Climate Landscape Response (CLaRe) phenometrics in southern AZ using PRISM and MODIS data to identify nascent populations of buffelgrass

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Introduction

Buffelgrass (*Pennisetum ciliare*) is an invasive perennial that threatens the Sonoran desert ecosystems by out-competing native species and altering fire regimes. Current adaptive management actions have concluded that efforts to control buffelgrass must include the targeted application of herbicide, but the herbicide is only effective if applied when the buffelgrass is photosynthetically active, or "green". Buffelgrass persists in the landscape in a highly-flammable senesced state and greens up periodically during the year when sufficient precipitation is received. The localized, heavy rains received during the monsoon season make it difficult to predict when and where it will be green and therefore susceptible to herbicide treatment. The need to enhance the effectiveness as well as optimize the timing of herbicide treatment for buffelgrass is a high priority for regional land managers.

Background

Previous research by Wallace et al. 2016 successfully mapped even low densities of buffelgrass (5%) by developing innovative metrics that coupled Moderate-resolution Imaging Spectroradiometer (MODIS) satellite imagery and PRISM precipitation data. These "Climate Landscape Response" (CLaRe) metrics leverage the degree of correlation between satellite-detected greenness and precipitation values in each 250m pixel. They expose buffelgrass due to its rapid green-up response to precipitation events, which is reflected in higher CLaRe correlation values.

Regional managers found the approach and results compelling, however the proposed monitoring strategy was unfeasible due to the lack of personnel dedicated to the tedious task of downloading, processing and tracking the necessary data. Managers also expressed greater interest in detecting new invasions as well as monitoring over landscape extents rather than in specific locations.

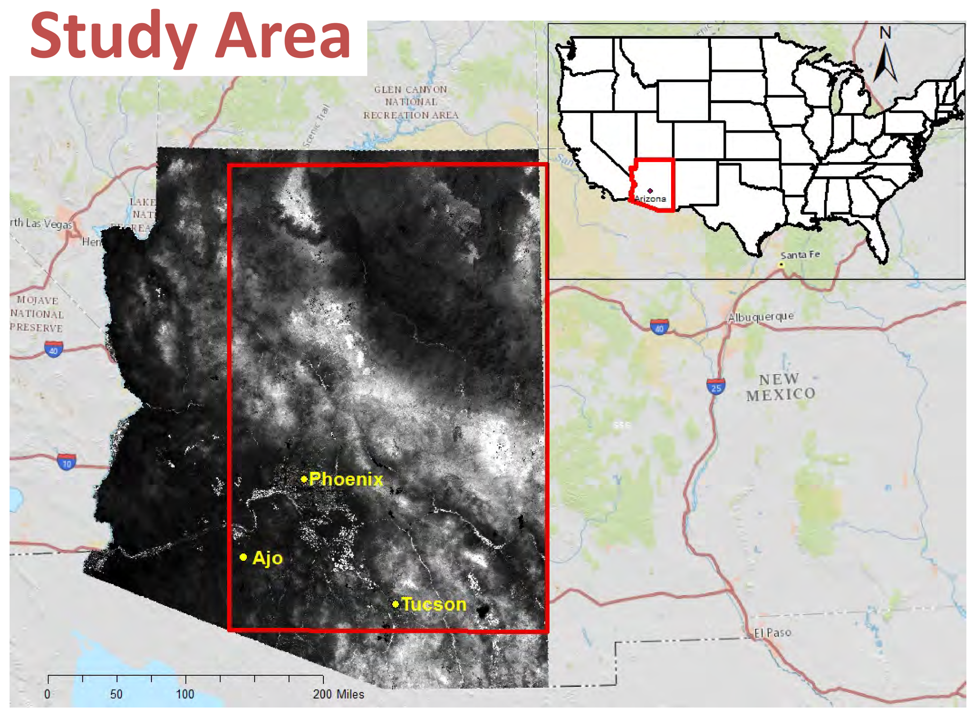
Buffelgrass greens up quickly, dries out, and persists in the landscape as highly flammable fuel.

Study Aims

This project seeks to translate the science of Wallace et al. 2016 into tools that land managers can use to promote buffelgrass management in Arizona by:

1) Using remote sensing data to regionally map where it is located and detect new infestations.
2) Create mapped products that could be used with web-based GIS methods.
3) Identify when and where buffelgrass is "green" (i.e., photosynthetically active) and suitable for herbicide treatment.

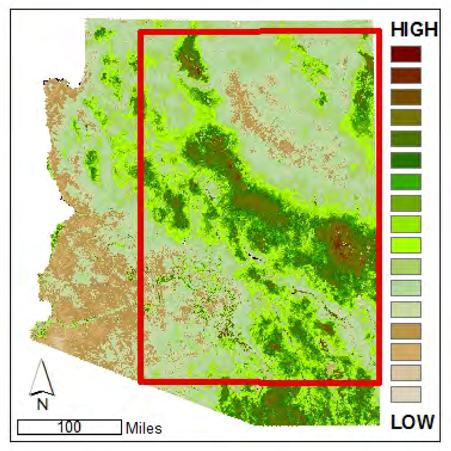
Study Area



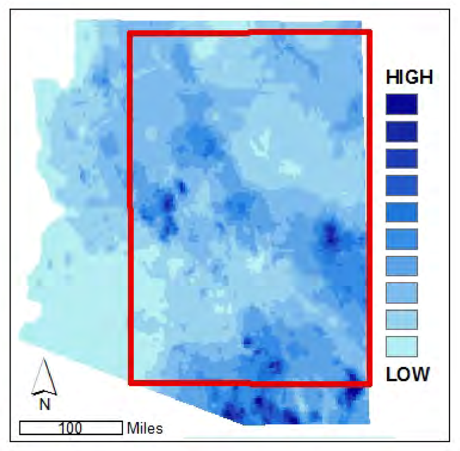
The study area is a rectangular shape in Arizona as shown above. It extends to Ajo Arizona in the west.

Data

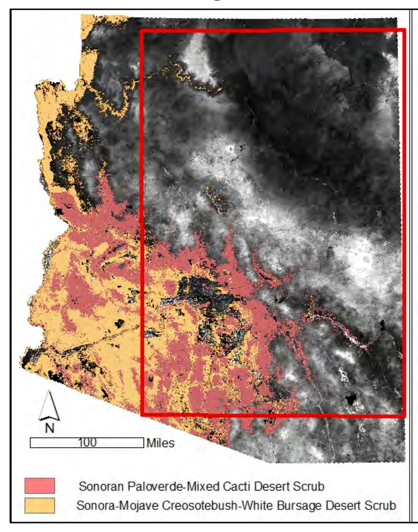
Four types of data were used in this study: MODIS, PRISM, a vegetation map and buffelgrass field data.



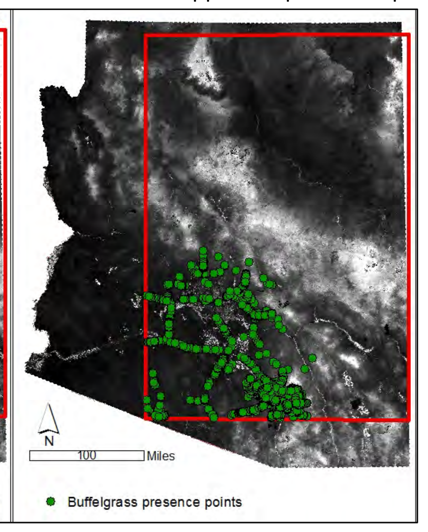
1. MODIS NDVI 8-day composite data for 2011 through 2016



2. PRISM PPT123 for the composite, i.e., the cumulative ppt for 3 prior time periods



3. Two types from the SWreGAP vegetation map (red=57, orange=60)



4. Buffelgrass field data compiled from various sources

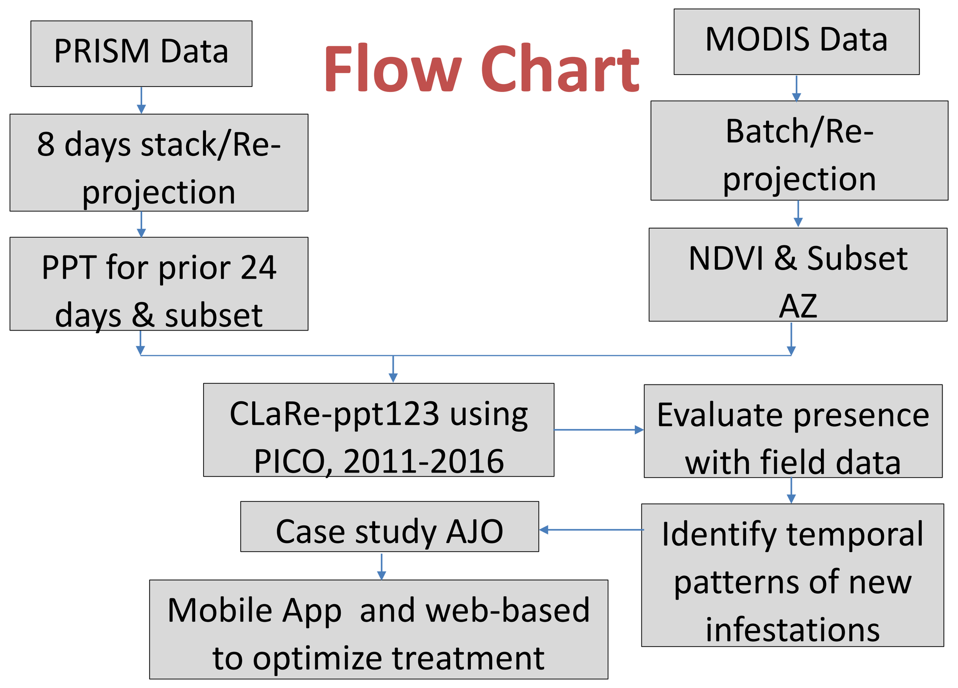
Methods

CLaRe metrics were calculated from MODIS and PRISM ppt123 data for 2011 to 2016 using the PiCo algorithm developed by NASA for a related project. Field data were used to evaluate CLaRe performance within the two vegetation types that host the majority of buffelgrass (BG) in the region (above).

To identify new infestations of BG, we used two approaches. First, we calculated BG presence models for the early years (~2012 = 2011,12,13) and the later years (~2015 = 2014,15,16), where a pixel is mapped as BG if it is one of the highest 20% of CLaRe values observed in at least 2 of 3 years within its vegetation type. Models for ~2012 and ~2015 were compared to look for transitions between native and BG. Second, CLaRe metrics were normalized for climate differences across years via a z-score transformation. These normalized images were input to an unsupervised classification to look for patterns that might reflect a new infestation.

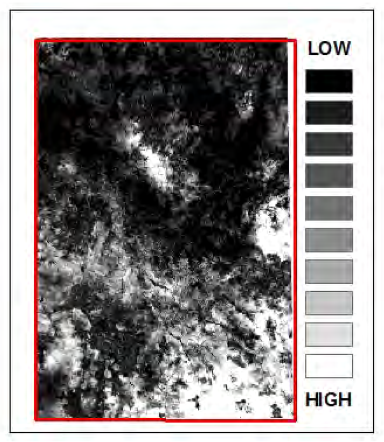
Chi-Sq tests were used to evaluate both the model differencing and the z-score classification approaches.

Flow Chart



Results

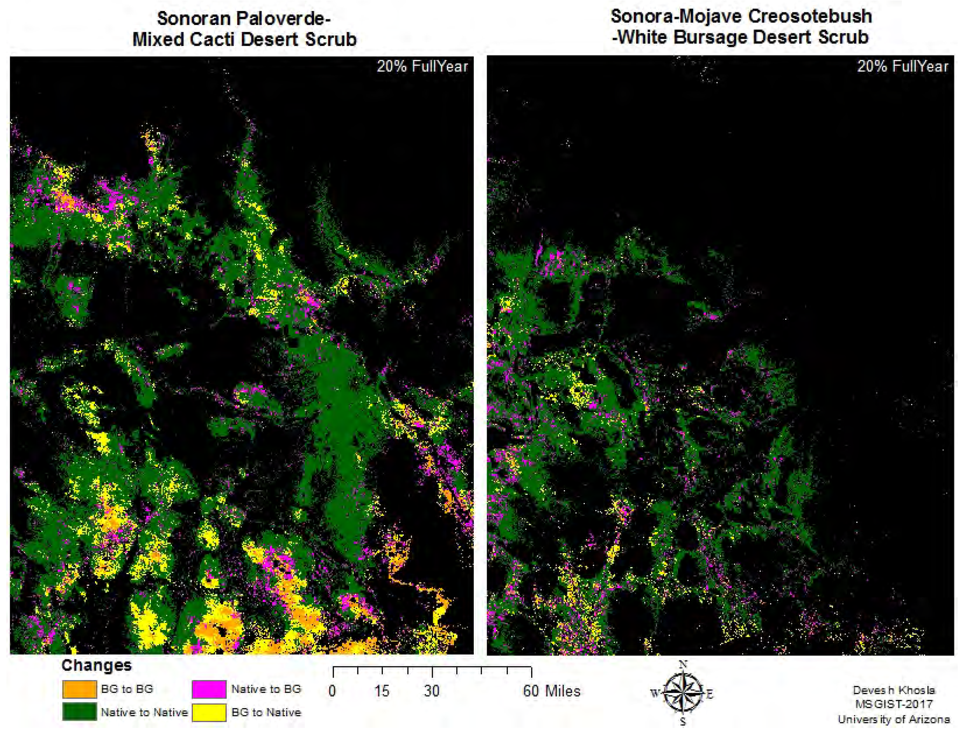
Regional CLaRe Metrics 2011 to 2016: T-test results show significantly higher CLaRe values at BG locations relative to random points for all years (below, R). This confirms CLaRe metrics are able to regionally stratify landscapes with higher BG content, extending their use from the local application of Wallace et al. 2016.



Pico Full Year				
Year	Mean(BG)	Mean(Ran)	BG:R	Significant
2011	0.264	0.127	>	**
2012	0.194	0.081	>	**
2013	0.157	0.108	>	**
2014	0.165	0.120	>	**
2015	0.032	0.021	>	**
2016	0.026	0.020	>	**
**Significant at the p = 0.001 level				

CLaRe ppt123 for 2011 is shown at left. This is the correlation coefficient between current NDVI greenness for a MODIS 8-day composite and the cumulative precipitation for the prior 3 time periods. T-test results at right show that BG CLaRe is significantly higher than at random points for all years 2011 to 2016

Model Differencing: Comparing ~2012 and ~2015 models using a 20% threshold reveal persistent BG (orange) especially in the south with suspected new infestations (magenta) commonly adjacent to the orange patches, as expected. Areas with CLaRe metrics that map as native in both ~2012 and ~2015 models are shown as green, and landscapes that transition from BG to native are shown as yellow.



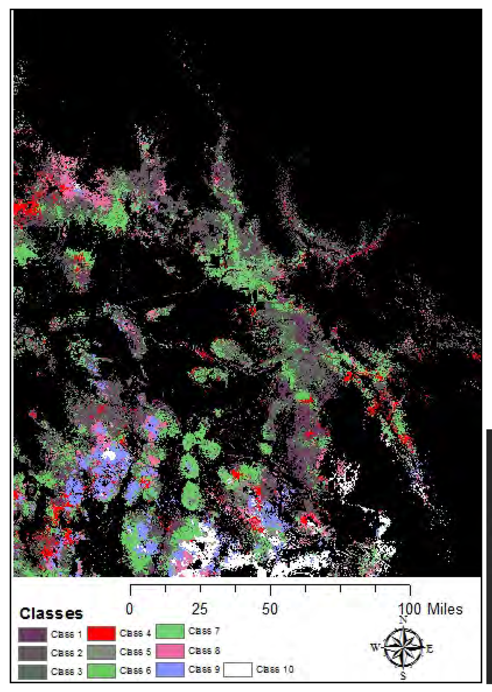
BG field data were used to calculate chi-square results of model ~2012 for both vegetation types because most of these data were collected before 2013. Observed versus expected partitioning of the BG presence data are significant (see tables below), confirming the model results. It is worth noting that BG intensity was not preserved in these data.

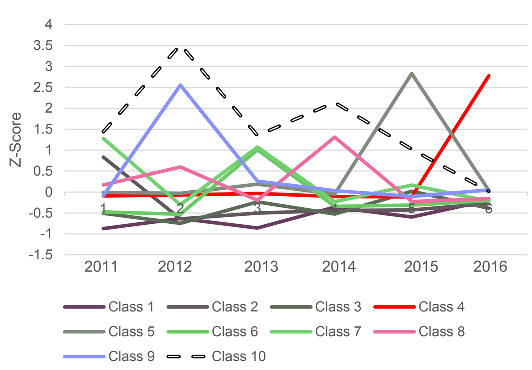
Type 57	Expected	Observed	Chi-Square
BG	521.2	1359	1346.5
Native	2110.7	1273	332.5
Total	2632	2632	1679.0
Alpha: 0.05, Significant			

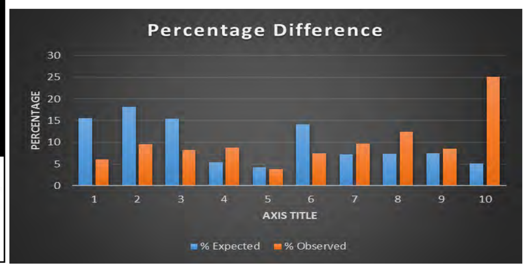
Type 60	Expected	Observed	Chi-Square
BG	41.80	60	7.90
Native	405.19	387	0.81
Total	447	447	8.73
Alpha: 0.05, Significant			

Chi-square for vegetation Sonora Paloverde mixed desert cacti scrub (type 57, L) and Sonoran-Mojave creosotebush-white bursage desert scrub (type 60, R), model ~2012

Z-Score Classification: An unsupervised classification of the stacked 6 years (2011-2016) of z-score transformed CLaRe metrics is shown below (L). The 10 classes requested correspond to the spectral signatures shown in the graph below (UR). Class 10 (white in map, with dashed signature) is the highest z-score across the years; chi-squared results with BG field data (LR) show BG presence points are strongly concentrated in this class. Class 4 (red) presents a profile expected of a new BG invasion, with "average" (near 0) CLaRe dynamics 2011 through 2015 and a spike to above average CLaRe in 2016. The current field data do not allow validation of these results, however, and a field campaign is planned.







Conclusions

This study showed promising results toward detecting nascent buffelgrass (BG) populations using multi-temporal CLaRe metrics, though much work remains. Model differencing reveal native to BG transitions with similar patterns and geographies to the multi-temporal z-score class with expected signature of "average" to "above average" CLaRe. Appropriate field data are required to validate these results and refine the methods.

Future Directions

Detection of new buffelgrass populations is a high priority for managers, and these research results will continue to be developed.

In addition, we are actively seeking funding to design and develop the mobile app that will leverage the processing stream used in this study, including regional calculations of CLaRe metrics with NASA PiCo models.

This research and the future web-based app will help managers detect, predict and monitor status of buffelgrass in their landscapes.

References

1. Arizona Sonora Desert Museum, https://www.desertmuseum.org/
2. Jung, M; Churkina, G; and Henkel K, 2006. " Exploiting synergies of global land cover products for carbon cycle modeling." Remote Sens Environ 101:534–53
3. Franklin, K.A.; Lyons, K.; Nagler, P.L.; Lampkin, D.; Glenn, E.P.; Molina-Freaner, F.; Markow, T.; Huete, A.R. Buffelgrass (Pennisetum ciliare) land conversion and productivity in the plains of Sonora, Mexico. Biol. Conserv. 2006, 127, 62–71.
4. Wallace, C.S.A.; Walker, J.J.; Skirvin, S.M.; Patrick-Birdwell, C.; Weltzin, J.F. and Raichle, H. 2016. "Mapping Presence and Predicting Phenological Status of Invasive Buffelgrass in Southern Arizona Using MODIS, Climate and Citizen Science Observation Data" Remote Sens. 8, 524.

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