Impact of Fuel Breaks on Annual Grass Invasion in the Sagebrush Ecosystem

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Skills for Undergraduate Participation in Ecological Research

Rylee Sharkey

Mentor: Morgan Roche

Instructor: Dr. Stacy Lynn

TA: Sean Geer

Names & Affiliations

Morgan Roche: Natural Resource Ecology Laboratory, Colorado State University
Madeline Gillet: Ecosystem Science and Sustainability, Warner College of Natural Resources, Colorado State University

Abstract

The sagebrush ecosystem is the most threatened ecosystem in the United States. With increased fire activity and drought conditions brought upon by climate change, this biome is susceptible to invasion by non-native annual grasses, primarily cheatgrass (*Bromus tectorum)*. Fuel breaks have been installed on BLM land in the Western United States with hopes to stop fires from spreading into intact swathes of sagebrush, but the environmental impacts of these fuel breaks are unknown. This research looked at the impact that different fuel break types have on the spread of annual herbaceous vegetation within the sagebrush system and how invasion near fuel breaks varies with changes in elevation. Using ArcGIS Pro and data downloaded from USGS and Science Base; we buffered fuel breaks, calculated vegetation averages for pre and post treatment using raster math, sorted fuel break sites into different groups by elevation, and analyzed each site for changes in invasion based on invasive annual grass (IAG) cover. Preliminary results show that invasions have increased within the 150 m buffer for certain fuel break types. At higher elevation fuel break sites, results typically show that invasion decreases or remains the same before and after installation. Specific fuel break types can help, or hinder invasion based upon outside ecological factors.

Introduction

Research Subject

The sagebrush ecosystem is the most threatened ecosystem in North America (Davies et al., 2011). Rising temperatures, drought conditions, and more frequent fires make this landscape vulnerable to invasion by invasive annual grasses (IAG), such as cheatgrass. (Mahood, 2019). When these grasses are introduced to a fire-disturbed landscape, they establish quickly and outcompete native species for resources. Once the sagebrush system is invaded by annual grasses, the system is unable to recover and it will rarely return to its natural vegetation composition again (Chambers et al., 2007). Such conversions from sagebrush to annual grasses have led to the loss of over half of the sagebrush ecosystem's initial extent (Mahood, 2019). These ecosystems are home to several endemic species, such as the Sage Grouse, which rely upon the sagebrush for habitat (Nelle et al., 2000) and which are an important ecosystem species.

Commented [GU1]: Such conversions from perennial to annual grasses have

Purpose

This study was created to assess the impact of fuel breaks on the spread of invasive annual grasses within the sagebrush ecosystem. The Bureau of Land Management and the United States Department of the Interior have been installing fuel breaks in sagebrush ecosystems since the 1950s with the goal of reducing wildfire spread into intact swathes of the sagebrush system (McGranahan, 2022). There is very little research on the effectiveness of these fuel break treatments or their long-term effects on the landscape and vegetation cover. We want to know what impact each fuel break treatment has on the invasion of annual grasses within the sagebrush ecosystem in regards elevation and historical vegetation composition (especially in regards to invasive annual grasses).

Stakeholders

The outcome of this project will benefit land managers in the Western United States, such as those in the United States Department of the Interior (DOI) and Bureau of Land Management (BLM). The outcome of this study will further inform us on the best practices for conserving the sagebrush ecosystem. If fuel breaks are facilitating the conversion of these areas to annual grasses, then the DOI and BLM may need to reassess their current management practices.

Key Terms

Fuel Break- fuel breaks refer to a variety of landscape treatments that are installed with the goal of slowing or stopping the spread of wildfire

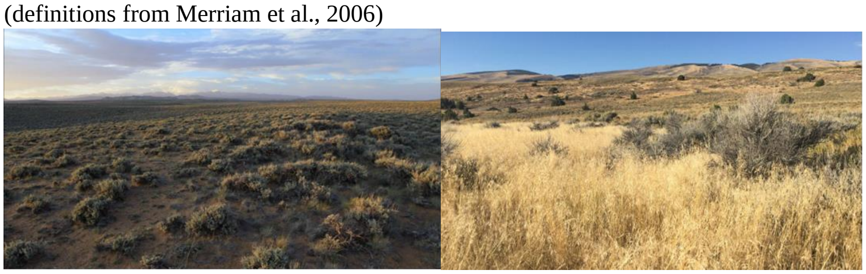
Green Strips- a type of fuel break treatment in which fire-resistant plant species and detritus are installed in a long strip

Brown Strips- a type of fuel break treatment in which prescribed burns and disking are used to remove fuels

Mowed Strips- a type of fuel break treatment in which fuel is removed mechanically to limit the height of fuel on the ground

Annual Invasive Grasses- refers to several species of non-native, invasive grasses. The most common being Cheatgrass.

(definitions from Merriam et al., 2006)



Natural Sagebrush Ecosystem (left)
(Image from PBS)
Sagebrush Ecosystem invaded by annual grasses (right)
(Image from Theodore Roosevelt Conservation Partnership)

Earlier Work

Understanding the relationship between the fire and grass cycle within the sagebrush ecosystem provides important context for this research. It all starts with fire. Climate change, lightning strikes, and human activity have all increased fire activity in the sagebrush ecosystem which leaves the land bare and ideal for invasive annual grasses to establish (Reis et al., 2018). Sagebrush typically grow far away from each other, but when annual grasses invade, they creates more fuel and connectivity within the sagebrush system. This allows wildfire to spread easier, which creates more opportunities for annual grass invasion and thus creates a positive feedback loop.

Commented [Ro2]: This whole section is really well written. You bring together a lot of complex processes and tell a coherent and powerful story, nice work!

Commented [Ro3]: This is a really great synthesis of how the grass-fire cycle establishes and impacts the sagebrush biome!

The sagebrush ecosystem has a lot of ecological and cultural value and it is pertinent that we protect it. This ecosystem is home to several endemic plant and animal species including the sage grouse and the namesake, sagebrush (Davies et al., 2011). Sagebrush provides food and shelter for wildlife, helps protect soil from erosion, and can even regulate the hydrologic cycle (Bansal et al., 2016). On top of these vital environmental services, Indigenous communities of the Western United States have utilized sagebrush for medicinal purposes, and have used other resources from the sagebrush system for hundreds to thousands of years. This land is intertwined in the cultures of the Shoshone, Paiute, Hopi, Navajo, and many other Native Peoples (Ryan, 2015) and we have a responsibility to protect this ecosystem to preserve both nature and culture.

Some research has explored the correlation between IAG cover and elevation within the sagebrush biome. Invasive annual grasses are found in greater abundance at lower elevations due to the warmer and drier climate (Davies et al. 2013). IAG are often drought resistant and this allows them to outcompete native plants that are better adapted to higher elevation. The species of invasive annual grass also differs based on elevation. Cheatgrass was more frequently found at elevations below 1500 meters and Medusahead (*Taeniatherum caput-medusae*) was found in greater abundance at elevations greater than 1500 meters (Chambers et al. 2014). Since these two species of IAG occur in different ecological zones and may require different management strategies, both are relevant to our study on fuel break impacts.

There hasn't been work that addresses the impact of fuel breaks on annual grass invasion in the sagebrush ecosystem. Many papers on annual grass invasion, fire regimes, climate, and fuel treatments within the sagebrush have been published (Shinneman et al., 2019), but none that combine all of these factors to determine the impact of fuel breaks on the spread of invasive grasses. One study from California looked at fuel breaks in relation to invasive plant abundance across multiple forest and scrubland systems. (Weise, *in review)* They found that invasive species abundance was 200% higher on fuel breaks than in nearby wildland areas (Merriam et al., 2006). The work of Merriam et al. informed our hypothesis and was highly relevant to our study within the sagebrush, but differences between Western and Californian sagebrush systems must be kept in mind.

Geographic Area of Interest

This study area is the Western Sagebrush Ecosystem, which covers 10 states in the Western United States.

Study Area Map:

Figure 1. Extent area of the Sagebrush Biome in the Western United States (Map credit: Rylee Sharkey, Data from: Jefferies et al. 2019 (U.S. Geological Survey))

Research Questions and Hypotheses

Research Question:

What is the impact of three different types of fuel breaks, i) green strips, ii) brown strips, iii) and mowed strips, on the invasion of annual grasses in the sagebrush ecosystem in regard to elevation, within a 150 meter buffer of each fuel break site?

Expected Outcome:

Fuel breaks within the sagebrush ecosystem increase the spread of invasive annual grasses, with (a) more invasion occurring around low elevation sites (b) areas with recent fire disturbance (c) and increased invasion within and near fuel breaks. Invasion is expected to increase under these conditions because they make the land extremely suitable for invasive annual grasses.

Commented [Ro4]: What about it? Disturbance?

Null Hypothesis:

Fuel breaks within the sagebrush ecosystem do not impact the rate of invasion of annual grasses across the elevation gradient.

Explanation:

We are more likely to see invasion of annual grasses at low elevations due to more frequent fire regimes and more favorable ecological conditions for cheatgrass and other invasive grasses to spread. When an invaded area is nearby, sagebrush systems are more susceptible to be invaded due to nearby invasive seed sources and an increased risk of wildfire transmission. Low soil moisture also leads to higher risk of fire which can leave the land vulnerable to invasion. The use of fuel breaks can also create unintentionally favorable conditions for IAG to establish which also increases the likelihood of future fires, which continues the grass-fire cycle (Pilliod et al. 2021).

Methods

1. Data Collection: We used data from a federal fuel break database developed by Weise et al. in review, modified in Roche et al. in review. This dataset includes all fuel breaks installed in the Western United States from 1953 to 2020. We analyzed fuel breaks that were installed in 2010 due to a large sample size and wide range of locations. This dataset is the first comprehensive fuel breaks data of the Western United States which makes this study novel. The second step to our data collection was finding and downloading additional datasets to use in our analysis. These datasets included Annual Herbaceous vegetation data (sciencebase.gov), Sagebrush Biome range extent (sciencebase.gov), and the Digital Elevation Model for the Continental United States (usgs.gov). This data is necessary for this

2. Data Entry and Processing: There were three main parts to our data processing (Figure 2). All downloaded data was imported into ArcGIS Pro 3.0.3. Data needed to be inspected for completeness before we did any work on the layer. Once all the data was complete and in the Contents Pane, we were able to use the 'Project Raster' tool to match all projections to the projection of the fuel break data: Albers Conical Equal Area. All raster data was in 30 x 30 meter resolution which was perfect for the amount of detail we wanted to analyze. We used the Sagebrush Biome layer as a perimeter in which to clip a raster data set using the 'Extract by Mask' tool. This made the data more manageable for processing. The last step for processing our data was buffering the fuel break polygons by 150 m. To get an idea of how IAG composition changed on and adjacent to fuel breaks.

3. Data Analysis: Annual Herbaceous vegetation cover data and the 2010 buffered fuel break polygons was used in each analysis to relate the percent change in invasive annual grass cover (2007, 2008, 2009 and 2018, 2019, 2020) to the implementation of fuel breaks (2010). The Digital Elevation Model (DEM) was used to see if invasion occurred at a different rate at varying elevations. Averages were used to calculate elevation and vegetation cover type around each buffer zone. Finally, a linear model was conducted to see if the results were statistically significant to understand how elevation influences annual grass invasion around different fuel breaks treatments including: green strips, brown strips, and mowed strips.

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Commented [Ro6]: Could combine these two sentences

4. **Methods Diagram**

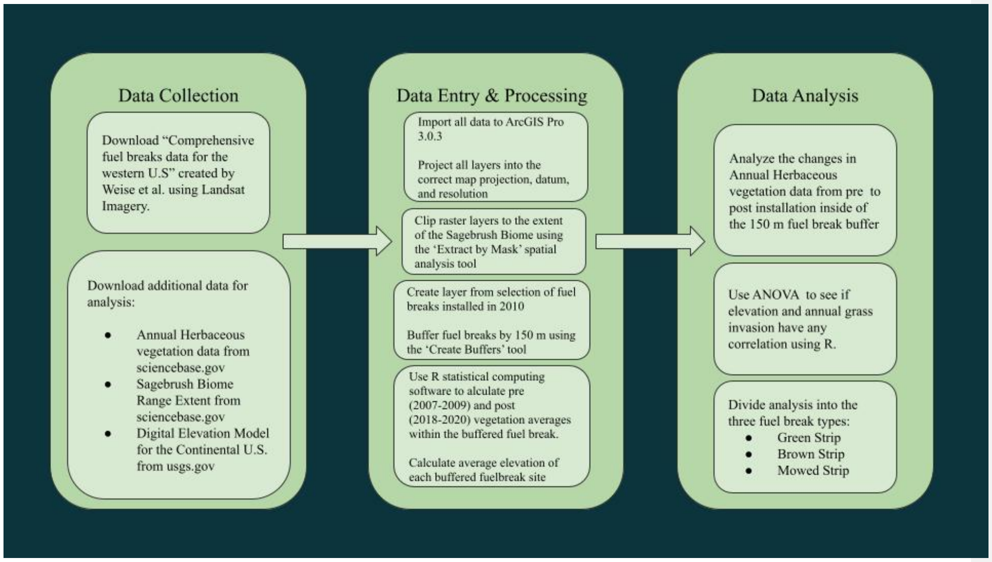

Figure 2: Project flow diagram: using ArcGIS Pro and R Studio to find relationship between annual grass invasions, fuel breaks, and elevation in the Sagebrush Ecosystem of the Western United States.

Results

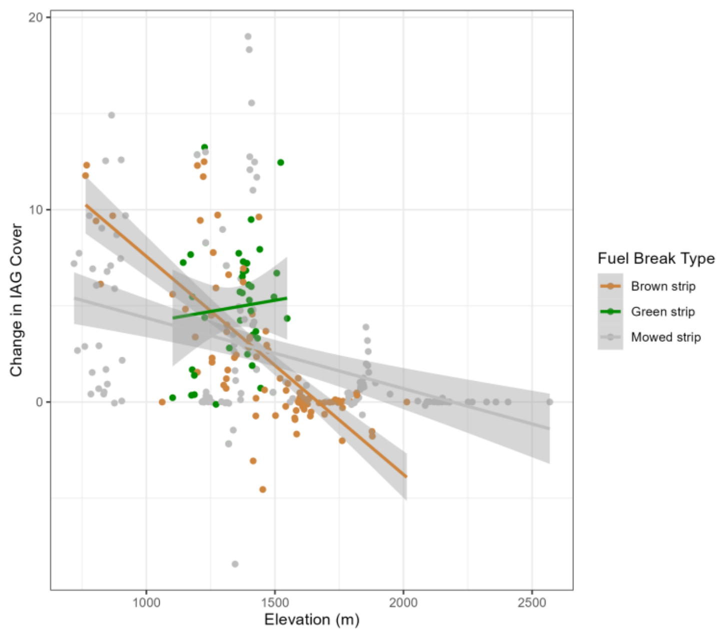

Figure 3. Change in invasive annual grass cover vs. elevation separated by fuel break type.

- A significant interaction ($p < 0.001$) indicates that fuel break type influenced the relationship between elevation and the change in annual grass cover between pre- and post- fuel break installation.
- Lower elevations (below 1500 meters) experienced increased invasion, while fuel breaks above 1500 m actually saw a decrease in annual herbaceous grass cover.
- Brown strips at low elevations experienced the greatest change in annual herbaceous vegetation
- Green strips were only implemented between 1100 and 1500 meters in elevation and vegetation comp increased in the higher (1500m) elevation range
- Mowed strips were used across the largest range in elevation and vegetation change decreased with increasing elevation

Commented [Ro7]: We can talk about how to phrase this to show what about the model was significant.

Commented [Ro8]: This very clearly explains the different patterns for the three fuel break types.

Discussion

Through statistical analysis, we determined that the correlation between change in annual herbaceous vegetation, fuel break type, and elevation is significant. This means that elevation and fuel break type both impact the way that IAG composition changes over time.

My hypothesis was supported, as we saw increased annual grass invasion at lower elevations and within the fuel break buffers. This is similar to findings from Davies et al, Merriam et al, and Shinneman et al., where IAG are typically more abundant at lower elevations and in areas surrounding fuel breaks.

Some potential setbacks to this research include the narrow elevational gradient that green strips were installed in 2010. This could have impacted results because we don't know the impacts that green strips would have at higher elevations. In other papers, such as Davies et al. 2013, it was stated that invasion typically occurs at low elevation so I don’t think that green strips would encourage invasion even though the data shows a slightly positive trend between IAG cover and increasing elevation.

The Annual Herbaceous Vegetation data was collected using remote sensing, which also is a limitation because the data doesn’t differentiate between specific IAG species. This was still valuable data to use, but specific species mapping could better inform management plans, as different species of IAG may respond differently to fuel break installation and disturbance.

Conclusions

This research is extremely novel and can provide valuable insight to land managers in their plans to conserve the sagebrush ecosystem. Fuel breaks are not a one-size-fits-all treatment for conserving the sagebrush system from grass invasion or from preventing wildfire from spreading. Brown strips and mowed strips increased invasion at lower elevation sites but seemed to be effective at elevations greater than 1500 meters. This could be caused by the lower risk of invasion and fire at high elevation sagebrush systems. Though we had limited data for green strips, there was a positive correlation between invasion and increasing elevation which may suggest that fire resistant species planting is not an effective treatment for sites greater than 1500 meters in elevation.

Future work regarding this research topic could look at which species of IAG are more likely to invade certain elevational bands and which fuel break treatment, if any, is most suitable for these situations. Knowing how different IAG species respond to fuel breaks, elevation, and fire regimes could provide even more insight on how to manage the sagebrush ecosystem.

This is the first study that attemps to understand patterns of invasion in areas on and surrounding fuel breaks. This research sets the ground work for how fuel break types influence annual grasses invasion at different elevational bands, but there is so much more work to be done with this dataset that can better inform management plans for the conservation of the sagebrush ecosystem.

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