LINKING GROUND-BASED MONITORING AND REMOTE SENSING TECHNIQUES TO ASSESS LOCAL- AND REGIONAL-SCALE PHENOLOGY ACROSS SOUTHERN AFRICA'S BROAD-LEAVED SAVANNAS.

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Phenological monitoring enables scientists to track the 'pulse of our planet' and has been highlighted as a key tool to assess future changes in ecosystems around the world. Long-term phenological datasets exist in many developed nations, particularly those in the northern hemisphere; however, emerging nations such as those found in southern Africa currently lack equivalent phenologically-inclined initiatives. Savannas are an important biome in this region and make up approximately half of the terrestrial land surface, making them a key ecosystem for southern Africa that provides ecosystem services for large proportions of the region's rural populations. The savanna biome is renowned for its complex, spatially heterogeneous vegetation structure with a mix of patchily-distributed trees/shrubs and a continuous grass layer. Savanna climates also show high annual variability with large differences in the amounts and onset dates of rainfall from year-to-year. The coupling of a complex vegetation structure and variable climates has resulted in a diversity of phenological strategies being observed within these dynamic systems. One of these strategies is the early-greening phenomenon – deciduous trees will drop their leaves at the end of the wet season and will then flush new leaves prior to the onset of seasonal rainfall during the driest period of the annual growing cycle. This seemingly risky strategy does provide these trees with advantages for an extended, competition free period of growth at the start of the growing season over their herbaceous neighbours (grasses), whose growth is restricted by the availability of water.

The early-greening phenomenon has been observed in savannas in Australia, Asia, South America and Africa, however, few studies have quantified the occurrence of this phenological strategy within southern Africa's savannas. I monitored the green-up phenology of the trees and grasses in a broad-leaved woodland in the Nylsvley Nature Reserve (NNR) in relation to rainfall at weekly intervals over three seasons (2012-2014). Each observed season experienced different environmental conditions from early-onset average rainfall (2012), to late-onset high (2013) or low rainfall (2014). Significant early-greening was only observed in the late-onset, low rainfall season, with some early-greening occurring during the 2013 season as well. The field data collected were then compared to values obtained through remotely sensed vegetation greenness indices (NDVI) and a tree green-up threshold of 20% of the total range of NDVI values was selected. Using this green-up threshold, we could identify whether trees had commenced green-up prior to the onset of rainfall across broad-leaved woodlands in southern Africa (Figure 1). Seven broad-leaved savanna sites with a similar vegetation

structure and composition to the NNR site were selected and NDVI and precipitation data (Tropical Rainfall Measuring Mission) were collected between 2002 and 2014. If the 20% NDVI threshold value was achieved prior to the first storm (>15 mm), an early-greening event was recorded for that year. We found that early-greening shows a latitudinal trend across southern Africa (R^2=0.74) with the Zambian sites exhibiting early-greening in 85% of the seasons measured, while the South African sites had only 20% early-greening occurring (Figure 2). The variability associated with the onset of green-up also showed a latitudinal trend with the Zambian sites having fairly consistent green-up onset within a two week window ($CV_{green\text{-}up\ dates}$=0.033), while the South African sites showed high temporal variability in their green-up start dates (CV=0.77) (Figure 2). The Zambian sites also experienced longer periods of early-greening prior to the onset of rainfall (20-30 days) than the South African sites (10-15 days) (Figure 2). By linking detailed long-term field data to remotely sensed imagery, improvements in the understanding and assessments of vegetation phenology can be made in these highly variable ecosystems. Information extracted at regional scales should provide a stronger platform for us to assess which changes in phenological cycles fall within natural cycles and which are being driven by changing climates.

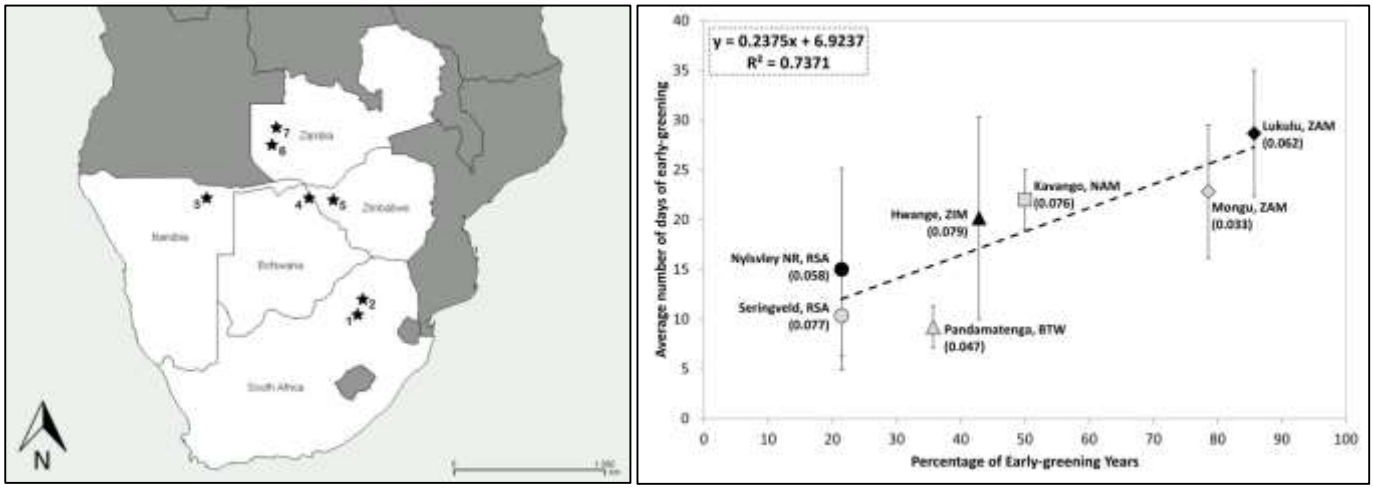

Figure 1: The locations of seven broad-leaved woodland sites: 1. Seringveld Conservancy (RSA), 2. Nylsvley Nature Reserve (NNR) (RSA), 3. Kavango region (NAM), 4. Pandamatenga (BOT), 5. Hwange National Park (ZIM), 6. Mongu Namushakende (ZAM), 7. Lukulu Kanoti (ZAM).

Figure 2: The relationship between the percentage of early-greening years between 2002 and 2014 and the mean±SE number of days of early-greening prior to the start of seasonal rainfall across seven broad-leaved woodland sites in southern Africa. Names, country codes and coefficients of variation for the green-up start dates (in parentheses) displayed next to each site.

Published work from this study:

Whitecross, M.A., Witkowski, E.T.F., Archibald, S. (2016) No two are the same: Assessing variability in broad-leaved savanna tree phenology, with watering, from 2012 to 2014 at Nylsvley, South Africa. *South African Journal of Botany* 105: 123–132. doi:10.1016/j.sajb.2016.03.016

Whitecross, M.A., Witkowski, E.T.F., and Archibald, S. (2017) Savanna tree-grass interactions: a phenological investigation of green-up in relation to water availability over three seasons. *South African Journal of Botany*, 108: 29-40.

Whitecross, M.A., Witkowski, E.T.F., and Archibald, S. (2016) Assessing the frequency and drivers of early-greening in broad-leaved woodlands along a latitudinal gradient in southern Africa. *Austral Ecology, in press*.