Applicant: Timothy J. Assal

Proposed Research: *Exploiting the deluge from space through scientific synthesis and collaboration*

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1. Background

Over the last two decades, the ecological research community has acknowledged the challenge to synthesize accumulating ecological information to improve scientific understanding and decision making in natural resources (Hampton and Parker 2011). Scientific synthesis integrates disparate information, skillsets and expert knowledge in an effort to yield novel insights that might have gone unrecognized (Pickett et al. 2007). In response to these needs, numerous synthesis centers have been established (e.g. National Center for Ecological Analysis and Synthesis, USGS Powell Center, etc.) which bring together scientists with broad backgrounds to create new knowledge by synthesizing existing data (Hampton and Parker 2011). A core principle of this movement is collaboration among disparate groups of people with diverging skillsets. This proposal was developed with this principle in mind, admittedly on a smaller level, and it will foster collaboration and scientific synthesis between several disparate groups of researchers at the Fort Collins Science Center.

Earth observation satellites continue to provide a broad array of data which represents an unprecedented opportunity in the field of ecology to answer questions about the rate and pattern of environmental change. Diverse types of multi-decadal, open data represent enormous potential for analysis over space and time and such studies can facilitate cross-site synthesis. However, this massive collection of data, known as the 'deluge from space', poses many theoretical, operational, and logistical challenges to those that hope to harness its power to answer questions in ecology. Furthermore, the potential to capitalize on this realm of spatial ecology cannot be fully realized without the integration of expert knowledge from program and place based scientists.

2. Objectives

I therefore propose a research plan designed to connect subject matters experts with the spatial and computational skills needed to capitalize on the vast collection of space based observations to address their science needs. My proposal outlines three projects, all of which are intended to address the status and trends of ecosystems subject to various forms of disturbance. I will collaborate with USGS colleagues that are ***program-based scientists*** (Patrick Anderson, Wyoming Landscape Conservation Initiative; Mark Vandever, Conservation Reserve Program) and ***place-based scientists*** (Craig Allen, Ellis Margolis, Collin Haffey, Jemez Mountain Landscape). The overall goals of this postdoctoral research are to: 1) conduct novel research in spatial science to address ecological questions, 2) provide a framework for utilizing disparate forms of landscape scale data to understand ecological disturbance and management actions that take place at multiple spatial and temporal scales, and 3) strengthen USGS research capacity and apply spatial science to new arenas. The research approach and methods, including how and where the research is to be conducted, are included in each subset of the research plan.

3. Link to USGS Science Strategy

My proposed research supports two of the science directions identified in the USGS Science Strategy: 1) *Understanding Ecosystems and Predicting Ecosystem Change* and 2) *Climate Variability and Change* (USGS 2007). The proposed research will support the first science direction through an understanding of the pattern and structure of sagebrush, montane forest and agricultural ecosystems and the changes associated with multiple disturbances in these systems. The work will generate multiple data sets that can be used by natural resource managers to assess the status and trends of these ecosystems over the last several decades. This work will support the second science direction through monitoring of land use and land cover change and insight into the response of these ecosystems to disturbance. The research will help to frame broad questions related to ecosystem resilience, resistance, persistence and vulnerability with regard to climate change and related natural and anthropogenic disturbance. The proposed research will also address the two critical crosscutting science directions identified by the Science Strategy Team through the integration of a broad array of spatial data with emerging technologies in computational ecology and open science.

4. Research Plan

Project 1: Time-series analysis of multi-resolution imagery to quantify sagebrush defoliation and mortality in southwest Wyoming

Research Objectives: As part of my postdoctoral research I will work with WLCI scientists and partners to develop a project which will: 1) evaluate the potential to use landscape scale remote sensing to detect the extent and/or severity of mortality, 2) use the data to assess the potential causes of these events.

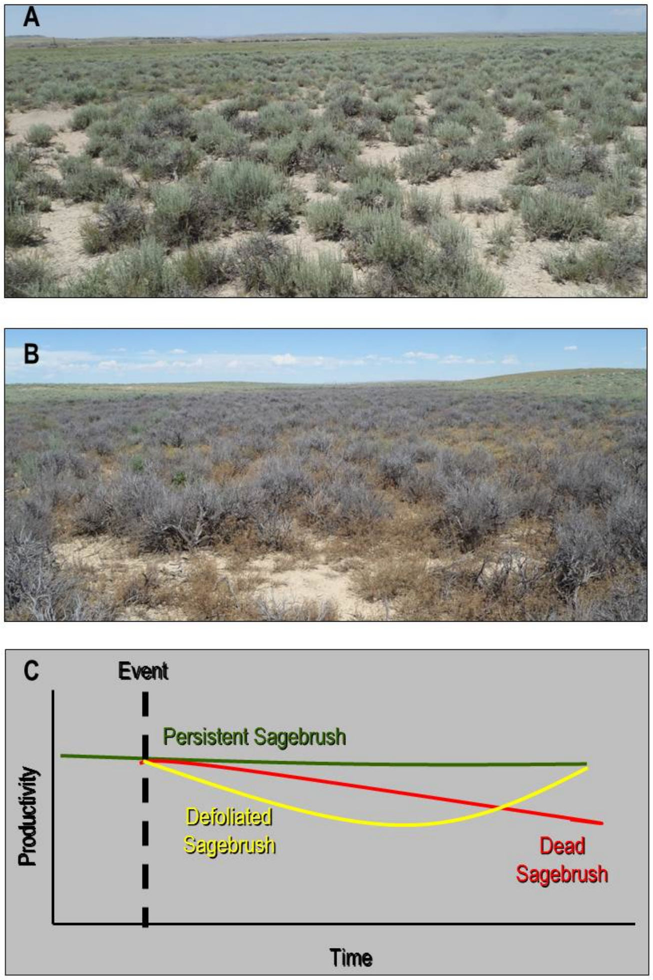
Background: The Natural Resources Conservation Survey (NRCS) and Wyoming Game and Fish Department (WGFD) have recorded an increase in observations of sagebrush mortality in southwest Wyoming between 2010 and 2014. There is concern these additional stressors on sagebrush ecosystems could affect sagebrush obligate species as mortality has been reported inside sage grouse core areas and pronghorn crucial winter habitat. The extent, mechanism and frequency of the event(s) are unknown at this time and research is needed to help answer these questions. On-going research to describe long-term characteristics of sagebrush ecosystems with remote sensing has been very successful (Homer et al. 2012), however, the short time frame (e.g. intra-seasonal) associated with these sagebrush events requires analysis over smaller intervals.

Research Goals:

Question1: *How is the productivity of sagebrush ecosystems affected by mortality and/or defoliation events?* This question will enable us to address an oft cited, but rarely tested capacity of remote sensing to detect these events. This information can be used to quantify the spatial extent and timing of the event(s).

Question 2: *What are the mechanisms that drive these events?* This question will expand our knowledge on the dynamics of sagebrush ecosystems with respect to disturbance agents from multiple stressors.

Proposed Methods: I will compute vegetation indices from MODIS time-series data (coarse spatial resolution; fine temporal resolution) as a coarse filter of productivity on biweekly intervals over the duration of the growing season from 2000 to 2015. I will use this information to identify potential areas of change (i.e. areas with anomalous productivity), then calculate the productivity of those areas from Landsat imagery (fine spatial resolution; coarse temporal resolution). I will use field observations from WLCI partners and the USGS to identify the annual productivity trajectory of areas of mortality and healthy sagebrush. I expect areas that have experienced mortality or defoliation to exhibit a decrease in productivity over some time period (see figure). The decrease in productivity can be captured as a deviation from the average long-term productivity of a site using linear trend analysis (Assal et al. 2016). If this approach is successful, I anticipate additional, quantitative field measurements may be necessary (in the future, TBD) to determine levels of severity within areas identified as sagebrush die-off.



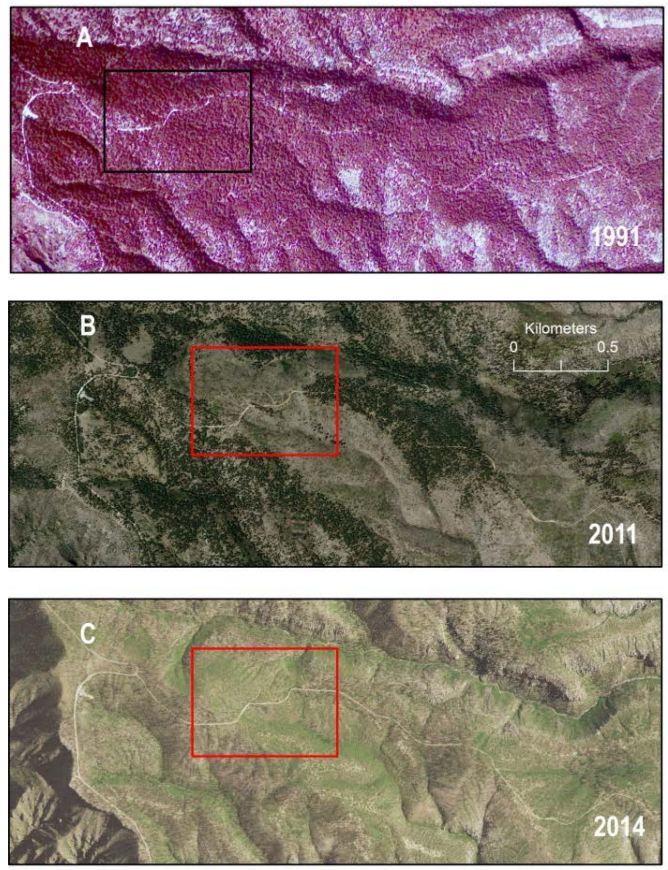
An area of persistent sagebrush in southwest Wyoming (Panel A, photo: M. Dematatis). An area of defoliated or dead sagebrush in southwest Wyoming (Panel B, photo: M. Dematatis). Hypothesized trajectory in productivity of sagebrush communities affected by disturbance events (Panel C).

Expected Products: Sagebrush communities are one of the five focal ecosystems within the WLCI and this work will expand the USGS research capacity in the WLCI, provide our partners with data, and develop a framework to assess potential causes and effects of disturbance in the sagebrush ecosystem. The work is expected to contribute to the remote sensing literature and generate a spatially explicit dataset that can be utilized in resource management and future scientific inquiry.

Project 2: Disturbance as a catalyst of change in the vegetation structure of the Jemez Mountains

Research Objectives: As part of my postdoctoral research I will work with the Santa Fe Field Station to develop a project which will: 1) address their research need(s), 2) expand my research capabilities, and 3) meet two of their 2016 objectives (expand their capacity for spatial analysis and strengthen the connection with FORT). My research is motivated by a lack of available data which limits investigation of many ecological questions. I plan to develop several data sets, using largely open data, to assess landscape scale changes at broad spatial and temporal scales in the Jemez Mountains.

Background: Numerous fires over the last several decades have eliminated many conifer trees in mid to upper elevations of Bandelier National Monument and surrounding Santa Fe National Forest. Over a century of fire suppression led to an increase in tree density and forest structure, where ladder fuels favored crown fire development (Allen et al. 2002). Large patches of forest that burned at moderate-high severity experienced high levels of mortality. Furthermore, limited forest regeneration after the Dome Fire (1996) was eliminated by the Las Conchas Fire (2011), along with many remnant patches of forest (see figure). There is concern that fires may have triggered a permanent or semi-permanent change from forest to shrubland or grassland in some areas where fires have removed the majority of seed sources (Goforth and Minnich 2008, Roccaforte et al. 2012). Resprouting species such as, *Quercus gambelii* and *Robinia neomexicana*, may become more prevalent on the landscape as this life-history trait may be an advantage in areas that have experienced frequent disturbance (Barton 2002, Roccaforte et al. 2012).



An area of forest in the Santa Fe National Forest (Panel A, 1991; image: National Aerial Photography Program). A portion of the area burned in the Dome Fire (1996) (Panel B, 2011, image: National Agriculture Imagery Program). The entire area burned in the Las Conchas Fire (2011) (Panel C, 2014, image: National Agriculture Imagery Program). Note: the forest remnants from the Dome Fire were killed in the Las Conchas Fire (red box).

Research Goals:

Question1: *How has the structure of vegetation changed in the Jemez Mountains over the last ~20 years?* This question will enable us to quantify the amount of vegetation change that has taken place from prior to the 1996 Dome Fire, before the 2011 Las Conchas Fire, and after the Las Conchas Fire.

Question 2: *Are woody plant communities with a resprouting life history strategy more resilient to multiple disturbances?* This question will expand our knowledge on the resilience of species with this life history trait in an area that has experienced multiple disturbances.

Proposed Methods: I plan to couple long-term field data and expert knowledge with moderate resolution satellite imagery (e.g. Landsat and SPOT) to model the dominant vegetation structure (e.g. forest, shrub, grassland, etc.) at three key points in time (before the Dome Fire, before the Las Conchas fire, and current vegetation) to determine trends in vegetation structure. I will utilize the aerial photo archive to scale up vegetation observations to Landsat data (Assal et al. 2014) and exploit differences in phenological traits of plant functional types to aid in discrimination of vegetation types (Assal et al. 2015).

Expected Products: My research will quantify the spatial and temporal change associated with multiple disturbances in an ecosystem that is forecast to experience warmer and drier conditions in the near future. The work is expected to contribute to the literature of recent ecosystem change and generate multiple spatially explicit datasets that can be utilized in resource management and future scientific inquiry.

Project 3: From field to landscape: Assessment of environmental benefits of the Conservation Reserve Program with spaced based observations

Research Objectives: As part of my postdoctoral research I will work with Mark Vandever (SEA Branch) and Sarah Carter to lend geospatial expertise to an ongoing project and will 1) develop a framework to link traditional ground based indices with remotely sensed metrics, and 2) apply the framework in a proof of concept exercise to quantify environmental benefits of CRP lands.

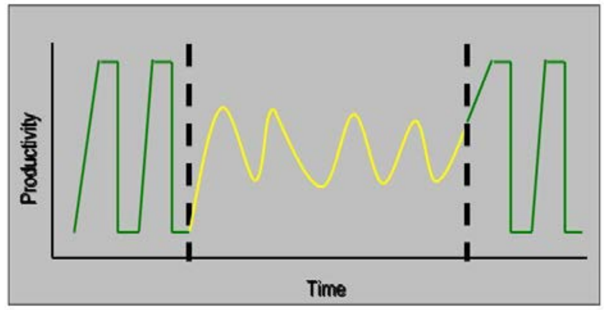
Background: Since 1985 the Conservation Reserve Program (CRP), administered by the U.S. Department of Agriculture, has allocated funds to private land owners in exchange for implementation of conservation practices. Initially, the CRP targeted marginal cropland for soil conservation, however, it has since been recognized for provision of additional benefits such as water quality, erosion control, wildlife habitat, and carbon sequestration (Vandever and Allen 2015). However, land tenure in the CRP program fluctuates and there is little information on the environmental services provided by these fields after the CRP contract expires. Fields which are not put back in cultivation and remain in grassland or woodland may continue to provide some level of conservation benefits and habitat quality that is not fully captured by economic models driven by active CRP acreage. Given the sensitive nature of the data and the extent of the program (currently over 23 million acres enrolled) little geospatial analysis has been applied to the program outside of land tenure patterns which reduced fragmentation of grassland habitat (Park and Egbert 2008). The program is starved for information and earth observation satellites may hold clues to the environmental benefits of CRP lands. The remote sensing archive provides a record in time for each CRP parcel which in some cases spans the duration of program tenure. We can use the record to glean information on characteristics related to environmental benefits of CRP fields. The well-established relationship between FORT and the CRP offers a unique opportunity to test new and efficient ways to evaluate environmental benefits of CRP lands into the future.

Research Goals:

Question1: *What are the productivity trajectories of fields enrolled in the CRP, and does the trajectory change once they are no longer enrolled in the program?* This question will generate important baseline information on the dynamics of CRP fields as measured from remotely sensed data.

Question 2: *How do characteristics of productivity compare with ground based metrics of habitat quality?* This will allow us to determine if field measured characteristics can be linked with space based observations to quantify environmental benefits.

Proposed Methods: Remotely sensed data have been used to quantify ecosystem services of agricultural and rangeland ecosystems lost to energy development via the impact on net primary production (Allred et al. 2015). However, in this study we cannot simply use the amount of productivity as a metric because irrigated agriculture fields likely have a higher productivity than CRP fields. Therefore, we must consider the characteristics of productivity over time, such as the stability of productivity with regard to CRP tenure. We expect fields with consistent productivity to provide greater environmental benefits than cultivated fields and we will use this mechanism to understand the durability of benefits after CRP contracts expire. For example, a field that remains in grass production will have stable productivity and continue to provide habitat structure for insect pollinators and wildlife, compared to a field that is returned to cultivation (see figure). I will use multi-temporal satellite imagery to develop baseline information on productivity of CRP fields using a pixel-wise approach (Assal et al. 2016). I will assess the relationship between field collected CRP data and space based observations to determine if the characteristics can be linked.



Hypothesized trajectory of a field with two growing seasons in cultivated agriculture (green), four growing seasons in CRP (yellow), followed by two growing seasons in cultivated agriculture (green). The black dotted lines indicate CRP enrollment. The agricultural seasons have a higher maximum productivity than CRP fields, but all of the vegetation structure is removed after harvest.

Expected Products: This work is expected to contribute to the literature of ecosystem services, and in particular, a case study for the use of remote sensing to evaluate the durability of ecosystem services on CRP lands.

5. Research Facilities

I will be based at the USGS Fort Collins Science Center which will provide the necessary office space and computing facilities. Much of the data needed for these projects will be accessed from the USGS EarthExplorer archive. Intermittent visits to field sites will be required and planned as needed.

6. Anticipated Operating Expenses

Item	Year 1	Year 2	Total
Scientific and Management Meetings (2x per year)	$3,800	$3,800	$7,600
Travel to Meet with Partners (2x per year)	$2,000	$2,000	$4,000
Publication Costs (Open Access)	$5,000	$5,000	$10,000
Total			$21,600

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