NASA DEVELOP National Program
Fall 2016 Project Proposal

NASA Jet Propulsion Laboratory
Southern Arizona Ecological Forecasting
Detection and Monitoring of Non-Native Invasive Grasses in National Parks of the Southwestern U.S.

Project Overview
Objective: To expand the capability of the National Parks Service for detecting, monitoring and targeting invasive, non-native buffelgrass across southern Arizona which threatens ecosystem stability and causes extensive damage to national park resources.

Community Concern: Invasive non-native grasses are rapidly spreading throughout parks in the southwestern U.S. In contrast to sparsely distributed native vegetation, invasive grasses such as buffelgrass (*Pennisetum ciliare*) can form large patches that carry fire quickly and broadly across the landscape. Repeated exposure of non-fire adapted native plants to fires fueled by grasses may ultimately transform ecosystems in national parks of the southwestern US and adjacent areas. Invasive non-native grasses also compete with native plants for water and nutrients, consequently reducing native plant productivity and diversity across the landscape. These declines greatly affect ecosystem services and visitor experiences within national parks. The National Park Service (NPS) and partner agencies face challenges to detect and monitor invasive grasses with limited resources. These agencies rely on plot-based measurements to inform management strategy, but remote sensing approaches can complement and expand the spatial extent and resolution as well as increase the temporal frequency of surveys to provide more rapid detection of invasive grasses. Such rapid detection can facilitate the identification of risk areas and the development of mitigation strategies to reduce the spread of invasive grasses.

National Application Area(s) Addressed: Ecological Forecasting
Study Location: Tucson, AZ
Study Period: January 2013 - December 2016; Forecasting to 2020

Advisor(s): E. Natasha Stavros (NASA Jet Propulsion Laboratory) and David Schimel, (NASA Jet Propulsion Laboratory)

Source of Project Idea: A previous partner (Joe Meiman, hydrologist) at the National Park Service, connected DEVELOP with Don Weeks (Physical Resources Program Manager of the Natural Resources Division) of the intermountain Regional Office. With his support and enthusiasm, DEVELOP hosted two webinars to introduce DEVELOP and find potential partners. Don received 10 project ideas from his colleagues. NPS then prioritized the projects by need of the region and DEVELOP reached out to these individuals to further assess feasibility and project details. This project stemmed from this collaborative process.

Partner Overview
Partner Organization(s):

Organization	POC (Name, Position/Title)	Partner Type	Boundary Org?
National Parks Service, Saguaro National Park Rincon Mountain District	Dana Backer, Park Ecologist	End-User	Yes*

USGS Southwest Biological Science Center	Cynthia Wallace, Research Scientist	Collaborator	No
USGS Southwest Biological Science Center	Dr. Seth Munson, Research Ecologist	Collaborator	No
Northern Arizona University (NAU)	Dr. Temuulen Sankey, Remote Sensing Scientist	Collaborator	No

End-User Overview

End-Users's Management Strategies:

The NPS utilize vegetation inventory and monitoring data collected by the NPS and other agencies to detect and monitor the spread of invasive species. Although some remote sensing approaches show promise, more research is needed to scale-up detection and track invasive species over the long-term. In particular, the NPS is interested in developing a buffelgrass detection method using fine-resolution WorldView (WV) 2-m data. If the method is successfully developed and applied over the study period (2013-2016), the resulting change detection models will provide critical information on where buffelgrass treatments are successful and where they are not. Since the development of Climate Landscape Response (CLaRe) phenometrics by the USGS, the NPS can capture the strength of the landscape greenness response to climate and expose buffelgrass due to its rapid and strong response to recent precipitation (Wallace et al., 2016-inpress). NASA Develop interns can then apply the two different algorithms to map buffelgrass presence using WV 2-m and MODIS 250-m data at Organpipe Cactus National Monument (OPCNM) and compare the results.

End-User's Capacity to Use NASA Earth Observations:

Current NPS practices use aerial surveys and ground-based methods to detect the abundance and distribution of buffelgrass across the lands they manage. Remote sensing tools can enhance the ability of NPS and partner agencies to map and monitor buffelgrass in their jurisdiction and in their region. Methods developed by the USGS, using the CLaRe phenometrics that couple MODIS and climate data, show promise for regionally mapping buffelgrass distributions and detecting nascent populations (Wallace et al. 2016 – in press). Within the areas of known buffelgrass, finer resolution WV data can be used to detail the geometry of buffelgrass spread and monitor the effectiveness of control treatments. Ultimately, the results of the two approaches will be used to help build spatial models to understand how management and environmental factors interact to influence its abundance and distribution.

Collaborator & Boundary Organization Overview

Collaborator Support:

The USGS and NAU have recently teamed with partner agencies across the Tucson, AZ area through the multi-year (2015 – 2020) Southern Arizona Resilient Landscape Collaborative funded by the Department of Interior. The program provides resources for national parks, the US Fish and Wildlife Service, the US Forest Service, the Bureau of Land Management, Pima County (which houses Tucson), and tribes to map and treat the invasive buffelgrass across broad reaches of the landscape. The USGS and NAU will contribute necessary ground-based data, imagery, and analysis tools to the project and will help the NASA DEVELOP team achieve objectives. The NAU collaborators will also provide feedback on the image analysis techniques based on their preliminary test results. The USGS Western Geographic Science Center has committed funds to support the regional analysis of buffelgrass distribution and phenological status via salary support for Wallace, who will contribute a hard drive containing MODIS and PRISM climate data, along with the algorithms, so the NASA Develop team can generate the

CLaRe phenometrics for the broad region (Southeastern Arizona) within which the finer-scale analyses will be conducted.

Boundary Organization Dissemination:
National Park Service - The NPS, NAU, and the USGS Southwest Biological Science Center will utilize end products to direct management actions to control buffelgrass spread, and will utilize results to build a near-term forecasting tool. These products will benefit Saguaro National Park, Organ Pipe Cactus National Monument, and adjoining management units in the Tucson, AZ region.

Project Communication & Transition Overview
In-Term Communication Plan:
We will arrange to have weekly or biweekly teleconferences to discuss project updates, objectives, and results. Additionally, DEVELOP participants may have the opportunity to present their data in additional activities outside DEVELOP in support of the NPS Centennial.

Transition Approach:
A potential WebEx presentation to NPS and Southern Arizona Resilient Landscape collaborators would be ideal as well as product distribution through e-mail.

Earth Observations Overview

Earth Observations:

Platform & Sensor	Parameter(s)	Use
Terra MODIS	Chlorophyll-a 8-day composite NDVI	The high temporal resolution in the MODIS dataset provides an ideal image source for characterizing buffelgrass phenology and leveraging the phenology in our classification criteria. These data will be coupled with PRISM climate data to produce CLaRe phenometrics for regional mapping of buffelgrass distribution and status.
TRMM and GPM	Study period of 2013 - 2016	These data sources provide additional variables that can be used as inputs into the MODIS phenology-based model that the USGS collaborators have developed and will be applied over larger areas in this project.
WorldView-2 and -3	All of the RGB, multispectral, and SWIR bands will be used to develop a sub-pixel classification method, mixture-tuned matched filtering (MTMF).	The mixture-tuned matched filtering method performed best at detecting small patches of buffelgrass within pixels in the NAU collaborators' preliminary analysis. This project will develop and apply the method over the larger area in this project.

Ancillary Datasets:
USGS Western Geographic Science Center_- PRISM Climate Data – Used to generate the CLaRe phenometrics

Modeling:
Phenology-based classification model that uses the CLaRe phenometrics derived from MODIS and climate data to map regional buffelgrass distribution and phenological status (POC: Cindy Wallace, U.S. Geological Survey)

Mixture-tuned match filtering classification software (POC: Temuuled Sankey, Northern Arizona University)

Software & Scripting:
R – Run the CLaRe phenology-based classification model
ENVI – Perform the WorldView image classification via the mixture-tuned matched filtering method.

Decision Support Tool & End-Product Overview

End Products:

End Product(s)	Partner Use	Datasets & Analyses	Software Release Category
Spatial Model using environmental and land-use factors to predict future risk of the spread of buffelgrass.	Partners from the NPS will be able to 1) Expand buffelgrass detection and monitoring capability across southern Arizona using proven methods in partnership with the Southern Arizona Resilient Landscape collaborative, and 2) Monitor the CGC signature of buffelgrass establishment and expansion using historical data.	MODIS phenology-based classification performed in R scripting software. Classification of WorldView images and matched filtering method used in ENVI-based software.	Options: 2

End-User Benefit:
We expect to expand on approaches that NPS and other agencies can use to detect, monitor, and target buffelgrass for removal treatments in different plant communities and landscape settings. We have previously framed our project within Saguaro National Park, which has spent considerable effort mapping and managing for buffelgrass control with recent herbicide applications, and we expect to provide important information for park staff on the utility of remote sensing approaches for monitoring the effectiveness of recent and future treatments. The regional mapping has many benefits for land managers, since they can monitor not only the area of their jurisdiction, but also adjacent areas. Using CLaRe phenometrics to predict phenological status is also highly beneficial. Buffelgrass remains dormant much of the year, but has short windows when it is photosynthetically active and vulnerable to herbicide. By mapping when and where buffelgrass is green using the CLaRe phenometrics, land managers can optimize their treatment activities, saving money. In addition, current results suggest that it is possible to detect nascent populations of buffelgrass comprising <5 percent of the landscape by monitoring the trends of these CLaRe phenometrics.

Project Timeline & Previous Related Work

Project Timeline: 1 Term: 2016 Fall (Start) to 2016 Fall (Completion)

Related DEVELOP Work:

Spring 2015 (USGS at University of Colorado) – Arizona Ecological Forecasting I: Mapping Invasive Tamarisk Monocultures in Havasu National Wildlife Refuge

Fall 2014 (USGS at University of Colorado) – Arizona Ecological Forecasting: Using Landsat 8 OLI and TIRS to Enhance Invasion Risk Assessment of Tamarisk (Tamarix spp.) in Topock Marsh, Havasu National Wildlife Refuge

Fall 2014 (Marshall Space Flight Center) – Cumberland Plateau Ecological Forecasting: Utilizing NASA Earth Observations to Map and Model the Spread of Invasive Asiatic Bush Honeysuckle on the Cumberland Plateau

Notes & References:

Notes: The USGS has recently developed effective methods to detect buffelgrass using imagery at multiple resolutions from a variety of platforms. Using MODIS imagery, USGS has developed a new and innovative suite of phenometrics (i.e. "Climate Landscape Response" or CLaRe metrics) that are proven to effectively map when and where the invasive buffelgrass is green in Saguaro National Park near Tucson, Arizona (Wallace et al. 2014, Wallace et al., in review). The CLaRe phenometrics used here explicitly incorporate precipitation and capture the strength of the correlation between the satellite greenness data and precipitation data (both lagged and cumulative). These phenometrics are effective in locating populations of invasive buffelgrass since the grass responds more rapidly and strongly to precipitation events than native vegetation (Fig. 1). Even small amounts of invasive buffelgrass in the landscape have a strong effect on the values of these phenometrics (Fig. 2). Given that many invasive species are successful because they can out-compete native species for limited resources, it is likely the CLaRe phenometrics will prove valuable for mapping other invasive species of regional extent in dryland ecosystems.

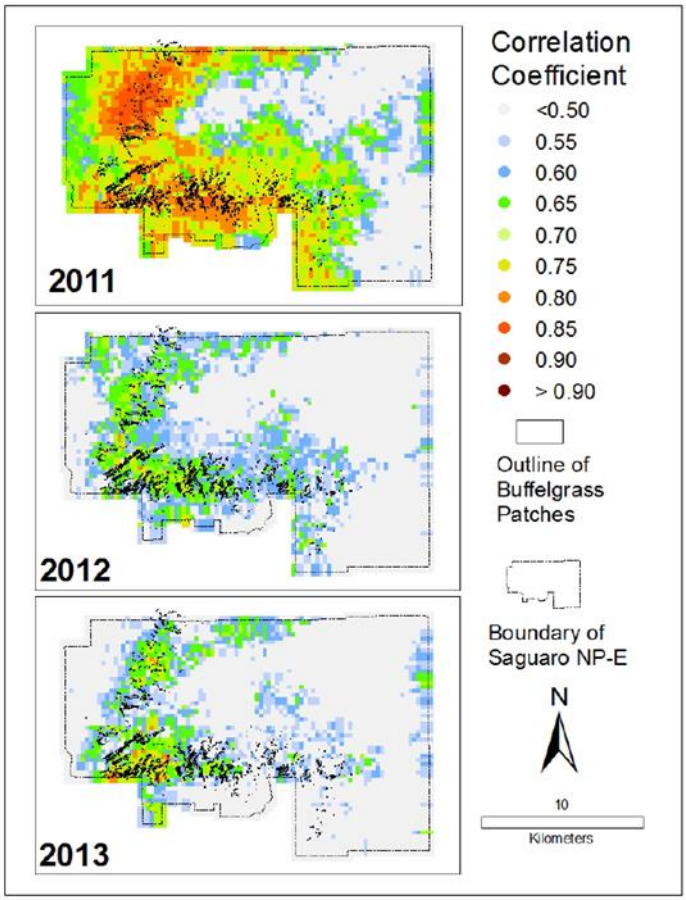

Figure 1. An example of one of the CLaRe phenometrics mapped in Saguaro National Park – East for 2011, 2012, and 20134. The CLaRe Phenometric displayed is the correlation between MODIS NDVI and the cumulative precipitation for the three 8-day time periods.

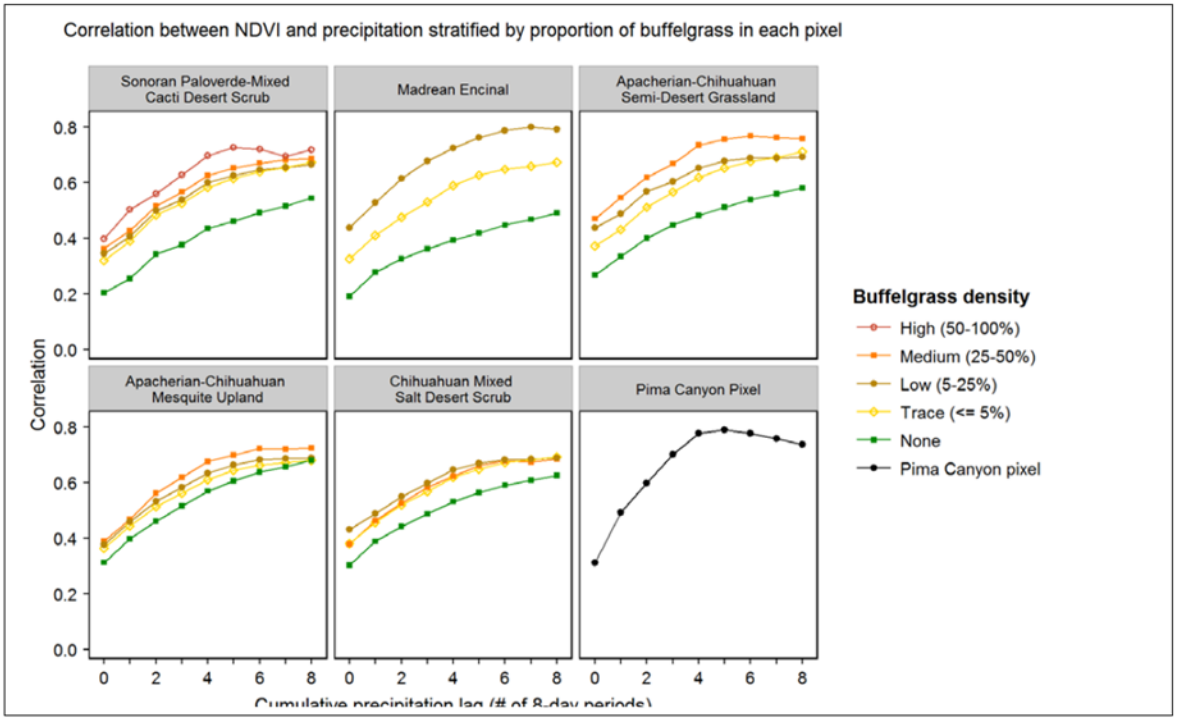

Figure 2. Correlation coefficients for various amounts of buffelgrass in the 5 dominant vegetation types at Saguaro National Park that have buffelgrass invasion. The correlations observed at Pima Canyon are also shown for comparison. In these graphs, the horizontal axis values represent the number of prior time periods over which precipitation is summed, with 0 = current precipitation, 1= precipitation from the previous time period, 2 = cumulative precipitation from the previous two time periods, and so on.

References:

Wallace, C.S.A., J.J. Walker, S.M. Skirvin, C. Patrick-Birdwell, J.F. Weltzin, and H. Raichle. 2014. Predicting treatment windows for invasive buffelgrass in southern Arizona using MODIS, climate and field data. Poster presented at American Geophysical Union Annual Meeting, San Francisco, CA.

Wallace, C.S.A., J.J. Walker, S.M. Skirvin, C. Patrick-Birdwell, J.F. Weltzin, and H. Raichle. In Press. Mapping Presence and Predicting Phenological Status of Invasive Buffelgrass in Southern Arizona using MODIS, Climate and Citizen Science Observation Data. Remote Sensing, Special Issue: Citizen Science and Earth Observation.