

Mapping the Cheatgrass-Caused Departure From Historical Natural Fire Regimes in the Great Basin, USA

James P. Menakis¹, Dianne Osborne², and Melanie Miller³

Abstract—Cheatgrass (*Bromus tectorum*) is an exotic grass that has increased fire hazard on millions of square kilometers of semi-arid rangelands in the western United States. Cheatgrass aggressively outcompetes native vegetation after fire and significantly enhances fire size and frequency. To evaluate the effect of cheatgrass on historical natural fire regimes, we combined cheatgrass data mapped from Advanced Very High Resolution Radiometer images of the Great Basin with Fire Regime Condition Class (FRCC) data mapped from plant succession data incorporated with several spatial data layers for the conterminous United States. These FRCCs depict the degree of departure from historical fire regimes resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, and canopy closure. While the FRCC data layer adequately depicted forest communities, it insufficiently depicted grassland and shrubland communities. By adding cheatgrass, FRCC 3 (areas that have been significantly altered from their historical range) increased by 20 percent on Federal lands to almost 60,522 square kilometers for the conterminous United States.

Introduction

In April 1999, the General Accounting Office (GAO) published a report recommending that the Secretary of Agriculture direct the Chief of the Forest Service to develop a cohesive strategy for reducing accumulated vegetation and maintaining it at acceptable levels on National Forests of the Interior West (US GAO 1999). In October 2000, the United States Department of Agriculture (USDA) Forest Service (FS) responded with the report, “Protecting People and Sustaining Resources in Fire-adapted Ecosystems: a Cohesive Strategy” (USDA FS 2000). This FS report establishes a framework that restores and maintains ecosystem health in fire adaptive ecosystems by directing the agency to:

- improve the resilience and sustainability of forests and grasslands at risk,
- conserve priority watersheds, species, and biodiversity,
- reduce wildland fire costs, losses, and damages, and
- better ensure public and firefighter safety.

To assist in the FS response to the GAO report, the Fire Modeling Institute (FMI) at the USDA FS Fire Science Laboratory, Rocky Mountain Research Station, Missoula, Montana, created spatial data layers to provide managers with national-level data on current conditions of vegetation and fuels (Schmidt and others 2002). FMI developed these spatial data layers, hereafter referred to as layers, to address the following questions (Schmidt and others 2002):

- How do current vegetation and fuels differ from those that existed historically?

¹Fire Effects Unit, Fire Science Laboratory, Rocky Mountain Research Station, Forest Service USDA, Missoula, MT.

²National Science and Technology Center, Bureau of Land Management DOI, Denver, CO.

³Bureau of Land Management, located at: Fire Science Laboratory, Rocky Mountain Research Station, Missoula, MT.

- Where on the landscape do vegetation and fuels differ from historical levels? In particular, where are high fuel accumulations?
- When considered at a coarse scale, which areas estimated to have high fuel accumulations represent the highest priorities for treatment?

They created these layers from ecologically based methods to map vegetation changes resulting from the departure of historical natural fire regimes (Hardy and others 2001). These layers have been subsequently used in a joint cohesive fuels management strategy developed by the FS and those Department of Interior (DOI) agencies with wildland fire management responsibilities. In this document, we will refer to these layers as the “Coarse Scale.”

One of the key Coarse Scale layers used in both cohesive strategies was Fire Regime Condition Class (FRCC). FRCC depicts the degree of departure from historical fire regimes resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, and canopy closure (table 1) (Schmidt and others 2002). During the development of the joint Cohesive Strategy, it appeared to rangeland managers that the Coarse Scale layers potentially underestimated the amount of area departed from historical fire regimes in grassland and shrubland communities. This appeared to be especially true in the Great Basin, where the exotic species cheatgrass (*Bromus tectorum*) has become widespread.

Cheatgrass is an exotic annual grass that has increased fire hazard on millions of square kilometers in the western United States (USDA FS 2002). Cheatgrass aggressively outcompetes seedlings of native vegetation after fire, particularly in semi-arid rangelands of the Interior West. The fuel bed created by cheatgrass results in significantly increased fire size and frequency, compared to the native shrub/grass vegetation that was historically present on

Table 1—Fire Regime Condition Class^a descriptions.

Fire Regime Condition Class	Fire regime	Example management options
FRCC 1	Fire regimes are within an historical range and the risk of losing key ecosystem components is low. Vegetation attributes (species composition and structure) are intact and functioning within an historical range.	Where appropriate, these areas can be maintained within the historical fire regime by treatments such as fire use.
FRCC 2	Fire regimes have been moderately altered from their historical range. The risk of losing key ecosystem components is moderate. Fire frequencies have departed from historical frequencies by one or more return intervals (either increased or decreased). This results in moderate changes to one or more of the following: fire size, intensity and severity, and landscape patterns. Vegetation attributes have been moderately altered from their historical range.	Where appropriate, these areas may need moderate levels of restoration treatments, such as fire use and hand or mechanical treatments, to be restored to the historical fire regime.
FRCC 3	Fire regimes have been significantly altered from their historical range. The risk of losing key ecosystem components is high. Fire frequencies have departed from historical frequencies by multiple return intervals. This results in dramatic changes to one or more of the following: fire size, intensity, severity, and landscape patterns. Vegetation attributes have been significantly altered from their historical range.	Where appropriate, these areas may need high levels of restoration treatments, such as hand or mechanical treatments, before fire can be used to restore the historical fire regime.

^aFire Regime Condition Classes (FRCC) are a qualitative measure describing the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, canopy closure, and fuel loadings. One or more of the following activities may have caused this departure: fire suppression, timber harvesting, livestock grazing, introduction and establishment of exotic plant species, introduced insects or disease, or other management activities.

these sites (USDA FS 2002). These repeated fires kill the remaining native plants (Monsen 1994). Since FRCC depicts departure from historical fire regimes, a change in vegetation from shrub/grass to one dominated by cheatgrass would change the assignment from FRCC 1 (fire regimes are within their historical range) to FRCC 3 (fire regimes have been significantly altered from their historical range, and the risk of losing key ecosystem components from fire is high). See table 1 for a full definition of FRCC.

In this paper, we evaluate whether the extent of FRCC 3 was underestimated in the cheatgrass type. We conducted the evaluation by combining a cheatgrass layer developed after the Coarse Scale project to several of the original Coarse Scale layers.

Methods

To map the effect of cheatgrass on historical natural fire regimes, we integrated several layers from two projects. We obtained a Cheatgrass layer classified from 2000 satellite imagery by the National Science and Technology Center (NSTC) at the Bureau of Land Management, Denver, Colorado, for the Great Basin. NSTC developed this layer as part of their Cheatgrass Community Mapping and Change Detection project. From the Coarse Scale mapping project, we used the Fire Regime Condition Classes, Potential Natural Vegetation Groups, and Current Cover Types version 2000 layers. Since Hardy and others (2000) and Schmidt and others (2002) explained the methods used in developing the Coarse Scale layers, we will not describe them here.

NSTC developed the Cheatgrass layer from a study of 26 scenes of Advanced Very High Resolution Radiometer (AVHRR) satellite images collected from March 3 to June 15, 2000. NSTC examined each image for quality, accuracy, and cloud cover, then created a Normalized Difference Vegetation Index (NDVI) for each scene. Next, NSTC selected two of the NDVI scenes based on comparisons to cheatgrass phenology data. The early spring scene (March 3, 2000) represented the period when cheatgrass greens-up, and the late spring (April 26, 2000) scene represented the period when cheatgrass cures (browns-out). Only areas that mapped both green-up and curing were mapped by NSTC as cheatgrass to create the Cheatgrass layer.

In the GIS, we combined the Cheatgrass layer with the Potential Natural Vegetation Groups and Current Cover Types version 2000 layers. When combined, spatial inconsistencies occurred because the layers came from different sources. We resolved these inconsistencies by excluding the areas mapped in the Cheatgrass layer that did not ecologically match classes in the Potential Natural Vegetation Groups or Current Cover Types layers. Since cheatgrass cannot ecologically occur in high elevations or wet grasslands, we excluded cheatgrass areas that occurred in the following Potential Natural Vegetation Groups classes: Spruce – Fir – Douglas-fir; Western spruce – fir; Lodgepole pine – Subalpine; Wet Grassland; and Alpine Meadows – Barren. We also excluded areas mapped as cheatgrass in the following Current Cover Type classes: Agriculture; Urban/Development/Agriculture; Water; and Barren. These cover types were also not mapped in the FRCC layer.

Finally, we combined the edited version of the Cheatgrass layer with the FRCC layer. Areas where cheatgrass occurred in FRCC layer classes FRCC 1 and FRCC 2 were assigned a new FRCC class called FRCC 3 – Cheatgrass. Areas where cheatgrass occurred in the FRCC layer class FRCC 3 stayed FRCC 3.

Results

The original Cheatgrass layer provided by NSTC mapped 127,396 square kilometers of cheatgrass in the Great Basin. From this, 22 percent (28,067 square kilometers) of the total cheatgrass area was excluded because of inconsistencies with Potential Natural Vegetation Groups and Current Cover Types version 2000 layers. Of this, only 4 percent (1,106 square kilometers) of the excluded cheatgrass area was in FRCC 1, 2, and 3, and the rest was in non-vegetative areas (like agriculture, urban, water, and barren). The final Cheatgrass layer (created for this projects) mapped 99,329 square kilometers of cheatgrass in the Great Basin.

Of the 99,329 square kilometers in the final Cheatgrass layer, 48,247 square kilometers (49 percent) was in the original FRCC 1 and 31,672 square kilometers (32 percent) was in the original FRCC 2. These areas, totaling 79,919 square kilometers (81 percent of the final Cheatgrass layer), were re-assigned to FRCC 3 – Cheatgrass (table 2) from the original coarse scale analysis. Since the rest of the area in the final Cheatgrass layer, 19,410 square kilometers (19 percent), was already in the original FRCC 3, they were kept as FRCC 3 and not reassigned to FRCC 3 – Cheatgrass.

Across the conterminous United States, incorporating cheatgrass into the original FRCC layer increased FRCC 3 by almost 11 percent (from 735,630 square kilometers to 815,549 square kilometers) (table 2). Figure 1 compares the difference in FRCC 3, before and after incorporating cheatgrass into the original FRCC layer for the western United States. Of the total reassigned area of FRCC 3 – Cheatgrass, 76 percent (60,522 square kilometers) occurred on federal ownership, increasing the original FRCC 3 by 20 percent (from 301,892 square kilometers to 362,414 square kilometers) (table 3).

When compared to the coarse scale fire regimes data, 53,516 square kilometers (67 percent) of the reassigned FRCC 3 – Cheatgrass was in the Historical Natural Fire Regime class III (35 – 100+ years; Mixed Severity) (table 2). In a historical natural fire regime with more frequent fires, 19,836 square kilometers (25 percent) of the reassigned FRCC 3 – Cheatgrass was in Historical Natural Fire Regime class I (0 – 35; Low Severity) (table 2).

Table 2—A summary of **all land ownerships** for the conterminous United States of historical natural fire regimes by fire regime condition classes with cheatgrass added. Summary does not include the following cover types: agriculture, barren, water, and urban/development/agriculture.

Historical natural fire regime	Fire Regime Condition Class (FRCC)				Total km ²
	FRCC 1	FRCC 2	FRCC 3 (without cheatgrass)	FRCC 3 – cheatgrass	
	Km ²	Km ²	Km ²	Km ²	
I. 0-35 years; low severity	705,430	695,976	313,605	19,836	1,734,847
II. 0-35 years; stand replacement	778,245	537,541	41,870	2,393	1,360,049
III. 35-100+ years; mixed severity	480,779	436,558	218,545	53,516	1,189,398
IV. 35-100+ years; stand replacement	210,708	142,847	141,757	4,174	499,486
V. 200+ years; stand replacement	196,511	55,470	19,853	0	271,834
Total	2,371,673	1,868,392	735,630	79,919	5,055,614

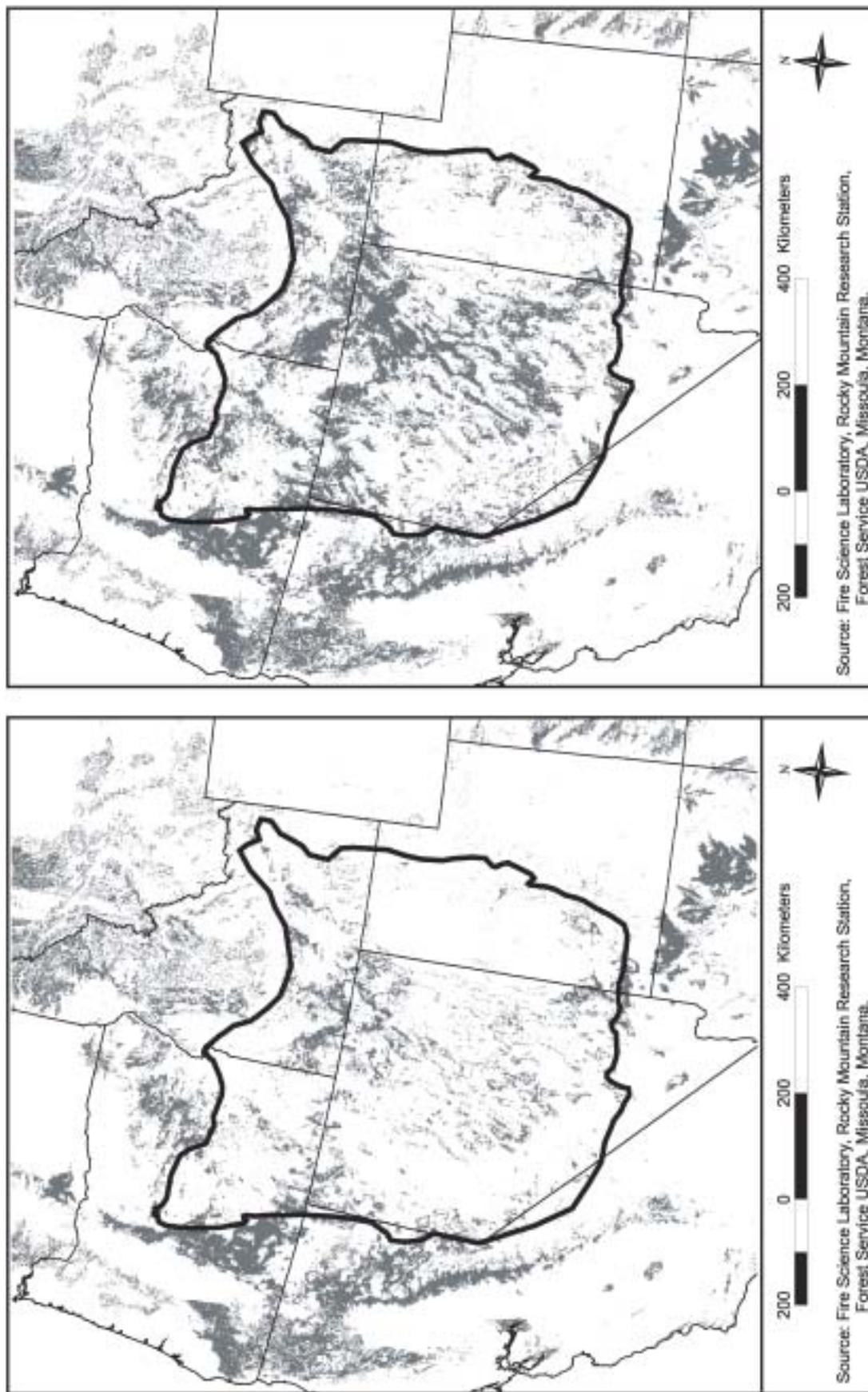


Figure 1—Comparison of Fire Regime Condition Class 3 without Cheatgrass added (left map) to Fire Regime Condition Class 3 with Cheatgrass added (right map). The boundary for the Great Basin is represented by the bold line.

Table 3—A summary of **federal land ownerships** for the conterminous United States of historical natural fire regimes by fire regime condition classes with cheatgrass added. Summary does not include the following cover types: agriculture, barren, water, and urban/development/agriculture.

Historical natural fire regime	Fire Regime Condition Class (FRCC)				Total km ²
	FRCC 1	FRCC 2	FRCC 3 (without cheatgrass)	FRCC 3 – cheatgrass	
	Km ²	Km ²	Km ²	Km ²	
I. 0-35 years; low severity	150,366	227,174	142,835	16,498	536,873
II. 0-35 years; stand replacement	96,230	126,701	2,938	1,475	227,344
III. 35-100+ years; mixed severity	290,685	198,692	85,341	39,284	614,002
IV. 35-100+ years; stand replacement	115,175	41,470	69,196	3,265	229,106
V. 200+ years; stand replacement	95,257	12,710	1,582	0	109,549
Total	747,713	606,747	301,892	60,522	1,716,874

Discussion

By incorporating cheatgrass spatial data for the Great Basin with the Coarse Scale FRCC layer for the nation, areas mapped as FRCC 3 increased by 11 percent. This would strongly suggest that the Coarse Scale FRCC layer underestimated FRCC 3 for rangelands and shrublands in the Great Basin. However, it would be difficult to extrapolate these numbers to the rest of the Continental United States. One could not use this Cheatgrass FRCC layer as a substitute for the Coarse Scale Version 2000 layers, because cheatgrass was only mapped for the Great Basin. The Coarse Scale layers were derived from national level data developed with the same methods throughout the conterminous United States (Schmidt and others 2002). This approach allows for uniform analysis and interpretation.

Unfortunately, we do not know of any national level spatial data that adequately maps exotic grasses. This might be the result of attempting to map these cover types at the wrong scale. Much of the departure from historical fire regimes in rangelands and shrublands involve the encroachment of exotic species into native communities resulting in changes in fire frequency and severity. This encroachment can be difficult to map with coarse scale spatial data (1 square kilometer pixels), because these species rarely dominate a pixel. Mid or fine scale spatial data (30 square meters or less) would probably be more appropriate.

Lastly, no accuracy assessment or field verification of the layers used in this project was conducted. Many authors have documented the difficulty in providing an accuracy assessment for coarse scale projects of 1 square kilometer pixel size or greater (Kloditz and others 1998; Loveland and others 1991; Schmidt and others 2002). This is because ground truth data is difficult and expensive to collect, and would only represent a very small portion of the study area (Schmidt and others 2002).

Management Implications

Cheatgrass has replaced native vegetation and increased fire hazard on millions of square kilometers in the western United States (USDA FS 2002). It

has been most successful in invading disturbed Wyoming big sagebrush and salt desert shrub communities, and its density and distribution have increased significantly in many ponderosa pine, pinyon juniper, antelope bitterbrush, and mountain brush communities (Monsen 1994). Its competitive and flammable nature makes it difficult to restore shrub/grasslands to their natural conditions. We have not previously had a consistent assessment of the distribution and extent of cheatgrass dominated areas in the Great Basin, the area with the greatest acreage of vegetation change caused by this species. This study provides the Department of Interior a much-needed perspective on the scale of the restoration effort required to convert these lands into healthy productive rangelands.

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