

Quantifying ecosystem response to disturbance: Long term vegetation changes in response to climate shifts.

Context

Semi arid savanna ecosystems are experiencing changes in structure, function, and composition driven by a combination of natural and anthropogenic factors (Galvin and Reid 2010; Bond et al. 2003; Bond & Midgley 2000). With global climate change predictions indicating that these regions will experience increased frequency and intensity of extreme events (in particular droughts), there is a high likelihood of drastic vegetation change which could be accompanied by decreases in biodiversity. Additionally, such change would be associated with modifications in resource availability for populations living within semi arid savannas, as such concerns about land degradation are inherently intertwined with concerns about human wellbeing and poverty. The socio-ecological implications of possible degradations in semi arid regions necessitate an improved understanding of ecological resilience of these regions.

The influence of climate shifts, such as that which occurred during the 1970s, on vegetation patterns is particularly acute in the semi arid savannas of southern Africa where climate, specifically mean annual precipitation, is the dominant regional control over vegetation distribution (Townshend and Justice 1986, Fuller and Prince 1996, Richard and Pocard 1998). As such, shifts in precipitation patterns or prolonged dry periods can potentially result in dramatic shifts in vegetation and irreversibly alter the state of these savanna landscapes

We rely on remotely sensed data and utilize a framework proposed by Westman and Leary (1986) and employed by Washington-Allen et al. (2008) to examine the response of savanna vegetation to climate change. Specifically we quantify spatial and temporal trends in vegetation in response to the globally recognized climate shift of the 1970's (Chavez et al 2003; Nicholson et al. 2000).

Study Site

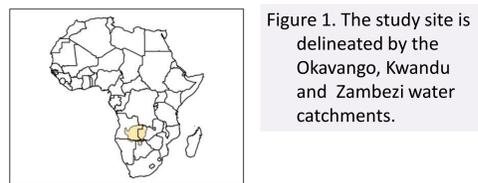
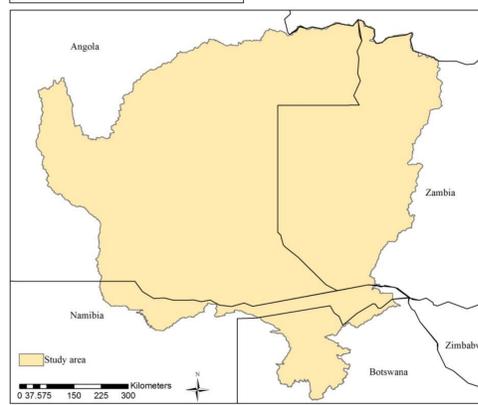


Figure 1. The study site is delineated by the Okavango, Kwandu and Zambezi water catchments.

The study area is dominated by the savanna biome. African savannas by nature are highly heterogeneous mixed woody-herbaceous systems which are capable of existing in multiple states (Scholes & Walker 1993, Hanan & Lehmann 2011).



Savannas ideally have high vegetation cover and heterogeneity and when considering shifts from one state to another, both vegetation amount and heterogeneity ought to be considered (Scholes & Walker 1993).

The quantity and heterogeneity of vegetation within African savannas is an ecosystem characteristic which reflects the state of the system and can be quantified over large spatial and temporal extents using remotely sensed data.

Data

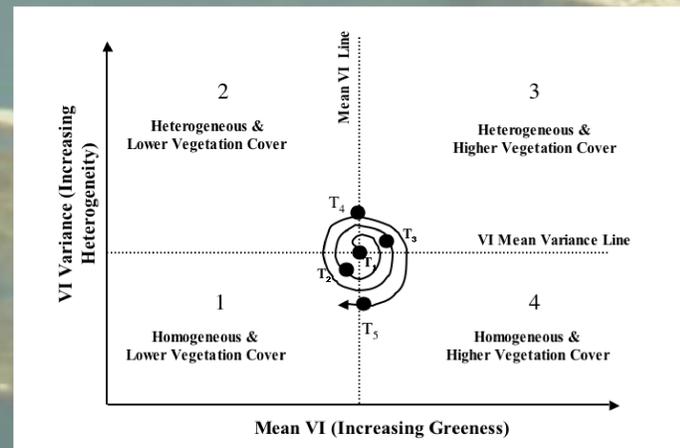
AVHRR, MODIS, and Landsat MSS & TM imagery. Rainfall station data from 15 stations located within the study site.

| Data source | 1974 | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2009 |
|-----------------|------|------|------|------|------|------|------|------|
| AVHRR | | | | | | | | |
| MODIS | | | | | | | | |
| Landsat MSS, TM | | | | | | | | |

Methods

- Hypergeometric analysis of station data is used to examine how the 1970's climate shift manifests itself in southern Africa.
- Mean-variance analysis used to assess change in system variables Mean NDVI quantifies the amount of vegetation and NDVI variance is a measure of heterogeneity (see Figure 2 for conceptual diagram).
- Persistence analysis

Figure 2. Conceptual diagram demonstrating the use of amount of vegetation and heterogeneity as system variables which can be used to characterize response to disturbance (adapted from Washington-Allen et al.(2008).



Results

Figure 3. Results - shown here for the Maun (a), Shakawe (b) and the Shakaweb (c) stations - from the hypergeometric test indicating that the latter period (post 1970's) is significantly drier than the pre 1970's period.

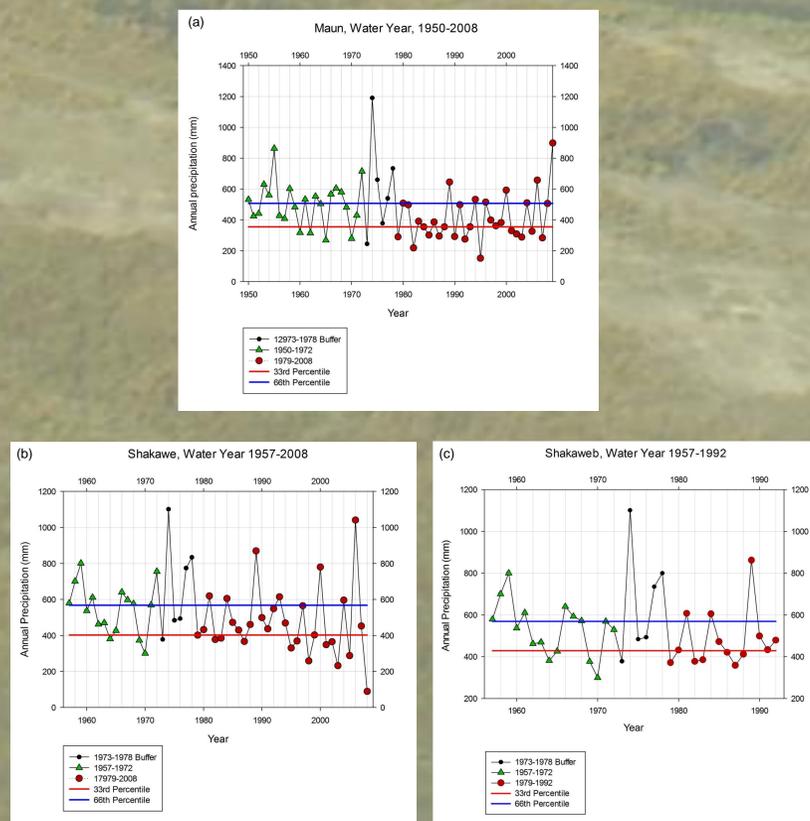


Figure 4. Results from the mean-variance analysis, showing an initial decrease in heterogeneity, followed by a consistent increase in both vegetation amount and heterogeneity.

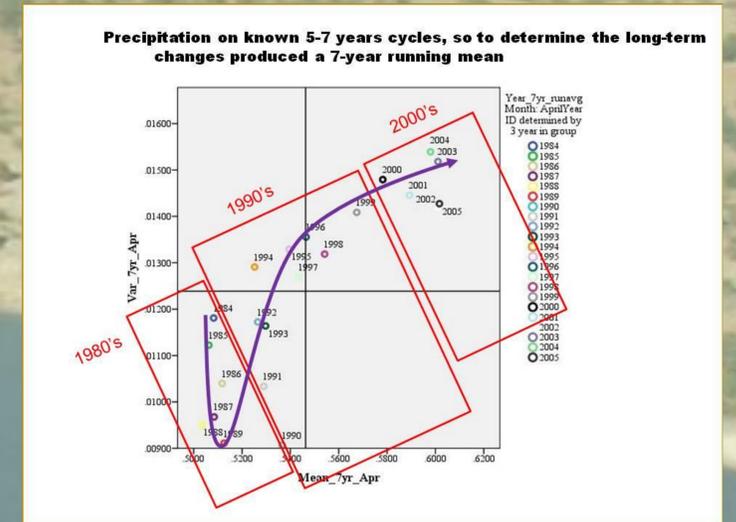


Figure 5. Results for the mean-variance analysis based on the Landsat MSS & Landsat TM data, enabling a characterization of the landscape pre- climate shift.

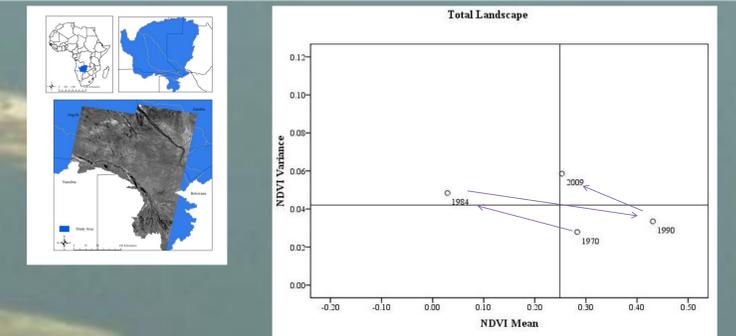
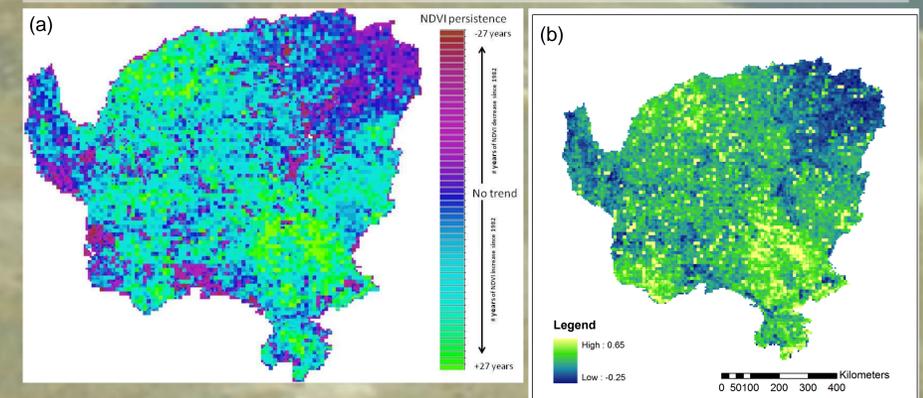


Figure 6. Results of the persistence analysis identifying the spatial variation in the long term mean NDVI trends. (a) shows the directional change in mean NDVI (vegetation amount) per pixel (b) shows a cumulative sum of mean NDVI change per pixel.



Conclusions

The 1970's climate shift resulted in a drier southern African landscape. In response to this shift in climate the overall heterogeneity continued to decrease until the late 1980's and then the landscape rebounded, continuously increasing in both mean (amount of vegetation present) and variance (heterogeneity). As noted in the introduction, savanna landscapes consist of a mosaic of grasses-trees-shrubs current analyses are exploring the spatial clustering of response identified in the persistence analysis and attempting to identify what variables are associated with the spatial clustering.