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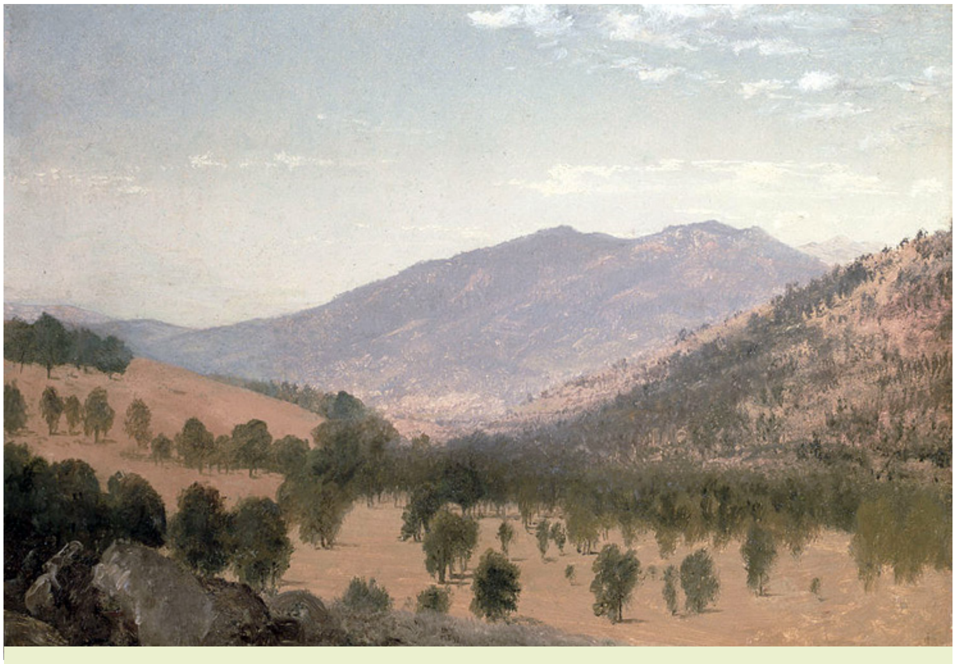
Back to the Future: Building resilience in Colorado Front Range forests using research findings and a new guide for restoration of ponderosa and dry-mixed conifer landscapes

In 1860, a typical ponderosa pine forest along the Colorado Front Range looked quite different from what is seen today. Back then, these forests were open and grassy enough for you to easily gallop your horse through, weaving between widely-spread out clumps of trees. Today, however, many of these same forests are much denser - crowded with smaller trees - making them vulnerable to large wildfires, insect epidemics and disease.



"Bergen Park" was painted by John Frederick Kensett circa 1870. The painting illustrates the open, spatially-variable structure of a ponderosa pine stand with an open understory typical of some Front Range forests at that time. (Bergen Park, at an elevation of 7800 ft., is located near Evergreen, CO, 25 miles west of Denver.)

Colorado's Front Range has experienced an increased number of large, high-severity wildfires over the past two decades. These fires have compromised watersheds, critical wildlife habitat, and caused concern about water quality, erosion and natural tree regeneration. According to Greg Aplet of the Wilderness Society, "We have been faced for some time with this looming and continuing problem of what to do about altered forest conditions, and the (associated) fire behavior and fire effects." Since the early 1990's forest managers and others have increasingly recognized the need for proactive forest management to make the landscape more resilient to fire and other disturbances, but have been challenged by a lack of clear goals based in scientific understanding.

The Front Range Roundtable -- formed in 2004 and representing the various agencies and organizations involved in forest management across 11 counties on the Colorado Front Range -- identified approximately 1.5 million acres in need of forest

SUMMARY

Historically, the ponderosa and dry mixed-conifer forests of the Colorado Front Range were more open and grassy, and trees of all size classes were found in a grouped arrangement with sizable openings between the clumps. As a legacy of fire suppression, today's forests are denser, with smaller trees. Proactive restoration of this forest type will help to reduce fuel loads and the risk of large and severe wildfires in the Colorado Front Range. Using the best-available information on the historical conditions of these forests to develop "desired conditions" for restoration, the Rocky Mountain Research Station has published Principles and Practices for the Restoration of Ponderosa Pine and Dry Mixed-Conifer Forests of the Colorado Front Range (RMRS-GTR-373).

This guide was produced and reviewed by a range of scientists and managers from federal agencies, environmental non-profits, and academia to address the unique forest structure and fire regime of this area as well as synthesize current Front Range forest science. It aims to help the management community understand the desired conditions for these forests, the principles behind the restoration recommendations made, and steps for implementing the principles. The guide is being released with a companion document, Visualization of Heterogeneous Forest Structures Following Treatment in the Southern Rocky Mountains, (RMRS-GTR-365) which allows users to "see" what the recommended treatments may look like at the stand level.

"The information we've provided helps to validate some of the work that managers are already doing and provides a blueprint for how it might be done within the context of their existing planning."

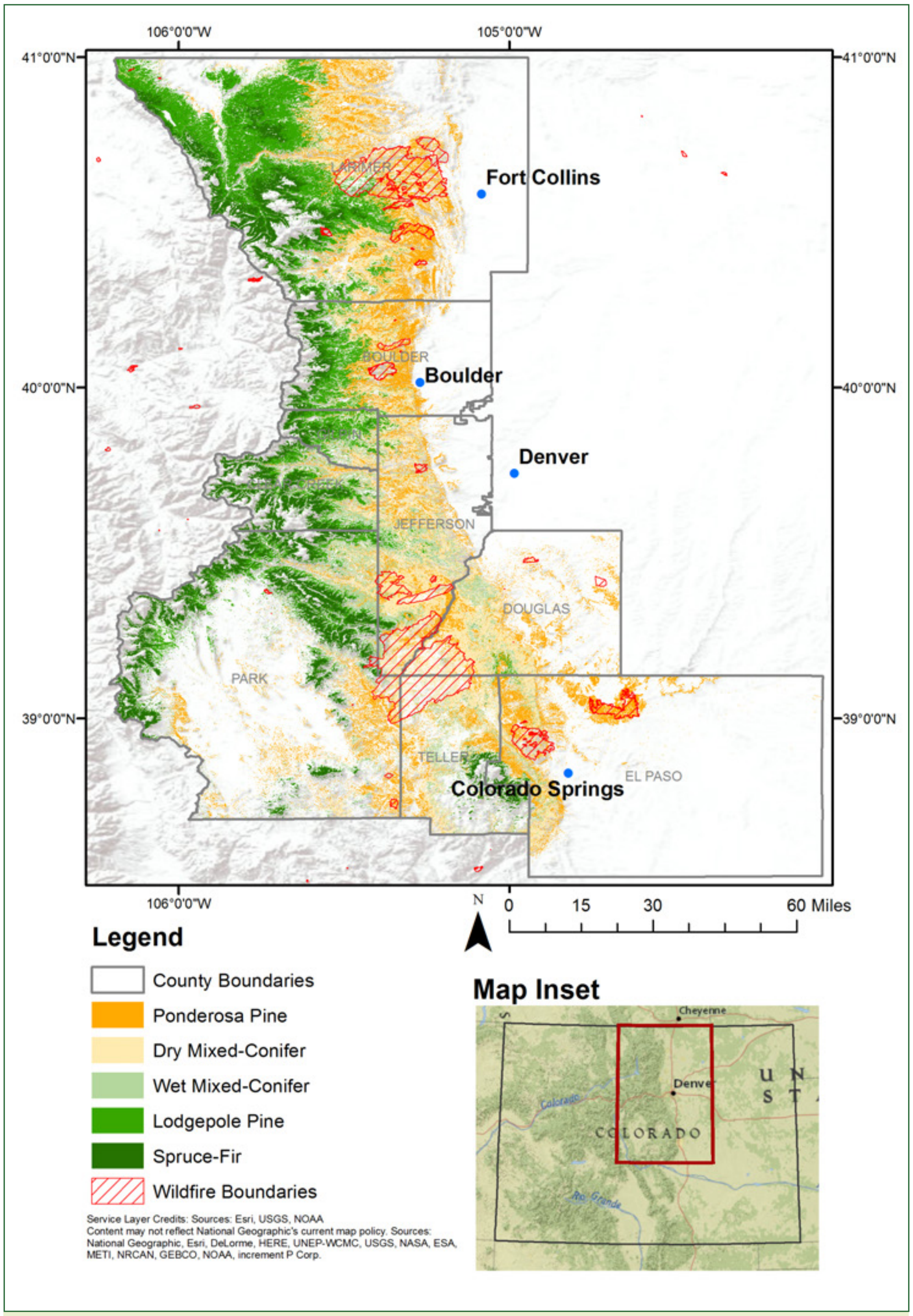
management to mitigate wildfire hazard, protect communities, and restore forest structure and composition in this area/region. Working with the Arapaho Roosevelt and Pike San Isabel National Forests, the Front Range Roundtable was an important part of the Collaborative Forest Landscape Restoration Program (CFLRP) award received by these national forests in 2010. The CFLR program supports the very types of restoration projects the Front Range Roundtable has prioritized. One of the provisions of the CFLRP was that there had to be a monitoring plan in place which measured progress toward "desired conditions" of these forests, but at the time when the grant was awarded, these desired conditions were undefined. Mike Battaglia, a USFS researcher, recalls, "At the time, we thought it would be easy to describe them. But when we convened these working groups, we realized that we really had no common definition for what forest restoration was in this area, and didn't know what our 'desired conditions' were."

The Colorado Front Range CLFRP's effort to define a common definition of forest restoration in the intervening years has led to a flurry of research on the ecology and historical conditions of Front Range forests. The recently published "Principles and Practices for the Restoration of Ponderosa Pine and Dry Mixed-Conifer Forests of the Colorado Front Range" (RMRS-GTR-373) provides a synthesis of information specific to Colorado's Front Range, while outlining a framework to guide forest management and treatment design criteria that can be used by land managers far and wide. Lead author Rob Addington of The Nature Conservancy says, "Our goal with this GTR was to explore ways of meeting fuels reduction objectives and changing wildfire behavior, but doing it in a way that considers how the forest was structured historically and what kind of forest we expect in the future."

Another goal of the authors for GTR-373 is to outline a process that promotes an inclusive and holistic multi-resource benefit approach to the Front Range's natural diversity of local landscapes and land ownership. Jonas Feinstein of the USDA Natural Resources Conservation Service says, "Early on, we recognized that the Front Range's dry forest types are roughly split in ownership between private and public lands, and that both good and "uncharacteristic" natural processes do not confine themselves to these ownership boundaries."

How will this restoration guide be useful for forest managers?

A ponderosa pine stand in the Front Range differs from one in California or the Black Hills



Extent of ponderosa and dry mixed-conifer forest types (along with other forest cover types) of the Colorado Front Range that are the subject of this GTR. Historically, mixed severity fire regimes in Front Range forests yielded highly heterogeneous landscapes that shaped a mosaic of forest conditions across the landscape (figure by R. Addington).

KEY FINDINGS

- Historical stand reconstruction shows that the ponderosa and dry mixed-conifer forests of Colorado's Front Range were more open and grassy than they are today, with a very variable mix of tree sizes that were often clumped together.
- Much of the Front Range is characterized by a mixed-severity fire regime, with low, moderate, and high-severity fire effects all having occurred historically, based on factors such as elevation and slope.
- The forest structure and composition of the Front Range is shaped at multiple scales by interactions among topography, natural disturbances such as fire, and forest developmental processes. This serves as a foundation for identifying priority areas for treatment and designing restoration projects across scales.

because physical site characteristics and weather of this area create unique fire behavior patterns and stand assemblages across the landscape. Several regional guides addressed managing western dry-mixed conifer forests (for example, Managing Sierra Nevada Forests [GTR-PSW-237], and Restoring Composition and Structure in Southwestern Frequent-Fire Forests [RMRS-GTR-310]), but none were specific to Colorado's Front Range, and so they lack sufficient detail for planning, project design, implementation and monitoring with the CFLRP collaborative management framework. Addington explains, "We began to think about how the Front Range is different than these other regions, then noticing that these other GTRs were gaining popularity. Even now, a lot of people are using GTR-310 on the Front Range as a guide for forest management, but we determined that there were some unique things about the Front Range that justified a restoration guide specifically for this area."

The GTR was produced and reviewed by a very large number

MANAGEMENT APPLICATIONS

- Using the knowledge gained from historical reconstruction (for example, the spatial variability in pre-settlement stands) to guide restoration is likely to have many benefits, including making the landscape more resilient to fire, drought, and insect outbreaks.
- The management framework as laid out in the GTR is: the identification of priority areas, planning treatments at the stand or landscape scale based on natural gradients, assessing how natural disturbance would interact with these gradients, and using that information to help develop actual on-the-ground treatments.
- The general outcomes of the management recommendations in the GTR are reduction in forest densities and surface and crown fuels, enhancement of spatial heterogeneity across scales, and retention of drought-and fire-tolerant species, old trees, and structures important for wildlife.

and wide range of scientists and managers from federal agencies, environmental non-profits, and academia, which has helped to ensure that parties with expertise and interest in the future of these forests have, importantly, had a hand in shaping the recommendations. Jeff Underhill, a Regional Silviculturalist with the USFS explains, "I would say externally, that this GTR will be useful for all of the partners that we work with, both federal and nonfederal. On the federal side, it will be useful for the line officers and people doing NEPA reports at the USFS, and people at NRCS and USGS. We also work with the Nature Conservancy, the Wilderness Society, and area Parks and Recreation offices. Outside of that, it could have utility for a whole range of people, including members of the public who are interested in this type of work. It is also a good primer on the ecology of Front Range forests for any USFS employees new to the area."

Tony Cheng, Director of the Colorado Forest Restoration Institute at Colorado State University emphasizes that this restoration framework is designed to be utilized within an interdisciplinary team context. "It requires bringing in not just timber and fuels people, but also the wildlife biologists, hydrologist, soil scientists, recreation people to really have a more integrated discussion about ecological integrity as a guiding principle in restoration."

How do today's Colorado Front Range Forests compare to historical conditions?

Understanding the unique local conditions – both past and present – is an important jumping-off point for forest restoration and identifying the desired endpoints. When researchers started to compile the available science for this GTR, they used information from all over – from the southwestern US to the Northern Rockies. They found plenty of evidence that there were some commonalities in ponderosa pine and dry-mixed conifer stands throughout the region – all were characterized historically by physical complexity and uneven-aged forests with a highly variable arrangement in clumps of trees and openings. But over the past several years, stand reconstruction work [See Box on Using Historical Forest Stand Reconstruction] on the Rocky Mountain Front Range from Laramie WY to Colorado Springs has revealed unique attributes of these forests.

Back in the mid-1800s, Front Range forests were more open and grassy, and stands were two to three times less dense. There were trees of all size classes in a "groupy-clumpy" arrangement, where the groups of

"The idea is not necessarily to use treatments to mimic what a fire would do on the landscape. What we want to do is to prepare the landscape to receive fire in a way that then preserves future options for forest recovery and sustainability by limiting the size of high severity burn patches," explains Cheng.

trees were separated by openings (usually less than one acre). At the landscape scale, there was a rich landscape mosaic with uneven-aged, mature forest maintained by low-severity fire that was intermixed with early- and mid-successional forest patches and shifting small openings created by very small patches of high-severity fire. The specific climate and soil productivity in this area affect, for example, the number of trees in a group, the proportions of groups vs. single trees, the size of the trees, and the stand density compared to the region as a whole.

Feinstein explains, "If you looked at historic conditions, dry forest types exhibited this wonderful diversity of forest structures that created small-scale topographic variation based on soils, moisture, and productivity gradients. It is these very small-scale gradients that promoted site-specific complexity and resulted in the unique local landscape diversity and evolutionary environment of the Colorado Front Range dry mixed-conifer forests." This structure has been both a driver and product of the historical fire regime. Much of the Front Range had a mixed-severity fire regime, with low, moderate, and high-severity fire effects all having occurred in these forests based on factors such as elevation and slope. The mix of tree sizes was maintained by frequent surface fire (with small patches of stand-replacing or high-severity fire), which left

Using Historical Forest Stand Reconstruction Data to Guide Restoration on the Front Range

How do you "reconstruct" a forest from the 1860s? A team of researchers (from RMRS, CFRI and Rocky Mountain Tree-Ring Research) set up a collaborative project called the Front Range Forest Reconstruction Network (FRFRNet), a regional sampling effort to provide locally-relevant reference conditions to guide restoration. The scientists installed one-half hectare plots (179 plots in total) throughout Front Range ponderosa and dry mixed-conifer forests, from Laramie, WY to Colorado Springs, CO, and looked for clues to the forests' past structure. Using tree ring analysis and signs of "old-tree" characteristics (e.g., flat tops, large diameter branches, bark color), they counted all trees that survived from pre-settlement times. They also looked at logs and stumps to account for the trees that used to be present before harvesting. Within these large plots, they set up smaller sub-plots to measure current tree density and they looked at fire scars to reconstruct the fire history.

From this research, a clear picture of what these forests looked like 150 years ago is emerging. This reconstruction is being used to guide the desired conditions for Front Range forest restoration. According to Battaglia, this research will be published in 2018 and available to managers for use in planning and implementation. A pilot study from Northern Colorado has been published and is available here.

Fire-scarred ponderosa pine tree at Hall Ranch Open Space, CO (right) indicating historical surface fire with low-severity fire effects. Tree ring analysis, used in historical forest stand reconstruction, provides important clues about a stands past disturbance history (photo P. Brown).

Paired historical and current photographs of the Cheesman Reservoir landscape (near Denver CO) illustrating the general increase in forest density and loss of openings that occurred from the late 1890's to 2000. These types of paired photos can help us to give scientists a broad idea of how forests have changed over time (photos from 2000 by M. Kaufmann).

much of the forest canopy intact but regularly reduced the constant build-up of surface fuels and kept trees from filling in the small grass-forb openings.

After decades of fire suppression, tree infill into these openings has created more of a closed-canopy forest today. Large-scale, high-severity fire has reduced the number of old trees and old-growth forests, with negative consequences for wildlife that rely on them. Low- and moderate-severity fires that are important for shaping the structure and composition of Front Range forests occur less frequently now than they did historically. It is less clear how the composition of the forest understory has changed, but it is assumed that the low-light availability combined with the accumulation of litter has had a negative effect, along with competition from non-native weed species.

According to Battaglia, "The landscape that we've reconstructed from the past was highly variable, having to do with time since the last fire and also factors such as slope, elevation, and soil type. We now know that 'thin to 40 and call it good' is not really a good approach to restoring these forests." So, where to start?

Restoration principles for Front Range Forests

The GTR describes principles for restoration of Colorado Front Range forests. Tony Cheng describes the way he sees the GTR being used as such: "We have a landscape-scale set of principles and concepts, and then we zoom down to stands where the silviculturalists or field-level people are operating. We provide a series of concepts and principles of what you would do in each area that would match the ecological attributes of fire-adapted ponderosa pine so far as we understand them." We present five of these restoration principles below.

Historical forest conditions guide restoration practices, but don't constrain them

Forest restoration is based on the principle that ecological systems were resilient to climatic fluctuations and natural disturbances historically, and therefore the historical conditions is a good starting point. The historical conditions improve our understanding of where current forest conditions are significantly different from historical conditions, and therefore where restoration should be prioritized. This provides benchmarks or targets for the development of desired conditions to be achieved through management and natural disturbances.

Restoration is based on models of local conditions

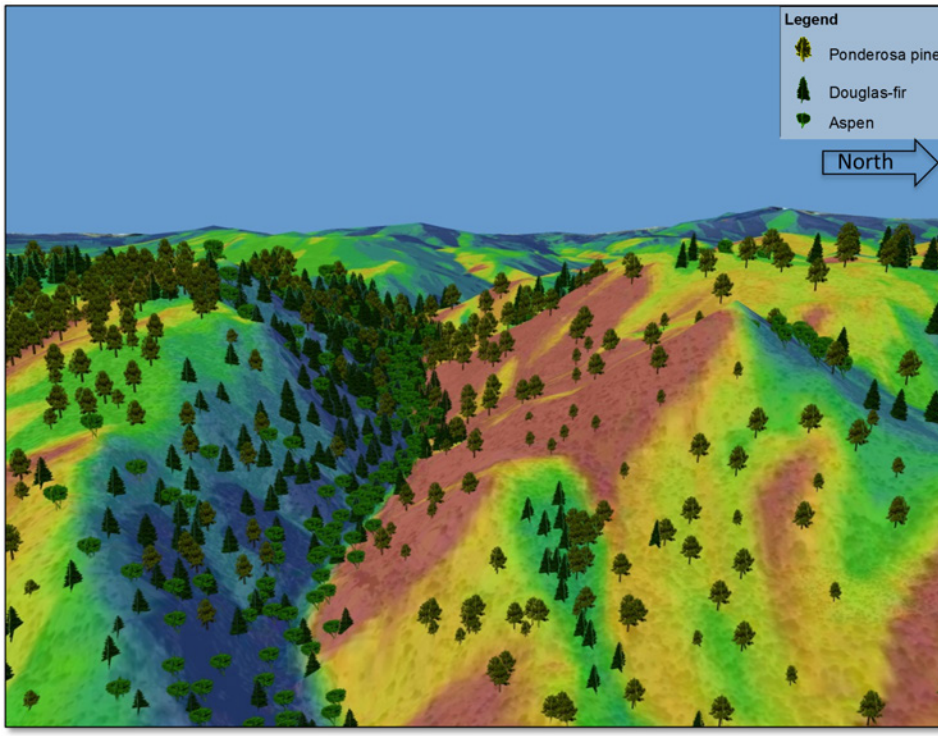
When thinking about restoration at a local level, it is important to consider how climate, physical factors, natural disturbances and forest developmental processes all come together to shape forest structure and composition. Consideration of how these factors would interact under intact disturbance regimes can help to develop a local ecological model to address questions of where to treat and how to design and implement treatments.

Restoration complements natural variation in forest structure by environmental gradients

The spatial pattern of trees at both the landscape and stand scales in mountainous terrain is heavily influenced by environmental gradients. The key environmental gradients for restoration work on the Front Range include latitude, elevation, slope position and steepness, aspect, and soils, and the influence these gradients have on solar radiation and moisture. In general, south-facing slopes are characterized by open, ponderosa pine woodlands with trees occurring both in groups and as scattered individuals. Forest density increases in areas with higher moisture, such as north-facing slopes. The proportion of Douglas-fir typically increases with increasing moisture. Aspen is also an important forest component, typically occupying areas with higher moisture availability. These gradients and their influence on tree patterns should factor into restoration planning.

Spatial scale provides an important organizational framework for restoration

Individual stands are part of a larger landscape, and GTR-373 stresses the importance of developing prescriptions based on the landscape context. The authors distinguish broadly between the landscape scale and the treatment scale, with strategic planning happening at the landscape scale and implementation being done at the treatment scale. The GTR describes how variation at fine scales "rolls up" to create patterns at broader scales, driven largely by site environmental conditions and interactions with disturbance regimes.



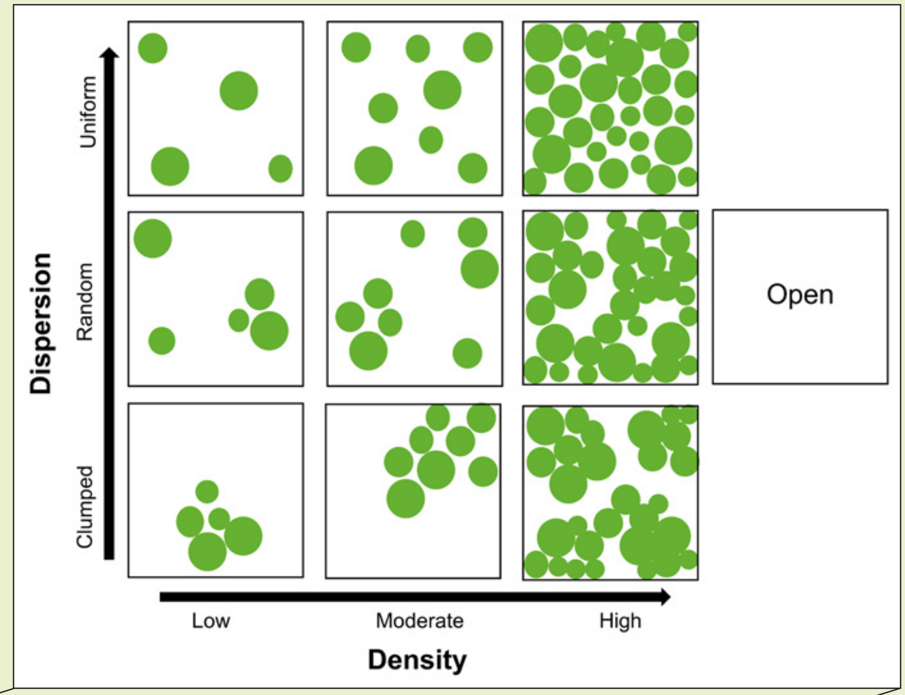
This figure shows the variation in forest structure on the Colorado Front Range, which reflects slope, aspect, and underlying moisture gradients. For example, south-facing slopes are characterized by open, ponderosa pine woodlands with trees occurring both in groups and as scattered individuals (red). Forest density increases in areas with higher moisture, such as north-facing slopes (blue) (figure by J. Feinstein and R. Addington).

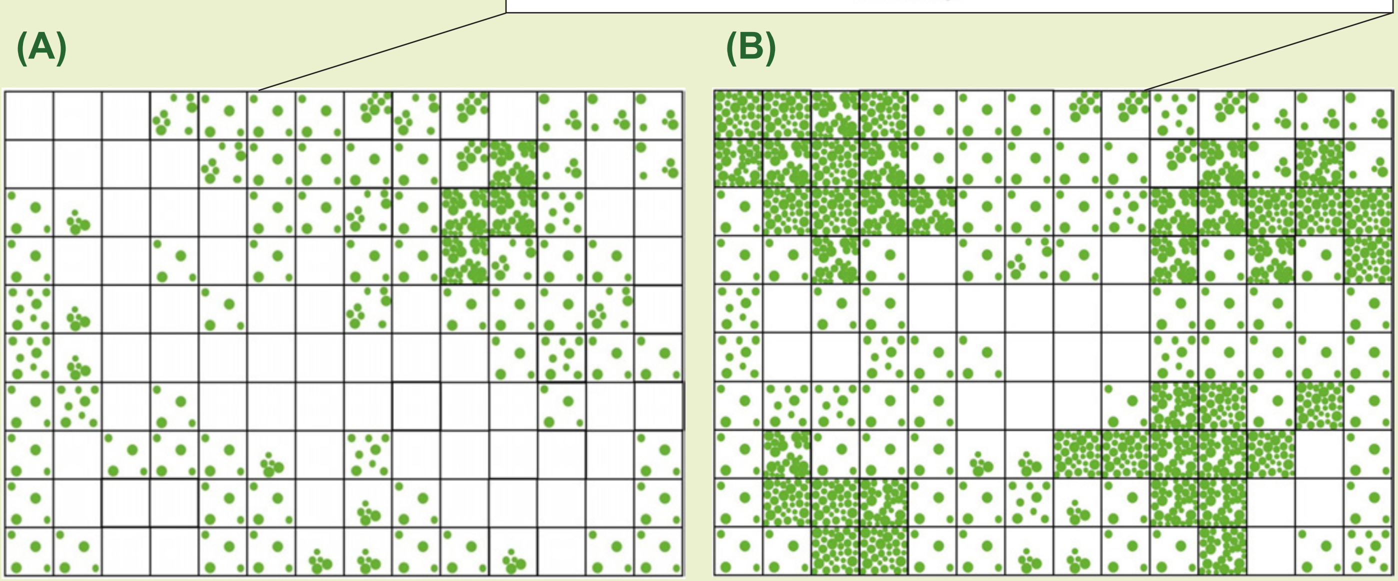
Natural patterns of tree mortality can help to guide restoration practices

Fire, insects and disease, wind-throw, and lightning are the primary natural disturbance agents affecting Front Range ponderosa pine and dry mixed-conifer forests. The GTR emphasizes the importance of understanding these natural patterns of tree mortality to provide information for restoration treatments, especially for the typical patch sizes created by fire and beetle kill, and the implications of these disturbances for stand structure. With this understanding and through field-based assessments, planners can then identify both common and rare structural elements on the current landscape and manage for those rare elements. For example, if openings are absent in the current landscape, then cutting patches (of variable sizes) may be an appropriate treatment option

VARIATION AT FINE SCALES CREATES PATTERNS AT BROADER SCALES

Scale provides an important organizational framework for planning in this GTR, beginning with broad landscape assessments and then working down to the fine-scale individual stands or treatment units. This shows the hypothetical range of variation in fine-scale (<1 acre) tree density and dispersion on Colorado Front Range forests. A "groupy-clumpy" stand is best represented in the lower left of the diagram, under low-density forest conditions and clumped dispersion patterns. Openings are a common feature at this scale. Variability in tree ages is represented by the different-sized green dots, with larger dots representing older trees and smaller dots representing younger trees (figure by Y. Dickinson).





Variation at fine scales (one acre = one box) "rolls up" to create patterns at broader scales, driven largely by site environmental conditions and interactions with disturbance regimes. (A) Open-stand structure likely characteristic of low-severity frequent fires where fine-scale variation is characterized by individual trees, small groups of trees, and openings. (B) Higher-density stand structure that may develop in areas with mixed-severity fire. The higher-density patches likely represent areas of higher productivity, which may burn with moderate to high severity during dry conditions. More open areas may be maintained by low-severity surface fire, or may be recovering from high-severity fire that caused fine-scale patches of complete tree mortality. In both cases (A and B), fire exclusion would result in gradual infilling of low-density patches to create a higher-density forest condition with more uniform tree dispersion (figure by Y. Dickinson).

to mimic fine-scale patches created by high-severity fire. If, however, the low-density forest patches that were once common are rare in the current landscape, then an uneven-aged group selection and retention approach that enhances spatial variability throughout the treatment area may be a good option.

Implementing Restoration Practices

The GTR lays out not only the "whys" for restoration of these forest types, but also explains the "hows" for practitioners. The basic framework for approaching restoration is: identify priority areas, plan treatments at the stand or landscape scale based on natural gradients, assess how natural disturbance would interact with these gradients, and use that information to help develop actual on-the-ground treatments. We have briefly summarized the seven restoration steps in the box to the right.

How does this type of forest restoration benefit the Front Range landscape?

The authors intend for this document to provide useful context for larger-scale landscape planning for Front Range land managers. Rob Addington explains, "The information we've provided helps to validate some of the work that managers are already doing and provides a blueprint for how it might be done within the context of their existing planning."

One of the main goals of forest restoration as laid out in the GTR is to influence fire behavior, especially in those areas currently susceptible to large-scale high-intensity fire due to high tree densities and canopy cover. This can be done through a combination of mechanical thinning and prescribed fire. The prescribed

RESTORATION PRACTICES FOR THE COLORADO FRONT RANGE

- **Step 1: Identify the ecological values, restoration goals, and desired conditions at the landscape scale practices**

  Once the most important broad ecological values (e.g., wildlife, biodiversity, and resilience to disturbances and climate change) are identified for specific landscapes, restoration goals should outline how to protect or enhance the ecological values, including: reducing the potential for broad-scale, active crown fire that results in large patches of tree mortality, enhancing landscape resilience to natural disturbances and climate change, and increasing native biodiversity.

- **Step 2: Assess the landscape conditions to identify treatment needs and priorities**

  The three components of the assessment process described in the GTR include a current vegetation condition assessment to identify treatment needs, a values at risk assessment to identify features that should be protected, and an opportunity assessment to identify treatment feasibility and the potential for meeting multiple objectives.

- **Step 3: Develop landscape treatment plans**

  The GTR lists a series of "key framing questions" for a landscape treatment plan that should lead to a more detailed landscape prescription that specifies the actual number of acres or proportion of the landscape to be treated, as well as the distribution of treatments across the landscape by different treatment types.

- **Step 4: Define goals and desired conditions at the stand scale**

  Stand-level planning should focus more on stand-scale features such as groups of trees and openings. Desired conditions at the stand or treatment scale then would describe expected proportions and spatial arrangements of different stand-scale structural elements.

- **Step 5: Assess current conditions at the stand scale**

  Individual treatment units should be assessed to determine the management approach necessary to achieve the goals and desired outcomes, most often accomplished through a pre-treatment forest inventory, which commonly includes a combination of aerial image evaluation and an on-the-ground forest inventory.

- **Step 6: Develop treatment plans and prescriptions**

  This step in the GTR is the most detailed, specifying the management objectives that should be included in the treatment plans and prescriptions, including proportion of trees in as scattered individuals vs. groups, retention of old trees, target number of snags, and many others. It then describes the elements of the treatment prescriptions, including how to go about planning density reductions and spatial distribution of trees with a focus on spatial heterogeneity.

- **Step 7: Monitor the trajectory of the restoration efforts**

  For each management objective, monitoring metrics or variables should be identified that can be measured both pre- and post-treatment in the same locations using the same methods. The GTR includes a series of questions to help managers plan effective monitoring programs at both the stand and the landscape level.

Both fire (left) and beetle kill (right) create natural patterns of tree mortality and result in landscape-scale heterogeneity in Colorado Front Range Forests. Understanding how these and other disturbances affect stand structure, along with identifying rare elements in the current landscape (e.g., openings, tree clumps) can help to guide restoration plans (figures by M. Chambers (l) and J. Briggs (r)).

fire element is important because burning influences nutrient cycling and cues germination or resprouting of some fire-adapted understory plant species. Battaglia says, "Even without these ecological benefits, if you don't burn, you get a buildup of needle litter and wood, and these high surface fuels are a big issue to deal with because they take so long to decompose."

Ideally, restoration treatments would be aimed at restoring the historical mixed-severity fire regime, but implementing prescribed burning treatments is challenging on the Front Range due to social perceptions and safety concerns. Thus, areas historically characterized by a predominately low- and moderate-severity fire regime represent the highest priority for restoration, through mechanical treatment and reintroduction of [prescribed] fire. "The idea is not necessarily to use treatments to mimic what a fire would do on the landscape. What we want to do is to prepare the landscape to receive fire in a way that then preserves future options for forest recovery and sustainability by limiting the size of high severity burn patches," explains Cheng.

Forest restoration is beneficial to other aspects of forest health as well. Addington says, "We think that these lower-density stands with trees arranged in the grouped spatial pattern with large openings like we saw historically -- this configuration will create a more resilient stand for the future under increased wildfire activity like we expect with climate change. This spatial arrangement will alleviate some of the drought stress due to lower tree densities and the breaks in the stand will also slow the spread of insects and disease."

What are barriers to forest restoration on the Colorado Front Range?

Will implementing the restoration plans in the GTR be simple? Probably not. "The prescriptions that we're talking about to achieve some of these desired future conditions, they're pretty complex – they're really the most complex prescriptions that I think that we have to implement," admits Underhill. He emphasizes the importance of prioritizing where we apply the more complex prescriptions with the overall objective of increasing heterogeneity at the landscape level.

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Prescribed fire is an important element of restoration in Colorado's Front Range because burning influences nutrient cycling and cues germination or resprouting of some fire-adapted understory plant species. Without this burning, needle litter and wood builds up on the forest floor, creating high levels of surface fuels. Pictured above is a prescribed fire in Manitou Experimental Forest, Pike National Forest, October 2014 (photo by S. Alton).

There is also the issue of cost and efficiency for people on the ground implementing these treatments. First, since there is a limited timber market on the Front Range, treatments end up being a net cost. Then, the restoration recommendations represent a different way of doing things, as foresters are used to working with even-aged stands with specific tree spacing. "With these more complex prescriptions, the cost of planning, prepping, and operating may actually go up," explains Cheng. "What we're trying to do is produce a variety of ecologically-beneficial attributes with these treatments, where the benefits are only going to be realized many years out. That's a big ask, since there's always pressure on managers to lower costs. And we are looking for managers to take that risk to build resilience of our forests into the future."

Does the GTR lay out recommended treatments and prescriptions in enough detail to overcome some of these barriers? Underhill explains, "I think that this GTR is at a somewhat higher level than being very prescriptive and the main utility is probably during the planning phase when we're working through NEPA actions and trying to design the projects to achieve the overarching objectives. But it's not prescriptive enough for field-grade implementation at this point." He thinks that it will take more time and data collection from monitoring to be able to write these more detailed prescriptions.

Cheng emphasizes the importance of getting feedback from managers to refine the ideas and recommended treatments in the GTR. "We're not saying: this is the way you ought to do it because we scientists say so. We're making assumptions about the future of forest dynamics and the relationship with fire. And so, we need feedback from people on the ground. We'd like to know under what conditions this GTR was helpful and when it actually facilitated meeting objectives of

Ponderosa pine woodland in the Roosevelt National Forest near Red Feather Lakes, CO, illustrating the more open, low-density stand structure more typical of Front Range forests in the mid 1800s (photo by P. Brown).

> *"We're not saying: this is the way you ought to do it because we scientists say so. We're making assumptions about the future of forest dynamics and the relationship with fire. And so, we need feedback from people on the ground."*

operational and cost efficiency, and also what didn't work and needs to be revised."

What is happening now and in the future with Front Range forest restoration?

Restoration treatments are being implemented at an increasing rate across the Front Range because of the CFLRP project, and RMRS scientists and collaborators are studying the outcomes of these treatments to provide feedback that will shape the way future treatments are designed and executed. The types of research happening now include: effectiveness of restoration treatments (that were implemented early in the CFLRP project); correlating the historical tree data with site characteristic information such as elevation, aspect, soil type, and site productivity; and computer simulations on the effect of restoration treatments on fire behavior.

Climate change is always a consideration in restoration treatments. Battaglia explains that the climate was cooler in the mid-1800s. From that time until the 1920s, there was a lot of stand regeneration due to both harvesting and also cooler conditions which led to fewer fires. "So what do you restore to? Does it make sense to try to restore to the cooler, moister climate, or do we try to use that information to move into the future?" he asks.

As we move into a predicted warmer and drier period, he suggests that the current differences between lower and upper montane areas within the Front Range forests may provide some insight. The upper montane is currently a little cooler and moister, and a little denser, with a higher proportion of Douglas-fir vs. ponderosa pine. "If I was hedging my bets, I would guess that the upper montane might start looking more like the lower montane with climate change. To plan for the future, I might be aggressive and manage my upper montane area to look more like my lower montane area, which we know received fire frequently in the past," explains Battaglia.

The publication of GTR-373 marks an important benchmark in Colorado Front Range forest research, which continues today with these and other studies on the past and present ecology of these forests. While restoration treatments are not expected to recreate the 1860s, the hope is that pushing the stand structure of these forests back towards past conditions, they will be more resilient for the future.

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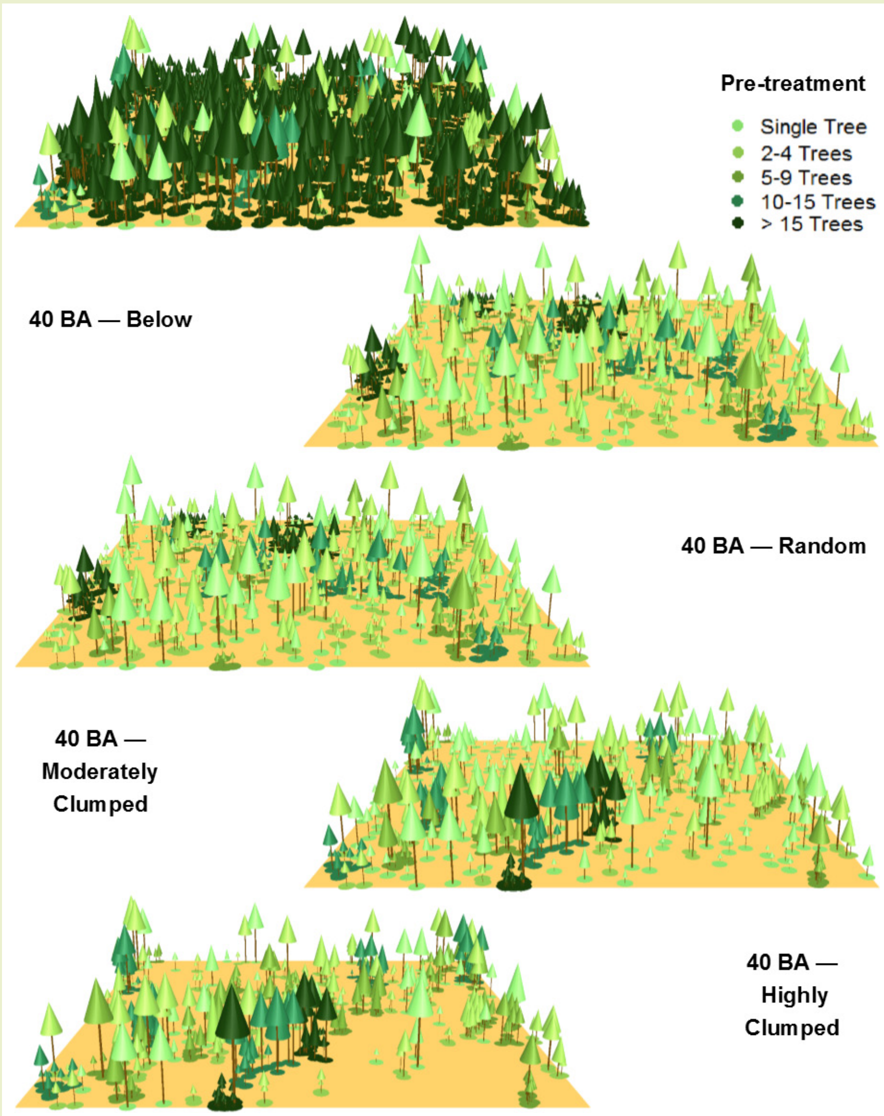
"What we're trying to do is produce a variety of ecologically-beneficial attributes with these treatments, where the benefits are only going to be realized many years out. That's a big ask, since there's always pressure on managers to lower costs. And we are looking for managers to take that risk to build resilience of our forests into the future."

Visualization guide for heterogeneous forest treatments

To address some of the challenges associated with implementing complex prescriptions, an effort by Colorado State University, the USFS and RMRS has produced a GTR as a companion guide to this one that helps managers start to envision how these prescriptions would look. The Visualization of heterogeneous forest structures following treatment in the southern Rocky Mountains manual allows planners, implementers and contractors to "see" what the recommended treatments may look like at the stand level. It imagines four different treatments across four stands with varying productivity that had been identified as candidates for ecological restoration. The treatments include a: thin from below, random tree selection, moderate clumping, and high clumping prescriptions. Each treatment is paired with a graphic showing the spatial pattern of the residual trees and openings, traditional stand-scale metrics, and a description of the fine-scale forest structure including individual trees, clumps of trees, and openings. This tool is intended to help communicate the outcomes of these complex silvicultural treatments to resource managers, contractors, specialists, and others when attempting to meet treatment objectives.



Pictured above is an example from the Visualization Guide. In this scenario, prior to treatment, the stand has a high density of small trees, a closed canopy, and small openings. Following treatments, mean stand density was greatly reduced while increasing the relative variability of tree density in all but the thin- from-below treatment. This increase in variability is an important restoration objective as outlined in the GTR (figure by Tinkham et al.).

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The following scientists were instrumental in the creation of this Bulletin:

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SCIENCE YOU CAN USE BULLETIN

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POSTAGE

The purpose of the Science You Can Use Bulletin: To provide scientific information to people who make and influence decisions about managing land.

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