Application of CFLRP monitoring to Forest Plan Monitoring of the Arapaho Roosevelt National Forest

Summary, discussion, and feedback

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Summary

The Colorado Front Range Collaborative Forest Landscape Restoration Project focuses on restoration treatments to reduce wildfire hazard while promoting additional ecological objectives such as increasing wildlife and understory diversity and reducing wildfire impacts to watersheds. Given the aligned objectives of landscape restoration and forest planning, we explored the potential application of CFLRP and related landscape monitoring efforts to forest plan monitoring with the Arapaho Roosevelt National Forest (ARNF) (Cannon et al., 2018a). First, we found that CFLRP forest structure monitoring provides robust information on impacts of individual treatments, but more extensive remote sensing approaches or data sources may be required for forest-wide analyses or planning. Second, although the Front Range CFLRP is not currently conducting landscape-scale analyses to quantify change in wildfire behavior or risk, there are flexible risk assessment frameworks to track wildfire risk and/or management accomplishments such as risk reduction to ARNF's multiple resources of interest—WUI, soils, wildlife habitat, etc.. The following sections provide a broad overview of the tools described in the full report (Cannon et al., 2018a) and the feedback provided by ARNF staff during three in-person presentations.

Background

The Collaborative Forest Landscape Restoration Program (CFLRP) promotes collaborative monitoring and planning of restoration treatments to achieve landscape-scale objectives related to reducing wildfire hazard and increasing forest resilience to disturbance by restoring forest structure. Likewise, the USDA Forest Service (USFS) 2012 planning rule requires that forests plan management activities to achieve landscape-scale objectives. The Colorado Forest Restoration Institute (CFRI) participates in monitoring and analyses with the Front Range CFLRP and other restoration programs in Colorado. CFRI is currently in an agreement with the Arapaho Roosevelt National Forest (ARNF) to pilot, present, and discuss how monitoring efforts from CFLRP may be adopted or adapted for forest planning at the ARNF. In April 2017, CFRI presented progress on the project to ARNF staff. In January 2018, the first phase of the project was completed, and CFRI produced a report of the findings (Cannon et al., 2018a). Overall this project reviewed monitoring efforts, methods, and results of the Front Range CFLRP pertaining to how restoration treatments impact: (1) forest structure, composition, and spatial patterns, (2) wildfire risk to wildland–urban interface, (3) wildfire risk to soil and water resources, and (4) wildlife habitat. The project took the approach of describing current monitoring efforts of the CFLRP related to each of these topics, and piloted similar analyses to demonstrate what metrics can be produced via adoption or adaptation of CFRLP protocols, and the extent to which these methods may apply to forest plan monitoring.

The current agreement between CFRI and the ARNF consists of CFRI presenting each section of this report to the ARNF staff in detail and producing a report summarizing the discussion and feedback from these presentations. CFRI presented on the first section of the report —pertaining to forest structure, composition, and spatial pattern—to the ARNF staff in February 2018. In April 2018, CFRI presented on the portion of the project related to protection of soil and water resources. In March 2019, CFRI presented the wildfire risk portion. Below is a summary of each section and the associated feedback from ARNF staff.

Forest structure, composition, and spatial pattern

Presentation summary

The CFLRP currently employs common stand exam protocols to measure plot-level changes in tree density and composition. The CFLRP monitoring plan (Barrett et al., 2017) calls for plot-level information to be supplemented with remotely sensed satellite imagery analysis to quantify stand-scale changes in canopy cover and to delineate and measure changes in the structure of large gaps. In general, restoration treatments of the CFLRP meet stated desired conditions. Overall, treatments reduce tree density, create larger gaps, and increase tree patch size diversity (Cannon et al., 2018b). One exception is that restoration treatments did not meet objectives to reduce Douglas-fir dominance by favoring its removal over ponderosa pine. Instead, restoration treatments of the CFLRP removed approximately 28% of the basal area of both Douglas-fir and ponderosa pine. It should be noted that preliminary analyses indicate that restoration outcomes are improving in more recent treatments (Barrett et al., 2019). This pattern was consistent throughout many early treatments of the CFLRP. In addition, though considerable progress was made toward desired conditions, post-treatment forest structure remains at higher densities with fewer gaps relative to historical conditions (Cannon et al., 2018b). Impacts on forest structure and composition from the Red Feather Project CFRLP treatments generally showed similar trends to CFLRP treatments as a whole (Cannon et al., 2018a). Although plot-based field monitoring is useful for many stand-scale questions, remote sensing approaches (e.g., Vogeler et al., 2018) may be required to inform landscape-scale forest planning.

Discussion and feedback from USFS Staff

ARNF staff generated suggestions for improving how monitoring efforts could be used to more closely address concerns for forest planning. The feedback from ARNF staff primarily focused on issues pertaining to: scale; economics, prescription, and planning; and consideration of other ecological objectives.

First, USFS staff at the ARNF generally agreed that the scale of the Common Stand Exam monitoring used by the CFLRP may be too small to inform forest planning and suggested that larger-scale analyses could be helpful to prioritize treatment type and placement. Remote sensing approaches such as Vogeler (2018) may address these concerns. In addition, CFRI is currently developing an analytical framework with NRCS to simulate how forest restoration treatments can be placed to approximate historical forest heterogeneity at larger scales. Similar analyses could be conducted in the northern Front Range to assess how restoration treatments can contribute to desired landscape structural changes.

Second, ARNF staff suggested that future analyses consider the feasibility and economics of treatments along with ecological outputs. Future treatments could be targeted with spatial analyses to identify feasible locations and treatment types that are most cost-effective at improving forest structure and reducing wildfire risk. The current analyses focus primarily on mechanical and prescribed fire treatments to reduce hazardous fuels and restore forest structure, but they could be extended to consider other objectives, such as prescriptions relevant to timber production or improvement of wildlife habitat. Such analyses can be useful for forest plan monitoring, but also for additional efforts such final reporting for the CFLRP and Joint Chiefs' Landscape Restoration Partnership Project.

Lastly, other feedback from ARNF staff related to how changes in forest structure and composition achieves other objectives such as improving understory herbaceous communities and wildlife habitat. ARNF can potentially infer the impact of forest management activities on understory plants with plot-level data currently collected during the CFLRP and other studies (Briggs et al., 2017). As part of the CFLRP monitoring, the Bird Conservancy of the Rockies is collecting landscape-scale data to study how restoration treatments may impact avian communities. We are also monitoring changes in canopy cover and distribution of "large gaps" for CFLRP. For this effort, we defined "large gaps" as areas > 80 feet in diameter with < 5% canopy cover. We chose this scale to approximate the neighborhood size most predictive of the change in resources and growth of regeneration (Boyden et al., 2012). However, other definitions of "gaps" could be used that are more relevant to wildlife or silvicultural objectives.

The next step for forest structure and composition monitoring is to continue communication with forest planning staff to determine which analyses and at what scale can best inform forest planning. At the time of these presentations, the Forest Program Manager position was temporarily filled, and the forest was granted a one-year reprieve from revising the Forest Plan. Thus, ARNF staff suggested delaying immediate feedback for a future date.

Fire behavior modeling

Presentation summary

The monitoring programs of the both the Front Range and Uncompahgre CFLRPs include components to monitor how individual restoration treatments alter fire behavior metrics such as torching and crowning indexes (Chambers, 2019; Young et al., 2013). However, landscape-scale monitoring of potential fire behavior has not currently been adopted by the Colorado CFLRPs. Several fire behavior modeling tools are available that could address landscape-scale fire behavior questions but they vary widely in capability and accessibility.

A comprehensive and flexible framework has been developed to assess wildfire risk to multiple resources that is highly relevant for forest planning (Thompson et al., 2016, 2013). Overall, this wildfire risk assessment framework incorporates three risk components including: (1) fire likelihood, (2) fire behavior, and (3) resource susceptibility to fire. The first component, burn probability modeling (Miller and Ager, 2013) can be achieved via tools such as FlamMap, Randig, IFTDSS, or FSIM. National data on wildfire probability is also available (Short et al., 2016). By simulating management effects on the second component—fire behavior—forest planners can compare a number of proposed management scenarios for planning and prioritization purposes. For example, FlamMap modeling software (Finney, 2006) can be used to model fire behavior metrics (such as flame lengths or crown fire activity) in untreated landscapes. Similar metrics can be generated for post-treatment landscapes to quantify change in fire behavior and wildfire risk compared to the baseline scenario. Estimating susceptibility of highly valued resources and assets (HVRAs) is the third component of the wildfire risk assessment framework. This is usually accomplished by describing how individual resources (such as timber, wildland–urban interface, wildlife habitat, etc.) will respond to levels of fire intensity (e.g., flame lengths) on a relative scale from -100 to +100 for complete loss to radical gain in value. For example, timber resources may see a small benefit from short flame lengths but will incur severe damage from high flame lengths; whereas fire of any intensity is damaging to the wildland–urban interface. Individual response functions can be developed by expert opinion (e.g., from resource specialists, Thompson et al., 2013). Together, data on wildfire probability, expected fire intensity, and response of individual resources to various levels of fire intensity can be combined to quantify wildfire risk to a suite of HRVAs.

We used the above framework to assess the impact of 14 fuels reduction treatments on mitigating wildfire hazard and risk to the wildland–urban interface near Red Feather Lakes. Details of the analysis and results are presented in Cannon et al. (2018a). Overall, this analysis found that because treatments were best characterized as mechanical-only treatments, there may have been a slight short-term increase in fire intensity level from management-related activities that increase fuels on the ground, resulting in increased risk to WUI. This is primarily because the Red Feather Lakes treatments were placed in areas of the landscape that had low potential for crown fire activity prior to treatments. In areas with denser forest and ladder fuels, mechanical treatments can effectively lower risk by reducing passive or active crown fire to surface fire. Prescribed fire on the same landscape was predicted to reduce risk to WUI. Overall, fuel treatment effects vary based on starting forest conditions, fuel treatment type, and placement relative to values at risk. In addition, metrics of wildfire WUI risk are sensitive to spatial definitions of the WUI, so it is important that these definitions be clearly articulated in goals and objectives so planning and monitoring are consistent.

Discussion and feedback from USFS Staff

The ARNF staff provided valuable feedback on how the wildfire risk assessment framework could be used for forest planning. This feedback related primarily to usability, flexibility, and objectivity. First, the ARNF staff discussed to what extent the forest had the necessary staff to manage spatial data on fuels and model fire behavior. The wildfire risk assessment is a modular framework where information on individual components (fire likelihood, fire intensity, and resource susceptibility) can be obtained from a number of sources. Fire likelihood is publicly available at a resolution suitable for Forest-wide analyses (Short et al., 2016). The analyses presented (detailed in Cannon et al., 2018a) used FlamMap to model expected fire intensity under a range of weather scenarios. This framework is modular in nature, and other sources of fire behavior information can be used to achieve similar means without this constraint. For example, more accessible tools such as the Interagency Fuel Treatment Decision Support System (IFTDSS), or more complicated tools like FSim (Finney et al., 2011) , can be used to generate spatial predictions of fire intensity. More complex fire behavior modeling tools such as Randig and FSim extend the capabilities of FlamMap with probabilistic weather scenarios, but they generate more complex data structures and require greater user expertise and computer resources.

Second, the analyses presented (detailed in Cannon et al., 2018a) simulate the effects of four levels of fuel hazard reduction treatments including: (1) mechanical thinning, (2) prescribed fire, (3) thinning and prescribed fire, and (4) untreated. These comparisons were made by simulating the effects of treatments based on published reports of treatment effects on canopy cover, canopy bulk density, and surface fuels (Fulé et al., 2012; Stephens et al., 2009; Stephens and Moghaddas, 2005; Ziegler et al., 2017). The ARNF staff suggested that management practices vary considerably from treatment to treatment and that "typical" effects may not be representative. For example, the impacts of prescribed fire in the current version of these models may not be representative of local effects, as the model is based on Sierran conifer forests rather than Colorado Front Range forests; anecdotal observations indicate that treatments on the Front Range may result in larger increases in canopy base height (Morici et al., 2019). Thus, predictions of prescribed fire outcomes may be somewhat conservative. However, the general framework presented above can be adjusted to match the effects of a range of treatment outcomes provided that information on surface and canopy fuels can be managed in a form suitable for updating the spatial inputs to fire behavior models. In addition, this framework can be expanded to incorporate intra-treatment variability in intensity provided spatial information on treatment intensity is known (Cannon et al., 2019).

Third, ARNF staff discussed the benefits and drawbacks of defining HVRA response functions. In general, there was a concern that eliciting expert opinion involves a fair degree of subjectivity. Guidance on response function definition is sparse, but response functions from past risk assessments may be a useful starting point (Thompson et al., 2013). Defining response functions for individual resources is typically done through a semi-formal process with input from experts. Although imperfect, this approach is modular and can be improved or replaced as scientific understanding on fire effects improves. There was also concern that relative important weights used to express a resource's significance for the Forest may be arbitrary. These relative importance weights are usually developed by line officers guided by policies and priorities expressed in forest planning documents. Changing policy or priorities can also render previous risk assessments invalid, but these are also easily updated in the framework.

Protection of soil and aquatic resources

Presentation summary

As with wildfire risk above, monitoring the effectiveness of treatments to reduce wildfire risk to soil and aquatic resources is not currently part of the Front Range CFLRP monitoring. However, related programs (e.g., Peaks to People Water Fund) provide insight into tools for monitoring and prioritization. Forest restoration and fuels reduction can mitigate wildfire risk to watershed values by reducing wildfire severity and post-fire erosion. Using the same wildfire risk assessment framework above (Scott et al., 2013), post-fire soil erosion modeling can be substituted for HVRA response functions to assess the potential risk mitigation of forest management practices on soil resources (Gannon et al., 2019). Management effectiveness at mitigating this risk depends on fuel treatment effectiveness at modifying fire behavior, and characteristics of soils, topography, and climate that control erosion potential. Reductions in post-fire erosion have been quantified for various conservation practices using a linked model approach that couples fire behavior and soil erosion models (Elliot et al., 2016; Jones et al., 2017). The expected benefits of treatments can be quantified by combining pre- and post-treatment wildfire and erosion modeling with spatially-explicit estimates of wildfire likelihood (Short et al., 2016). As with wildfire risk to WUI, treatment effects on fire behavior can be modeled in FlamMap. Here, crown fire activity (fire type) was used as a proxy for burn severity (Tillery and Haas, 2016) instead of flame lengths. Post-fire erosion can be estimated with the Revised Universal Soil Loss Equation (RUSLE, Renard et al., 1997) calibrated with field-measured effects on cover and soil erodibility by level of burn severity (Larsen and MacDonald, 2007). Sediment delivery to streams can then be estimated using an empirical model of hillslope sediment delivery ratio (Wagenbrenner and Robichaud, 2014). This method has been shown to make reasonable post-fire erosion predictions for the range of slopes (≤ 40%) that are feasible for forestry work, and can be coupled with sediment transport models to scale gross erosion predictions to watershed-scale sediment yields (Gannon et al., 2019).

We used the above framework to assess the impact of 14 fuel reduction treatments near Red Feather Lakes. Details of the analysis and results are presented in Cannon et al. (2018a). The projected reduction in sediment delivery to streams among the 14 treatments is approximately 120 Mg, and reductions in sediment delivery ranged from 50-70%. It should be noted that although percent reductions were relatively similar among treatments, absolute reduction in sediment delivery among the 14 treatments was considerable; the least impactful treatment reduced post-fire sediment delivery by only 0.2 Mg, while the most effective treatment is expected to reduce sediment delivery by 22.2 Mg. This 100-fold difference in effectiveness among individual treatments can result from a number of factors such as differences in fire and erosion potential. That is, the ability to reduce wildfire risk to these resources is constrained if initial fire or erosion potential is low. Compared to the entire ARNF, the area treated by this project in Red Feather Lakes does not have high erosion potential due to shallow slopes and coarse soils, which is often the case for areas accessible to large mechanized logging equipment. However, these analyses can identify areas where erosion risk can best be mitigated with forest management (Gannon et al., 2019).

Discussion and feedback from USFS Staff

The wildfire-related erosion and sediment transport modeling described here includes numerous data sources and models that require a large investment in data stewardship and modeling expertise. Because the fire simulation modeling components are similar to those used for the wildfire risk to WUI analysis, many of the same concerns apply here. Accurately modeling treatment effects on forest structure is important, and if details of individual treatment effects are known, their impact on post-wildfire erosion can be more precisely modeled. In addition, the wildfire risk assessment framework presented here compares treated and untreated post-wildfire erosion. However, there are potential impacts to soils from the fuel hazard reduction treatments themselves that are not considered. For example, conducting forest operations in some areas requires the construction of road networks, and mechanical machinery used in forest operations may create soil disturbances. A similar modeling study in California projected that the increase in erosion from forest treatments was only three percent (Elliot et al. 2016). While management operations to reduce fuel hazard may themselves contribute slightly to erosion, the expected benefits of reduced sediment after treatment are likely to outweigh these additional inputs.

Other tools and resources to consider

The development of landscape-scale tools for monitoring restoration impacts on forest structure, wildfire hazard, and erosion may also be complemented with additional tools and resources to fulfill regulatory requirements for forest plan monitoring under the 2012 planning rule.

The Westwide Drought Tracker's time series platform (https://wrcc.dri.edu/wwdt/time/) can be used to display both long term and monthly trends in precipitation and temperature for predictive service areas. The EPA's new Critical Loads Mapper platform https://clmapper.epa.gov/ facilitates efficient analysis of atmospheric deposition in aquatic and terrestrial ecosystems. The Rangeland Analysis Platform may be particularly relevant for forest plan monitoring for grasslands such as the Pawnee https://rangelands.app/. The Platform leverages Landsat data ground-truthed with thousands of BLM and NRCS NRI plots via machine learning to generate trends and maps of indicators such as perennial, annual, and bare ground cover at multiple scales for user uploaded polygons. While it is not a substitute for allotment-scale monitoring, it can be used to evaluate broad-scale trends, effects of disturbances, and large scale management interventions, such as prescribed fire. Reporting outputs for large fires occurring in the forest may be obtained from the Monitoring Trends in Burn Severity program (https://www.mtbs.gov/) when there are fires greater than 1,000 acres. This program can be used to evaluate acreages burned under different severity categories. Headwaters Economics socio-economic indicators applications (https://headwaterseconomics.org/dataviz/forest-indicators/) can be used to track trends in numerous social and economic measures, including trends in WUI development, for user selected counties that encompass or border the national forest.

Other resources for forest plan monitoring will be operational in the near future. Staff at the Bird Conservancy of the Rockies (IMBCR) are currently working on identifying lists of potential focal species for all the forests in Region 2, which will facilitate efficient analysis of trends via their Avian Data Center (http://rmbo.org/v3/avian/Home.aspx). They are also working on updating the Avian Data Center with new Region 2 avian sensitive species to support monitoring and location identification at the forest plan scale. Staff in the Forest Inventory and Analysis program are also working on tools that will facilitate the use of FIA data for forest plan monitoring questions associated with forest structure, function, and composition.

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