

Sensitivity to Spatial and Temporal Scale and Fire Regime Inputs in Deriving Fire Regime Condition Class

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Abstract—The Fire Regime Condition Class (FRCC) is a composite departure measure that compares current vegetation structure and fire regime to historical reference conditions. FRCC is computed as the average of: 1) Vegetation departure (VDEP) and 2) Regime (frequency and severity) departure (RDEP). In addition to the FRCC rating, the Vegetation Condition Class (VCC) and Regime Condition Class (RCC) are produced to indicate the status of each. FRCC assessments are applied as ecological condition measures across the U.S. for land and fire management plans, National Environmental Policy Act documents, project plans, burn plans, and agency reporting. Input data to FRCC computation include proportions of different successional stages within biophysical settings, estimates of current fire frequency and severity, historical reference conditions for successional stages, frequency, and severity, and the analysis area extent. Hydrologic unit maps, frequently referred to as Hydrologic Unit Codes (HUCs), for regional and local assessments and LANDFIRE Map Zones for national assessments commonly represent the analysis extent area. Mapping methods and quality have substantially improved with the development of the FRCC Mapping Tool with the associated User Guide and Tutorial. Our tests of mapping FRCC indicate that resulting FRCC metrics are highly sensitive to analysis scales of landscape extents, assumptions of current and historical fire regimes, and resolution of input maps. Examples of these effects and management implications are presented along with recommendations. We conclude that, when appropriately mapped, the Strata FRCC is a very useful measure of ecological condition, while the Stand FRCC is a very useful measure for prioritizing local vegetation and fuel treatments. The Regime Conditions of frequency and severity are highly useful for prioritizing wildland and prescribed fire options, as well as for designing vegetation and fuel treatments.

Introduction

The Fire Regime Condition Class (FRCC) is a composite departure measure that compares current vegetation structure and fire regime to historical reference conditions. Measures of departure as indicators of ecological condition and resilience to disturbance originated during the 1990s (Morgan and others 1994; Keane and others 1996; Hann and others 1998). The original FRCC concepts and definitions were presented at the conference ‘Integrating spatial technologies and ecological principles for a new age in fire management’ in Boise, Idaho, USA, June 1999 (Hardy and others 2001; Hann and Bunnell 2001; Schmidt and others 2002).

The various methods of generating FRCC assessments, described in the Interagency Fire Regime Condition Class Guidebook (Barrett and others 2010), were developed in 2003 by an interagency working group and The Nature Conservancy (TNC). Following development of the first guidebook, the National Interagency Fuels Technology Team (NIFTT) was formed to support technology transfer for FRCC, along with LANDFIRE and other fire and fuel management technical projects and products. NIFTT is now managed by the Wildland Fire Management Research & Development group under the

title Wildland Fire Management Research & Development Fuels and Fire Ecology group (WFMRA-FFE).

The intent in developing the FRCC process was to provide managers with a relatively simple, fast, and effective way to evaluate landscapes across the wide array of biophysical settings throughout the U.S. The result of the process is a measure that characterizes landscape health in terms of vegetation and fire regimes in relation to those that existed during the historical pre-EuroAmerican settlement reference era. In completing the FRCC assessment, managers fulfill reporting requirements and gain useful information about naturally functioning ecosystems for planning tasks ranging from broad to fine scales.

The generation of Regime Condition Class (RCC), Vegetation Condition Class (VCC), and Fire Regime Condition Class (FRCC) assessments at various scales and for a wide variety of landscapes is dependent upon landscape-scale input data. Fire *frequency* in an FRCC context is the average number of years between fires across all pixels of the biophysical setting and its landscape perimeter. Fire *severity* refers to the proportion of all pixels in the upper canopy layer of green vegetation that is consumed in the fire. High fire severity refers to a consumption of upper layer vegetation of over 75%, while moderate severity is 25-75% consumption, and low severity refers to areas where less than 25% of the green canopy is consumed. The VCC measure compares the distribution of successional classes across all pixels of each Biophysical Setting to pre-EuroAmerican reference composition. FRCC is

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a classification of the average of the fire regime and vegetation departures (RDEP and VDEP, respectively).

The VCC layer is a quantification of the amount of departure of current vegetation compared to simulated historical vegetation reference composition. Three condition classes represent levels of low departure (VCC 1, 0–33%), moderate departure (VCC 2, 33–66%), and high departure (VCC 3, 66–100%) (Barrett and others 2010). Low departure means that the distribution of area between successional classes within biophysical settings is similar to the pre-EuroAmerican settlement conditions, while a high departure means that some successional classes are over or under represented, or that uncharacteristic vegetation dominates the area. Uncharacteristic vegetation is generally composed of native vegetation with a composition and structure that did not occur historically or exotic plant species. High values for VDEP/VCC do not necessarily mean higher risk for wildfire occurrence, rather it is a measure of ecological departure of the vegetation.

FRCC, as with other models, is dependent upon input data. Although input data is available from various sources; in some instances, or locations, input data may not be available. For example, in developing the input spatial layers of fire frequency and severity for creation of coarse-scale data for fire and fuel management, data was collected from historical fire databases; however, there were many instances where data were not available or appeared to be in error and hence not included (Hardy and others 2001). This was particularly the case on large areas of private land where the federal fire occurrence database did not contain data. In the current Landscape Fire and Resource Management Planning Tools Prototype Project (LANDFIRE) system, the Succession Class (SCLASS) input layer is available for determination of VDEP and VCC, but fire frequency and severity are not provided for determination of the RDEP or RCC (www.landfire.gov). The raw data for determination of fire frequency and severity are available from LANDFIRE, Monitoring Trends in Burn Severity (MTBS), and local data sources (Hamilton and Hann, this Proceedings). In many cases, expert opinion and local knowledge may assist in accumulating the most accurate input data.

In this study, we compare four approaches for deriving FRCC, and its components VCC and RCC, in a case study in a western juniper, sagebrush steppe ecosystem. The first approach is an unaltered VCC product available at the LANDFIRE data distribution website; the other approaches utilize the FRCC Mapping Tool (Hutter and others 2010). During this assessment, we evaluate the fire regime (RCC) and vegetation (VCC) variables at various scales, ranging from entire landscapes to individual stands. Assessments for the fire regime variables *frequency* and *severity* are included.

Methods

Study Area

The study area encompasses 275,000 hectares of Juniper Mountain located in Owyhee County of southwestern Idaho (116°W, 43°N, Figure 1). The area is dominated by mountain big sagebrush steppe (*Artemisia tridentata* ssp. *vaseyana*),

low sagebrush (*Artemisia arbuscula*), mountain riparian, and western juniper (*Juniperus occidentalis* ssp. *occidentalis*) LANDFIRE Biophysical Settings (BpS). Across the area, western juniper has been expanding into areas previously dominated by sagebrush steppe. The area is rich in wildlife and summer grazing by livestock occurs across the area on private and public lands.

The elevation in the area ranges from 1480 m to 2074 m. Precipitation ranges from 300 to 600 mm, increasing with elevation. Soil types include mountain loams and clay loams. The majority of the winter precipitation is snow while the majority of the spring precipitation is rain, with a dry summer and fall. The annual average temperature varies from a low of -6.6 °C in December to 26.7 °C in July.

Input Data

In each of the four scenarios, there are five common input layers needed to assess VCC and RCC: Biophysical Settings (BpS; Figure 2), Succession Classes (SCLASS; Figure 3), and the three Hydrologic Unit Code layers, (HUC 8, 10 and 12; Figure 4 and Table 1). Two of these layers, BpS and SCLASS, are models developed by the LANDFIRE Prototype Project (Long and others 2006; Holsinger and others 2006; Rollins 2009) and are available at the LANDFIRE data distribution site (<http://landfire.cr.usgs.gov/viewer/>).

The BpS layer is a vegetation data product that is intended to provide land managers with a description of potential natural vegetation expected to occupy a site based on biophysical factors such as soil, slope, precipitation, and growing season length and associated historical disturbance dynamics (Barrett and others 2010; Rollins 2009). This model of the

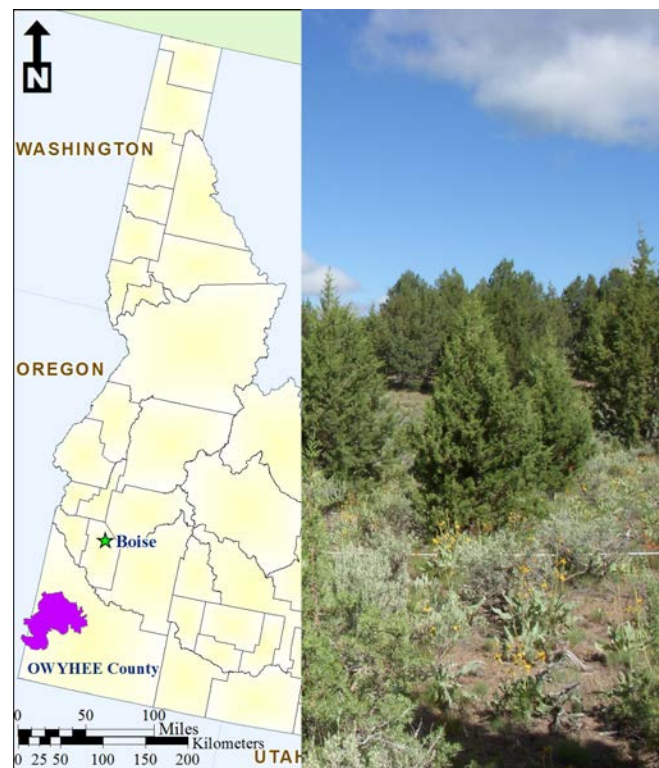


Figure 1—Study area in southwestern Idaho.

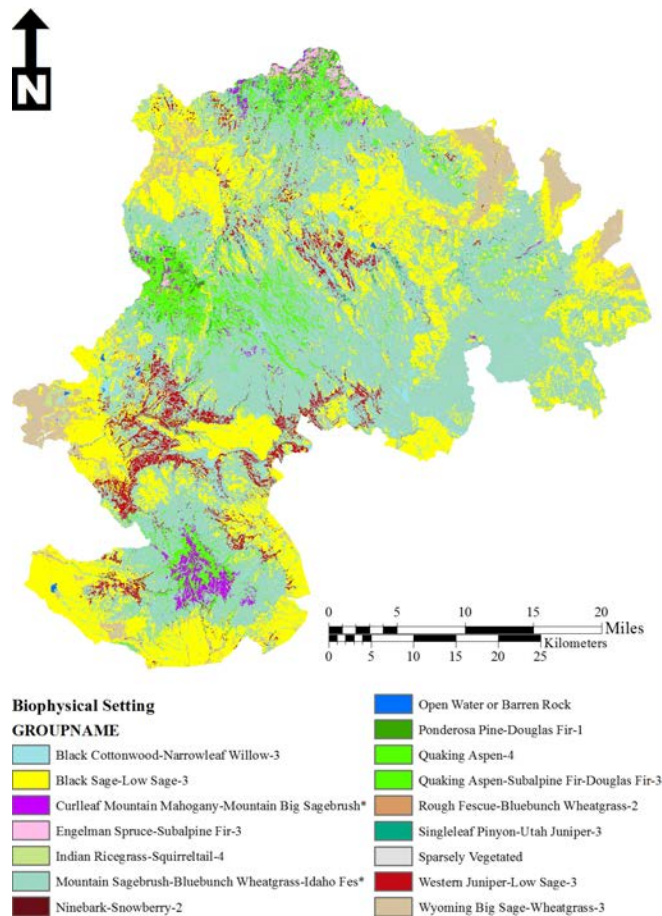


Figure 2—Biophysical settings within the study area.

vegetation depicts an approximation of the plant communities that existed prior to Euro-American Settlement. Dominant mapped BpS types within the study area include Mountain Big Sagebrush Steppe and Low Sagebrush (Figure 2).

The SCLASS layer represents the current successional state of vegetation within a Biophysical Setting including vegetation species composition, cover, and height ranges of successional states (Barrett and others 2010; Holsinger and others 2006; Long and others 2006; Rollins 2009). These stages include five succession classes (A, B, C, D, and E) as well as sparsely vegetated, uncharacteristic native vegetation (UN) and uncharacteristic exotic vegetation (UE). The succession classes represent seral stages of plant communities. A large portion of the area is mapped as UN vegetation in the SCLASS layer because western juniper has been expanding into areas historically dominated by sagebrush steppe vegetation (Figure 3).

The purpose of the HUC layers is to serve as landscape calculation units for the FRCC algorithm assessment. The size of each HUC delineation determines the total pixel count for which the composition of a given metric class is calculated. FRCC is a scale-dependent metric (Barrett and others 2010). In the U.S., subbasins (HUCs) are commonly selected for local FRCC assessment to represent boundaries applicable to fire regime variation within the study area (Figure 4). The hydrologic unit code layers at the 8th, 10th,

and 12th level are available from the USGS Water Resources website (<http://water.usgs.gov/GIS/huc.html>).

Scenarios

We compare four approaches to calculating FRCC ecological departure metrics. Each of these approaches requires common input layers of BpS, SCLASS, and HUCs but vary in use of software and the frequency and severity inputs (Table 1). Scenarios #2, #3, and #4 utilized the FRCC mapping tool (FRCC_{MT}; Barrett and others 2010; Hamilton and others 2014a). FRCC_{MT} is a GIS application that uses the amounts of SCLASS, frequency, and severity within a BpS and the appropriate HUC scale to calculate the outputs. Output layers include FRCC, RCC, VCC, and their associated departures at the Landscape (HUC), Strata (BpS), and Stand (SCLASS) scale. Spatial scale for all inputs and outputs was 30-meter pixel. The spatial extents of the landscape and strata HUC layers was somewhat different for Scenario #1 versus 2, 3, and 4. The scale of time for calculation of the departure and class outputs for FRCC, RCC, and VCC was the 2008 year of LANDFIRE mapping compared to the historical reference conditions.

Scenario #1 is the most commonly used data used in ecological assessments for local, regional, and national fire, fuel, and vegetation management planning and monitoring applications; it is the LANDFIRE Refresh 2008 VDEP and VCC layers. This method is simply a download from the LANDFIRE data distribution site and does not require running the FRCC mapping tool software (Figure 5). FRCC,

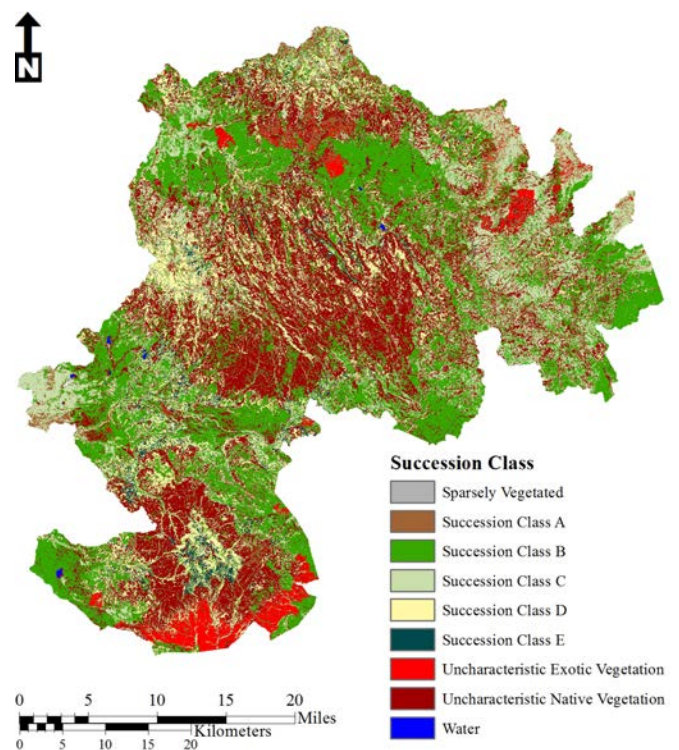


Figure 3—Succession classes within the study area. A – early successional; B – mid successional, closed canopy; C – mid successional, open canopy; D – late successional, open canopy; E – late successional, closed canopy.

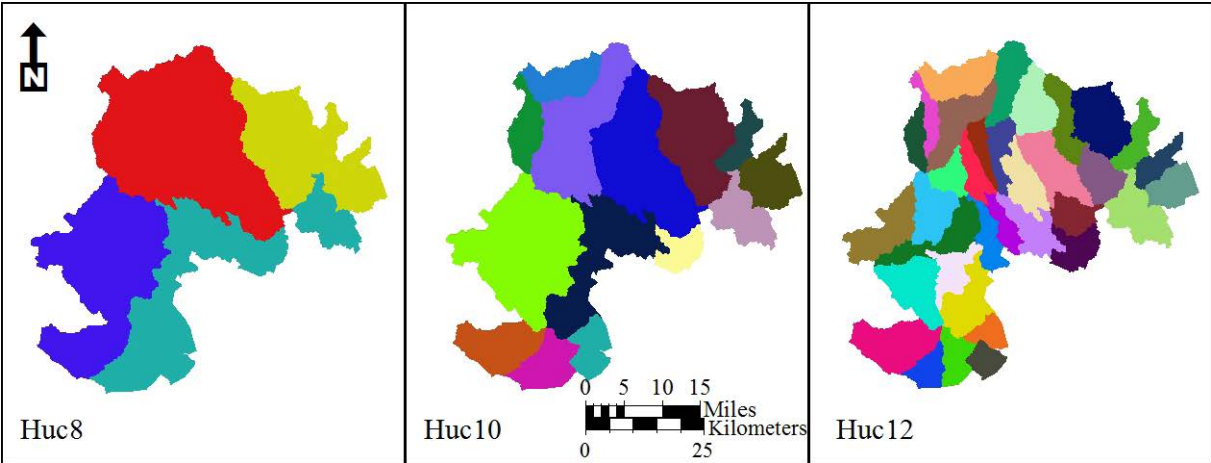


Figure 4—Hydrologic Unit Code Layers within the study area as defined by the U.S. Geological Survey available at <https://water.usgs.gov/GIS/huc.html>.

Table 1—Scenario Inputs and Outputs.

Scenario	Source	INPUTS				OUTPUTS			
		BPS	S-Class	HUC	Source of Current FRQ and SEV	Vegetation	Regime	Strata FRCC	Stand FRCC
1	Download from LANDFIRE	BPS Group	S-Class	LANDFIRE 8, 10,12	NA	VCC/VDEP	NA	NA	NA
2	Run FRCC _{MT}	BPS Group	S-Class	Other source 8, 10, 12	NA	VCC/VDEP	NA	NA	Stand FRCC
3	Run FRCC _{MT}	BPS Group	S-Class	Other source 8, 10, 12	Expert opinion	VCC/VDEP	RCC/RDEP	Strata FRCC	Stand FRCC
4	Run FRCC _{MT}	BPS Group	S-Class	Other source 8, 10, 12	LANDFIRE Disturbance Layer Wildland Fire Assessment Tool (WFAT)	VCC/VDEP	RCC/RDEP	Strata FRCC	Stand FRCC

RDEP, and RCC are not currently available to download from LANDFIRE, and RCC or FRCC were therefore not possible to derive for Scenario #1.

Scenario #2, 3, and 4 apply methods that use the FRCC_{MT} and the common input layers described above. In Scenario #2, 3, and 4 we derived VDEP and VCC using HUCs obtained from the USGS Water Resources website, which were not identical to the HUCs used by LANDFIRE to derive the downloadable VCC layer used in scenario #1. The study area boundary for scenarios 2, 3, and 4 were generated by selecting most of the HUC 12s within the HUC 8s, but not all as was done by LANDFIRE for scenario #1. Therefore the spatial scale of the landscape analysis area was a slightly different delineation of HUCs for scenarios 2, 3, and 4 as compared to Scenario #1. The FRCC_{MT} calculation of the VDEP and VCC departure of SCLASS from historical SCLASS reference composition was based on the 2008 year of mapping.

Scenario #3 uses the FRCC_{MT}, the common input layers, and additional data in the form of an expert opinion for current fire frequency and severity. The expert opinion (Table 2)

contributes data about the fire frequency and fire severity for each major BpS group in the study area. This expert opinion comes from study of the local fire history literature and local field studies. The spatial scale of variation in the BpS and SCLASS assignments was at a 30-m pixel, while a single expert opinion estimate of fire frequency and severity was applied uniformly across the BpS for each HUC. The scale of time for FRCC_{MT} calculation of the VDEP and VCC departure of SCLASS from historical SCLASS reference composition was the 2008 year of mapping; a single time year, same as for Scenarios #1 and #2. The scale of time for estimating the average fire frequency and severity expert opinion across the BpS and HUC area was general, approximately early 1900s to current. This average was then compared to the reference conditions which were the average for the pre-settlement period.

Scenario #4 also uses the FRCC_{MT}, the common input layers, and additional data about the fire frequency and fire severity. The fire frequency layer was developed through analysis of LANDFIRE disturbance layers spanning a 10 year time period from 1999 through 2008 (Hamilton and

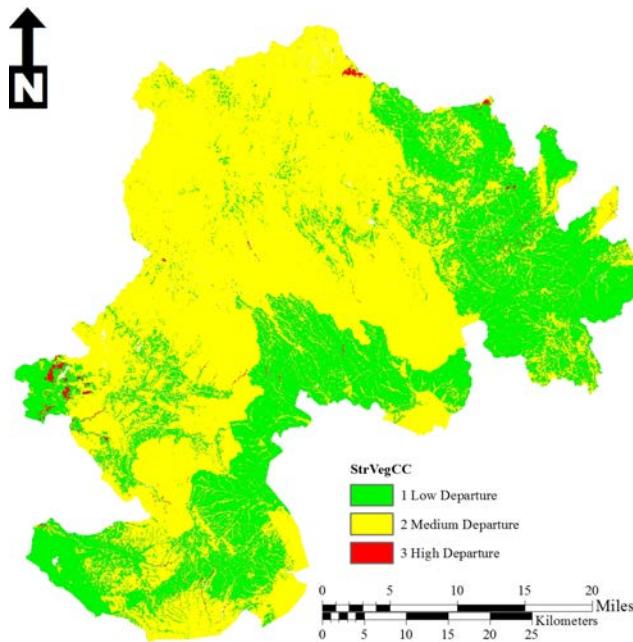


Figure 5—Scenario #1. Strata Vegetation Condition Class downloaded from LANDFIRE and clipped to the study area boundary.

Hann, this Proceedings). The fire severity layer was developed through use of LANDFIRE fuels layers and the Wildland Fire Assessment Tool (WFAT; Hamilton 2014b). The WFAT generates the FRCC severity metric at a pixel scale through use of a series of algorithms that analyze inputs of fuels and fire effects layers combined with a weather scenario. In this scenario, the scale of the BpS and SCLASS input layers to FRCC_{MT} was at a 30-m pixel, same as for Scenarios #1, #2, and #3. However, differing substantially from Scenario #3, this Scenario the variation of fire frequency and severity occurs at the 30-m pixel scale common to BpS and SCLASS, rather than as a single estimate across the whole BpS extent. In addition, the scale of time for the fire frequency summary of fire disturbances downloaded from LANDFIRE and MTBS for BpS with more frequent historical fire regimes was the 1999 to 2008 period, essentially only

a single decade, as contrasted to approximately 100 years for Scenario #3. As indicated previously, in substantial contrast to Scenario #3, the fire severity was modeled using WFAT at a 30-m pixel based on the LANDFIRE fuels data from 2008.

Results

We noted different results in VCC, RCC, and FRCC outputs depending on the input layers and parameters. Inputs and selected outputs for each scenario are listed in Table 1. The four columns on the right of the table list the output layers generated for each scenario. The output layer common to each scenario is the Vegetation Condition Class (VCC) layer.

Scenario #1 outputs consist of only two data layer results, the Strata VCC and VDEP layers. These data layers are available at the LANDFIRE data distribution website. The basis of these calculations is the departure of SCLASS composition of each BpS from reference conditions. The historical vegetation reference condition composition of SCLASS types are a simulation generated with the disturbance dynamics model Vegetation Dynamics Model (VDDT; Barrett and others 2010; Beukema and others 2003; LANDFIRE-Vegetation Condition Class 2014). The Strata VCC shows moderate and low departure across the study area, meaning that the distribution of successional classes within BpS types is only departed from historic conditions at low or moderate levels. From a user perspective, this would be the easiest of the scenarios, as the VDEP and VCC data layers can be downloaded directly from LANDFIRE. However, we found this scenario to be the most prone to possible misinterpretation for several reasons: 1) The VDEP and VCC layers may be used by an uninformed user to infer more than just vegetation departure from historical reference, such as inference about the FRCC, the fire regime, or resilience; 2) The process of downloading just the VDEP or VCC does not provide the user the opportunity to review the SCLASS to BpS layer assignments and modify or recognize potential errors; and 3) The scale of landscape summary used by LANDFIRE may not fit the scale appropriate for the application.

Table 2—Current fire frequency (FRQ) and severity (SEV) estimated with expert opinion according to this table for Scenario #3. FRQ refers to the average number of years between subsequent fires. SEV stands for severity, which in a LANDFIRE and FRCC context is defined as the % removal of biomass caused by the fire.

Expert Opinion for Input Data of Scenario #3					
BpS GROUPNAME	Area (ha)	Reference FRQ years	Reference SEV %	Current FRQ years	Current SEV %
Mountain Sagebrush-Bluebunch Wheatgrass-Idaho Fescue	128090	550	1100	1120	80
Black Sage-Low Sage	79670	885	337	2250	50
Black Cottonwood-Narrowleaf Willow	17760	661	222	1120	22
Quaking Aspen	17360	1100	1100	1150	80
Wyoming Big Sage-Wheatgrass	15810	559	662	225	90
Western Juniper-Low Sage	10740	998	226	2250	50
Curlleaf Mountain Mahogany-Mountain Big Sagebrush	3750	664	226	1150	50
Quaking Aspen-Subalpine Fir-Douglas-Fir	2280	554	446	1120	65

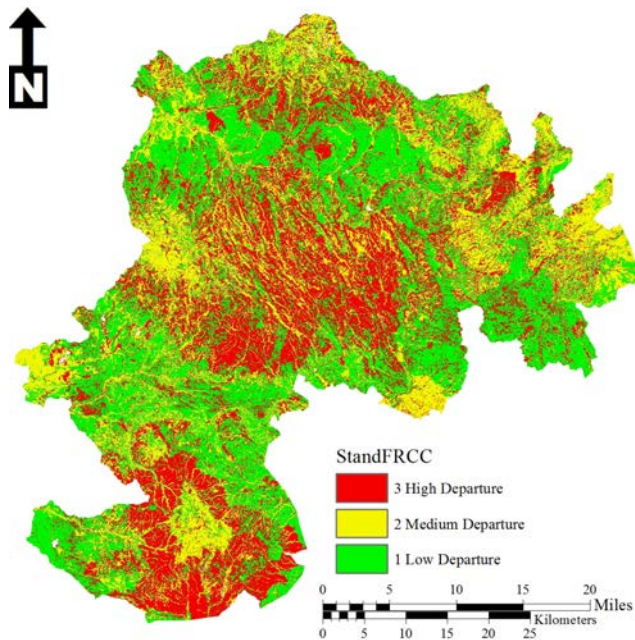


Figure 6—Scenario #2-4. Strata Vegetation Condition Class derived using the FRCC mapping tool.

Scenario # 2 is a method that includes the use of the FRCC_{MT}. We generated three data outputs, the Strata VCC and VDEP and the Stand FRCC layers (Figures 6 and 7). These layers are calculated using the FRCC algorithms described in the FRCC Guidebook. Strata VCC for Scenario #1 (downloaded from LANDFIRE; Figure 5) and Scenario #2-4 (derived using FRCC_{MT}; Figure 6) are relatively similar. We observed some differences between VCC derived according to Scenario #1 and #2 procedures due to the differences in the HUC layers used in the two analyses. A different HUC

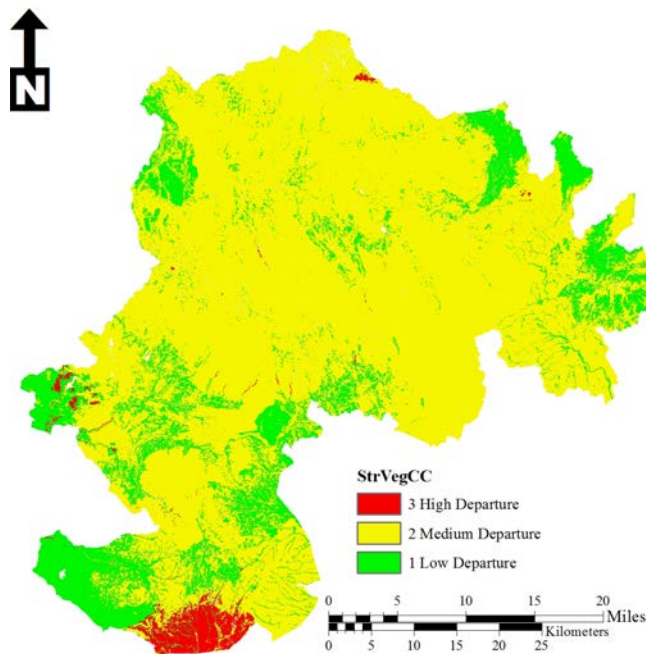


Figure 7—Scenario #2. Stand FRCC shows high ecological departure in areas where western juniper has expanded into areas classified as mountain big sagebrush steppe biophysical setting.

delineation results in a different total pixel count and differences in SCLASS counts that then affects the composition calculations. Stand FRCC (Figure 7) clearly shows high ecological departure in areas where western juniper has replaced sagebrush steppe while remaining areas show low or moderate departure from historic reference conditions. These results bring forth an important concept relative to interpretation of these data. The SCLASS layer in itself has no value without the context of its BpS and the reference composition. In contrast, the Stand FRCC has considerable stand-alone value as it identifies the SCLASS pixels that are in excess or in deficit compared to their BpS historical reference composition. From a user perspective, this would be the second easiest of the scenarios, as the process requires the use of the FRCC_{MT} to output the VDEP and VCC, but the input SCLASS and BpS data layers can be downloaded from LANDFIRE, modified if appropriate, and the user can choose the scale of landscape summary. We found this scenario to be somewhat prone to possible misinterpretation for a similar reason as the first scenario. The VDEP and VCC outputs from the FRCC_{MT} may be used by an uninformed user to infer more than just vegetation departure from historical reference, such as inference about the FRCC, the fire regime, or resilience. However, because the user has evaluated the BpS, SCLASS, and scale of landscape summary this misinterpretation is less likely.

In Scenario #3 and #4, we derive RCC (Figure 8 and 10) and FRCC (Figure 9 and 11) in addition to VCC. The RCC derived using expert opinion for current fire frequency and severity departures via inputs in the Frequency and Severity Editor in FRCC_{MT} (Scenario #3) shows moderate ecological departure across most of the area (Figure 8). This departure can be explained by the fact that most of the study area has missed 1-3 fire cycles resulting in a shift from shrub and

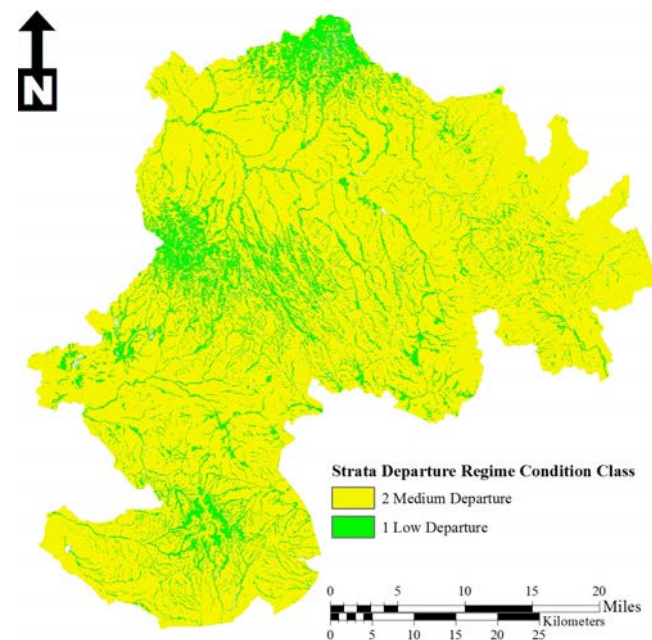


Figure 8—Scenario #3. Strata Regime Condition Class derived using expert opinion for current fire frequency and severity.

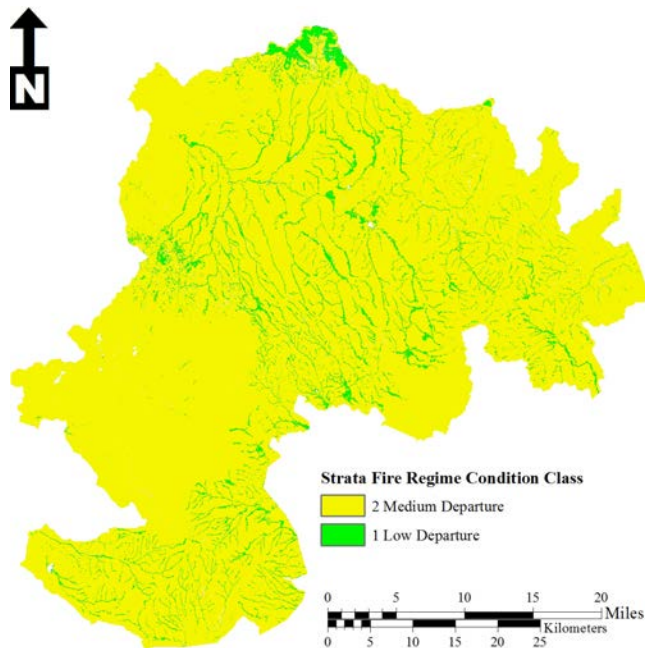


Figure 9—Scenario #3. Strata FRCC derived using expert opinion for current fire frequency and severity.

grass fuels to woody tree fuels. This is most likely due to reduction of potential fire starts and spread because of loss of grass fuels via excessive livestock grazing within the area during the early 1900s and fire suppression since the 1930s. In addition, the scale of time for the Scenario #3 estimate using expert opinion was an average for the period of early 1900s to current for fire frequency and the last two decades for fire severity. RCC derived using the LANDFIRE disturbance layers (Scenario #4) shows a high ecological

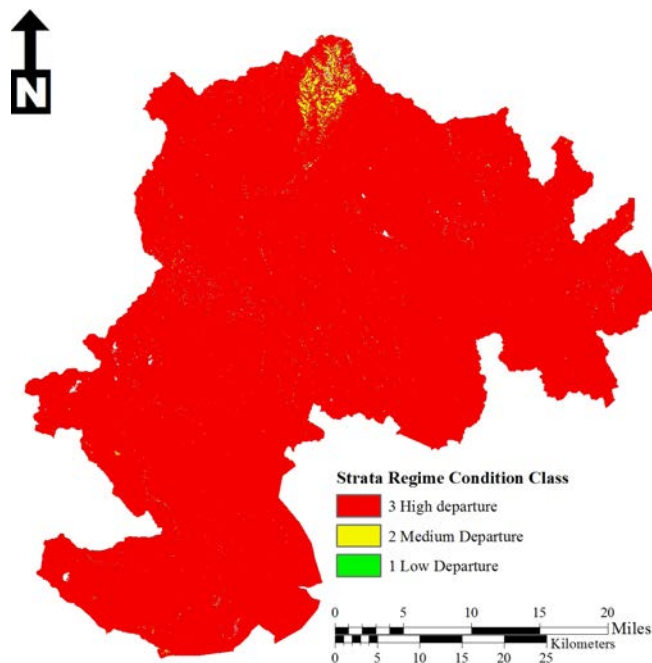


Figure 10—Scenario #4. Strata Regime Condition Class derived using fire perimeters from 1984-2008 (from MTBS) and the Wildland Fire Assessment Tool to derive current fire frequency and severity.

departure for the entire area (Figure 10). The fire frequency input layer generated from LANDFIRE disturbance layers only incorporates fire disturbances for a relatively short time period, approximately two decades prior to 2008 (1989-2008). In Scenario #3 and #4, we also derived the Fire Regime Departure as the average of VDEP and RDEP and subsequently classified it to FRCC (Figure 9 and 11). From a user perspective, Scenario #3 would be more difficult than Scenario #1 or 2, but less difficult than Scenario #4. The process requires the use of the FRCC_{MT} to output the VDEP and VCC, RDEP and RCC, and FRCC. We found these two scenarios to be much less prone to possible misinterpretation as it requires the user to closely evaluate the FRCC_{MT} input and output data and methods.

Discussion

The result that is common to each scenario is the VDEP and VCC layers. With these four scenarios, the results for Scenario #1 differ from the results of Scenarios #2, #3 and #4. Our analysis indicates that this is a consequence of the slight differences in the delineation of the HUC input layer. For all scenarios, the BpS and SCLASS download versions from LANDFIRE were not modified, essentially held as a constant. The LANDFIRE methodology for developing this layer includes all of the HUC 12 units encompassed in the HUC 8 units, whereas in our processing, some of the HUC 12s on the edge were clipped from the HUC 8 layer. Thus the VDEP and VCC algorithms receive different values on the edges of the study area, hence producing different results.

The Regime Condition Class (RCC) or the Regime Departure is computed by comparing the current fire frequency and severity to the historic reference condition. RCC is therefore highly dependent on methodologies used to estimate current and historic frequency and severity. In Scenario #3, we used expert opinion and long-term knowledge of the local area to estimate the current fire frequency and severity as an average over a relatively long time period of early 1900s to 2008. In Scenario #4, for fire frequency we calculated the current fire interval from the LANDFIRE disturbance layers and MTBS data attributed with a fire disturbance. This accounted for a relatively short two-decade time-period of 1989-2008 for fire frequency. Fire severity was modeled for the conditions of 2008, a single year time period. In addition, the Scenario #3 applied a single estimate of frequency and severity across all pixels of a BpS within a HUC 8, while in Scenario #4 the frequency and severity were modeled at the pixel scale and summarized for each BpS within a HUC 12. The two methods of estimating fire frequency and severity result in different outputs where in this case Scenario #3 resulted in mostly RCC 2 (Figure 8) while Scenario #4 resulted in mostly RCC 3 (Figure 10).

We attribute this difference to both the temporal and spatial resolution differences in current fire frequency and severity methods. For frequency, the expert opinion (Scenario #3, Figure 8) applied long-term knowledge of the area and estimated in the range of 100 years while our use of

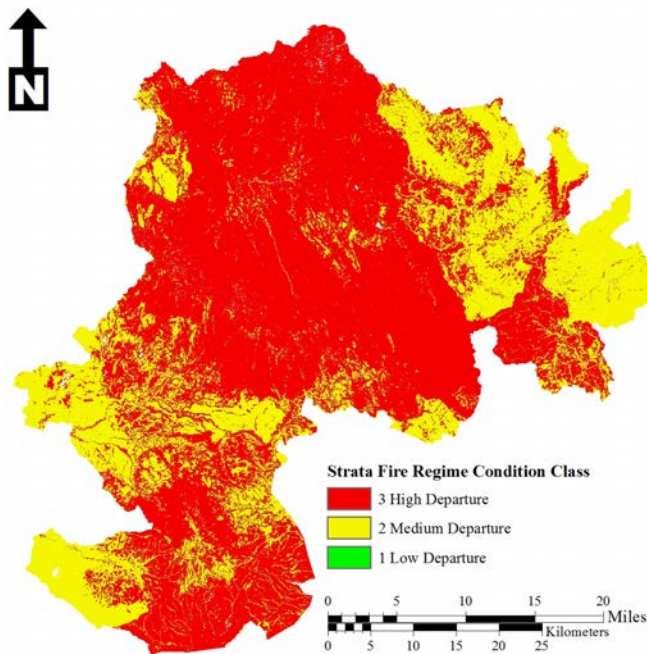


Figure 11—Scenario #4. Strata FRCC derived using fire perimeters from 1984–2008 and the Wildland Fire Assessment Tool to derive current fire frequency and severity

the LANDFIRE disturbance and MTBS datasets only incorporated information since 1989, approximately two decades. Areas with a fire frequency longer than 15 years could easily be misrepresented by this dataset with a shorter time span. On the other hand, expert opinion can be subjective and incorrect. Ideally, a fire perimeter dataset spanning a time-period longer than any fire return interval within the study area should be used in the RCC assessment. These long-term fire-atlas datasets are not currently available. However, the interim expert opinion can be combined with available data to create a combination of the two approaches that improve on both methods (Hamilton and Hann, this Proceedings). In addition, the differences in temporal scale were substantial, as the expert opinion assignment was at the BpS by HUC 8 scale, while the frequency datasets were analyzed at the BpS by HUC 12 scale. Similar differences in temporal and spatial scales of methods for determining severity resulted in a similar pattern of results as occurred with frequency.

The Strata FRCC is determined by averaging the VDEP (0–100) and the RDEP (0–100) producing values ranging from 0 to 100 and then classifying into low (0–33), moderate (33–66), and high (66–100) (Barrett and others 2010). This method of calculating FRCC weights these two variables equally and is considered to be a more comprehensive measure of ecological status (FRCC Guidebook, Chapter 2, page 32). Scenario #3 results in a stratum FRCC dominated by class 2 (Figure 9) while Scenario #4 results in mostly class 3 (Figure 11). Even though the VDEP and VCC are identical for Scenario #3 and #4, RDEP and RCC are mostly class 2 for Scenario #3 and class 3 for Scenario #4, resulting in the FRCC layers in Figure 9 and 11. When evaluating an FRCC output, it is important to recognize that FRCC departure consists of the average of VDEP and RDEP where one

of the components may express a high ecological departure while the other may not. From a management implication perspective it is important to look at the VDEP and RDEP values and their distribution more intently than the broad three class results of VCC and RCC. Upon closer inspection, we find that the shift to the class 3 can be caused by minor increases in departure values that cross class thresholds. From a restoration prioritization perspective, the actual departure of the FRCC, VCC or RCC class of 2 may be borderline to Class 1 or to Class 3. While Class 1 may require maintenance activities Class 3 may require restoration activities. Although the FRCC, VCC, or RCC class may be useful from a visual mapping perspective we find it very important to focus on the departure values and closely evaluate areas that close to class thresholds.

The Stand FRCC represents pixels with SCLASS types that are over- or under-represented compared to the SCLASS reference composition for the BpS. Stand FRCC in Figure 7 shows that the sagebrush steppe BpS is highly departed in areas over-represented by uncharacteristic native vegetation, western juniper in this case. The Stand FRCC map is useful to management because it spatially identifies areas that are strong candidates for management activities, either conservation of under-represented SCLASS types or restoration of over-represented SCLASS types. In-depth evaluations of the outputs from the FRCC_{MT} in conjunction with field visits, can help prioritize treatment areas or design conservation strategies. The fire severity departure modeled with WFAT, demonstrated in Scenario #4, also has high potential for application at the stand scale.

The strength of the FRCC at three different scales (stand, strata BpS/HUC, and Landscape), combined with VDEP and VCC and RDEP and RCC outputs provides a very strong set of variables for evaluation of the condition of the fire regime, land health, and resilience to disturbance. In essence, the stand scale provides information at the pixel scale concerning SCLASS conditions that may be in excess or deficit from historical to support local conservation or restoration strategies. The RCC at the strata scale provides a ranking between BpSs for condition of the fire regime and used to prioritize efforts to change frequency or severity of fire at local or regional scales. Further investigation of the frequency and severity layers can support evaluation of BpS resilience to fire. The FRCC measure at strata scales, with its combination of vegetation and regime, provides data for evaluating land health locally and regionally. The landscape scale with its condition class measure across a large HUC area provides data useful for regional or national summary or prioritization.

Conclusions

- The VCC output is highly sensitive to the analysis extent. We recommend a standardized hydrologic unit layer available for download in conjunction with the LANDFIRE inputs of BpS and SCLASS. We further recommend that the HUC 8 layer is not clipped to specific analysis area

boundaries, rather than the study area consists of selected HUC 8 units. It is recommended that the analysis area is large enough to reflect the historic range of variability within the BpS types.

- The VCC output is highly sensitive to the SCLASS layer used in the analysis. The user should pay attention to the development year of the SCLASS layer and determine if recent succession or disturbances have occurred that may have changed the SCLASS layer.
- The SCLASS, fire frequency, and fire severity layers are highly sensitive to the BpS layer as it is the summary unit within a HUC. The extent of the BpS can substantially affect the summary calculations of SCLASS, fire frequency, and fire severity. Users should evaluate the BpS layer to assure that it represents the vegetation types provided in the LANDFIRE BpS model descriptions. Fire frequency and its effect on RCC are highly sensitive to temporal resolution of the fire perimeter data. The difference in spatial scale between expert opinion assigned to BpS and HUC versus 30-m fire disturbance frequency calculation can be substantial. We recommend careful considerations when selecting the current inputs for frequency and severity. Expert opinion is recommended if the available fire atlas data has a shorter timespan than the fire return interval for the BpS in question. From a national perspective, we recommend a standardized approach to analysis of the various fire disturbance data (Hamilton and Hann, this Proceedings).
- The FRCC methodology needs to have additional metrics or specifications that indicate how much *frequency* and *severity* are above or below reference conditions. Current reporting of FRCC frequency and severity departures do not provide information of whether fires burn more or less frequently or severely compared to the reference condition. The FRCC_{MT} and Guidebook provide metrics for evaluating VDEP and VCC as to SCLASS types that are under- or over-represented. This same type of information should be available for frequency and severity as it is important for land management treatment planning and implementation.
- The latest version of LANDFIRE does not include any of the FRCC metrics except VDEP and VCC. Although other metrics were available in the past, they are not currently available as downloads from the LANDFIRE website. The FRCC_{MT} derives these additional metrics, such as Strata FRCC, Stand FRCC, Relative Amount, Frequency Departure, and Severity Departure. FRCC_{MT} may be the only standardized ecological departure and resilience tool for planning documents. We recommend continued emphasis on technology development and transfer of these important concepts, data, tools, and management implications. The complete suite of FRCC metrics are highly valuable as ecological measures of status and resilience (Hamilton and Hann, this proceedings) for application in management activity prioritization, planning, and gaining understanding from the public. These metrics are complex to compute and can be subject to error in calculation

and interpretation. We recommend incorporation of these data and processes in the web-based decision support systems for fire, fuels, and vegetation management.

- Depending on the objective, some FRCC measures are more suitable than others. For example, the FRD or FRCC or RDEP or RCC measures may be useful to infer land health, ecological status, or trends in resilience in discussions with management teams or the public, but may not be useful for prioritization or planning of specific projects. In contrast, Stand FRCC and VDEP or VCC, whose development is an output from SCLASS current composition as compared to reference composition for the BpS at a single point in time, may be useful for the prioritization and planning of vegetation management projects. Comparison of VDEP and VCC changes over multiple time periods can be used to infer trend. Of major value to fire and fuel management is the perspective of the fire frequency departure and condition, and ability to determine how much needs to be burned or not burned, to achieve the historical range of fire frequency. The fire severity departure and condition can be used for a different application with emphasis on severity of fire effects on the upper layer of vegetation, which may result in changes in SCLASS.

In summary, we recommend continued use of FRCC, VCC, RCC, and associated measures as ecological metrics for landscape, strata, and stand scale ecological status and resilience to disturbance. However, the input spatial and tabular data impacts the output and must be evaluated to manage for quality results and interpretations.

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