Regional Vegetation Responses to Drought in the Southwest U.S.A. - A Precipitation Use Efficiency Analysis by combining MODIS satellite and PRISM

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Introduction

A severe multiyear drought has greatly impacted the Western United States based on El Niño–Southern Oscillation (ENSO) studies (Ropelewski, 1987), tree-ring data analysis (Stahle et al., 2009), and research on changes in precipitation regimes (Redmon, 2002). Consequently, the resilience and vulnerability of impacted biomes and their biophysical elements to climate variability, and in particular, to changes in precipitation patterns are considered important critical issues in understanding the responses and fate of Southwest ecosystems to long-term drought variability and climate change.

Objectives

In this work, we addressed both local site and regional vegetation responses, at inter-annual temporal scales to drought in the Southwest using high temporal frequency satellite time series data of vegetation photosynthetic activity from the NASA-Moderate Resolution Imaging Spectroradiometer (MODIS)sensors; and precipitation data from PRISM datasets. Our objective was to assess vegetation-hydrologic linkages through the analysis of Precipitation Use Efficiencies (PUE) across continuous temporal- spatial scales.

Motivation

The main motivation behind this work is our interest to characterize vegetation responses to climate variability through the use of remote sensing. In this context, we want to follow the model of Precipitation Use Efficiency (PUE) as a method to assess vegetation responses,

$$PUE = \frac{ANPP}{MAP}$$

Where **ANPP** is Aboveground Net Primary Productivity and **MAP** is Mean Annual Precipitation.

Data & Methods

- We used the South West Regional GAP (SWRGap) land cover data, resampled from 30m to 4 km and for this initial work.

-Datasets from the satellite sensor, **MODIS** (**MOD13A3 Monthly 1km 2000-2008**), were usedover a 150x40 km studyarea(Fig.1). We resampled the 1km MODIS data to 4 km retaining only good and high quality (QA) pixels.

- The PRISM 4 km precipitation data was obtained from Oregon State University, and spatially registered with the satellite data, in order to apply the Precipitation Use Efficiency (PUE) model on a puxel by pixel basis over a regional window.

-An example of PUE, MAP, and NDVI relationships is shown in Fig. 5 for AVHRR and MODIS data for pixels from Lucky Hills and Kendall.

-Using annual data from 2000-2008, inter-annual anomalies were calculated for MAP, NDVI, and PUE on a pixel basis (see Fig. 3).

Study Area

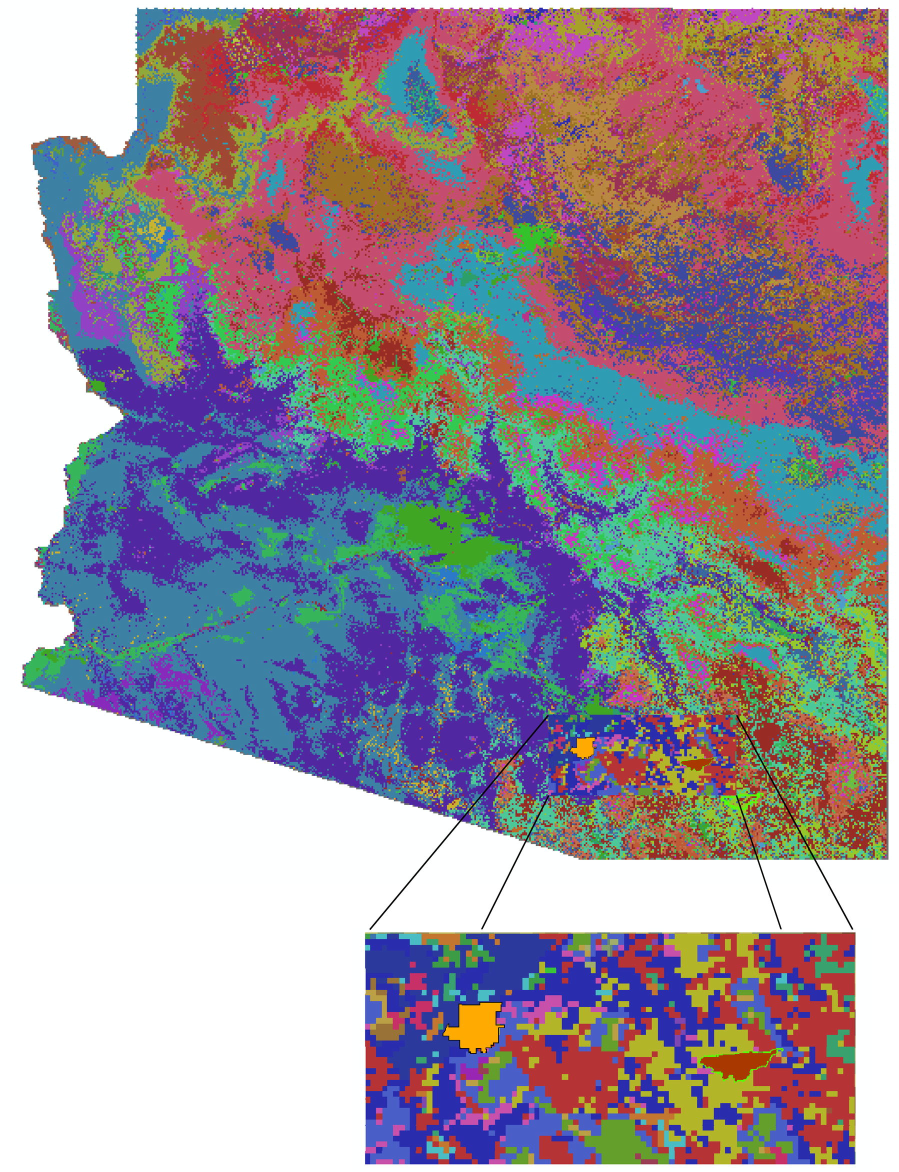

Fig.1 Rectangular section below was used as the study area for this preliminary analysis. This layer represents the SWRGap land cover data and includes the Santa Rita Experimental Range (SRER) and Walnut Gulch Experimental Watershed (WGEW) sites.

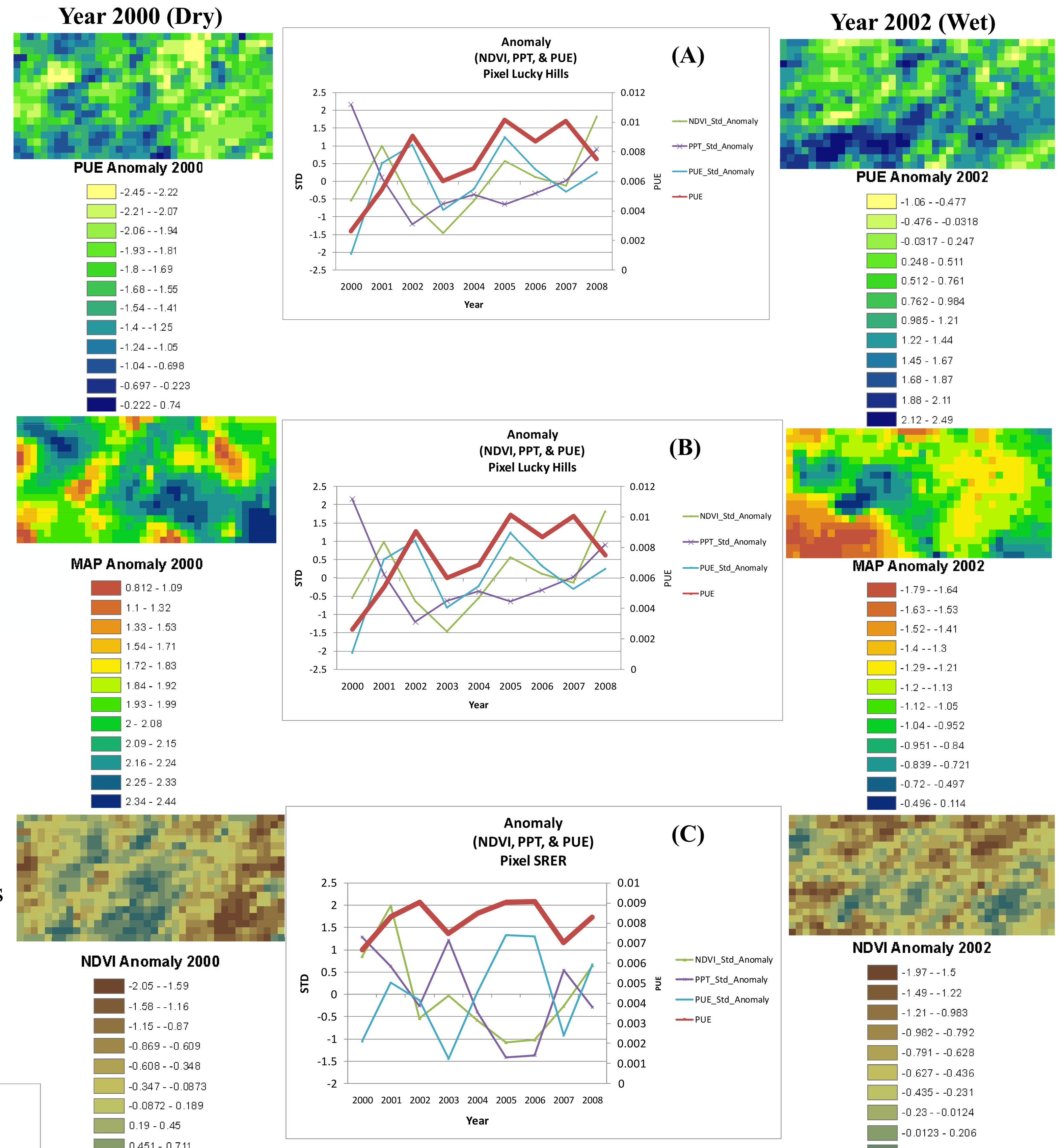

Fig. 3 NDVI, PUE, &MAP Anomalies and PUE for pixels selected within the area of study (A) Kendall Site, (B) Lucky Hills and (C) SRER

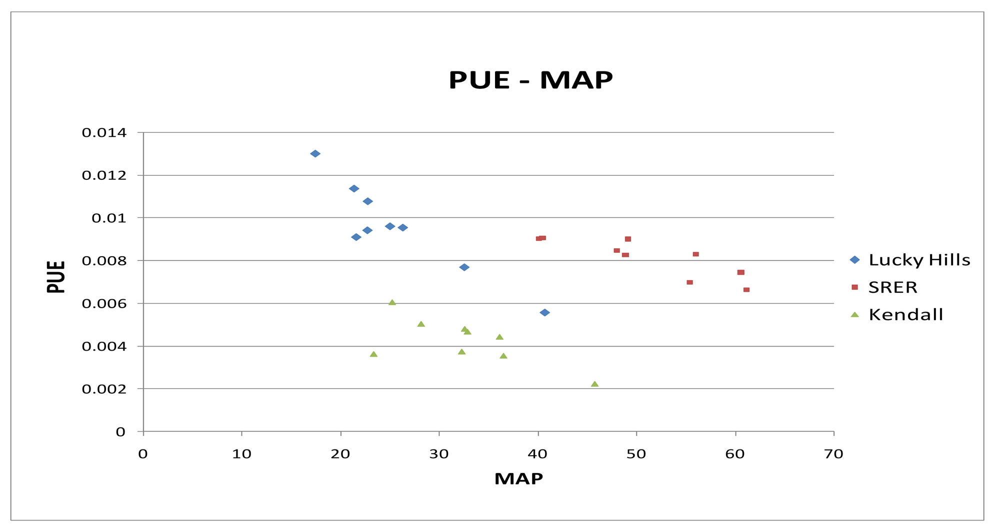

Fig. 4 PUE-MAP relationship for pixels in Lucky Hills, Kendall and SRER

we can observe an increasing trend on PUE over the 9 years that differs from the SRER site- possibly related to differences in land cover. Further research will help us clarify these differences. Also, comparisons of anomalies images for a wet (2000) and dry (2002) year provides spatially distributed PUE information, that enables us to visualize and understand future requirements to continue studying the regional behavior of vegetation-hydrology linkages.

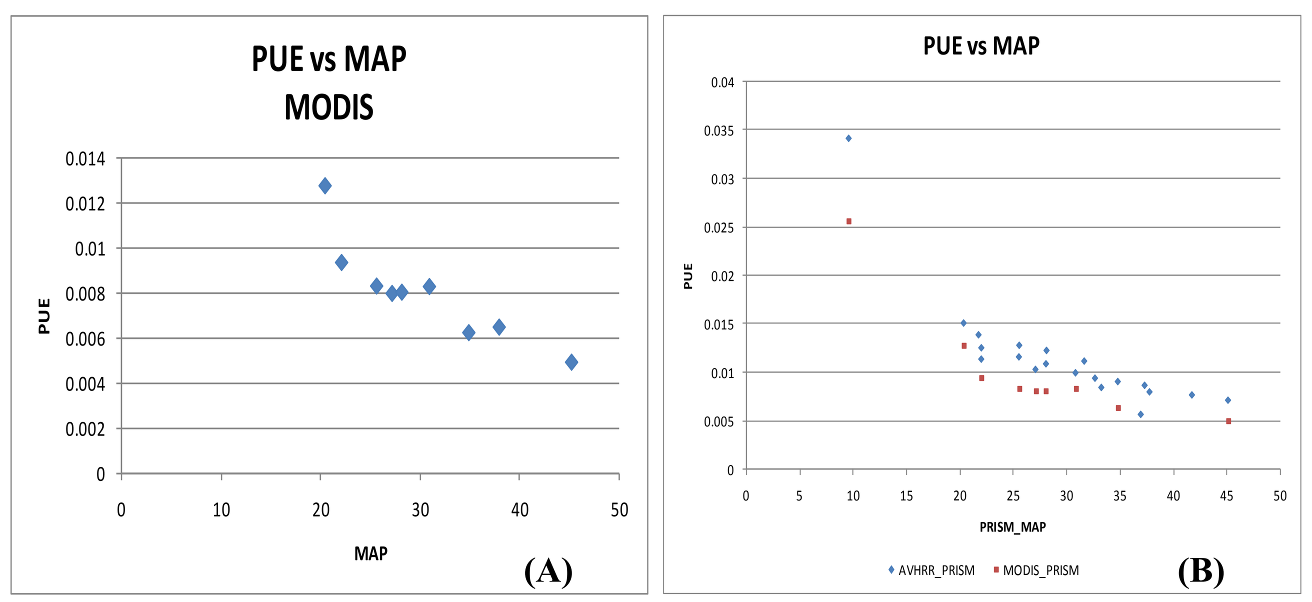

Fig. 5 PUE-MAP with MODIS and AVHRR for a MAP obtained from PRISM (A) and TRMM (B) correlation

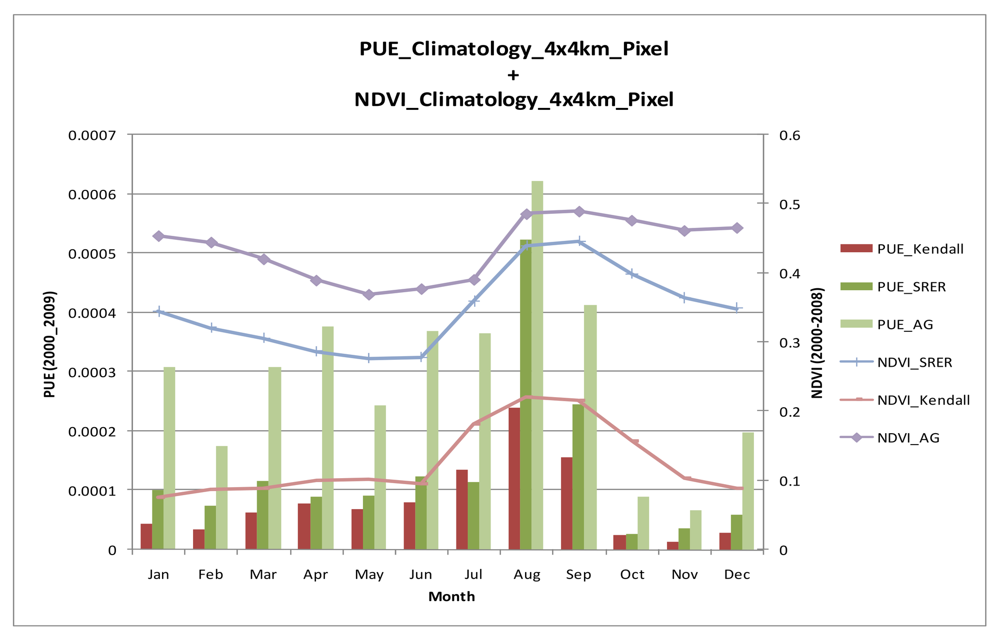

Fig 2 NDVI and PUE 'Seasonal Climatology' for three different sites in the area of study.

Results

The climatology of PUE and NDVI for different sites (Fig. 2) enables us to observe PUE with more historical NDVI data, and across sites with some differences that might be influenced by different land cover types.

Fig. 3 shows the anomalies for NDVI, PUE, and MAP along with PUE. We can observe in some of the pixels selected e.g. fig. 3(A) the NDVI anomaly is in phase with PUE and out of phase with rainfall. This could be related to more efficient use of rainfall by plants in drier years. In the case of fig. 3 (B), also an opposite phase between NDVI anomaly and PUE occurred, however these (A) & (B) were part of the WGEW and for the (C) plot the NDVI anomaly is completely out of phase with PUE, this case could be caused mainly by changes in vegetation type where according to the SWRGap information, Mesquite Upland Scrub prevails in this region, and could contribute significantly to this behavior. In the other two cases, there were Grassland for Kendall and Creosotebush and Thorn Srcub for the Lucky Hills site.

In fig. 4, the relationship based on PUE and MAP is shown for pixels within WGEW and SRER areas. For WGEW cases a similar relation is obtained and is where the PUE model stands, at low rainfall, plants become more efficient using water and a steady point when ANPP(NDVI) stays constant and varying depending on the vegetation type. As an example of previous experimentation using AVHRR, MODIS, and PRISM data for a 100x100 km window around similar area, the PUE-MAP is depicted in fig.5. This was an initial approach that requires further analysis due to differences in the VI agreement between MODIS and AVHRR. The incorporation of AVHRR NDVI into this type of analysis will allow us to identify long-term drought effects over arid regions.

Future Work

In this work, an exploration of an area in the Southwest region was made through integration of datasets from the MODIS satellite with precipitation datasets PRISM.

- An important step to followfrom this research, will be the incorporation of datasets from older sensors, such as AVHRR (1981) and probably Landsat (1972), in order to catch El Nino years.

- The use of the Tropical Rainfall Measuring Mission (TRMM) satellite will provide higher temporal resolution on rainfall (daily) and allow for extension to more regional levels, including northern Mexico.

- Finally, a quantitative analysis of the correspondence between land cover types, rainfall and VI datasets within the Southwest region will be pursued at annual, quarterly, monthly and daily time steps (to more effectively capture vegetation interactions with rainfall pulse events).

References

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