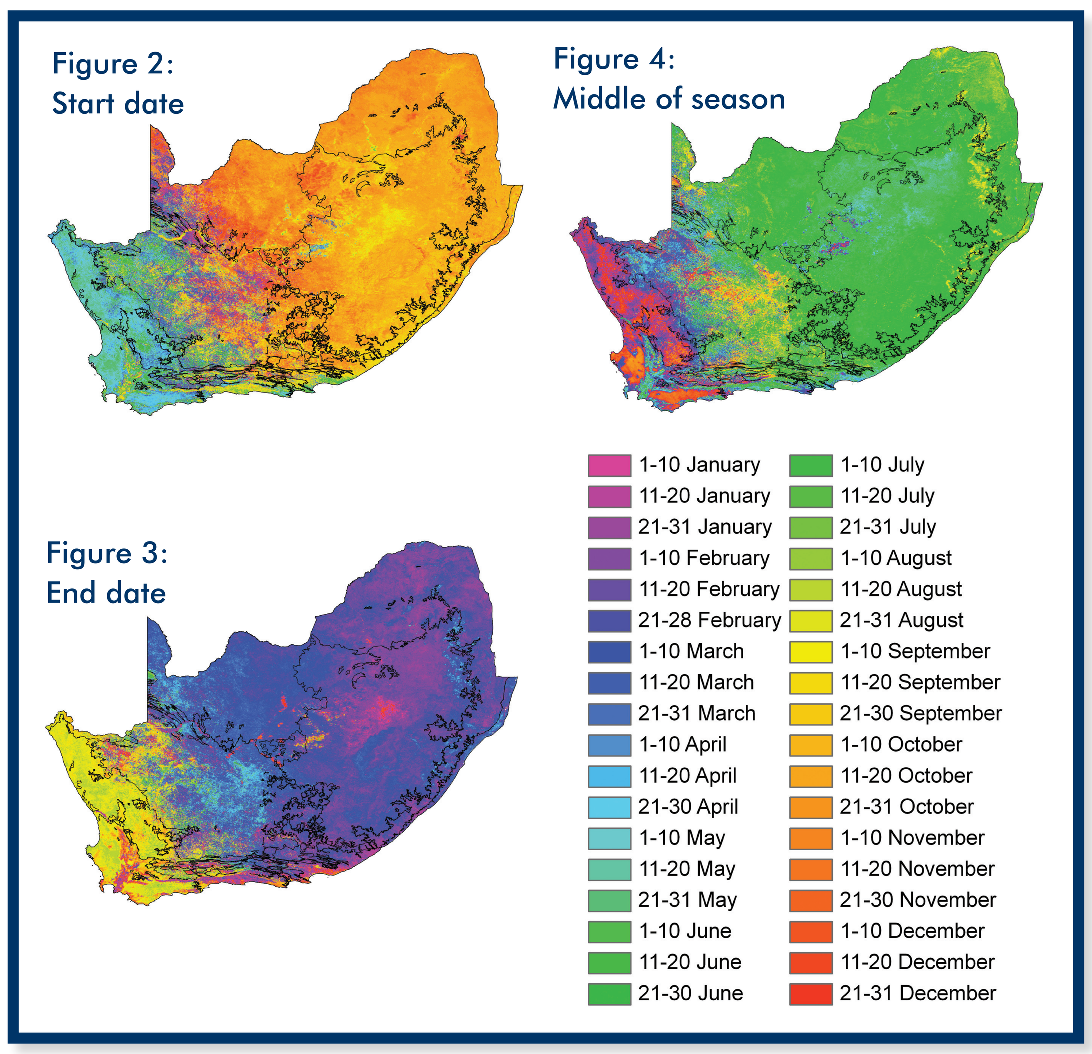
- Long-term means, standard deviations (SD) or coefficients of variation (CV) were calculated and mapped for phenometrics shown in **Figure 1**
- Transformed areas (e.g. cultivated land, built-up areas) as well as a 1 km-buffer, were excluded for the classification of biomes.

LONG-TERM MEANS AND INTER-ANNUAL VARIABILITY

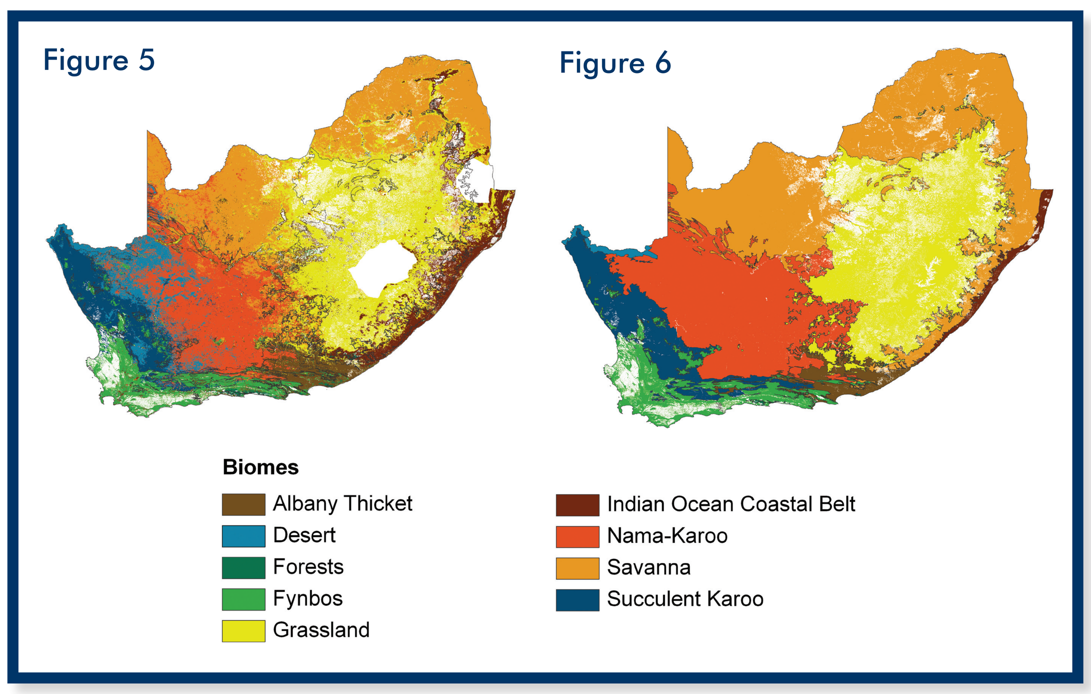
- Maps of the end date show that the 10% analyses are influenced by the green-up of fire scars in the beginning of the growing season as well as the occurrence of fire late in the growth season in the Savanna biome
- The SD for start, middle and end dates are significantly lower in the 20% than the 10% threshold analyses (**Table 1**)
- The Grassland, Savanna, Indian Ocean Coastal Belt, Forest, Albany Thicket and Nama Karoo biomes coincide with summer rainfall with a start date in September/October, middle of season in February and end date in June. Only the Forest biome has slightly earlier start and end dates
- The Succulent Karoo, Fynbos and Desert biomes coincide with winter rainfall with a start date in May, middle of season in late August and end date in February
- The Nama Karoo and Desert biomes have the highest SD for date-related phenometrics, indicating a low predictability in their seasonal dynamics
- Grassland, Savanna and Indian Ocean Coastal Belt biomes have the lowest SD for date-related phenometrics of all biomes, indicating a higher predictability in their seasonal vegetation dynamics
- Biomes with the highest productivity (large integral) are the Indian Ocean Coastal Belt and Forest biomes, followed by Albany Thicket
- Grassland has the lowest inter-annual variability in productivity (CV for large integral) at 15% while Nama Karoo and Desert biomes have the highest CV of 35% and 40% respectively (**Table 1**). Large inter-annual variability in vegetation production occurs in areas where rainfall is low and highly unpredictable.

Table 1: Summary of the results for the 20% threshold analyses from histograms of start date (**Figure 2**), start date SD, middle of season (**Figure 3**), middle of season SD, end date (**Figure 4**), end date SD, large integral and large integral CV

Biome	Start date	Start date SD (decades)	Middle of season	Middle of season SD (decades)	End date	End date SD (decades)	Large integral	Large integral CV (%)
Grassland	11-20 Oct	2	11-20 Feb	2.5	1-10 Jun	2	8	15
Savanna	21-30 Sep	2.5	1-10 Feb	3	21-30 Jun	2.5	6	20
Indian Ocean Coastal Belt	1-10 Oct	2	11-20 Feb	2.5	21-30 Jun	2.5	12	20
Forest	21-31 Aug	4	1-10 Jan	2	21-31 May	4	15.5	20
Albany Thicket	11-20 Sep	5.5	21-31 Jan	5	11-20 Jun	4.5	9	35
Nama Karoo	21-31 Oct	9	21-28 Feb	5.5	1-10 Jul	8.5	4.5	35
Succulent Karoo	11-20 May	3.5	11-20 Aug	3	1-10 Jan	6	4.5	25
Fynbos	11-20 May	4	21-31 Aug	3	1-10 Feb	5	5	30
Desert	1-10 May	8	21-31 Aug	5	11-20 Feb	6	2	40



The predicted biomes calculated from phenometrics are shown in **Figure 5**. It follows similar patterns to the biomes defined in terms of vegetation structure and climate (**Figure 6**). All nine biomes are differentiated. Areas of confusion are associated with biome boundaries e.g. Savanna and Grassland, Desert and Nama Karoo.



Figures 5 and 6: (Left) Predicted biomes according to decision tree analyses and (right) biomes after Mucina and Rutherford, 2006 respectively

DECISION TREE ANALYSES OF PHENOMETRICS

The random forest analysis has produced reliable predictions from the input sample data. Using all the phenometrics the overall prediction has an R^2 of 0.75, while R^2 values for individual biomes range from 0.62 to 0.94.

CONCLUSIONS

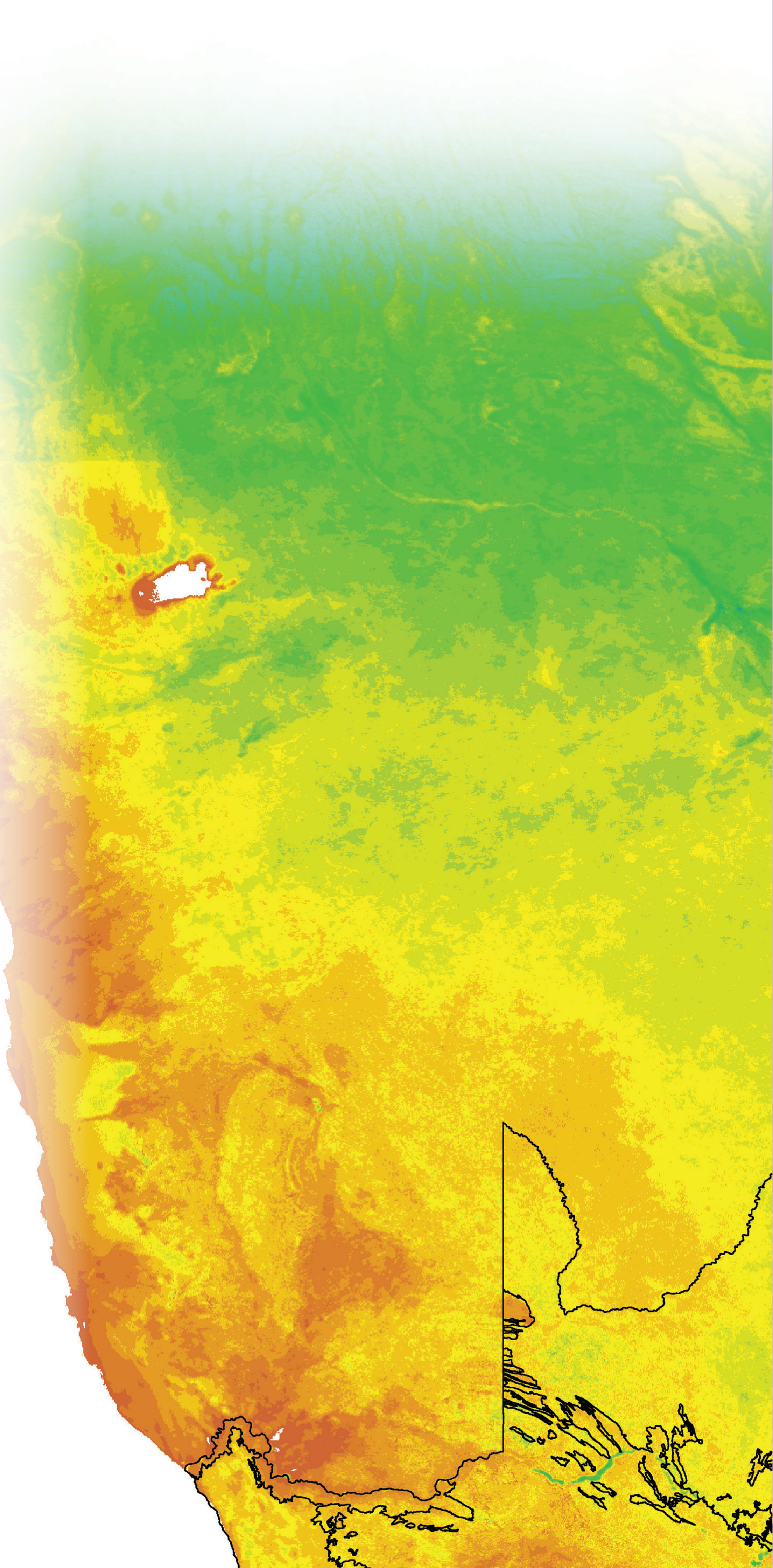
Analysis of satellite-derived phenology allows improved understanding of the function and dynamics of regional vegetation[1,3]. The magnitude as well as inter-annual variability in seasonal cycles and productivity can be investigated on a biome basis. Inter-annual variability is biome-specific and further analyses are essential for monitoring long-term changes in phenology.

The decision tree classification, based on mean phenometrics and their inter-annual variability, was comparable with biome classification (R^2 of 0.75), based on vegetation structure and climate variables. Vegetation zones can thus be defined and mapped, based on actual observations of vegetation dynamics.

Long-term satellite data are valuable in monitoring vegetation phenology in developing an understanding of impacts related to climate change.

REFERENCES

1. B. W. Heumann, J. W. Seaquist, L. Eklundh, and P. Jönsson, "AVHRR derived phenological change in the Sahel and Soudan, Africa, 1982-2005," Remote Sensing of Environment, vol. 108, pp. 385-392, 2006/11/24 2007.
2. P. Jönsson and L. Eklundh, "TIMESAT – a program for analyzing time-series of satellite sensor data," Computers & Geosciences, vol. 30, pp. 833-845, 2004.
3. B. C. Reed, M. White, and J. F. Brown, "Remote Sensing Phenology," in Phenology: An Integrative Environmental Science, Schwartz, Ed. Netherlands: Kluwer Academic Publishers, 2003, pp. 1-17.
4. L. Muncina and M. C. Rutherford, "The vegetation of South Africa, Lesotho and Swaziland," in Sterlitzia. vol. 19, L. Muncina and M. C. Rutherford, Eds. Pretoria: South African National Biodiversity Institute, 2006.



To understand the impact of climate change better, long-term satellite data provide a valuable monitoring tool to study its effect on recurring natural phenomena, such as the start and end of vegetation growth.