Rio Grande National Forest –Assessments 1 and 3 Ecosystem Integrity, Systems Drivers and Stressors for Terrestrial Ecosystems

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Assessments 1 and 3 assess available information about ecosystem integrity and stressors and threats to integrity on the Rio Grande National Forest, as outlined in Forest Service Handbook 1909.12, Chapter 10, Section 12.1 and 12.3.

Introduction

In this assessment, we address the ecosystem integrity of the major terrestrial ecosystems on the Rio Grande National Forest. We also discuss the drivers, stressors, and threats to ecosystem integrity on the forest. A separate assessment report addresses the ecosystem integrity of aquatic and riparian ecosystems on the Rio Grande National Forest, although some information about riparian ecosystems is presented here.

An ecosystem is composed of living organisms (plants, animals and microbes) and their nonliving environment (climate and soil for terrestrial ecosystems; aqueous environment and substrate in aquatic ecosystems). These components interact so that the system: captures and stores energy as biomass; has a trophic structure; circulates nutrients; and changes over time (ecological succession). Assessing ecosystem integrity is required by the Forest Service planning rule. Integrity is measured by whether or not the dominant characteristics of the ecosystem:

- are within the range of what would occur “naturally” (natural range of variability), and
- can stay within that range as each ecosystem is influenced by stressors such as climate change, as well as development and other uses of the forest.

The primary ecosystem described in this assessment is terrestrial. Terrestrial ecosystems include forested areas, non-forested (rangelands) and alpine ecosystems. These are the “dry” areas outside of lakes, streams, and other wet areas. There are two other ecosystems - riparian areas are the ecosystems along streams, lakes, and other water bodies; and aquatic ecosystems are the streams, lakes, and other water bodies that support fish and other aquatic species. Some information about riparian ecosystems is presented here; full assessments of both riparian and aquatic ecosystems are found in a separate report.

Information Sources and Gaps

A variety of information sources were used for this assessment. They are outlined below.

- State and transition modelling
- Forest map layers
- Stand exam and forest inventory and analysis plot data
- Colorado Natural Heritage Program Reports
- The South Central Highlands Guide (Romme et al. 2009) and other published literature
- The 1996 Rio Grande Revised Land and Resource Management Plan and associated Final Environmental Impact Statement
- Insect and disease reports for the forest and state of Colorado (Eager et al. 2012, CSFS 2014)
- Climate change-related publications and reports (Rondeau et al. 2012, Vose et al. 2012, Alexander and Keck 2015)

The modelling we did to look at the natural range of variability and ecosystem integrity did not specifically include climate change. Climate change and the associated gradual increase in temperature will alter growth rates and mortality. Species habitat may move higher and more northward as a result.

But most importantly, with a changing climate, we expect more extreme weather, climate conditions, and disturbances such as wildfires, insect and disease outbreaks, droughts, and floods. Therefore, some of the simulation results may not hold and there may be other unanticipated conditions due to the effects of climate change.

We need studies to increase understanding of the local fire return interval as influenced by the rain shadow effect in our drier forest types. We have started this effort on a portion of the forest, but a more intensive, widespread effort is warranted.

It is unclear how climate change, beetle-kill, and the past fire suppression strategy will impact our ability to allow fire to play its historic role as a disturbance agent. In addition, we are also uncertain how allowing fire on the landscape with such high fuel loadings will impact the desired conditions in specific forest types.

Connectivity of habitat is an indicator of ecosystem integrity. It can be assessed in a variety of ways and with a variety of metrics. We do not have a comprehensive connectivity analysis on the Rio Grande National Forest, which would be helpful in assessing current habitat conditions.

Existing Forest Plan Direction

Our desired conditions in the current Rio Grande Forest Plan are:

- Maintain biological diversity by maintaining, to the extent possible, habitat composition, structure, pattern, and disturbance frequencies similar to those that result from natural disturbances such as insects, disease, and fire.
- Manage rangeland vegetation for a mixture of seral stages, with most areas in mid to high seral stages and specific desired conditions in each allotment management plan.
- Ensure riparian areas and floodplains are healthy, fully functioning ecosystems. Vegetation is diverse and is generally in later-seral condition, to provide site stability.
- Recognize the role fire plays in ecosystem dynamics, and use it as a management tool when and where it does not threaten human life, property, or resources needed to support long term industries.

Standards and guidelines in our current Forest plan were written to move the forest towards these desired conditions. Our current standards and guidelines require we retain coarse woody debris and snags during timber harvest, provide direction on revegetation, old growth, and retention of aspen. We have standards and guidelines that pertain to the timing, amount, and regulation of livestock grazing. We have standard and guidelines related to silviculture that guide the type and intensity of harvesting we can allow.

In our current Forest Plan we have guidelines for projects to consider potential insect or disease outbreaks to meet the objectives of each management area. We base thinning and other forestry measures on values of, and risks to, adjacent private lands, as well as public land. We prioritize areas where values to be protected exceed the cost of protection (e.g. areas adjacent to subdivisions, metropolitan areas, recreation sites, or areas of concentrated public use). In project areas with existing infestations, our activities are designed to minimize the risks of spreading the infestation, while still providing habitat for those wildlife species dependent on the presence of insects and diseases.

The current Rio Grande Forest Plan does not include any guidance related to climate change.

Scale of Analysis

Our modeling assessment encompasses about 1.7 million acres of forests, woodlands and grasslands on the Rio Grande National Forest. We added a buffer of 6.2 mi (10 km) around the Rio Grande National Forest boundary to encompass the broader landscape context, containing forests, woodlands and shrublands.

Identify Key Ecosystem Characteristics (12.13):

In order to assess the ecological integrity of the terrestrial ecosystems, we chose key ecosystems characteristics. These are attributes that we can use to predict whether future conditions will have ecological integrity. Below the key ecosystem characteristics are listed by ecosystem type. These are discussed in later sections of this document.

Table 1. Key ecosystem characteristic for terrestrial ecosystems on the Rio Grande National Forest

Key Ecosystem Characteristic	Source
Diversity of vegetation – amount and distribution of vegetation structural stages	State and transition modelling
Landscape Disturbances and Patterns	1996 Forest Plan, literature review
Connectivity and Human-caused Fragmentation	Forest map layers
Late successional habitats	State and transition modelling
Snags and down woody material	Stand exam and forest inventory and analysis plot data
Rare communities and special habitats	Colorado Natural Heritage Program reports

System Drivers and Stressors

Drivers and stressors to the ecosystems of Rio Grande National Forest include succession, wildfire, insects and disease, climate change, management, livestock grazing, weather-related events such as droughts and floods, other natural disturbances such as beaver activity, exotic species invasion, and tree encroachment. The drivers and stressors for each particular ecosystem vary widely.

Succession is the natural change in the composition, structure, and function of an ecosystem over time during long periods without major disturbances. As trees and plants grow and compete for limited resources, the species, size, and amount of the trees and plants that compose an ecosystem change.

Wildfire is a natural part of the ecosystems on the Rio Grande National Forest. The historical fire regime varies widely across the different ecosystems. For example, the spruce-fir forests that dominate the Rio Grande National Forest generally experienced infrequent, stand-replacing fires while the mixed conifer forests experienced a more moderate fire regime with more frequent, but less severe (mixed-severity) fire.

Under the current Forest Plan, we recognize fire's role in ecosystem dynamics and use it as a management tool when and where it does not threaten human life, property, or resources needed to support long term industries. Our management of naturally occurring ignitions to include ecological benefit objectives is approved forestwide, although emphasis toward a suppression oriented response is higher in some areas. The option to consider the ecological benefit of naturally occurring ignition is not prohibited in any management area except for MA 8.22 – Ski-based Resorts.

Insect and disease outbreaks are major ecological processes that shape the conditions of forests. As we learn more about the complicated relationships that occur in the forest ecosystem, we are coming to

realize that insects and diseases play an important role in the cycles of forest growth and decline and in the creation and maintenance of key wildlife habitat components. Without the influence of "change agents" in the forest (fire, insects, and disease), the forest would stagnate and eventually become homogeneous, with a resultant negative impact on biodiversity and resilience to disturbance. These change agents are an integral part of forest ecosystem processes, but still pose a challenge to forest management.

Two types of insects – bark beetles and defoliators – are currently affecting the Rio Grande National Forest. In addition, three groups of pathogens are affecting the Forest - dwarf mistletoe, root diseases, and stem decays. The biggest change currently happening on the forest is the result of the current spruce beetle outbreak. The spruce beetle (*Dendroctonus rufipennis*) is a native insect that attacks and kills mature Engelmann spruce. Historically, under the right conditions, spruce beetles can have large, intense outbreaks over expansive areas of forest. They are a part of spruce-fir forest ecology and a key disturbance agent. Since the early to mid-2000s, large spruce beetle outbreaks have occurred on several forests in Colorado and Wyoming, including the Rio Grande. Aerial surveys suggest that the spruce beetle affected 300,000 acres on the Rio Grande National Forest from 2000-2011 (Eager et al. 2012). Since that time, an even larger proportion has been impacted by spruce beetle, which makes it the most widespread forest pest for the state of Colorado for several years running (CSFS 2014). Many areas affected by spruce beetle have 80 to 100 percent mortality of mature Engelmann spruce. Due to the large amount of spruce-fir forests on the Rio Grande National Forest, this outbreak will have long-lasting effects on all aspects of the forest such as timber harvest, wildlife habitat, recreation access, carbon storage, and others. These effects are highly variable and may be positive or negative. As an example, some wildlife species thrive in this type of habitat while others do not.

Our current Forest Plan includes guidelines for considering potential insect or disease outbreaks at the project level to meet the objectives of each management area. We base thinning and other forestry measures on values of, and risks to, adjacent private lands, as well as public land. We prioritize areas where values to be protected exceed the cost of protection (e.g. areas adjacent to subdivisions, metropolitan areas, recreation sites, or areas of concentrated public use). In project areas with existing infestations, our activities are designed to minimize the risks of spreading the infestation, while still providing habitat for those wildlife species dependent on the presence of insects and diseases.

Climate change affects ecological conditions such as precipitation and temperature, in addition to its more visible effects from changes to the rate of disturbances such as wildfires and insect outbreaks. Related to this are the weather-related stressors such as **droughts and floods** that may be more common with a changing climate.

The exact effect of climate change on the ecosystems of the Rio Grande is unknown, but some general trends are clear. Changes in temperature will change the growth of tree species (Rondeau et al. 2012, Vose et al. 2012), and this change may vary based on the particular species. Lower soil moisture will likely lead to higher levels of tree mortality and less regeneration. We predict tree habitat will move upward in elevation and northward in latitude and it is unclear whether tree species dispersal can keep up with this movement (Vose et al. 2012). We think some ecosystems are particularly susceptible to climate change-related impacts. Plant and animal species in high-elevation alpine ecosystems, such as the Uncompahgre Fritillary Butterfly, may be pushed to extinction if warming temperatures reduce their habitat (Alexander and Keck 2015).

Climate-driven extreme weather events will likely have rapid, dramatic effects on ecosystems. Multi-year droughts are linked to numerous other stressors and disturbances. Wildfires will increase, along with insect infestations, invasive species, flooding, erosion, and sedimentation (Vose et al. 2012).

When we wrote the 1996 Rio Grande Forest Plan, climate change theory was undeveloped and mostly unknown. Because of this, our Forest Plan does not include any language related to climate change. We recommend addressing climate change in our revised Forest Plan. Research suggests that we should be building off of the parts of the ecosystems that improve resilience and resistance to climate change, including unique ecological attributes such as fens, riparian zones (Seavy et al. 2009), and the parts of the spruce-fir forest that resisted, or were unaffected by the spruce beetle outbreak. A proactive approach for climate change may call for a rigorous reexamination into how we monitor change and adapt management practices, such as timber harvesting, salvage logging, and grazing practices, among others.

We already implement management practices, such as thinning and fuel treatments, that reduce fire hazard, competition, and increase resilience to a changing climate in the drier forest types, although they currently only affect a small portion of the landscape. We are currently developing bioclimate models for 13 tree species. This work will provide us with projections for how the suitability of habitat for these major species may change under a changing climate. These results will provide another source of information to consider as we develop future management options.

Management activities such as timber harvest, thinning, and prescribed fire are a relatively minor driver and stressor on the forest and are implemented on less than 0.2 percent of the Rio Grande National Forest each year. However, the impact to the ecosystem of these activities varies based on the intensity, the specific activity, and the ecosystem, not just the acreage of the activity, and generally lasts longer than simply the year implemented. In addition, the roads associated with these activities, even temporary ones, can negatively impact the forest and its habitat. Intensive selective cutting of certain species and size classes in the past may still be affecting the ecosystem structure, composition and function of the forest (USDA Forest Service 1996).

Livestock grazing is one of the multiple uses of the Rio Grande National Forest. The rural communities around the Rio Grande National Forest depend on ranching and national forest grazing for their economic livelihood. To ensure it is responsibly done, we have standards and guidelines in the current Forest Plan regarding the timing, amount, and regulation of livestock grazing. We need to evaluate and potentially adjust these standards and guidelines based on monitoring data. This is particularly true for low elevation riparian areas, which are especially vulnerable to climate change impacts.

Historically, extensive livestock grazing practices affected not only shrublands but dramatically influenced lower elevation forests by removing fine, herbaceous fuels which altered fire regimes (Romme et al. 2009).

Man-made disturbance, like fragmentation due to roads, can lead to reduced ecosystem function and biodiversity, (Haddad et al. 2015) and can affect habitat size and connectivity. This particular stressor is assessed in a later section of this report.

Terrestrial Ecosystems - Our Approach

To assess the ecosystem integrity on the Rio Grande National Forest, we used landscape-scale state and transition modelling to estimate historic conditions of the vegetation through natural range of variation simulations. State and transition models can be thought of as box and arrow diagrams, where boxes represent state classes describing vegetation composition and structure and the arrows represent the transitions, the drivers and stressors that cause vegetation change, such as growth, mortality, disturbance, and management. These models are particularly useful for assessing trends where multiple drivers and stressors act simultaneously on the landscape. We also used this modelling to estimate how conditions may change into the future, with and without management. As a result, we can use these modelling results to evaluate the similarity or difference of current conditions to historical conditions (within the natural

range of variability), and how that may change in the future as an indicator of ecological integrity. This work was performed by the Institute for Natural Resources at Oregon State University. The data sources they used for this modelling were LANDFIRE biophysical setting maps and descriptions along with Forest information on existing vegetation. Within the Forest boundary these biophysical setting descriptions were cross-walked to the Forest land-type association layer created prior to the 1996 Forest Plan and also compared to the current Forest vegetation layer. The land-type association layer combined similar land types based on ecological potentials considering climate, physiography, soils, hydrology, and potential natural vegetation based on information available in the early 1990s. Land types and land type associations contain multiple vegetation cover types so cannot be used to describe actual existing vegetation except at a broad scale, since they may not capture local variations in vegetation type and seral stages. For example, the spruce-fir forest mix includes the lodgepole pine vegetation type (found only on the northern part of the Forest) along with stands that are currently aspen dominated with a potential vegetation type of spruce-fir. Minor vegetation types such as limber and bristlecone pine are included with other major ecosystem types.

Although we prefer to use field data from forest stand examinations, there is not enough current field sampled data available, especially considering the large spruce-beetle outbreak that is quickly changing our forests. Forest stand examinations also would not give us the necessary information for rangeland ecosystems. We have set up contracts for new forest stand examinations but the workload is large enough that two summer field seasons are needed. As a result, this data is not yet available for us to use in analyzing the natural range of variation of the local ecosystems.

This modelling approach fits well with the landscape-level analysis needed for forest planning, but we need to evaluate the results cautiously because the data comes from different sources, and lacks precision. We have also incorporated the draft results of some change detection work done by the Forest Service Remote Sensing Applications Center to get a better understanding of the state of the forest now that spruce-beetle has impacted so many areas. Using the remote sensing data and modelling results also required the least amount of forest level support, which was important given the current budget and staffing levels and workloads.

In addition to using state and transition modelling to look at the amount and diversity of ecosystem types and structure classes, we analyzed other key ecosystem characteristics either qualitatively, by tying them to the state and transition modelling, or through separate analysis using available stand exam or other data.

Terrestrial Ecosystems – Forested, Non-Forested, Alpine

Terrestrial ecosystems include forested, rangeland, and alpine ecosystems.

The current Rio Grande Forest Plan provides direction on terrestrial ecosystem integrity. Our plan objectives emphasize using prescribed natural fire and management –ignited fire where forest ecosystems evolved under the influence of wildfire. This includes using fire as a management tool. Our objectives also emphasize maintaining natural or near-natural appearing landscapes in all areas of the forest. Several standards are designed to maintain the biological diversity of the Forest for the future. These include management direction for the retention of coarse woody debris, snags (dead standing trees), the inventory and assessment of old growth during project planning, aspen management, and the use of spatial-analysis concepts in project planning. The management areas in our current Forest Plan keep much of the Forest outside of wilderness undeveloped.

Our ecosystem modeling assessment encompasses about 1.7 million acres of forests, woodlands (pinyon-juniper) and grasslands ecosystems on the Rio Grande National Forest and surrounding landscape (figure

1). We added a buffer of 6.2 mi (10 km) around the Rio Grande National Forest boundary to encompass the broader landscape context, containing forests, woodlands and shrublands. Based on the modelling parameters, we modeled eight of the major terrestrial ecosystems types with similar vegetation dynamics and assessed them individually, in addition to two ecosystem types that occur primarily outside the Forest (table 2). The landscape proportion in each ecosystem is shown in figure 2 and their spatial distribution is shown in figure 1.

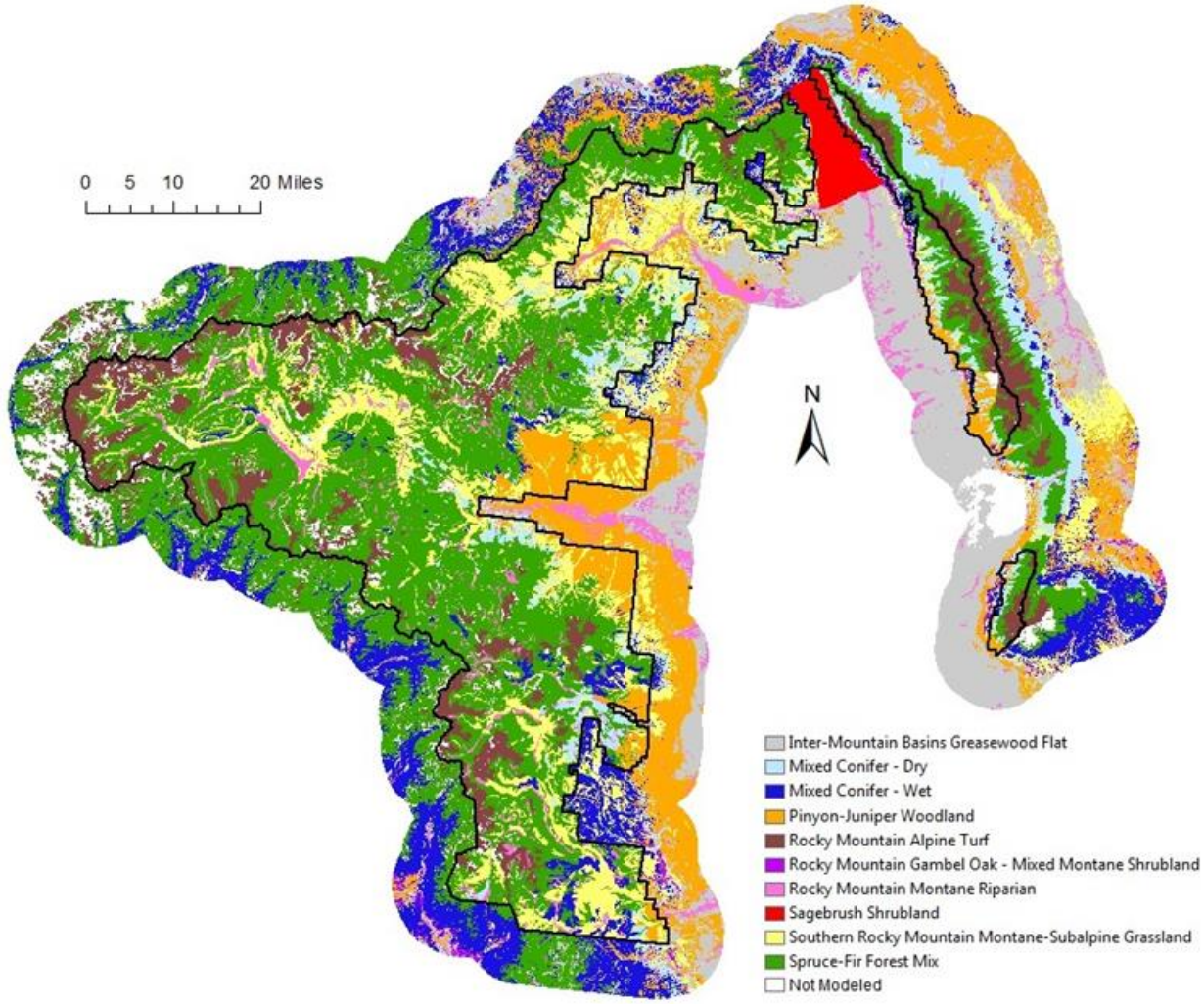

Figure 1. Map of ecosystems on the Rio Grande National Forest. The Forest boundary is shown in black, and the landscape context area included a 6.2 mile buffer around the forest.

Identify Ecosystems (12.11):

Based on the modelling process used, the majority of the Rio Grande National Forest is in the spruce-fir forest mix (48 percent) ecosystem type. Other ecosystem types that dominate the forest include the Southern Rocky Mountain montane-subalpine grassland (16 percent) and Rocky Mountain alpine turf (13 percent), followed by mixed conifer – dry (8 percent) and pinyon-juniper woodland (6 percent). A general description of each of these ecosystem types follows the figures and tables below. We compiled this information from the literature cited as well as the South Central Highlands Guide (Romme et al. 2009). However, very few studies or site-specific local research regarding ecosystem reference conditions or

plant associations have been completed on the forests or woodlands located on the eastern, rain shadow side of the San Juan Mountains. Romme et al. (2009) focused primarily on the wetter, warmer western side of the San Juan Mountains which best reflects local conditions in the Engelmann spruce-subalpine fir vegetation type in the wettest areas along the Continental Divide. Away from the Continental Divide, the rain shadows created by complex mountain topography create conditions where the vegetation types present are affected more by aspect and slope. The relatively cooler temperatures on the eastern side of the San Juan Mountains have also influenced vegetation composition.

Table 2 lists the ecosystems modeled for this assessment. Acres in each ecosystem are reported for the Rio Grande National Forest only and the landscape context area (including a 6.2 mi buffer), and omits areas that have snow, rock or other non-vegetated cover. Rio Grande National Forest acres also omit private inholdings within the forest.

Table 2. Ecosystems modeled for the Rio Grande National Forest assessment

Ecosystem	National Forest System Acres	Rio Grande National Forest + Context Area Acres
Spruce-Fir Forest Mix	929,645	1,442,390
Mixed Conifer-Wet	42,718	423,037
Mixed Conifer-Dry	94,925	265,311
Rocky Mountain Alpine Turf	191,800	260,063
Pinyon-Juniper Woodland (includes low elevation grasslands)	100,070	582,015
Rocky Mountain Gambel Oak - Mixed Montane Shrubland	1,224	25,951
Southern Rocky Mountain Montane-Subalpine Grassland	304,136	505,593
Rocky Mountain Montane Riparian	61,932	124,363
Sagebrush Shrubland	5,014	43,525
Inter-Mountain Basins Greasewood Flat	128	439,750
	1,731,592	4,112,000

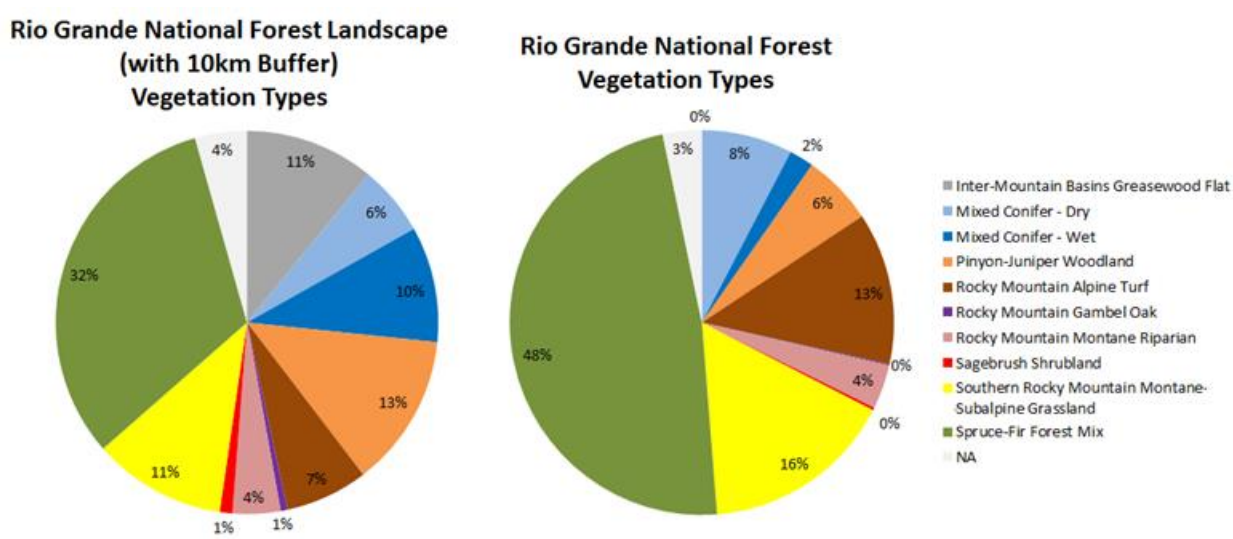

Figure 2. Proportion of the landscape occupied by each ecosystem across the entire modeled landscape (including 6.2 mi buffer) (left) and on the Rio Grande National Forest only (right). NA refers to areas that have snow, rock or other non-vegetated cover.

Spruce-Fir Forest Ecosystem

The core portion of the spruce-fir forest ecosystem is comprised primarily of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) associations. Significant areas within this type are dominated by quaking aspen (*Populus tremuloides*), sometimes with a conifer component, depending upon successional status. These subalpine conifer forests represent the highest elevation forests in the area, ranging in elevation from about 9,000 to 11,500 feet. They occur along a variety of gradients, including gentle to very steep mountain slopes. Sites are cold year-round, and precipitation is predominantly snow, which may persist until late summer.

Prior to human-caused disturbance, the two most significant broad-scale disturbance types in these communities were stand-replacing fires and bark beetle outbreaks (Baker and Veblen 1990, Veblen et al. 1994, Veblen 2000). In-between punctuations of these broad scale forest disturbances, finer-scale processes such as insect infestations, avalanches, blow-down events and fungi shaped the structure and composition of spruce and fir stands (Veblen et al. 1989, Veblen et al. 1991a, Lertzman and Krebs 1991, Roovers and Rebertus 1993).

With late-lying snow-packs and frequent summer precipitation within in these high elevation forests, there are typically long intervals between fires and fires that initiate when fuels are not sufficiently dry are small in extent. Fires in these systems are often driven by regional weather patterns and only after extended dry periods do these systems experience extensive fire. When fires do occur in these forest types during drought periods, they are often more severe than fires at lower elevations because of the fuel buildup. Fire return intervals in the nearby San Juan Mountains in these systems were historically about 300 years, with many stands escaping fire for many hundreds of years (Romme et al. 2009) and with intervals varying with moisture regimes and topography. Post-fire, the dominant conifers usually re-established by reseeding or aspen established by root-sprouting (Stahelin 1943, DeByle and Winokur 1985, Johnson and Fryer 1989, Veblen et al. 1991a, Turner et al. 1997). Fires (particularly at lower elevations) were typically followed by the rapid re-establishment of aspen with spruce-fir growing up in the understory, which would gradually displace aspen after several hundred years. As fire disturbance is compounded increasingly more with insect outbreak and climate change it is predicted aspen will become increasingly prevalent in subalpine systems (Kulakowski et al. 2013).

Spruce beetle (*Dendroctonus rufipennis*) are endemic insects whose larvae feed on the phloem of large Engelmann spruce trees (Furniss and Carolin 1977, Schmid and Frye 1977, Schmid and Mata 1996). While most of the time beetle populations exist at relatively low-densities, they periodically explode into an outbreak and will kill most of the large diameter trees in affected areas over thousands of hectares (Romme et al. 2009). Spruce budworm (*Choristoneura occidentalis*) is another native insect that can kill or repress smaller fir trees and sometimes explode from low-level populations into periodic outbreaks. While one common line of thinking is that fire may be more severe or frequent after beetle mortality events, there is little scientific evidence to support that and there are studies that contradict it (Bebi et al. 2003, Andrus et al. 2015).

Human-caused disturbances in these high-elevation stands are usually less severe than in other forest types. Because these forest types are typically more difficult to access than lower elevation stands, clear-cut logging and road building came later to them. Clear cut logging practices had serious implications for spruce-fir forests in terms of stand regeneration and the connectivity of mature forests. On the Rio Grande, harvest levels peaked in the late 1960s/early 1970s at around 30 MMBF a year (USDA Forest Service 1996). Given this is about twice the amount being harvested in recent years, these clear cuts probably weren’t that extensive, covering about 4,000 acres a year.

Despite policies of fire exclusion, spruce-fir forests have remained relatively unchanged because fire return intervals are naturally long relative to the amount of time we have been suppressing fires. Fire suppression activities in lower-elevation systems, though, have reduced the frequency of fires burning into higher elevation systems (Barrett 1994, Baisan and Swetnam 1997).

Mixed Conifer-Wet Ecosystem

This mixed conifer zone includes the transition zones between the higher elevation spruce-fir ecosystem and the drier mixed conifer type where Douglas-fir is the most common species. Locally this type is referred to as "cool-moist" mixed conifer. The mixed conifer-wet ecosystem is dominated by Douglas-fir (*Pseudotsuga menziesii*), and various combinations of white fir (*Abies concolor*), Colorado blue spruce (*Picea pungens*), Engelmann spruce (*Picea engelmannii*), or subalpine fir (*Abies lasiocarpa)* with Ponderosa pine (*Pinus ponderosa*) occurring incidentally or absent. Significant areas within this type are dominated by quaking aspen (*Populus tremuloides*) which may have a significant conifer component. In the absence of fire, mixed conifers tend to replace the aspen community over long time frames. Elevation typically ranges from about 8,000 to 11,000 feet. Understory vegetation is comprised of a wide variety of shrubs, graminoids, and forbs depending on soil type, aspect, elevation, and other factors.

The cool-moist mixed conifer forests are characterized by lethal fires occurring at long intervals (over 100 years) with occasional small, less severe fires (Fule et al. 2009, Romme et al. 2009). Wet mixed conifer stands have less frequent fire return intervals compared to dry mixed conifer. When fires do finally burn through these stands after a long period of no fire, the fuel that has built up will create for a higher intensity fire than what is observed in the dry mixed conifer forests. In some cases after a high severity fire, aspen can remain the dominant species, depending on the extent and severity of the fire and the amount of conifer seed sources present.

Fungal infections and insect outbreaks play a role in stand dynamics. Spruce budworm, which effect fir trees, typically maintain low populations but periodically experience exponential growth patterns. These budworms likely alter stand dynamics of mixed conifer stands which include *Abies* species during these outbreak periods.

The combined factors of fire exclusion, selective logging and climate have altered dry mixed conifer stands more, but even in wet mixed conifer stands, there are also some areas with dense growth of smaller trees and little to no Douglas-fir regeneration and a reduced aspen component.

Mixed Conifer-Dry Ecosystem

In general, the mixed conifer-dry ecosystem can include a mix of conifer species, including ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), blue spruce (*Picea pungens)* and smaller amounts of aspen (*Populus tremuloides*). This drier mixed conifer type has been subdivided into a warm-dry (high ponderosa pine component) and cool-dry (can include limber pine (*Pinus flexilis*), bristlecone pine (*Pinus aristata*), along with small amounts of pinyon (*Pinus edulis*) or juniper (*Juniperus* species) at lower elevations) local types to characterize the variability that can be found across the Forest. The modelling process included the ponderosa pine vegetation type in this ecosystem. With fire suppression, more shade tolerant conifers (e.g., Douglas-fir, white fir, and blue spruce) tend to increase in cover in late successional stages. This ecosystem is generally found between 7,000 to 9,500 feet in elevation, and occupies higher elevations on south facing slopes than north facing slopes.

The warm-dry mixed conifer systems have more frequent, less severe fires (20 to 50 years) with rarer more severe fires. Historically, stands were characterized by relatively open stand structures as a result. However, there was heterogeneity and thus there were patches of denser stands. Median fire intervals in

the nearby San Juan National Forest for these systems were 18 to 28 years (Romme et al. 2009), but fire regimes vary even within the mixed conifer subclasses along moisture continuums (Korb et al. 2013). Where these stands experience high severity fires, there is the possibility for them to be converted to mountain shrublands.

Like wet mixed conifer stands, fungal infections and insect outbreaks, including spruce budworm, play a role in stand dynamics. Heavy livestock grazing and fire suppression likely have especially influenced the warm/dry mixed conifer forests due to their accessibility to livestock and departure from their frequent fire regimes. This grazing compounded the influence of fire suppression by further increasing the time between fires. Logging likely altered mixed conifer forests, particularly the dry mixed conifer stands, due to selective removal of ponderosa pine. The combined factors of fire exclusion, selective logging and climate have created dry mixed conifer stands that are comprised of smaller trees than historically.

Rocky Mountain Alpine Turf Ecosystem

The Rocky Mountain alpine turf ecosystem is widespread above upper timberline. Dominant species include boreal sagebrush (*Artemisia arctica*), several *Carex* species, tufted hair grass (*Deschampsia caespitosa*), *Festuca* species, Ross' avens (*Geum rosii*), Bellardi bog sedge (*Kobresia myosuroides*), cushion phlox (*Phlox pulvinata*), and alpine clover (*Trifolium dasyphyllum*). These alpine environments typically occur above 11,000 feet and are characterized by cool temperatures, high wind, short growing seasons, and intense light. Alpine turf at these elevations is interspersed with rocky outcrops and talus slopes. Soils in these systems are shallower on steeper and more exposed slopes. There are generally considered to be four main vegetation types in these systems: fellfield, dwarf willow, turf and wetlands (Baker 1983, Thilenius 1975 and Dick-Peddie 1993).

Fellfield communities are typified by shallow soils and short cushion plants with relatively low canopy cover. Turf communities usually occur in more protected areas and thus have deeper, better developed soils. Turf systems consist of grasses and forbs and have higher canopy cover than fellfield communities. Wetlands occur in poorly drained soils where water accumulates and consist of willows in some places and herbaceous communities in others. Dwarf willow vegetation communities occur where there is late-lying summer snowpack.

As with other non-woody ecosystems, reference conditions for alpine systems are not well-known. Given the heavy sheep grazing that occurred in many of these alpine communities, it is likely that plant composition is altered, that water runoff patterns are different and that erosion has been increased. Mining is another human activity that has likely heavily influenced these systems where it has occurred. Roads and development associated with mining have reduced vegetation cover, provided pathways for non-native species, altered water run-off patterns and erosion (Somers and Floyd-Hanna 1996, Paulson and Baker 2006). Additionally, mine tailings from mining activities have caused water pollution problems and increased soil toxicity. Finally, in more recent years, the more popular alpine systems have suffered impacts from heavy recreation uses.

Pinyon-Juniper Woodland Ecosystem

In the pinyon-juniper woodland ecosystem, common trees include two-needle pinyon (*Pinus edulis*), Rocky Mountain juniper (*Juniperus scopulorum*), and Utah juniper (*Juniperus osteosperma*). These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus and ridges, particularly those with rocky soil characteristics. Understory composition consists of sparse perennial grasses, annual and perennial forbs, and sparse shrubs.

Pinyon and juniper systems can be classified as persistent woodlands, savannas or wooded shrublands depending on canopy structure, understory composition and historical disturbance regimes (Romme et al.

2008). Historic fire rotations varied but were generally quite long (e.g., many centuries). The longest fire return intervals likely occurred in the persistent woodlands, and intervals were likely shorter in the other two classes, but there is less confidence in the understanding of fire behavior in these types. The Forest includes combinations of the three types, but this has not been defined or mapped.

Stand dynamics may be more driven by climatic fluctuations, insects, and disease than fire (Eisenhart 2004, Romme et al. 2008). There are two important ips species beetles that can cause pinyon trees to die within the same season that they are attacked (Romme et al. 2009). Beetle outbreaks are often aligned with drought conditions in these systems. Root disease such as black stain root disease can also significantly alter pinyon stands.

Pinyon-juniper are lower-elevation systems that are highly accessible by people and therefore have seen significant human influences related to grazing, tree removal, wood cutting, fire suppression and development (Scurlock 1998). Understory composition changes in these systems are impossible to ascertain given limited to no historical information for pinyon-juniper woodlands.

Heavy, year-round grazing started occurring in the late 1800s throughout pinyon-juniper systems and became more moderate when the Taylor Grazing Act was enacted in 1934. Where grazing continues now, there are substantial changes to the flora structure and composition (Fleischner 1994). Even where grazing is much reduced from heavy past usage, there may still be a legacy of changed vegetation. Livestock grazing also led to tree removal for better livestock forage, causing significant fragmentation to pinyon and juniper systems (Knight et al. 2000) and unknown ecological consequences.

Expansion of pinyon and juniper woodlands is a concern in some areas, such as lower elevation meadows and areas with grassy understories. Although pinyon-juniper density has likely increased to some extent in the recent past on the Rio Grande National Forest, the current extent compared to past distribution has not been well analyzed. Fire exclusion in pinyon and juniper systems cannot be the primary mechanism for expansion and infill of these woodlands as fire was never very frequent in these systems and therefore they are not likely departed from historic fire return intervals in most places (Romme et al. 2008), though there is less certainty in pinyon-juniper savannas. Other drivers of expansion may be ongoing natural expansion, recovery from heavy grazing or tree removal, climate change or elevated carbon dioxide levels (Romme et al. 2009).

Rocky Mountain Gambel Oak Shrubland Ecosystem

The Rocky Mountain Gambel oak shrubland ecosystem is very uncommon on the Rio Grande National Forest, occurring where Gambel oak (*Quercus gambelii*) is the dominant species, often associated with serviceberry (*Amelanchier spp*), sagebrush (*Artemisia spp*) and various additional species of shrubs, grasses, and forbs. It occurs at 6,600 to 9,570 feet elevation on all aspects. Currently, Gambel oak is only found at the north end of the San Luis Valley near Poncha Pass where patches of oak can be seen on the slopes of the Sangre de Cristo Mountains. It is also a minor component in the ponderosa/dry mixed conifer type west of highway 17. Its distribution may be limited by low temperatures across much of the low elevation parts of the Forest.

Studies in Mesa Verde National Park show that Gambel oak and service berry dominated shrublands are, at least partly, maintained by fire. The shrublands there have much shorter fire return intervals than the pinyon-juniper stands and recover from fire much more quickly (Floyd et al. 2000).

Southern Rocky Mountain Montane-Subalpine Grassland Ecosystem

The Southern Rocky Mountain montane-subalpine grassland ecosystem occupies elevated plains, valleys, hills and mountain sideslopes ranging from nearly level to very steep topography. Dominant species

include Thurber fescue (*Festuca thurberi*), Arizona fescue (*Festuca arizonica*), and several other grasses, forbs, and sedges. Elevation generally ranges from about 7,000 to 10,000 feet.

The only historical information pertaining to mountain grasslands in southern Colorado are a few anecdotal accounts. Additionally, very few sites escaped intensive livestock grazing and those that did are often anomalous due to steep topography or other conditions. Thus, it is difficult to know how departed these grasslands are from historical conditions. It is thought that bunchgrasses covered greater than half of these grasslands with sod grasses and forbs filling the interspaces so total vegetation cover was nearly 80 to 90 percent (Romme et al. 2009). Litter amounts were relatively high due to the biomass of the bunchgrasses and bare ground was minimal. Soil surface horizons were thick with organic matter and soil erosion and compaction were also minimal (Romme et al. 2009).

Natural drivers of these grasslands were grazing by native ungulates and fire. Native ungulates in these systems likely moved through these systems as needed and the extent and severity of their grazing varied. Fire regimes associated with these grasslands is correlated to the fire regimes of the forests surrounding them. The lower elevation Arizona fescue grasslands were likely characterized by frequent, low-severity fire regimes while the higher elevation Thurber fescue grasslands experienced less frequent and more severe fires (Romme et al. 2009). These fires functioned to turnover nutrients, reduce litter, stimulate new plant growth, and eliminate woody plant growth.

Heavy grazing occurred in these mountain grasslands in the late 1800s and early 1900s which likely resulted in altered plant composition and structure as well as ecosystem function. Livestock grazing interferes with nutrient cycling and plant succession, increases bare soil, compaction, and erosion. Livestock typically graze grasslands differently than native herbivores do. Where grasslands are dominated by Kentucky bluegrass (*Poa pratensis*), a non-native species that increases with disturbance (e.g. livestock grazing), there is commonly minimal litter, compacted soil and erosion issues (Turner and Paulsen 1976).

Rocky Mountain Montane Riparian Ecosystem

The Rocky Mountain Montane riparian ecosystem corresponds to the willows and sedges on floodplains land-type association. This ecosystem represents numerous riparian types occurring as relatively small, linear stringers in the upper montane/subalpine zones. These systems are highly variable and generally consist of one or more of the following five basic vegetation forms: cottonwoods, willows, sedges and other herbaceous vegetation, aspen, or conifers (often blue spruce, except at higher elevations where Engelmann spruce is more common, and subalpine fir). Due to human reliance on water and the sensitivity of these systems, riparian systems have possibly been altered more by human activities than any other.

Development, livestock grazing, logging, agriculture, mining, roads, recreations, dams, diversions and exotic species all play a role in how these systems are composed and function today. When settlers first started establishing within and around the present-day Rio Grande National Forest, they removed riparian trees for fuel and structure building and then later built dams and diversions. These dams regulated water flow, blocked aquatic organisms and altered erosional processes. A drop in water tables and the elimination of flooding dramatically altered plant composition and structure, notably causing the decline of cottonwoods and willow systems.

Heavy livestock grazing in the late 1800s and early 1900s eliminated or reduced woody riparian cover, which functions to retain higher water tables and stabilizes banks. Mining affected riparian areas by introducing pollutants and causing increased erosion into these systems. Logging caused increased sedimentation into stream systems. Though not a problem on the Forest, the introduction of non-native

species like salt cedar (tamarisk) and Russian olive trees have dramatically altered plant composition, structure and altered water table dynamics (Dick-Peddie 1993).

Current information suggests that riparian areas may require increased management focus in regards to potential effects associated with climate change. Low-elevation riparian areas, and seeps and springs, in drier vegetation types are particularly vulnerable to management activities that may contribute to these effects and require an adaptive response to potential changes. Primary activities that may need additional attention include grazing by domestic and native ungulates, roads, and travel management influences.

In areas within or downstream of stands that have experienced heavy beetle kill, streams may have altered timing of spring runoff patterns due to earlier and quicker snowmelt (Pugh and Small 2012).

Sagebrush Shrubland Ecosystem

The sagebrush shrubland ecosystem is a dry shrubland type that occurs mostly adjacent to the Rio Grande National Forest. Sagebrush shrublands are dominated by *Artemisia tridentata* and other shrubs. Historically the understory of these communities were comprised of bunchgrasses and forbs, although with the introduction of non-native species both composition structure of the understories have changed where they are present.

Sagebrush shrublands in the Rio Grande National Forest were heavily grazed in the late 1800s and the early 1900s before grazing became more regulated under the Taylor Grazing Act (Rogers 1964). While sagebrush shrublands were grazed by native ungulates prior to Euroamerican settlement, livestock moved through these systems and grazed them differently. Livestock grazing not only alters plant composition and structure though selective grazing of palatable plants (Caldwell 1984) and removal of biomass, but also influences soil through compaction (and then future plant establishment), erosion (Thurow et al. 1988), and nutrient cycling (Semmartin 2004).

Another consequence of grazing is that along with fire suppression efforts, it may have increased fire intervals in sagebrush systems through reduction of fine fuels. However, introduction of cheatgrass (*Bromus tectorum*), an invasive annual grass, can serve to increase fire frequency through a positive feedback cycle (Whisenant 1990). Fire in sagebrush systems reduces decadent sagebrush stands, promotes understory growth and nutrient cycling and creates a mosaic of sagebrush structures and community types across a broad landscape. Regardless of fire severity, fire in sagebrush is stand-replacing (Sapsis and Kauffmann 1991) and sagebrush can be slow to reestablish. Historic fire regimes are difficult to ascertain directly and likely varied with sagebrush type, elevation and other abiotic factors. Estimates of fire rotations for sagebrush systems generalized across the west from a few studies (Baker 2006) are 325 to 450 years for low sagebrush, 100 to 240 years for Wyoming big sagebrush, and 70 to 200 years for Mountain Big sagebrush. If these estimates are correct for the Rio Grande National Forest sagebrush shrublands, than they are not likely very departed from their historic fire intervals. A reduction in fire occurrence in this type may allow conifer encroachment into shrublands.

Intermountain Basins Greasewood Flat Ecosystem

The Intermountain Basins greasewood flat ecosystem, also called Intermountain salt shrubland, is a dry shrubland system dominated by *Sarcobatus vermiculatus* and which also includes *Atriplex* and *Artemisia* species. If there is an herbaceous layer, it is typically dominated by grasses. It is found mostly adjacent to the Rio Grande National Forest and occupies substantial areas at low elevations around the Forest.

Greasewood systems experienced heavy grazing in the Rio Grande region during Euroamerican settlement. While greasewood itself is not browsed (Daubenmire 1970), understory grass composition may have shifted with heavy grazing and by the introduction of invasive and forage grasses that were able

to establish with an initial reduction in cover. Greasewood re-sprouts quickly after fire but grasses will initially dominate the recovering community. Human disturbance such as road building and overgrazing-induced erosion that interrupt the hydrologic cycles in these systems may influence the composition and structure of these communities.

Habitat Structural Stage Classification

For this assessment, we also characterized vegetation condition into habitat structural stages developed by USDA Forest Service Region 2 (table 3). We refer to canopy cover 0 to 10 percent as grass/shrub, 10 to 40 percent as open, 40 to 70 percent as 'mid' and 70 to 100 percent as closed in the descriptions below. A habitat structural stage category for aspen-dominated stands with variable size and canopy cover was also added for this analysis.

Table 3. Definitions of habitat structural stages used to characterize ecosystem condition

Habitat Structural Stage	Size Class	Tree Canopy Cover
1M- Natural Meadow	-	-
2S- Natural Shrubland	-	-
1T/2T- Grass/Shrub, Previously Trees	all	0-10%
3A- Sapling-Pole 10-40% cover	sapling-pole (0-9" DBH)	10-40%
3B- Sapling-Pole 40-70% cover	sapling-pole (0-9" DBH)	40-70%
3C- Sapling-Pole >70% cover	sapling-pole (0-9" DBH)	>70%
4A- Mature 10-40% cover	mature (9+" DBH)	10-40%
4B- Mature 40-70% cover	mature (9+" DBH)	40-70%
4C- Mature >70% cover	mature (9+" DBH)	>70%
Aspen	all	all

Of the forested area, most of the landscape is comprised of mature, open stands (4A), with grass/shrub, open sapling-pole, mid cover mature, and aspen each comprising about 10 percent of the landscape. In the broader Rio Grande National Forest landscape including the context area, natural shrublands (2S) comprise a substantial portion of the landscape, and the proportion of the landscape occupied by sapling-pole trees is greater.

Vegetation Modelling Results – Assessment of Ecosystem Integrity (12.14), including a Description of the Natural Range of Variation (12.14a or b), and Status and Trends (12.14c):

Historically, roughly 30 percent of the Rio Grande National Forest was comprised of natural meadows and (few) shrublands. The remainder of the Rio Grande National Forest was dominated by forests, including about 16 percent in aspen stands. Forested canopy cover under natural range of variation was projected as 31 percent conifers with mid cover (40 to 70 percent canopy cover), 14 percent conifer with closed (over 70 percent canopy cover) conditions, and 8 percent open (under 40 percent canopy cover) conifer stands. Historical projections indicate that most of the Rio Grande National Forest was comprised of mature conifer trees (42 percent) with 11 percent in smaller sapling-pole sizes. Only 1 percent of the Rio Grande National Forest is expected to be in grass/shrub with forested potential (habitat structural stage 1T/2T) under historic conditions, indicating rare stand-replacing disturbance.

Table 4. Current number of acres in each habitat structural stage, based on maps of current vegetation and incorporating recent, large disturbances

Habitat Structural Stage	Rio Grande National Forest Acres		Rio Grande National Forest and Landscape Context Area	
	Acres	Percent	Acres	Percent
1M- Natural Meadow	495,936	29%	765,656	19%
2S- Natural Shrubland	6,366	0%	509,226	12%
1T/2T- Grass/Shrub, Previously Trees	190,270	11%	349,223	8%
3A- Sapling-Pole 10-40% cover	171,678	10%	566,786	14%
3B- Sapling-Pole 40-70% cover	101,526	6%	620,641	15%
3C- Sapling-Pole >70% cover	5,256	0%	161,572	4%
4A- Mature 10-40% cover	376,921	22%	458,371	11%
4B- Mature 40-70% cover	173,329	10%	345,847	8%
4C- Mature >70% cover	44,635	3%	68,793	2%
Aspen	165,675	10%	265,884	6%

Figure 3. Comparison of habitat structural stage classes under natural range of variation equilibrium, current conditions (time zero) and future projections under no management at 20, 50, 100, 300 and 500 year time steps across all ecosystems within the Rio Grande National Forest. Error bars show ± 1SD across 10 replicate simulations.

Current conditions on the Rio Grande National Forest contain abundant grass/shrub with forested potential (habitat structural stage 1T/2T). Current conditions also contain more sapling-pole trees and a much greater proportion (31 percent) of open stands compared to natural range of variation conditions. The abundance of grass/shrub and open conditions are largely a result of a severe spruce beetle outbreak and a recent large wildfire over the past several years. The proportion of aspen at present is also smaller than projected under natural range of variation, due to fewer wildfires under contemporary conditions. Very large and intense disturbances were rare in our simulations and did not substantially influence natural range of variation condition. In short, the Rio Grande National Forest overall is currently

moderately to substantially departed from typical natural range of variation conditions, with the degree of departure varying by ecosystem (Table 5).

Table 5. Departure from the natural range of variability for each ecosystem based on vegetation modeling results

Ecosystem	Departure from Natural Range of Variation			
	Substantially Departed	Highly Departed	Slightly Departed	Not Departed
Spruce-Fir Forest Mix	X			
Mixed Conifer-Wet	X			
Mixed Conifer-Dry			X	
Rocky Mountain Alpine Turf				X
Pinyon-Juniper Woodland		*X		
Rocky Mountain Gambel Oak – Mixed Montane Shrubland		X		
Southern Rocky Mountain Montane-Subalpine Grassland		*X		
Rocky Mountain Montane Riparian	*X			
Sagebrush Shrubland			X	
Inter-Mountain Basins Greasewood Flat			X	

* indicates less confidence in the model results for that ecosystem.

Projected future conditions indicate overall recovery toward the natural range of variation as the result of natural processes. Future estimates suggest there may be slightly less aspen than expected under the natural range of variation due to lower contemporary wildfire levels. The projected future proportion of mature trees is also greater than under the natural range of variation, particularly in forests with closed canopy conditions. In sum, our modeling indicates that the Rio Grande National Forest will likely move from currently departed conditions toward the natural range of variation as it recovers from recent disturbance. However, it may remain somewhat departed from the natural range of variation due to lower overall levels of wildfire resulting from fire suppression.

Across the entire Rio Grande National Forest, the effects of management are small. This is not surprising, as the extent of management treatments is extremely small, with less than 0.2 percent of the landscape treated with management activities each year. However, the impact to the ecosystem of these activities varies based on the intensity, the specific activity, and the ecosystem, not just the acreage of the activity, and generally lasts longer than simply the year implemented. In addition, the roads associated with these activities, even temporary ones, can negatively impact the forest and its ecosystems. The extent of management activities also varies by ecosystem. Ecosystem structure, composition and function may still be experiencing the legacy effects of past clearcutting, road-building and grazing practices.

Drivers and stressors varied widely among ecosystems across the Rio Grande National Forest. The dominant drivers across the landscape include growth and mortality, livestock grazing, and (in some cases) wildfire. Wildfire affected three times more area under the natural range of variation conditions than contemporary conditions due to contemporary fire suppression. Other drivers included insects and disease, weather-related events (e.g., droughts and floods), other natural disturbances (e.g., beaver activity in riparian areas), and management. Overall, management treatments such as thinning, prescribed fire, and timber harvest are implemented on less than 0.2 percent of the Rio Grande National Forest each year, although this varies by ecosystem, indicating that management (other than wildfire suppression) is a

relatively minor driver and stressor at a landscape scale. However, the impact to the ecosystem of these activities varies based on the intensity, the specific activity, and the ecosystem, and generally lasts longer than simply the year implemented.

The modelling that was done to look at the natural range of variability and ecosystem integrity did not specifically include climate change. Climate change and the associated gradual increase in temperature will alter growth rates and mortality. Species habitat may move higher and more northward as a result. But most importantly, with a changing climate, we expect more extreme weather, climate conditions, and disturbances such as wildfires, insect and disease outbreaks, droughts, and floods. Therefore, some of the simulation results may not hold and there may be other unanticipated conditions due to the effects of climate change.

Vegetation Modelling Results – Ecosystem by Ecosystem - Assessment of Ecosystem Integrity (12.14), including a Description of the Natural Range of Variation (12.14a or b), and Status and Trends (12.14c):

Spruce-Fir Forest Ecosystem

Model simulations indicate that about 70 percent of the spruce-fir forest ecosystem was historically dominated by conifer species, with the remaining 30 percent in aspen. Under historic conditions, modelling suggests 60 percent of the ecosystem was occupied by mid and closed conifer cover, with only 8 percent of the landscape in open conifer cover. A very small proportion (1 percent) of the landscape contained grass/shrub conditions resulting from stand-replacing disturbance.

The vegetation modelling suggests that the spruce-fir forest ecosystem is currently substantially departed from the natural range of variation due to the effects of recent wildfires and a large, multi-year spruce beetle outbreak, which caused substantial spruce mortality, opened canopy conditions, and created patches of grass/shrub across wide areas. A much larger amount of this type is currently categorized as open, with low canopy cover, than was estimated under historic conditions from the model simulations. The proportion of aspen in the spruce-fir forest ecosystem is also currently lower than historic projections, but should increase following the recent disturbances.

This result is not necessarily in agreement with the published literature. The modelling of historic conditions included moderate spruce beetle outbreaks, but did not include the rare, extreme spruce beetle outbreaks like the one the Rio Grande National Forest is currently experiencing. Literature (Eager et al. 2012, Romme et al. 2009) indicates that in these spruce-fir forests, spruce beetles generally persist in low-level, widespread populations that have little effect on forest structure, but that they periodically have very large outbreaks, where the “beetles may kill millions of mature pine or spruce trees over areas of thousands of hectares.” Since the modelling did not include these large, explosive outbreaks, the spruce-fir forests may not be nearly as departed from the natural range of variation as the modelling suggests.

Future projections for the spruce-fir forest ecosystem generally show a trajectory of recovery toward the natural range of variation conditions over time. The current overabundance of grass/shrub conditions largely disappears in the first 20 years of projections, and open conifer forests are mostly replaced by mid- and closed cover forests over the first century of projections. Aspen stands increased in short-term and mid-term projections. Longer-term projections, however, show a decline of aspen stands to levels roughly 10 percent lower than under the natural range of variation, mostly due to lower levels of wildfire under contemporary conditions due to fire suppression.

Management treatments in the spruce-fir ecosystem include broadcast burning, group selection, planting of trees, salvage harvest, shelterwood harvest, and stand clearcut. In total, these treatments represent

roughly 0.1 percent of the area occupied by spruce-fir on the Rio Grande National Forest (1,277 acres per year).

Mixed Conifer-Wet Ecosystem

Model simulations for the mixed conifer-wet ecosystem indicate that historically, a small proportion (2 percent) of the ecosystem was in grass/shrub conditions, 13 percent was comprised of aspen stands, and the remaining 85 percent was dominated by conifers. Within the conifer-dominated areas, most of the trees were mature, with 72 percent of the ecosystem in mid to closed conifer cover.

This vegetation modelling suggests the mixed conifer-wet ecosystem is substantially departed from the natural range of variation. Only 20 percent of this ecosystem is currently dominated by conifers with mid- to high canopy cover, less than a third of the historic proportion. Current conditions also contain much more grass/shrub and aspen due to recent disturbances. Mature trees currently occupy half of their historic extent, with a greater proportion under low canopy cover.

A recent mixed-conifer synthesis (Colorado Forest Restoration Institute 2010) suggests that it is unclear how departed from the natural range of variation these cool-moist mixed conifer forests are and that more information is needed. This report also suggests that the lack of intermediate-sized fires due to fire suppression and management has led to the loss of historic variability in these forests and that we should "create conditions in which mixed-severity fires, intermediate to large in size, can be allowed to burn with acceptable risk and cost."

Future projections show short-term increases in aspen-dominated stands as areas currently occupied by grass/shrub recover through seral aspen stages. The proportion of aspen gradually decreases to a level lower than the historic estimates due to less wildfire in the contemporary disturbance regime due to fire suppression. Over time, the projected proportion dominated by conifers increases and mature trees occupy a greater proportion of the landscape. Overall, the mixed conifer-wet ecosystem recovers toward the natural range of variation in our simulations, but ends up with less aspen and more closed forests than the natural range of variation condition.

Management treatments in the mixed conifer-wet ecosystem include broadcast burning, salvage harvest, and thinning. These treatments represent an annual treatment rate of 0.6 percent of the ecosystem each year (282 acres).

Mixed Conifer-Dry Ecosystem

Model simulations indicate that under historic conditions, roughly 10 percent of the mixed conifer-dry forest area was in grass/shrub condition. The remainder was in conifer-dominated stands, with 25 percent open cover, 57 percent in mid cover and 8 percent of the area in closed condition. A majority of the ecosystem contained mature trees (61 percent), while about 30 percent of the ecosystem was in sapling-pole stages.

Current conditions in the mixed conifer-dry ecosystem contain similar levels of grass/shrub conditions and similar area in open forest conditions, compared to the natural range of variation. There is currently a larger proportion of sapling-pole size trees than under the natural range of variation, and also slightly less closed forest. However, this ecosystem is currently only slightly departed from the natural range of variation based on model simulations. This is surprising in that it is generally thought that the warm-dry mixed conifer types are more departed from the natural range of variation than cool-moist mixed conifer (Colorado Forest Restoration Institute 2010). Given that the dry mixed conifer forest type has a more frequent fire regime than other types, such as wet mixed conifer and spruce-fir, it is generally thought to have been more impacted by fire suppression and thus more departed from historic conditions.

Future projections indicate that growth and succession will likely increase the proportion of mature trees and mid-closed canopy cover in the mixed conifer-dry ecosystem over time. Overall, the mixed conifer-dry ecosystem shows less current departure than many other ecosystems on the Rio Grande National Forest and a trajectory toward future conditions that are moderately departed from the natural range of variation.

Wildfire was moderately frequent under historical conditions, but is more infrequent under contemporary conditions, due to fire suppression. Insect outbreaks, such as Douglas-fir beetle and mountain pine beetle, affected an average of 0.5 percent of the mixed conifer-dry ecosystem annually historically, but model simulations suggest that, due to more larger trees and closed canopy stands in the future, under the current fire regime, these conditions may lead to more insect outbreaks.

Management treatments in the mixed conifer-dry ecosystem include broadcast burning, planting of trees, salvage harvest, and thinning. In total, these treatments represent an annual treatment rate of 0.5 percent of the ecosystem (469 acres per year).

Rocky Mountain Alpine Turf Ecosystem

Current conditions show a high proportion of late-seral conditions, similar to those under the natural range of variation. Future projections also maintain most of the ecosystem in late-seral conditions, with disturbances even more rare in future projections. The South Central Highlands Guide (Romme et al. 2009) describes heavy sheep grazing in this type and speculates that historically, the vegetation structure and distribution is similar to today, but with different species composition in the areas with heavy grazing.

Pinyon-Juniper Woodland Ecosystem

Modelling suggests that historically 5 percent of the pinyon-juniper woodland was in grass/shrub, 35 percent in open canopy cover and 60 percent in mid canopy cover. Most of the area was dominated by mature trees.

Current conditions are highly departed from the natural range of variation in the pinyon-juniper woodland ecosystem, with a much higher amount (60 percent) of the area in grass/shrub. Of the remaining landscape, almost all contains open cover woodlands, with smaller sapling-pole trees dominant. The high level of departure is at least partially related to the assignment of the low-elevation grasslands land type association to the pinyon-juniper woodland ecosystem. If some of the mapped grass/shrub areas are actually natural grasslands and had been classified into a grassland ecosystem instead, the level of departure from the natural range of variation would be lower.

Under future projections, the pinyon-juniper woodland recovers from highly departed current conditions over several centuries. Long-term projections indicate future conditions within the natural range of variation. However, the trend toward increasing tree cover may not actually occur if the grassland land type association is not at least moderately susceptible to tree invasion.

Succession and insect outbreaks, such as pinyon ips, were the most influential drivers of vegetation dynamics in the pinyon-juniper woodland ecosystem, with wildfire relatively rare. Management treatments in the no-action scenario include broadcast burning, mastication, and thinning, summing to an annual treatment rate of 0.4 percent (443 acres per year).

Rocky Mountain Gambel Oak Shrubland Ecosystem

Model simulations indicate that historically a high proportion of the Rocky Mountain Gambel oak shrubland ecosystem was in late-seral, closed shrub conditions, with some open patches and a low proportion of early-seral conditions.

Current conditions for the Rocky Mountain Gambel oak shrubland ecosystem indicate a roughly equal representation of seral stages. However, future projections under contemporary conditions show nearly all of the ecosystem moving to late-seral, closed conditions due to contemporary fire suppression.

Succession and wildfire were the only drivers modeled in the Gambel oak shrubland ecosystem. Projections indicate much lower levels of wildfire under contemporary conditions compared to historic conditions.

Southern Rocky Mountain Montane-Subalpine Grassland Ecosystem

Model simulations indicate that most of the landscape in this ecosystem was occupied by grasses with some shrub and tree cover possible under the natural range of variation. However, we have lower confidence in the projections for this ecosystem and the underlying models used.

Current conditions contain a greater proportion of early seral grasslands with lower shrub and tree cover than under the natural range of variation. Future projections generally indicate a return toward the natural range of variation conditions.

Drivers in the montane-subalpine grassland ecosystem historically included succession, wildfire, and tree encroachment. In future projections, livestock grazing was the dominant driver, affecting over 5 percent of the landscape each year. Modelling showed tree encroachment rates were higher under future conditions. Management consists of prescribed fire, at a rate of 471 acres per year.

Rocky Mountain Montane Riparian Ecosystem

Model simulations indicate that, historically, 63 percent of the ecosystem had open to mid canopy cover, with the remaining 37 percent in closed cover conditions. However, we have lower confidence in the projections for this ecosystem and the underlying models used.

Current conditions contain 30 percent of the riparian vegetation in mid canopy cover, substantially less than under the natural range of variation. Future projections indicate a gradual decline of mid cover areas over time. This trend away from the natural range of variation is due to the much longer fire return interval under contemporary conditions.

Management data indicates that less than 20 acres per year is treated in this ecosystem.

Gage and Cooper (2013) suggest that a variety of factors have caused many high-to middle-elevation riparian shrublands to be outside the natural range of variation, due to exotic species invasion, herbivory and trampling by livestock and native ungulates, and changing hydrologic regimes and beaver populations.

Sagebrush Shrubland Ecosystem

A qualitative assessment of model results show that much of the sagebrush shrubland ecosystem was historically comprised of mid- and late-successional classes, with roughly 20 percent containing some juniper cover.

The vegetation modelling suggests that the current condition of the sagebrush shrubland ecosystem varies based on whether the area is inside or outside the Rio Grande National Forest. This may be a true difference or may simply be an artifact of the data sources used. The portion of this ecosystem outside the national forest boundary is predominantly in early and mid-successional classes with few exotic annual grasses present. The portion of this ecosystem within the national forest boundary is mostly in late-successional classes and is slightly departed from the natural range of variation.

Under future projections, exotic annual grass species and juniper expansion displace much of the native sagebrush. Projections also show an increase in early-seral shrubs such as rabbitbrush (*Chrysothamnus* and *Ericameria* species).

Under historic conditions, wildfire was the dominant driver of vegetation dynamics, whereas under projected future conditions, livestock grazing is the dominant driver in this system, affecting almost 7 percent of the ecosystem on average each year. Exotic invasion also impacted 0.6 percent of the ecosystem annually, and tends to increase the frequency of wildfire where it occurs.

No management treatments were modeled in this ecosystem, as it occurs mostly outside of the Rio Grande National Forest.

Intermountain Basins Greasewood Flat Ecosystem

A qualitative assessment of the natural range of variation indicates open grass and shrub conditions dominated this ecosystem historically, with some early-seral conditions containing sparse shrubs also present.

Currently, a greater proportion of the Intermountain basins greasewood flat ecosystem is mapped in open grass/shrub conditions than projected under the natural range of variation. Overall, model results indicated that this ecosystem is slightly departed from the natural range of variation.

Future projections show a large increase in exotic species and an introduction of wildfire into this ecosystem, which naturally experiences little or no fire due to lack of fuels.

Historically, only succession and weather-related disturbances were modeled in this ecosystem, including impacts of drought and very wet years. Under contemporary conditions, livestock grazing is the primary driver, followed by wildfire, weather, and exotic invasion.

Vegetation Modelling Summary – Assessment of Ecosystem Integrity (12.14):

In summary, the spruce-fir and aspen forests are, in particular, undergoing rapid change due to a recent, large outbreak of spruce beetle and a recent large wildfire. High levels of mortality in mature Engelmann spruce in many areas have produced abundant open stands and dead standing and down wood. This, in turn, is allowing regeneration of aspen and an increasing trend in aspen forests.

It is difficult to determine whether the terrestrial ecosystems on the Rio Grande National Forest are within the range of what would occur naturally. Modelling results indicate that the terrestrial ecosystems on the Rio Grande National Forest are, in general, moderately to substantially departed from what would occur naturally. However, the determination of the range of natural conditions is not an exact science. The spruce beetle modelling did not include the rare, extreme spruce beetle outbreaks like the one we are currently experiencing, but more moderate outbreaks. We know that these large spruce beetle outbreaks happened historically and this suggests, along with the long fire return interval in spruce-fir, that this ecosystem is not departed from historic conditions. In the end, we don’t really know with any certainty what effect past logging has had in these forests and whether this latest spruce beetle outbreak is a completely natural phenomenon or one influenced by climate change.

In other cases as well, the published literature is not necessarily in agreement with the modelling we used here, making it difficult to know with any certainty how departed some of these types are from the natural range of variation. The dry mixed conifer type is thought to be highly departed from its natural range due to its more frequent fire return internal and fire suppression over the last century. The modelling we used here suggests this type is only slightly departed. This discrepancy may be due to the modelling assumption of a 100 year fire return interval for the dry mixed conifer type, which is higher than the 20 to

50 year fire return interval discussed in the literature. Wet mixed conifer was found to be substantially departed from its natural range of variation by the modelling. It is surprising that the wet mixed conifer type would be more departed than the dry type, since it has a less frequent fire regime. While there is little area with high cover (over 70 percent) in the wet mixed conifer type on the Forest; this may be due to recent heavy mortality from insects such as spruce budworm or past wildfires and needs to be investigated further.

Over the long term (many decades to hundreds of years), models project most forested ecosystems recovering towards the natural range. However, due to fire suppression, we may expect to see somewhat less aspen in the future than would likely exist naturally, as well as other changes in the structural composition of forests.

Across the entire Rio Grande National Forest, the effects of management are small. This is not surprising, as the extent of management treatments is extremely small, with less than 0.2 percent of the landscape treated each year. However, the impact of these activities to the ecosystem varies based on the intensity, the specific activity, and the ecosystem, not just the acreage of the activity; and generally lasts longer than simply the year implemented. In addition, the roads associated with these activities, even temporary ones, can negatively impact the forest and its habitat. The extent of management activities also varies by ecosystem.

Assessment of Ecosystem Integrity (12.14): Landscape Disturbances and Patterns

Overview of the Rio Grande National Forest Landscape

The Rio Grande National Forest is a diverse landscape with a wide variety of vegetation communities. On and just surrounding the Rio Grande National Forest, sagebrush shrublands and greasewood flats dominate the lowlands, with pinyon-juniper woodlands intergrading into them. Pinyon and juniper may be encroaching into what were recently grasslands or shrublands due to: past grazing, which potentially limits competition from herbaceous plants; fire exclusion, which allows more woody growth; and changing climate. Aside from pinyon and juniper, the foothill zone is a mixture of grassland, common mountain shrubs such as currants, rabbitbrush, chokecherry, skunk bush, limited areas of mountain big sagebrush, low sages, and mountain mahogany.

Above the foothill zone begins the lower elevation portion of the montane zone. Here mixed conifer forests are interspersed with aspen stands and montane grasslands. Douglas-fir and ponderosa pine are the dominant trees in the montane zone. Ponderosa pine generally grows in scattered, park-like stands with abundant grass growth of Arizona fescue and mountain muhly in the understory. Douglas-fir intermingles with ponderosa pine on north-facing slopes and in ravines. With elevation gain, Douglas-fir eventually replaces the ponderosa pine. Two important seral species in the montane zone are aspen and lodgepole pine on the northern edge of the Forest. The Rio Grande National Forest represents the southern geographic range for lodgepole. White fir commonly occurs in the upper elevations of the montane zone on the southern two-thirds of the Forest.

Fire can be a large determinant of which vegetation community types are where, and in turn, the vegetation community types drive fire cycles. Frequently after fire in conifer stands, aspens establish and conifers will come up through their understories and gradually replace them. After a severe fire, mixed conifer stands may convert to montane shrublands.

Moving up in elevation, the forest becomes denser and transcends into the subalpine forests. Subalpine stands are dominated by Engelmann spruce intermixed with subalpine fir. These two tree species form the

most extensive forested cover type on the Forest. Arizona fescue and mountain muhly dominate areas that are too dry for tree growth. Rocky slopes and dry, gravelly areas will often support limber and bristlecone pine. It is broken only by drainages, outcrops of rock, or fire disturbance. Aspen is the major seral species in this zone, due primarily to past natural fire disturbance. South-facing slopes, which are hotter and drier environments, have stands of Thurber fescue grassland. The spruce/fir forest receives the most precipitation of all the forest types. A great quantity of snow falls in this zone, which accumulates all winter and lasts into early summer. The trees protect the snow from melting or blowing away. Because of this, there are plants adapted to high amounts of moisture and a cold environment. Rocky Mountain whortleberry typically forms dense mats and is adapted to the cool, moist environment under Engelmann spruce.

At higher elevations, cooler temperatures and later lying snowpack create wetter conditions which burn less readily. When conditions are right in higher elevation stands, often after several years of drought, fires that do initiate typically burn through all the accumulated fuel with high severity and over large areas. At the highest elevations, forests give way to stunted trees with krummholz life forms and alpine vegetation communities. A willow/sedge community often occurs at the transition into alpine zones. A tremendous variety of plants inhabit the high alpine regions that are adapted to harsh conditions. Low-growing sedge, kobresia, and forb (broad-leaved herbaceous plants) communities dominate these alpine systems.

Riparian ecosystems border the streams that run through all these ecosystems; varying significantly depending on elevational gradient and geology. Overstory vegetation can be dominated by any of the conifer species discussed; or by blue spruce, willow, alder, aspen, or cottonwood; depending on elevation. The understory (plants growing underneath the taller plants) may be dominated by a variety of sedge, bluegrass, reedgrass, bentgrass, tufted hairgrass, rush, or many other water-adapted graminoid (grasses and grasslike plants) or forb species. Although riparian areas are generally only a very small percentage of the land area, they have high species diversity and density, and high productivity. Riparian systems are dynamic and adapted to hydrological disturbance regimes. Historically, water tables and stream flooding on the Rio Grande National Forest were partly regulated by beaver dams, but with the reduction of beaver across the range, the abundance of beaver ponds and their associated communities have declined.

Snowpack accumulates throughout the winter, particularly at higher elevations, and then as temperatures rise in the spring it slowly melts; more quickly at lower elevations where it is warmer. Some plant communities are dependent on spring flooding such as the lower elevation greasewood and wetlands. Large disturbances in the higher elevations that influence canopy cover such as timber harvest, fire, beetle induced mortality, or changing climates can alter the timing of snowmelt. When snow melts quickly, rather than slowly, there are direct consequences for plant growth and for animals living in stream systems; and less directly but consequentially for other animals in, or dependent on, these communities. Also where there are explosive pulses in snowmelt combined with soil that is bare or disturbed (from roads, timber harvest, livestock grazing or fire), soil erosion and sedimentation into streams can create problems for aquatic organisms throughout the stream systems. Additionally, the placement of roads in watersheds can alter water runoff patterns so vegetation receives water differently than it would in the absence of the road (e.g. water can be cut off from places that used to be in its pathway).

Major Disturbance Types

A variety of disturbance agents affect the landscape of the Rio Grande National Forest. One indicator of ecosystem integrity is whether these disturbance processes are occurring with the same magnitude and intensity as they did historically. This section looks at the patterns in landscape processes and disturbances for the various terrestrial ecosystem types.

Fire

Wildland fire is a component of many of the ecosystems on the Rio Grande National Forest, both as an ecological driver and as an ecological stressor, depending on the system. Some of the plant species are fire-adapted, with traits such as thick bark or prolific sprouting after fire, enabling them to persist in a frequent-fire environment. Other systems like ponderosa pine require disturbances such as fire to maintain stand health and stability.

A natural fire regime refers to the overall pattern of fires in vegetation over time, without modern human mechanical intervention, that is characteristic of a natural region or ecosystem. The fire regime includes vegetation and fuels characteristics, fire frequency, fire intensity and behavior, and ecological effects.

Fire regimes generally vary in severity and frequency over a moisture and elevation continuum with lower severity, more frequent fires occurring at lower elevations (which are drier); and higher severity, less frequent fires occurring at higher elevations. Historically, highly variable, mixed-severity fires maintained patchy and diverse vegetation structure and composition. This patchiness provides varied and productive habitat for many different plant and animal species.

Fire regimes can be generalized according to vegetation type. For example, the Engelmann spruce/subalpine fir cover type is usually characterized by infrequent and often high-intensity surface fires, in combination with a long fire return interval (100 to 300 year); sporadic crown fires and higher-intensity surface fires that kill most, but not all, vegetation. Many of these long-return interval fires cover medium to large areas (1,000 to 10,000 acres) (Mutch 1991). The warm-dry mixed conifer systems have more frequent, less severe fires (20 to 50 years) with rarer, more severe fires.

The fire regimes for the various ecosystems on the Rio Grande National Forest were included in the vegetation modelling. Historical fire probabilities were based on literature and expert opinion. Contemporary fire probabilities were based on an analysis of burn perimeters from the monitoring trends in burn severity records for each ecosystem, with the assumptions listed in table 6.

Table 6. Return intervals, and estimated annual acres burned for historic conditions (left) and contemporary conditions (right)

Ecosystem	Historic Conditions		Contemporary Conditions	
	Annual Acres Burned	Fire Return Interval (years)	Annual Acres Burned	Fire Return Interval (years)
Inter-Mountain Basins Greasewood Flat	0	10,000	0	6,600
Mixed Conifer - Dry	1,634	100	545	300
Mixed Conifer - Wet	296	150	89	500
Pinyon-Juniper Woodland	318	400	170	750
Rocky Mountain Alpine Turf	547	500	37	7,400
Rocky Mountain Gambel Oak - Mixed Montane Shrubland	26	100	2	1,650
Rocky Mountain Montane Riparian	793	100	88	900
Sagebrush Shrubland	33	150	2	2,600
Southern Rocky Mountain Montane-Subalpine Grassland	1,734	200	267	1,300
Spruce-Fir Forest Mix	2,053	500	1579	650
Average acres burned per year	7,434		2,777	
Percent of Rio Grande National Forest burning per year	0.4%		0.1%	

Departures from the natural fire regime are referred to as the condition class. A fire regime condition class of 1 is the least amount of departure from the natural regime; the area is within the historical range of variability and at low risk of losing key ecosystem components. A fire regime condition class of 3 is categorized by a high departure from the natural regime with high risk of loss of key ecosystem components and exhibits a highly altered composition and structure of vegetation and fuels. Under wildland fire management and suppression policies of the last 100 years, the fire regime in much of the west has been altered, sometimes significantly. Other activities such as timber management, grazing, invasive species, and rural/urban development contribute to conditions that are uncharacteristic of the natural fire environment. To help restore fire to its historical role in the ecosystems on the Rio Grande National Forest, we conduct broadcast burning at an average rate of 860 acres per year (10-year annual average 2004-2014).

From 1994 to present, there have been an average of 10 to 20 wildland fires per year on the forest, with 94 percent being contained at less than 10 acres. The majority are naturally ignited, with 76 percent of wildland fires caused by lightning. Managing naturally occurring ignitions to include ecological benefits is approved Forestwide; although site-specific values at risk, or existing fuel, weather, and climate conditions may require fire managers to consider full suppression. Key vegetation habitat types such as late-successional spruce-fir, pinyon pine, and Engelmann spruce forests are also very susceptible to wildland fire and are only sustainable through a strict full suppression strategy.

Insects and Disease

Several insects and diseases significantly influence the structure and composition of the forests on the Rio Grande National Forest. While these insects and diseases are natural disturbance agents beneficial to the creation and maintenance of many ecological functions for wildlife species, high amounts or outbreaks may be damaging to other habitat components. In the subalpine zone, the most important forest insects and diseases are the spruce beetle, *Dendroctonus rufipennis*, root-decay fungi, *Heterobasidion* sp. and *Armillaria* sp., and western balsam bark beetle, *Dryocoetes confusus*. In the montane zone, the most important forest insects and diseases are the mountain pine beetle, *Dendroctonus ponderosae*, the Douglas-fir beetle, *Dendroctonus pseudotsugae*, the western spruce budworm, *Choristoneura occidentalis*, western tent caterpillars, *Malacosoma* sp., and the dwarf mistletoes, *Arceuthobium* spp. The foothill zone is influenced by pinyon ips, *Ips confusus*. There is currently heavy mortality from these disturbance agents on the Rio Grande National Forest due to the high amount of large, older age forests, the warmer, drier climate, and the intense drought that occurred in the late 1990s and early 2000s (Eager et al. 2012).

The spruce beetle is a bark beetle that infests all species of spruce in North America. On the Rio Grande National Forest, Engelmann spruce is the principal host. The spruce beetle may persist for hundreds of years in spruce stands as a rarely encountered, endemic insect. Under the right conditions, they may have huge, intense outbreaks over large areas of forest (Eager et al. 2012, Romme et al. 2009).

Since the early to mid-2000s, large spruce beetle outbreaks have occurred on several forests in Colorado and Wyoming, including the Rio Grande. Aerial surveys show that the spruce beetle affected up to 300,000 acres on the Rio Grande National Forest from 2000 to 2011 (Eager et al. 2012). Since that time, more forest has been impacted by spruce beetle, which makes it the most widespread forest pest in the state of Colorado for several years running (CSFS 2014). Many areas on the Rio Grande National Forest affected by spruce beetle have 80 to 100 percent mortality.

Under average conditions, the susceptibility of a stand to spruce beetle infestation is dependent on its physiographic location, the average diameter of spruce in the stand, and the proportion of spruce in the canopy. In general, spruce stands in well-drained creek bottoms, with average diameters greater than 16

inches, basal areas greater than 150 square feet, and canopies comprising more than 65 percent spruce, are highly susceptible to outbreaks. However, under epidemic population levels all sizes of Engelmann spruce can be infested and killed. Under the current outbreak, saplings less than 5 inches diameter have been killed in the highest beetle population areas.

The spruce beetle is native to spruce ecosystems and populations of this insect have always been present in the area. Most of the time, beetle populations exist at relatively low levels with infrequent irruptive outbreaks. It is difficult to measure the frequency of these large mortality events on the Rio Grande National Forest prior to Euroamerican settlement. There has been one earlier spruce beetle outbreak between 1980 and 1985 on the Del Norte District of the Rio Grande National Forest.

Root diseases impact trees in several ways; killing them by windthrow or girdling of the roots; and stressing host trees, making them susceptible to secondary agents, such as bark beetles or drought. Root disease fungi co-evolved with their hosts in equilibrium. Disease centers would expand, then break up as they became filled with immune or tolerant species. Later, as the fungus died out of these areas (reducing, but not eliminating inoculum levels), more susceptible species would appear, starting the cycle again. Management actions such as fire control and selective-logging practices often promote the spread of root disease by favoring the regeneration of more susceptible tree species (in particular, true firs and Douglas-fir) and by leaving stumps which become new food sources for the fungi.

On the Rio Grande National Forest, the two most common root diseases are Armillaria, caused by *Armillaria sp*., and annosus, caused by *Heterobasidion annosum. Armillaria* root disease is found on all commercially important species of conifers and hardwoods in the area (James and Goheen 1980). The disease affects trees of all ages, though smaller and less vigorous trees typically succumb more rapidly to the girdling action of the fungus. *Armillaria* is particularly damaging to the true-fir hosts.

Heterobasidion annosum causes root and butt decay in trees of all age classes. On the Rio Grande National Forest, annosus root disease is most prevalent on white and subalpine fir. In the past, it was identified on white fir in several locations on the Conejos Peak and Saguache Ranger Districts (James and Gilman 1979). James and Goheen (1980) also found annosus infection in their roadside survey of true-fir mortality centers in Southern Colorado.

Scattered subalpine fir mortality is often a combination of armillaria root disease and western balsam bark beetle. Significant mortality of subalpine fir occurred after the drought in the early 2000s on the Rio Grande National Forest, scattered throughout stands with older subalpine fir (Eager et al. 2012).

The mountain pine beetle, a native insect, attacks and kills pine trees. Although the predominant host species are lodgepole pine and ponderosa pine; on the Rio Grande National Forest, mountain pine beetle will also attack limber pine, bristlecone pine, and even pinyon pine (Eager et al. 2012). During low population phases, this beetle attacks any stressed pine trees. When a large number of host trees are stressed due to drought or other factors, the population of mountain pine beetles can grow very large and start to target healthy trees (Eager et al. 2012).

While mountain pine beetle has gotten a lot of attention in the Rocky Mountain Region, the Rio Grande National Forest has only small to moderate amounts of lodgepole, ponderosa, limber, and bristlecone pine forests and recent population levels have remained relatively low, so the effect on the forest hasn’t been as great as it has been region-wide.

Mountain pine beetles exist wherever ponderosa pine grows on the Rio Grande National Forest, and scattered tree-killing by this insect may always be found somewhere in the foothills zone. A 1940 report

on insect control documents that 3,900 acres of ponderosa pine were affected by the mountain pine beetle and that efforts were made to control the infestation (USDA Forest Service 1940).

Mountain pine beetle activity rose after the drought of the late 1990s and early 2000s, but has declined since then. Much of this activity was in the north-eastern portion of the forest. Suppressing wildfires over the last 100 years has had an immense influence on the density and age distribution of ponderosa pine stands. With fewer fires to thin stands and create openings where regeneration could become established, ponderosa pine is growing in dense, even-aged, mature stands with few young trees. Stands with these features are susceptible to infestations of mountain pine beetle.

The Douglas-fir beetle attacks and kills mature Douglas-fir trees. It prefers older and injured trees, especially fire-damaged or scorched trees (Eager et al. 2012). It is most prevalent in dense stands with large trees. Douglas-fir beetle has caused noticeable mortality since the 1996 forest plan was released, especially after the drought of the late 1990s and early 2000s. Currently, mortality from Douglas-fir beetle is low, with some scattered patches of recent mortality (Eager et al. 2012).

The western spruce budworm is the most prominent defoliating insect on the Rio Grande National Forest. A native species, it is the most widely distributed and destructive defoliator of coniferous forests in western North America. The budworm feeds on Douglas-fir, white fir, subalpine fir, blue spruce, and Engelmann spruce. This insect causes defoliation of tree tops and understory host trees. It rarely kills its host outright, but years of defoliation can weaken trees and make them susceptible to bark beetles (Eager et al. 2012).

Western spruce budworm activity has recently declined after being at a high level on the Rio Grande National Forest (Eager et al. 2012). Budworm activity is generally greater in multi-storied stands because these stands provide a “safety-net” when the larvae drop down through the canopy on silk threads, looking for new foliage (Eager et al. 2012).

Swetnam and Lynch (1989) performed a tree-ring reconstruction of the history of western spruce budworm outbreaks on the Colorado Front Range and the Sangre de Cristo Mountains of New Mexico. At least nine outbreaks were identified between 1700 and 1983, their average duration was 12.9 years. The average interval between initial years of successive outbreaks was 34.9 years. Ryerson et al. (2003) performed a tree-ring reconstruction on the history of spruce budworm outbreaks in the San Juan Mountains of the Rio Grande National Forest. They identified 14 widespread budworm outbreaks over the past 350 years. They also found that regular outbreaks occurred for at least the past 600 years and have been regionally synchronous across the Rio Grande National Forest, with peaks in activity at approximately 25 to 40 year intervals, and larger events at 83-year intervals.

A history of fire exclusion and passive management has resulted in stand structures favorable to spruce budworm (Eager et al. 2012). However, tree-ring analyses are inconsistent as to whether outbreaks since the early part of the twentieth century have been more extensive and damaging than in previous decades (Swetnam and Lynch 1989, Ryerson et al. 2003).

Western tent caterpillar is the most significant defoliator of deciduous trees on the Rio Grande National Forest. The larvae of this native insect may feed on plants in at least a dozen genera, including oaks, roses, poplars, and birches. Most important, the larvae feed gregariously on the leaves of aspens and construct silken tents within their crowns. Repeated defoliation of aspen by this insect results in branch die-back and tree mortality. When large areas of aspen die as a result of repeated defoliation, the clones fail to regenerate, causing openings or changes in forest type.

The first reference to a tent caterpillar outbreak on the Rio Grande National Forest was found in an unpublished history of the forest (USDA Forest Service 1929). The report refers to a tent caterpillar infestation along the Conejos River which began in 1914 and spread to 300 to 400 acres by 1929. The same report mentions that 20 years previously (1894) the caterpillars had killed all the aspen in that same locality. A tent caterpillar outbreak which began in 1976, southeast of Pagosa Springs on the San Juan National Forest, spread into Chama Basin on the Rio Grande National Forest by the early 1980s (Raimo 1984b, Raimo 1985). By 1984, the area of severe aspen defoliation occurring on both Forests had increased to 94,000 acres. The tent caterpillar populations began to subside in 1985. However, defoliation by western tent caterpillar has been significant in recent years on and adjacent to the Rio Grande National Forest (Eager et al. 2012).

The number and size of tent caterpillar outbreaks depends on the number and size of contiguous areas of mature aspen. The vegetation modelling s done suggests that historically, aspen dominated 23 percent of the forested lands on the Rio Grande National Forest. Today, aspen occupies approximately 14 percent of the forested lands. Therefore, tent caterpillar outbreaks today may be smaller and less numerous than those that occurred prior to settlement.

Dwarf mistletoes are parasitic flowering plants which damage their hosts by reducing growth, lowering wood quality, and killing or predisposing the trees to attack from other pests. Although losses from dwarf mistletoe are not as visible as those caused by insects, the cumulative impacts on growth and mortality are considerable over the life of the forest.

Of over 1,200 stand exams collected from 1996 to 2015, 18 percent included field observations of mistletoe, which included about 40 percent of the stand exams in Douglas-fir and ponderosa pine. Three species of dwarf mistletoe are found on the Forest - lodgepole pine dwarf mistletoe (*Arceuthobium americanum*), ponderosa pine dwarf mistletoe (*A. vaginatum* ssp. *cryptopodum*), and Douglas-fir dwarf mistletoe (*A. douglasii*). Though occasionally found on other hosts, each of the dwarf mistletoes is largely specific to its host species.

Although little documentation exists with regard to the history of dwarf mistletoe conditions on the Rio Grande National Forest, we know that these parasites have been in North America at least since the Miocene period, or at least 25 million years (Hawksworth 1978). The co-evolution of host and parasite has resulted in a highly specialized relationship in which the two were essentially in balance. Historically, fire played a major role in determining the distribution of dwarf mistletoe by affecting stand composition and sanitizing infested stands. With fire suppression, the distribution and impacts of dwarf mistletoes have undoubtedly increased. Past management practices, such as the incomplete removal of infested trees in timber sale areas, and the perpetuation of uneven-aged stand conditions (that promote the spread of dwarf mistletoe from overstory to understory trees), have also accentuated the distribution and impacts of the disease. At present, the magnitude of growth loss and mortality due to mistletoe on the Forest, though considerable, has not been documented.

An outbreak of pinyon ips, triggered by the drought in the late 1990s and early 2000s, led to heavy mortality of pinyon trees in southwest Colorado (Eager et al. 2012). Although pinyon mortality was recorded on the Rio Grande National Forest, it was found at lower levels relative to the forests west of the Continental Divide. On the Rio Grande National Forest, Pinyon ips usually affects only small clumps and individual trees (Eager et al. 2012).

The vegetation modelling that was done included background or endemic insect and disease activity as well as larger insect outbreaks. The rates assumed for these larger outbreaks are in table 7.

Table 7. Insect outbreak parameters for the vegetation modelling based on expert feedback. Background/endemic insect and disease activity was modelled separately

	Spruce-Fir Forest	Mixed Conifer-Wet	Mixed Conifer-Dry		Pinyon-Juniper Woodland
Parameter	**Spruce beetle**	**Douglas-fir beetle***	**Douglas-fir beetle***	**Mountain pine beetle**	**Pinyon ips**
Interval between outbreaks (years)	100-200	35-50	35-50	50-70	35-50
Duration of outbreak (years)	10	5	5	5	5
Susceptible stands (in terms of tree size, canopy cover and structure)	large 40-100% canopy cover, single-story and multi-story	large 40-100% canopy cover, multi-story only	large 40-100% canopy cover, multi-story only	large 40-100% canopy cover, single-story and multi-story	medium 10-70% canopy cover
Post-outbreak stand structure (in terms of tree size and canopy cover)	large 40-70% canopy cover, medium 10-40% canopy cover, aspen	medium 10-70% canopy cover	medium 10-70% canopy cover	medium 10-70% canopy cover	small 10-70% canopy cover
Proportion of susceptible stands transitioning during outbreak	20%	15%	15%	25%	18%

* Where insect outbreaks include impacts of western spruce budworm defoliation, predisposing stands to outbreaks

The modeled spruce beetle outbreaks did not include extreme outbreaks, such as the spruce beetle outbreak that recently occurred on the Rio Grande National Forest. These were thought to be too rare to model. Therefore, the outbreaks represented in the model represent moderate- but not extreme-severity events.

Disturbance Summary

In summary, a variety of disturbance agents affect the landscape of the Rio Grande National Forest, including fire, insects, and disease. Some of these disturbances are happening more frequently than their historic rates, others less frequently. Due to fire suppression policies, fire is generally affecting the landscape at lower than historic rates. This also affects the levels of insects and disease. For instance, less frequent fire leads to denser, mature, even-aged ponderosa pine stands that are susceptible to mountain pine beetle. It can also lead to conditions favorable for outbreaks of dwarf mistletoes, root diseases, and western spruce budworm. In contrast, lower amounts of aspen have led to lower levels of western tent caterpillar. With a changing climate, it is thought that large fires and insect outbreaks will increase in frequency and size (Vose et al. 2012).

Assessment of Ecosystem Integrity (12.14): Connectivity and Fragmentation

Habitat connectivity is an indicator of ecosystem integrity. Within various forest types, connectivity differs depending on the disturbance regimes and ecosystems processes that maintain them. Species need to be able to move and interact throughout a landscape. This ability can aid a species and its survival in general and especially when their environment is changing. It can also help maintain genetic diversity within a species.

Connectivity can be assessed in a variety of ways and with metrics such as patch size, edge length, and the percent of forest interior. A comprehensive connectivity analysis has not been completed on the Rio Grande National Forest, but some general patterns can be seen in the maps below. Figure 4 shows the connectivity of the Rio Grande National Forest with the other national forests, national parks, and federal land adjoining it. Wilderness and roadless areas are also shown. Figure 5 shows the areas currently in late-successional forest.

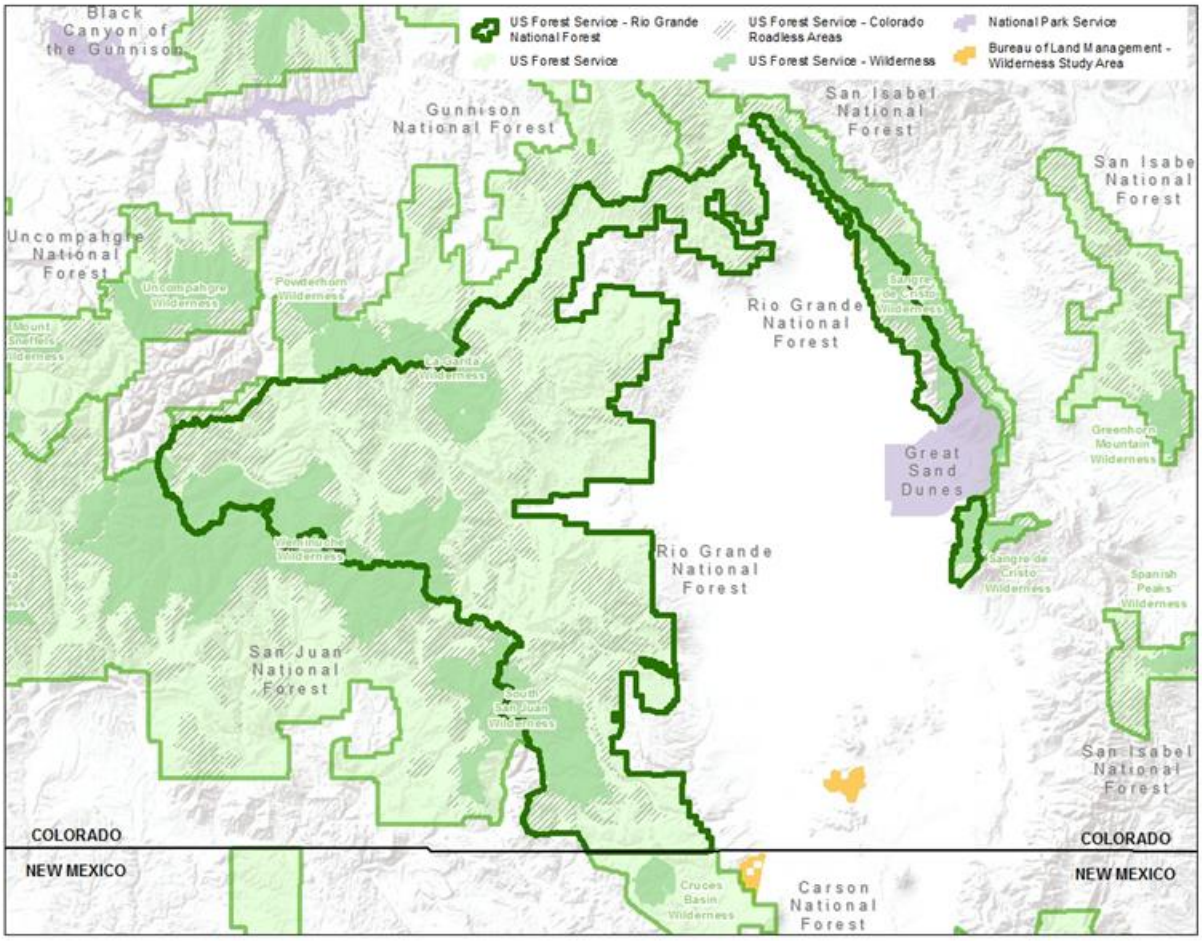

Figure 4. Map of the Rio Grande National Forest, including wilderness, roadless areas, and nearby national forests, national parks, and other federal land

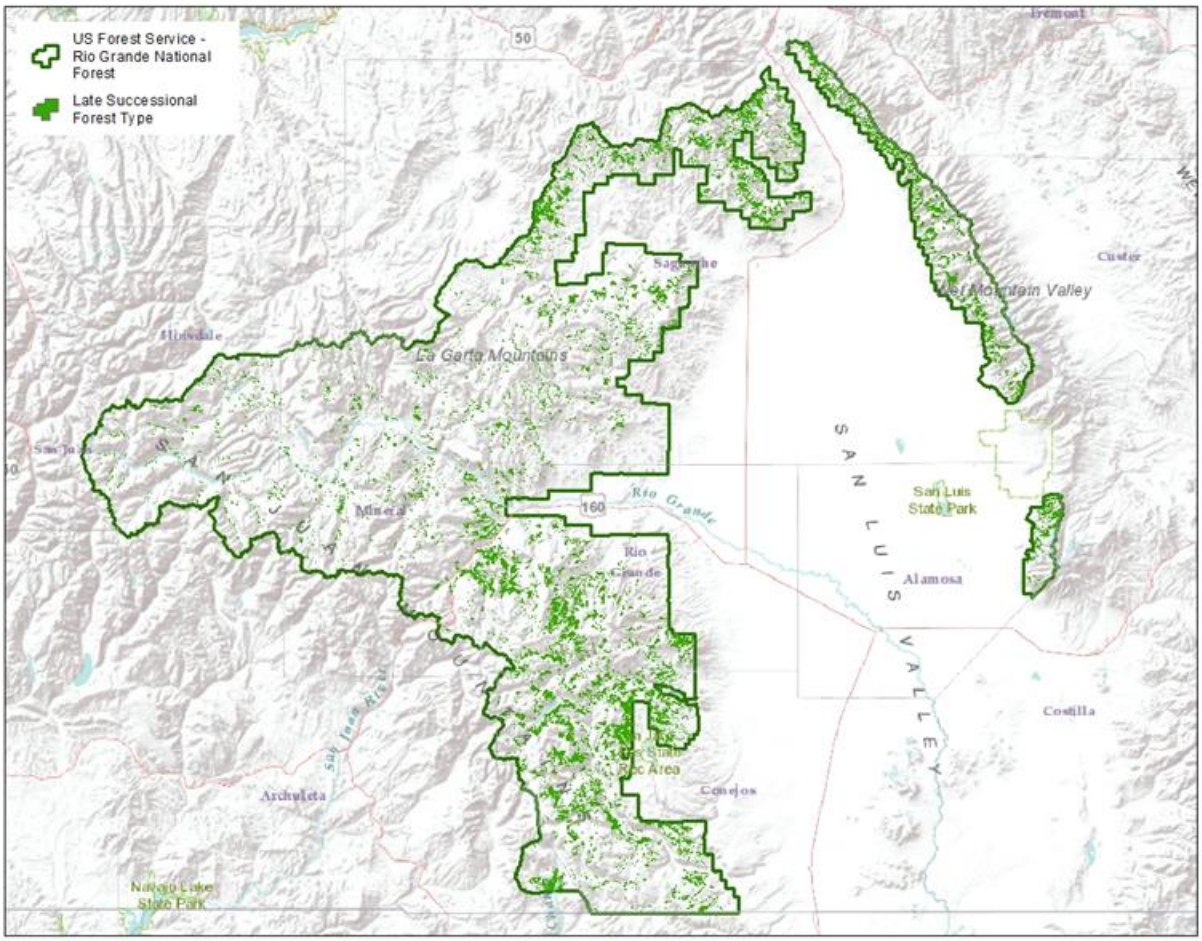

Figure 5. Map of current late-successional habitat on the Rio Grande National Forest.

Human land uses can fragment forests and grasslands into smaller patches of habitat. This fragmentation affects both habitat size and connectivity, can increase predation, and is especially problematic for species needing large uninterrupted areas of habitat for survival. Increased fragmentation is associated with decreased ecosystem function and biodiversity (Haddad et al. 2015).

In order to assess human-caused fragmentation on the Rio Grande National Forest, several map layers were analyzed. Metrics include measures of fragmentation such as roads, as well as measures of large, intact landscapes such as wilderness. Metrics consist of:

- acreage in designated wilderness
- acreage in roadless areas under the 2012 Colorado Roadless Rule
- acreage in research natural areas
- acreage covered by roads (maintenance levels 2 through 5 Forest Service roads included) and railroads, with a 300 foot buffer
- acreage in private in-holdings

Estimates were made for each land type association and are listed below. Estimates are acres in each land type association, with the percentage of each land type association calculated as well.

Table 8. Acreage and percentage of each land type association currently in designated wilderness, in roadless areas, or part of a research natural area

Land Type Association Name	Total Acres of Land Type Association	Acres in Designated Wilderness / %	Acres in Roadless Areas / %	Acres in Research Natural Areas / %	Total Acres / %
Engelmann Spruce on Mountain Slopes	992,157	199,706 / 20%	276,648 / 28%	7,699 / 1%	**484,052 / 49%**
Aspen on Mountain Slopes	41,384	1,231 / 3%	16,040 / 39%	0 / 0%	**17,271 / 42%**
White Fir and Douglas-fir on Alpine Summits	145,899	8,452 / 6%	42,978 / 29%	1,123 / 1%	**52,553 / 36%**
Alpine Sedges and Forbs on Alpine Summits	273,469	118,190 / 43%	76,273 / 28%	5,857 / 2%	**200,321 / 73%**
Ponderosa Pine and Douglas-fir on Mountain Slopes	17,015	771 / 5%	7,510 / 44%	403 / 2%	**8,685 / 51%**
Pinyon on Mountain Slopes	65,425	1,454 / 2%	5,742 / 9%	5,174 / 8%	**12,370 / 19%**
Gambel Oak on Mountain Slopes	3,596	172 / 5%	1,689 / 47%	0 / 0%	**1,861 / 52%**
Arizona Fescue on Mountain Slopes	317,028	18,799 / 6%	73,235 / 23%	73 / 0%	**92,107 / 29%**
Thurber Fescue on Mountain Slopes	29,958	1,217 / 4%	5,113 / 17%	266 / 1%	**6,596 / 22%**
Willows and Sedges on Floodplains	79,099	13,181 / 17%	12,805 / 16%	65 / 0%	**26,052 / 33%**
Nonvegetated Areas on Mountain Slopes	62,762	18,258 / 29%	26,818 / 43%	232 / 0%	**45,308 / 72%**
Western Wheatgrass and Other Low-Elevation Grasslands on Alluvial Fans	54,323	6 / 0%	1844 / 3%	1561 / 3%	**3411 / 6%**
Engelmann Spruce on Landslides	31,968	4,799 / 15%	12,065 / 38%	0 / 0%	**16,864 / 53%**
Blank	8,305	1,677 / 20%	1,089 / 13%	187 / 2%	**2,954 / 36%**

You can see that a large percentage of the area in several of the land type associations is protected from human-caused fragmentation by virtue of it being in a designated wilderness area, roadless area, or research natural area. However, some land type associations, such as Pinyon on mountain slopes, Arizona Fescue on mountain slopes, and Thurber Fescue on mountain slopes, are less protected from human-caused fragmentation and have less than 30 percent of their area in designated wilderness, roadless areas, and research natural areas. This is especially the case for Western wheatgrass and other low-elevation grasslands on alluvial fans, which has only 6 percent of its area in these categories.

Table 9. Acreage and percentage in each land type association that is covered by roads and railroads, with a 300 foot buffer, or that is in private in-holdings

Land Type Association Name	Total Acres in Land Type Association	Acres in Roads and Railroad with Buffer / %	Acres in Private In-holdings / %	Total Acres / %
Engelmann Spruce on Mountain Slopes	992,157	42,918 / 4%	18,568 / 2%	**61,485 / 6%**
Aspen on Mountain Slopes	41,384	2,788 / 7%	1,568 / 4%	**4,355 / 11%**
White Fir and Douglas-fir on Alpine Summits	145,899	4,642 / 3%	1,829 / 1%	**6,471 / 4%**
Alpine Sedges and Forbs on Alpine Summits	273,469	2,732 / 1%	826 / 0%	**3,558 / 1%**
Ponderosa Pine and Douglas-fir on Mountain Slopes	17,015	22 / 0%	226 / 1%	**247 / 1%**
Pinyon on Mountain Slopes	65,425	2,686 / 4%	8,848 / 14%	**11,535 / 18%**
Gambel Oak on Mountain Slopes	3,596	80 / 2%	4 / 0%	**84 / 2%**
Arizona Fescue on Mountain Slopes	317,028	26,802 / 8%	32,262 / 10%	**59,064 /19%**
Thurber Fescue on Mountain Slopes	29,958	2,435 / 8%	4,775 / 16%	**7,211 / 24%**
Willows and Sedges on Floodplains	79,099	9,153 / 12%	12,966 / 16%	**22,119 / 28%**
Nonvegetated Areas on Mountain Slopes	62,762	890 / 1%	2,697 / 4%	**3,587 / 6%**
Western Wheatgrass and Other Low-Elevation Grasslands on Alluvial Fans	54,323	6,233 / 11%	12,355 / 23%	**18,588 / 34%**
Engelmann Spruce on Landslides	31,968	1,907 / 6%	755 / 2%	**2,662 / 8%**
Blank	8,305	237 / 3%	1,560 / 19%	**1,797 / 22%**

You can see that some land type associations have more human-caused fragmentation due to roads, railroads, and private in-holdings than others. Five of the land type associations – pinyon on mountain slopes, Arizona fescue on mountain slopes, Thurber fescue on mountain slopes, willows and sedges on floodplains, and Western wheatgrass and other low-elevation grasslands on alluvial fans – have more than 15 percent of their area impacted by roads, railroads, and private in-holdings. The other land type associations have less fragmentation due to these factors, with usually less than 10 percent of their areas impacted.

Assessment of Ecosystem Integrity (12.14): Late-successional Habitats

Late-successional habitats are an important part of a healthy ecosystem. They tend to have forest structure elements, such as large, older trees, large snags, and multiple canopy layers, that are important to some wildlife species, such as the Canada lynx (*Lynx canadensis*).

In order to assess the presence and change in late successional habitats through time, the state and transition modelling done by Oregon State University was used. This work modelled the presence of various habitat structural stages under current conditions and into the future. Late successional here is defined as habitat structural stages 4B and 4C for any of the cover types (except pinyon-juniper where there is no 4C) and is discussed below. Habitat structural stage class 4B corresponds to areas with mature trees (9 inches and larger) with 40 to 70 percent canopy cover. Habitat structural stage class 4C corresponds to areas with mature trees (9 inches and larger) with more than 70 percent canopy cover.

Based on these criteria, currently, only about 13 percent of the forest is late-successional (figure 5, table 10). This is projected to increase under current plan direction to 19-27 percent in the next 20-50 years. Even so, this is less than the amount (35 percent) thought to be in late successional habitat under historic conditions. If, as predicted, disturbances such as large fires and insect outbreaks increase in frequency due to climate change (Vose et al. 2012), the forest may have even less late successional habitat than model predictions suggest. In general, most forest types have less late successional habitat than under historic conditions (table 10).

Table 10. Proportion of various forest types in late successional habitat under historic conditions, current conditions, and in the future, based on state and transition modelling

	Percentage of Forest Type in Late Successional Habitat			
Forest Type	**Historic Conditions**	**Current Conditions**	**In 20 years**	**In 50 years**
Mixed Conifer - Dry	41%	30%	37%	45%
Mixed Conifer - Wet	53%	10%	21%	34%
Pinyon-Juniper Woodland	48%	3%	7%	16%
Spruce-Fir Forest Mix	46%	13%	24%	35%
All (including non-forest types)	35%	13%	19%	27%

Assessment of Ecosystem Integrity (12.14): Snags and down woody material

Snags and down woody material are essential for ecological integrity. They serve a variety of purposes, such as providing valuable wildlife habitat and supporting nutrient recycling. At least 84 terrestrial vertebrate species of wildlife rely on snags in Colorado (Hoover and Wills 1984). Snags are key for cavity nesting species such as woodpeckers, small forest owls, bats, and small mammals. Down woody material is important for water quality and reducing soil erosion.

From stand exam data collected on the Rio Grande National Forest (over 1200 exams collected from 1997 to 2015), the average number of large snags (12 inches in diameter and larger) has increased over time, especially since the spruce beetle outbreak (figure 6). Because stand exam data is biased towards the suitable timber base and the most recent stand exams were focused on the areas undergoing the most change, these values may not be representative of the forest as a whole. So in addition, we examined snag estimates using the forest inventory and analysis plot data (about 300 plots collected from 2002 – 2014) since the forest inventory and analysis plots give us a more unbiased, representative look at the forest as a whole (figure 7). In either case, it is clear that there has been a dramatic increase in the number of large snags on the forest, from about 5 per acre to about 15 to 25 per acre.

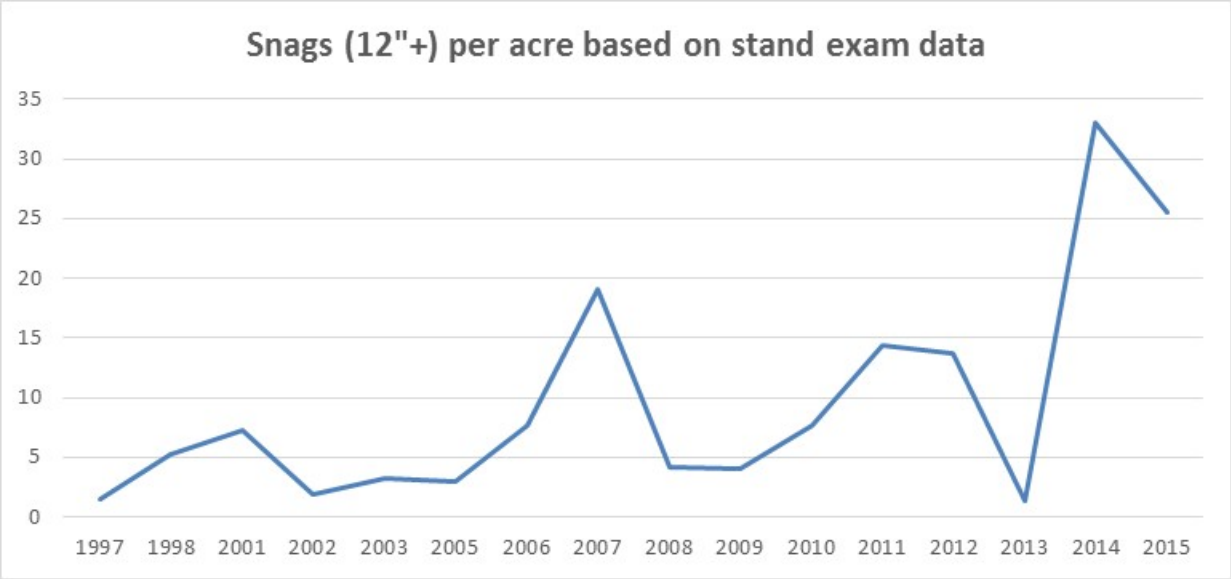

Figure 6. Snags per acre over time based on stand exam data collected on the Rio Grande National Forest

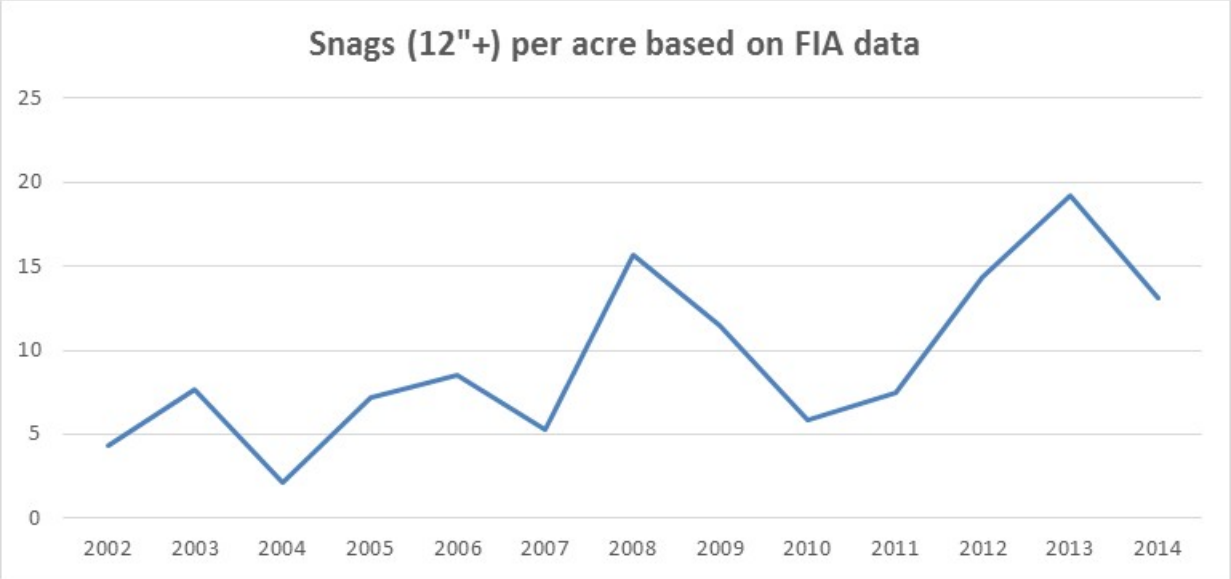

Figure 7. Snags per acre over time based on the forest inventory and analysis plot data collected on the Rio Grande National Forest

Table 11 compares the average snag estimates from stand exam data (2006 to 2015) and forest inventory and analysis plot data (2006 to 2014) to the minimum amounts recommended in the 1996 Rio Grande Forest Plan and to the minimum amounts suggested in the South Central Highlands Guide (Romme et al. 2009). The minimum requirements for retained snags in the 1996 Rio Grande Forest Plan are the minimum requirements for adequate wildlife habitat and ecosystem function and were taken from table III-1 and associated with a standard related to biodiversity. The minimum value for ponderosa pine was updated based on the Management Indicator Species Amendment in 2003.

Table 11. Snag estimates and suggested amount by forest type

Forest Type	Average Snags per acre from Stand Exam Data[a]	Average Snags per acre from Forest Inventory and Analysis data[a]	Minimum Snags per Acre[b]	South Central Highlands Guide
Spruce-Fir	45.0 / 31.4 / 20.8 (345 exams)	32.0 / 18.8 / 11.5 (86 plots)	2 (12”)	Sample old growth stand had 14.2 snags/acre with an average dbh of about 17 inches.
Lodgepole Pine	13.3 / 7.0 / 4.3 (44 exams)	3.0 / 3.0 / 3.0 (4 plots)	2 (10”)	
Aspen	14.1 / 7.4 / 4.7 (125 exams)	10.1 / 5.4 / 3.0 (44 plots)	2 (12”)	Cavity-nesting species preferred snags that averaged 50ft tall and 16” dbh (range 5-25”).
Douglas-Fir	11.5 / 7.0 / 4.4 (168 exams)	12.9 / 8.6 / 5.1 (24 plots)	2 (12”)	
Ponderosa Pine	3.3 / 1.9 / 1.3 (60 exams)	9.3 / 6.0 / 2.7 (11 plots)	3 (14”)	Minimum density of 1 14” snag to 2 10” snags based on current old growth. “In truth, we simply do not know densities or quantities of dead wood in the pre-1870 ponderosa pine forests of the South Central Highlands section.” For wildlife, minimum recommended densities are 1.73 – 5.2 snags/acre (10-20”), but these may be higher than what existed prior to fire exclusion and higher than necessary to maintain functional communities.

a - Values are snags per acre 10”+ / 12”+ / 14”+

b - Based on Table III-1 in the 1996 Plan, with the minimum diameter in parentheses

In general, data suggests that the forest is well-above the minimum amount of snags recommended for the various forest types. The only exception to this is in the ponderosa pine forest type, where both the stand exam and forest inventory and analysis data suggest that there is less than the desired 3 to 14 inch snags per acre.

Using this same stand exam set, only a portion of the exams included data collection on down woody material. Approximately 140 of the exams (2012 to 2015) collected data on down woody material using fuel transects. In addition, 300 exams (2014 to 2015) collected data on down woody material using fixed area plots. These two data sets were summarized to get the average down woody piece count (3 inch and above) per acre and average down woody biomass (tons per acre) by forest type.

This data suggests that the forest has a large volume of down woody material. The amount of down woody material 3 inches and larger in size varies heavily by forest type, as seen in table 12. It also varies heavily from stand to stand within a given forest type. The spruce-fir forest type has the highest levels of down woody material (3 inches and larger) and there was a large amount of variation in the down wood estimates for this type, varying from a minimum of less than 1 ton per acre to a maximum of 343 tons per acre. In general, the various forest types have more than the minimum amount recommended in the 1996 forest plan. The one exception to this is the ponderosa pine type, which averaged about 2.5 tons per acre, less than the suggested 4 to 9 tons per acre. These recent stand exams are the best data the forest has on

down woody material, but as noted earlier, these recent exams were specifically done in the areas undergoing the most change and may not be representative of the forest as a whole.

The forest inventory and analysis plot data did not include enough down wood information to allow for analysis.

Table 12. Down woody material estimates (3”and above) and suggested amount by forest type

Forest Type	Averages of Down Woody Material (3”+) from Stand Exam Transect Data	Averages of Down Woody Material (3”+) from Stand Exam Fixed Area Plot Data	Minimum Downed Logs (tons/acre)[a]	South Central Highlands Guide
Spruce-Fir	986 pieces/acre 83.6 tons/acre (56 exams)	260 pieces/acre 14.1 tons/acre (184 exams)	10-15 tons/acre	Sample old growth stand had 83 stems/acre of fallen dead trees with an average diameter of 17.5 inches.
Lodgepole Pine	211 pieces/acre 5.6 tons/acre (1 exam)	297 pieces/acre 7.9 tons/acre (25 exams)	5-10 tons/acre	
Aspen	748 pieces/acre 11.2 tons/acre (16 exams)	231 pieces/acre 7.0 tons/acre (44 exams)	3-5 tons/acre	
Douglas-Fir	313 pieces/acre 9.3 tons/acre (27 exams)	215 pieces/acre 7.6 tons/acre (29 exams)	5-10 tons/acre	
Ponderosa Pine	74 pieces/acre 2.7 tons/acre (10 exams)	99 pieces/acre 2.2 tons/acre (4 exams)	4-9 tons/acre	Downed logs should be a min of 2 pieces having 12” diameter based on current old growth. “In truth, we simply do not know densities or quantities of dead wood in the pre-1870 ponderosa pine forests of the South Central Highlands section.”

a - based on Table III-1 in 1996 Plan

In summary, as a result of the recent spruce beetle epidemic, the Rio Grande National Forest currently has a large amount of snags and down woody material, particularly in the spruce-fir forest type. These areas were often previously classified as late successional habitat (structural stages 4B and 4C) and will be important for assessing connectivity of habitat. As snags fall and down woody material decays, these values will most likely decrease. How fast this happens will depend on the forest type and a variety of other factors. Still, given the slow nature of these processes, a large quantity of snags and down woody material will persist on the forest, especially in the spruce-fir forests, into the foreseeable future. Long term, it is hard to predict how snag and down woody amounts may change. Disturbances such as large fires and insect outbreaks are predicted to increase in frequency in the Southwest due to climate change (Vose et al. 2012), in which case this high level of snags and down woody material may be maintained long into the future. We hope to develop snag and down wood prediction estimates later in the planning process.

Assessment of Ecosystem Integrity (12.14): Rare Communities and Special Habitats

Rare Communities

Colorado has more than 500 recognized terrestrial and aquatic plant communities (Colorado Natural Heritage Program website 2015). Many of these communities are considered rare either because they have always been rare or because they have become imperiled directly or indirectly by human-induced changes such as habitat loss, the introduction of exotic species, the alteration of natural disturbance regimes, or climate change. Aside from having intrinsic value, the loss of these rare communities may induce cascading ecosystem disturbances. In addition, a wider variety of species reduces our vulnerability to the impacts of climate change (USDA Forest Service 2011). Recognizing and protecting rare plant communities is crucial to preserving Colorado's diverse natural heritage. The Colorado Natural Heritage Program Methodology ranks species and communities according to their rarity or degree of imperilment and the importance of associated conservation areas. By prioritizing conservation efforts on rare communities and conservation areas that the Colorado Natural Heritage Program has identified that are relevant to the Rio Grande National Forest, we can ideally prevent the decline of the communities most at risk.

The current Rio Grande National Forest Plan FEIS, appendix E, describes six significant natural plant communities that had been identified by the Colorado Natural Heritage Program, shown below. At that time, there had been only a low-intensity search effort and inventory on the Forest for exemplary natural plant communities. Communities shown as relatively rare on the Forest by the Colorado Natural Heritage Program were probably attributed to low search effort and limited documentation in the Colorado Natural Heritage Program's database, rather than true rarity. The rarity of these six plant communities needs to be investigated further as the forest moves through the forest plan revision process.

Table 13. Significant natural plant communities on the Rio Grande National Forest, as identified by Colorado Natural Heritage Program, as part of the 1996 forest planning process

Arizona fescue-slimstem muhly	*Festuca arizonica-Muhlenbergia filiculmis*
Arizona fescue-mountain muhly	*Festuca arizonica-Muhlenbergia montana*
bristlecone pine/Arizona fescue	*Pinus aristata/Festuca arizonica*
pinyon pine-(one-seed juniper)/scribner needlegrass	*Pinus edulis-(Juniperus monosperma)/Stipa scribneri*
ponderosa pine/Arizona fescue	*Pinus ponderosa/Festuca arizonica*
Douglas-fir/common juniper	*Pseudotsuga menziesii/Juniperus communis*

Conservation Areas

Since the 1996 plan was written, additional data collection on the lands on and around the Rio Grande National Forest has been done by the Colorado Natural Heritage Program. In order to determine if any new areas with rare plant communities or species warrant attention, three Colorado Natural Heritage Reports were examined - the Saguache Closed Basin Inventory (Rondeau et al. 1998), the Inventory of Rio Grande and Conejos Counties (Kettler et al. 2000), and the Baca Grande Biological Assessment 2005 (Sovell 2006). These reports describe approximately 100 different potential conservation areas. This list was then filtered to only include those areas:

- with a biodiversity rank of B1 or B2 (outstanding or very high biodiversity significance),
- that are at least partially on the Rio Grande National Forest, and

- that are relevant based on an updated spreadsheet (October 2015) provided by Colorado Natural Heritage Program of ecological element occurrence on the Rio Grande National Forest.

Table 14 has the list of 14 potential conservation areas on the Rio Grande National Forest that fit these criteria. All of these areas have a B2 biodiversity rank and are described below.

Table 14. Potential conservation areas on the Rio Grande National Forest

CNHP Report	Potential Conservation Area
Saguache Closed Basin	660 Road Site
Saguache Closed Basin	Deadman Creek
Saguache Closed Basin	Elephant Rocks
Saguache Closed Basin	Head of Spanish Creek
Saguache Closed Basin	San Luis Lakes/Sand Creek
Rio Grande and Conejos	Alamosa River at Government Park
Rio Grande and Conejos	Cedar Spring Uplands
Rio Grande and Conejos	East Butte
Rio Grande and Conejos	Fivemile Park
Rio Grande and Conejos	Grayback Mountain
Rio Grande and Conejos	Hot Creek
Rio Grande and Conejos	Park Creek at Summit Pass
Baca Grande	Cottonwood Creek – Western Sangres
Baca Grande	Spanish Creek

The 660 Road Site - this site supports one of the largest populations known for *Neoparrya lithophila*, the rock-loving neoparrya, a south-central Colorado endemic plant. The site is over 75 percent privately owned with National Forest System land in the southern quarter.

Deadman Creek - this site supports a good example of the globally rare *Draba smithii (*Smith whitlow-grass). It also supports the state's exemplary and largest occurrence known of the rare *Populus angustifolia-Juniperus scopulorum* woodland (narrowleaf cottonwood-Rocky Mountain juniper montane riparian forest), a population of *Oncorhynchus clarki virginalis* (Rio Grande cutthroat trout), and a breeding colony of *Corynorhinus townsendii pallescens* (pale lump-nosed bat). A portion of this site is part of a research natural area within a wilderness area on the Rio Grande National Forest. A portion was also acquired by the Rio Grande National Forest as part of a land exchange in 2009. A small portion of this site is still privately owned.

Elephant Rocks - this site supports a medium-sized population of the *Neoparrya lithophila (*rock-loving neoparrya), a south-central Colorado endemic plant. There are also several other unique species of concern that aren't tracked as Element Occurrences by the Colorado Natural Heritage Program). The majority of this site is federally managed by the Bureau of Land Management and Rio Grande National Forest, of which part is a State Natural Area.

Head of Spanish Creek – this site includes a good occurrence of the globally rare mustard *Draba smithii (*Smith whitlow-grass), one of only eight known occurrences. The site is within the Sangre de Cristo wilderness area of the Rio Grande National Forest.

San Luis Lakes/Sand Creek – This site contains occurrences of eight plant communities, of which four are globally rare, four rare plant species, two rare mammal subspecies, seven rare birds, and one globally rare invertebrate species. This includes *Carex simulata* (wet meadow) and *Populus angustifolia/Salix drummondiana-Acer glabrum* (montane riparian forest). A portion of this site appears to be on the Rio Grande National Forest.

Alamosa River at Government Park – As described in the Inventory of Rio Grande and Conejos Counties (Kettler et al. 2000), this site supports several plant communities vulnerable on a global scale - *Alnus incana*-mixed *Salix* species (thinleaf alder-mixed willow species), *Carex simulata* (wet meadows), *Populus angustifolia/Alnus incana* (montane riparian forest), *Salix monticola*/mixed forbs (montane riparian willow carr), and *Salix monticola*/mixed graminoids (montane riparian willow carr). Approximately half the site is on the Rio Grande National Forest. The Colorado Natural Heritage Program Report notes that heavy grazing, heavy recreation use and the presence of Forest Service Road 250 have resulted in an abundance of non-native species. Water quality in the Alamosa River is an ongoing concern (Kettler et al. 2000).

Cedar Spring Uplands – As described in the Inventory of Rio Grande and Conejos Counties (Kettler et al. 2000), this site contains occurrences of *Neoparrya lithophila* (rock-loving neoparrya), *Pinus edulis/Stipa comata* (pinyon pine/needle-and-threadgrass woodland), and *Pinus edulis/Stipa scribneri* (pinyon pine/Scribner needlegrass woodland). The majority of the site is located in the Forest Service Spring Branch Research Natural Area.

East Butte – this site contains an excellent occurrence of *Neoparrya lithophila*, the rock-loving neoparrya. The site is located on public land managed by the Forest Service and Bureau of Land Management. Part of the site is incorporated into the Forest Service Elephant Rocks Special Interest Area.

Fivemile Park – this site contains occurrences of several moonworts (*Botrychium spp.)* that were noted as being imperiled and vulnerable in the Inventory of Rio Grande and Conejos Counties (Kettler et al. 2000). The site is located on the Rio Grande National Forest. The plant occurs on or near an old logging road that has been closed.

Grayback Mountain - this site contains occurrences of *Machaeranthera coloradoensis* (Colorado tansy-aster), *Pinus aristata/Ribes montigenum* (Upper montane woodland), and *Carex aquatilus* (Montane wet meadow). It is located on the Rio Grande National Forest. A Forest Service road, radio tower, and pipeline occur within or adjacent to the site.

Hot Creek –this site contains occurrences of *Gila pandora* (Rio Grande chub), *Astragalus Ripleyi* (Ripley's milkvetch), *Neoparrya lithophila* (rock-loving neoparrya), *Carex utriculata* (beaked sedge perched wetland), *Alnus incana/*mesic forb (thinleaf alder/mesic forb riparian shrubland), *Picea pungens/Cornus sericea* (blue-spruce/red-osier dogwood riparian forest), and *Pinus ponderosa/Festuca arizonica* (ponderosa pine/Arizona fescue woodland). The site is located on public land managed mainly by the Colorado Division of Wildlife and the Forest Service, with smaller amounts owned by private individuals. Part of the site is contained in the Forest Service Hot Creek Research Natural Area.

Park Creek at Summit Pass - this site contains an occurrence of *Machaeranthera coloradoensis* (Colorado tansy-aster). It is one of the largest populations documented in Colorado with approximately 700 plants. The site is located on the Rio Grande National Forest.

Cottonwood Creek – Western Sangres - this site supports occurrences of a globally imperiled plant community (*Populus angustifolia-Juniperus scopulorum* woodland) and a globally vulnerable plant community (*Psuedotsuga menziesii/Betula occidentalis* woodland).

Spanish Creek - this site supports an occurrence of a globally imperiled plant community (*Populus angustifolia-Juniperus scopulorum* woodland).

Special Habitats

There are also areas that are generally thought of as rare or special from a plant and animal habitat perspective and warrant additional conservation considerations. These special habitat areas generally have an outsized contribution to species diversity relative to their actual size or they may be habitat for species found nowhere else.

- Wetlands, which are sensitive to natural and human-caused stressors and often support a high amount of species diversity.
- Fens, which are unique and irreplaceable wetland types. The Rio Grande National Forest is currently working with Colorado Natural Heritage Program to map and rank the fens on the forest. This project will provide us with additional information about the forest's fen resources.
- Riparian areas, especially low elevation riparian areas, such as cottonwood/alder forests. This includes the narrowleaf cottonwood - Rocky Mountain juniper montane riparian community, which is imperiled in Colorado as well as globally imperiled (Sovell 2006).
- Ponderosa pine forests where fire has been allowed to play its natural role. One example of this is Hot Creek Research Natural Area.
- Aspen, especially the lower to middle elevation drier types of aspen communities mixed with Douglas-fir and other mesic species.
- Oakbrush, which is rare in the San Luis Valley and on the Forest and support a unique assemblage of wildlife species (approximately. 2,600 acres on the Rio Grande National Forest).
- Alpine fell fields and other special areas in alpine tundra.
- Caves and Mines, which are unique geological features that provide important habitat components for several of the 11 bat species known to utilize the Forest.

Terrestrial Ecosystems – Summary of Assessment of Ecosystem Integrity (12.14):

We examined a variety of key ecosystem characteristics for the terrestrial ecosystems of the Rio Grande National Forest. We assessed the amount and distribution of vegetation structural stages, including late-successional habitat, through state and transition modelling. We also used published literature to assess the natural range of variation for these ecosystems. We also assessed landscape patterns, fragmentation, snags and down woody material, and rare communities and special habitats. This work suggests the following:

- The spruce-fir and aspen forests are, in particular, undergoing rapid change due to a recent, large outbreak of spruce beetle and a recent large wildfire. High levels of mortality in mature Engelmann spruce in many areas have produced abundant open stands and dead standing and down wood. This, in turn, is allowing regeneration of aspen and an increasing trend in aspen forests.
- It is difficult to determine whether the terrestrial ecosystems on the Rio Grande National Forest are within the range of what would occur naturally. Modelling results indicate that the terrestrial ecosystems on the Rio Grande National Forest are, in general, moderately to substantially departed from what would occur naturally. However, some model assumptions and results do not agree with published literature. We know that very large spruce beetle outbreaks happened historically, but we

don't really know with any certainty whether this latest spruce beetle outbreak is a completely natural phenomenon or one influenced by climate change. The departure from the natural range of other types, such as mixed conifer, is uncertain as well.

- Currently only about 13 percent of the forest is in late-successional habitats based on the selection criteria we used. We expect this to increase under current plan direction, but future predicted levels are still less than the historical estimates of late-successional habitat. If, as predicted, disturbances such as large fires and insect outbreaks increase in frequency due to climate change, the forest may have even less late successional habitat than our model predictions suggest.
- Generally, the amount of snags and down wood on the forest is sufficient and higher than any known reference values. The one exception to this is in the ponderosa pine type. The lower amounts in the ponderosa pine type may be due to fire exclusion and the resulting departure from the natural fire regime, which is more significant in these lower elevation forests.
- Fragmentation on the forest varies by land type. Some types, especially Western wheatgrass and other low-elevation grasslands on alluvial fans, are more fragmented or have lower amounts in protected designations such as wilderness, roadless areas, or research natural areas. We recommend considering ways to improve this as part of plan revision.

Many opportunities exist to help us work towards reducing risk and adapting to climate change and the drivers and stressors of the various ecosystems. These include:

- Continuing to restore fire to its historical role on the forest. This may be through broadcast burning or through management of naturally occurring ignitions to include ecological benefits.
- Maintaining diversity on our forests, including the protection of any rare communities and special habitats known to occur on the Rio Grande National Forest.
- Testing non-traditional restoration treatments that achieve heterogeneous conditions at a variety of scales (Underhill et al. 2014).
- Restoring our riparian areas in any way we can. This could mean modifying standards and guidelines to ensure continued protection of these areas from sedimentation and erosion. It could also mean trying novel restoration activities, such as the reintroduction of beaver.
- Monitoring and regulation of livestock grazing.

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Appendix A. Spatial Data Documentation for the Rio Grande National Forest Planning Assessment

Several types of spatial data were used to support the state-and-transition simulation modeling (STSM) on the Rio Grande National Forest (RGNF). This appendix describes the spatial data layers, their sources, and the processing steps used to generate the final data for the STSM assessment. Spatial data covering the area within the RGNF was provided by the RGNF, and we added a 6.2 mi (10 km buffer) zone around the RGNF to encompass the broader landscape context. Data sources varied within and outside the RGNF for each spatial layer and are described below. All spatial data were converted to 120m grid cell rasters, and projected into the North American Datum 1983 Albers projection.

Ecosystems

Ecosystems represent broad vegetation types with similar vegetation, soil, climate and disturbance regimes. They are also called potential vegetation types (PVTs), ecological response units (ERUs), and biophysical settings (BPSs). Each ecosystem corresponds to a single STSM, describing the vegetation dynamics within that type. More details about STSMs can be found in Appendix B. The final data layer containing the ecosystem map is called ERU.tif.

Data Sources

Within the RGNF, the ecosystem map was based on Land Type Associations (LTAs) mapped by the RGNF, received on 12/09/2014. For the surrounding (6.2 mi buffer) landscape, ecosystems were based on the LANDFIRE Biophysical Settings (BPS) map (www.landfire.gov, metadata: http://www.landfire.gov/NationalProductDescriptions20.php). A full list of LTAs and BPSs found in the study area and their assignment to a modeled ecosystem is in table 15.

Table 15. Crosswalk of the 10 ecosystems modeled in the RGNF assessment to land type associations (LTAs) on the RGNF and to biophysical settings (BPSs) in the 6.2 mi buffer outside the RGNF. NA indicates a non-vegetated ecosystem that was not modeled.

Model Code	Ecosystem Name	Name of LTA (RGNF) or BPS (Outside RGNF)	Location
LF_2811440	Rocky Mountain Alpine Turf	Alpine Sedges and Forbs on Alpine Summits	RGNF
LF_2811590	Rocky Mountain Montane Riparian	Willows and Sedges on Floodplains	RGNF
R3_GAM	Rocky Mountain Gambel Oak - Mixed Montane Shrubland	Gambel Oak on Mountain Slopes	RGNF
R3_MCD	Mixed Conifer - Dry	White Fir and Douglas-fir on Alpine Summits	RGNF
R3_MCD	Mixed Conifer - Dry	Ponderosa Pine and Douglas-fir on Mountain Slopes	RGNF
R3_MCW	Mixed Conifer - Wet	Aspen on Mountain Slopes	RGNF
R3_MSG	Southern Rocky Mountain Montane-Subalpine Grassland	Arizona Fescue on Mountain Slopes	RGNF
R3_MSG	Southern Rocky Mountain Montane-Subalpine Grassland	Thurber Fescue on Mountain Slopes	RGNF
R3_PJO	Pinyon-Juniper Woodland	Western Wheatgrass and Other Low-Elevation Grasslands on Alluvial Fans	RGNF
R3_PJO	Pinyon-Juniper Woodland	Pinyon Pine on Mountain Slopes	RGNF
R3_SFM	Spruce-Fir Forest Mix	Engelmann Spruce on Mountain Slopes	RGNF
R3_SFM	Spruce-Fir Forest Mix	Engelmann Spruce on Landslides	RGNF
NA	NA	Nonvegetated Areas on Mountain Slopes	RGNF
NA	NA	Unknown	RGNF
LF_2811440	Rocky Mountain Alpine Turf	Rocky Mountain Alpine Fell-Field	Outside RGNF
LF_2811440	Rocky Mountain Alpine Turf	Rocky Mountain Alpine Dwarf-Shrubland	Outside RGNF
LF_2811440	Rocky Mountain Alpine Turf	Rocky Mountain Alpine Turf	Outside RGNF
LF_2811590	Rocky Mountain Montane Riparian	Rocky Mountain Montane Riparian Systems	Outside RGNF
LF_2811590	Rocky Mountain Montane Riparian	Rocky Mountain Subalpine/Upper Montane Riparian Systems	Outside RGNF
R3_GAM	Rocky Mountain Gambel Oak - Mixed Montane Shrubland	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	Outside RGNF
R3_ISS	Inter-Mountain Basins Greasewood Flat	Inter-Mountain Basins Greasewood Flat	Outside RGNF
R3_ISS	Inter-Mountain Basins Greasewood Flat	Inter-Mountain Basins Mixed Salt Desert Scrub	Outside RGNF
R3_MCD	Mixed Conifer - Dry	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	Outside RGNF

Model Code	Ecosystem Name	Name of LTA (RGNF) or BPS (Outside RGNF)	Location
R3_MCW	Mixed Conifer - Wet	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Outside RGNF
R3_MCW	Mixed Conifer - Wet	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - Low Elevation	Outside RGNF
R3_MCW	Mixed Conifer - Wet	Rocky Mountain Aspen Forest and Woodland	Outside RGNF
R3_MCW	Mixed Conifer - Wet	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland - High Elevation	Outside RGNF
R3_MCW	Mixed Conifer - Wet	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	Outside RGNF
R3_MSG	Southern Rocky Mountain Montane-Subalpine Grassland	Rocky Mountain Subalpine-Montane Mesic Meadow	Outside RGNF
R3_MSG	Southern Rocky Mountain Montane-Subalpine Grassland	Southern Rocky Mountain Montane-Subalpine Grassland	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Inter-Mountain Basins Semi-Desert Grassland	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Southern Rocky Mountain Ponderosa Pine Woodland	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Southern Rocky Mountain Juniper Woodland and Savanna	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Southern Rocky Mountain Ponderosa Pine Savanna	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Rocky Mountain Lodgepole Pine Forest	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Southern Rocky Mountain Pinyon-Juniper Woodland	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Colorado Plateau Pinyon-Juniper Woodland	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Western Great Plains Foothill and Piedmont Grassland	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Inter-Mountain Basins Juniper Savanna	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Western Great Plains Shortgrass Prairie	Outside RGNF
R3_PJO	Pinyon-Juniper Woodland	Rocky Mountain Foothill Limber Pine-Juniper Woodland	Outside RGNF
R3_SAG	Sagebrush Shrubland	Inter-Mountain Basins Montane Sagebrush Steppe	Outside RGNF
R3_SAG	Sagebrush Shrubland	Inter-Mountain Basins Semi-Desert Shrub-Steppe	Outside RGNF
R3_SAG	Sagebrush Shrubland	Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	Outside RGNF
R3_SAG	Sagebrush Shrubland	Inter-Mountain Basins Big Sagebrush Shrubland	Outside RGNF
R3_SAG	Sagebrush Shrubland	Rocky Mountain Lower Montane-Foothill Shrubland	Outside RGNF
R3_SAG	Sagebrush Shrubland	Inter-Mountain Basins Montane Sagebrush Steppe - Mountain Big Sagebrush	Outside RGNF
R3_SAG	Sagebrush Shrubland	Inter-Mountain Basins Montane Sagebrush Steppe - Low Sagebrush	Outside RGNF

Model Code	Ecosystem Name	Name of LTA (RGNF) or BPS (Outside RGNF)	Location
R3_SAG	Sagebrush Shrubland	Colorado Plateau Blackbrush-Mormon-tea Shrubland	Outside RGNF
R3_SFM	Spruce-Fir Forest Mix	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Outside RGNF
R3_SFM	Spruce-Fir Forest Mix	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Outside RGNF
NA	NA	Barren-Rock/Sand/Clay	Outside RGNF
NA	NA	Inter-Mountain Basins Sparsely Vegetated Systems	Outside RGNF
NA	NA	Open Water	Outside RGNF
NA	NA	Perrennial Ice/Snow	Outside RGNF
NA	NA	Rocky Mountain Alpine/Montane Sparsely Vegetated Systems	Outside RGNF

Data Processing

The LTA Layer (including the Baca area) was converted to a raster with 120m grid cells. Cell values were assigned based on the maximum LTA area contained in each grid cell. The crosswalk in Table A1 was applied to the LTA layer to assign an ecosystem to each grid cell. At the request of the RGNF, a sage grouse habitat layer (poncha_sagegrouse_habitat.shp, received 2/10/2014) was used to refine the ecosystem layer. In the final ecosystem map, only the area defined as sage grouse habitat in this layer was classified as Sagebrush Shrubland, and all other cells originally assigned to Sagebrush Shrubland were reassigned to Inter-Mountain Basins Greasewood Flat. Also by request of the RGNF, the Western Wheatgrass and Other Low-Elevation Grasslands on Alluvial Fans LTA (originally crosswalked to a Colorado Plateau Grassland ecosystem type) was reassigned to the Pinyon-Juniper Woodland ecosystem.

In the 6.2 mi buffered landscape context area, the LANDFIRE Biophysical Settings (BPS) layer (LANDFIRE 2012 1.3.0) was resampled from 30m to 120m using the majority resampling method (the value of the resulting 120m cell was the mode of the 30m input cells). The resulting 120m BPS layer was clipped to the project boundary and crosswalked as described in Table A1. The BPS ecosystem layer was erased within the RGNF boundary, and the BPS and LTA ecosystem layers were mosaicked into the final raster in tif format.

Current Vegetation Conditions

In addition to the ecosystems used to describe each major vegetation type, we also used a separate set of vegetation maps to characterize the current composition and structural characteristics of the vegetation in each modeled pixel. These maps were then used to assign each cell to a state class within the appropriate STSM. The final data layers containing this information are called RGNF_StCl_HRV_Updated.tif (for historic conditions) and RGNF_StCl_Updated.tif (for contemporary conditions).

Data Sources

Within the RGNF, current vegetation conditions were based on the FSVeg layer provided by the RGNF, received 10/16/2014. This layer was subsequently updated to reflect canopy cover percentages calculated using a canopy cover layer developed by the Remote Sensing Applications Center (RSAC) (rg_2014_canopycover.img raster, received 2/3/2015) to account for recent spruce beetle mortality (see *Data Processing*). Within the RGNF boundary, the LANDFIRE Succession Class (S-Class) map (LANDFIRE 2010 1.2.0) was used for the Rocky Mountain Alpine Turf and Rocky Mountain Montane Riparian STSMs because LANDFIRE models were used in those areas (LF_2811440 and LF_2811590 respectively) (www.landfire.gov, metadata: http://www.landfire.gov/NationalProductDescriptions17.php).

For the surrounding (6.2 mi buffer) landscape context area, current vegetation conditions for forested areas were based on Nationwide Forest Imputation System (NaFIS) maps (http://blue.for.msu.edu/NAFIS/data.html, metadata: http://blue.for.msu.edu/NAFIS/metadata/mz28/mz28_nnplt1_meta.html). In non-forested areas outside the RGNF, LANDFIRE S-Class data was used (www.landfire.gov, metadata: http://www.landfire.gov/NationalProductDescriptions17.php).

Data Processing

Within the RGNF, the original canopy cover values in the FSVeg layer were updated to new values from the RSAC canopy cover layer, representing recent tree mortality related to spruce beetles. The zonal statistics tool was used to calculate the average canopy cover value in the RSAC canopy cover raster within each FSVeg polygon. The result was an additional attribute in FSVeg containing an updated canopy cover value representing conditions after the spruce beetle outbreak, which was used in the

subsequent assignment of the FSVeg map to STSM state classes. Tree size did not change and retained the original FSVeg values. Within the forest boundary, FSVeg was used to categorize current vegetation conditions, except for where Rocky Mountain Alpine Turf or Rocky Mountain Montane Riparian ecosystems occurred. In those areas, LANDFIRE models (LF_2811440, LF_2811590) were used, and so input data was LANDFIRE S-Class rather than FSVeg. The crosswalks (outlined below) used the following fields from FSVeg to assign state classes: TotalTree (as updated to include RSAC canopy cover values), SIZE_CLASS, LAYERING, and HAB_STR_ST.

In the 6.2 mi buffer landscape context area, the NaFIS gridded map was resampled to 120m using the nearest resampling method. Areas covered by forest STSMs were clipped out of the resampled NaFIS grids and crosswalked to state classes as outlined below. The crosswalks used the following fields from NaFIS to assign state classes: CANCOV, POTR5_BA, LAYERS, and QMDA_GE_3. In non-forested areas, LANDFIRE S_CLASS was resampled to 120m using the majority resampling method. The erase tool was used to remove grid cells in forested areas where NaFIS data was used.

All data sources (FSVeg, S-Class, and NaFIS) were crosswalked to STSM state classes as outlined in the rule set below. One rule set was used for contemporary conditions to model future projections, and another was used for historic conditions. The historic conditions rule set is a modified version of the rule set below, and reclassifies the state classes containing exotic species to the most similar native state class. Differences between the two maps were minor. Once the crosswalks were applied, the FSVeg, NaFIS, and LANDFIRE current vegetation rasters were mosaicked into the final state class rasters.

The following rule set was used to allocate each cell in the current vegetation map to a state class within the appropriate STSM:

Region 3 Forest and Woodland Models: SFF, MCW, MCD, PJO

a. MCW model (Mixed Conifer Wet)

Rule set using FSVeg Data (for use within the RGNF boundary):

```
If ((AA_PCT)>40) Then StateClass = Aspen:Aspen
Else If ((TotalTree)<10) Then StateClass = 'Early A:GFB'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M')) Then StateClass = 'MC-T:F.vcm'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S')) Then StateClass = 'MC-T:E.vcs'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M')) Then StateClass = MC-T:N.vmm'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S')); Then StateClass = 'MC-T:M.vms'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M'));" Then StateClass = 'MC-M:J.vom'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S')); Then StateClass = 'MC-M:I.vos'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='L')) Then StateClass = 'MC-T:D.mcs'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='L')) Then StateClass = MC-T:L.mms'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='L')) Then StateClass = 'MC-I:H.mos'
Else If (TotalTree)>=70) Then StateClass = 'MC-T:C.sc'
Else If ((TotalTree)>=40)) Then StateClass = ' MC-T:K.sm'
Else If ((TotalTree)<40)) Then StateClass = 'MC-I:G.so'
Else If ((HAB_STR_ST)='1M')) OR (((HAB_STR_ST)='1T')) OR ((FSFOR.HAB_STR_ST)='2S'))Then StateClass = 'Early
A:GFB'
```

Rule set using Gradient Nearest Neighbor (GNN) data (for use outside of the RGNF boundary):

```
If ((POTR5_BA)>16.2)) Then StateClass = 'Aspen:Aspen'
Else If ((CANCOV)<10)) Then StateClass = 'Early A:GFB'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>1)) Then StateClass = 'MC-T:F.vcm'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) Then StateClass = 'MC-T:E.vcs'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>1)) Then StateClass = 'MC-T:N.vmm'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) Then StateClass = 'MC-T:M.vms'
```

Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>=2)) Then StateClass = 'MC-T:J.vom'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) Then StateClass = 'MC-M:I.vos'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=25) Then StateClass = 'MC-T:D.mcs'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=25) 40Then StateClass = 'MC-T:L.mms'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=25) 40Then StateClass = 'MC-I:H.mos'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=13) Then StateClass = 'MC-T:C.sc'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=13) Then StateClass = 'MC-T:K.sm'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=13) Then StateClass = 'MC-I:G.so'
Else If ((QMDA_GE_3)<13));" Then StateClass = 'Early A:GFB'

b. SFM Model (Spruce Fir Forest Mix)

Rule set using FSVeg Data (for use within the RGNF boundary):

If ((AA_PCT)>40)) Then StateClass = ' Aspen:Aspen '
Else If ((TotalTree)<10)) Then StateClass = 'Early A:GFB'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M')) Then StateClass = 'SFM-T:F.vcm'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S')) Then StateClass = 'SFM-T:E.vcs'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M')) Then StateClass = ' SFM-T:N.vmm'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S')) Then StateClass = ' SFM-T:M.vms'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M')) Then StateClass = 'SFM-M:J.vom'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S')) Then StateClass = ‘SFM-M:I.vos’
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='L')) Then StateClass = 'SFM-T:D.mcs'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='L')) Then StateClass = ' SFM-T:L.mms'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='L')) Then StateClass = 'SFM-I:H.mos'
Else If ((TotalTree)>=70) Then StateClass = 'SFM-T:C.sc'
Else If ((TotalTree)>=40) Then StateClass = ' SFM-T:K.sm'
Else If ((TotalTree)<40) Then StateClass = 'SFM-I:G.so'
Else If ((HAB_STR_ST)='1M')) OR (((HAB_STR_ST)='1T')) OR ((FSFOR.HAB_STR_ST)='2S')) Then StateClass = 'Early A:GFB'

Rule set using Gradient Nearest Neighbor (GNN) data (for use outside of the RGNF boundary):

If ((POTR5_BA)>16.2)) Then StateClass = ' Aspen:Aspen '
Else If ((CANCOV)<10)) Then StateClass = 'Early A:GFB'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>=2)) Then StateClass = ' SFM-T:F.vcm '
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) Then StateClass = ' SFM-T:E.vcs '
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>=2)) Then StateClass = ' SFM-T:N.vmm'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) Then StateClass = ' SFM-T:M.vms'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>=2)) Then StateClass = 'SFM-T:J.vom'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) Then StateClass = 'SFM-M:I.vos'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=25) Then StateClass = 'SFM-T:D.mcs'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=25) 40Then StateClass = ' SFM-T:L.mms'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=25) 40Then StateClass = 'SFM-I:H.mos'
Else If ((CANCOV)>=70) Then StateClass = 'SFM-T:C.sc'
Else If ((CANCOV)>=40) Then StateClass = ' SFM-T:K.sm'
Else If ((CANCOV)<40) Then StateClass = 'SFM-I:G.so'

c. MCD Model (Mixed Conifer Dry)

Rule set using FSVeg Data (for use within the RGNF boundary):

If ((TotalTree)<10)) Then StateClass = 'MCD:A.GFB'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M'));" Then StateClass = 'MCD:M.vcm'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S'));" Then StateClass = 'MCD:l.vcs'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M'));" Then StateClass = 'MCD:T.vmm'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S'));" Then StateClass = ' MCD:R.vms'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='M'));" Then StateClass = 'MCD:K.vom'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='V') AND ((LAYERING)='S'));" Then StateClass = 'MCD:E.vos'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='L') AND ((LAYERING)='M'));" Then StateClass = 'MCD:L.mcm'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='L') AND ((LAYERING)='S'));" Then StateClass = 'MCD:H.mcs'

Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='L') AND ((LAYERING)='M'));" Then StateClass = 'MCD:S.mmm'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='L') AND ((LAYERING)='S'));" Then StateClass = ' MCD:Q.mms'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='L') AND ((LAYERING)='M'));" Then StateClass = 'MCD:J.mom'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='L') AND ((LAYERING)='S'));" Then StateClass = 'MCD:D.mos'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='M'));" Then StateClass = 'MCD:G.smc'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='M'));" Then StateClass = ' MCD:P.smm'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='M'));" Then StateClass = 'MCD:C.smo'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='S')) OR (((SIZE_CLASS)='E'));" Then StateClass = 'MCD:F.ssc'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='S')) OR (((SIZE_CLASS)='E'));" Then StateClass = ' MCD:O.ssm'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='S')) OR (((SIZE_CLASS)='E'));" Then StateClass = 'MCD:B.sso'
Else If ((HAB_STR_ST)='1M')) OR (((HAB_STR_ST)='1T'));" Then StateClass = 'MCD:A.GFB'

Rule set using Gradient Nearest Neighbor (GNN) data (for use outside of the RGNF boundary):

If ((CANCOV)<10)) Then StateClass = 'MCD:A.GFB'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>=2)) Then StateClass = 'MCD:M.vcm'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) StateClass = 'MCD:l.vcs'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>=2)) Then StateClass = ''MCD:T.vmm'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) StateClass = ' MCD:R.vms'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)>=2)) Then StateClass = 'MCD:K.vom'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=40) AND ((LAYERS)<=1)) Then StateClass = 'MCD:E.vos'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=25) AND ((LAYERS)>=2)) Then StateClass = 'MCD:L.mcm'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=25) AND ((LAYERS)<=1)) Then StateClass = 'MCD:H.mcs'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=25) AND ((LAYERS)>=2)) Then StateClass = 'MCD:S.mmm'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=25) 40AND ((LAYERS)<=1)) Then StateClass = 'MCD:Q.mms'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=25) AND ((LAYERS)>=2)) Then StateClass = 'MCD:J.mom'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=25) AND ((LAYERS)<=1)) Then StateClass = 'MCD:D.mos'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=13) Then StateClass = 'MCD:G.smc'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=13) Then StateClass = ' MCD:P.smm'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=13) Then StateClass = 'MCD:C.smo'
Else If ((CANCOV)>=70) Then StateClass = 'MCD:F.ssc'
Else If ((CANCOV)>=40) Then StateClass = ' MCD:O.ssm'
Else If ((CANCOV)<40) Then StateClass = 'MCD:B.sso'

d. PJO Model (Pinyon Juniper Woodland)

Rule set using FSVeg Data (for use within the RGNF boundary):

If ((TotalTree)<10)) Then StateClass = ' PJO:GFB'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='L')) OR (((SIZE_CLASS)='V')) Then StateClass = 'PJO:G.mvc'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='L')) OR (((SIZE_CLASS)='V')) Then StateClass = ' PJO:J.mvm'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='L')) OR (((SIZE_CLASS)='V')) Then StateClass = 'PJO:D.mvo'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='M')) Then StateClass = 'PJO:F.smc'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='M')) Then StateClass = 'PJO:I.smm'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='M')) Then StateClass = 'PJO:C.smo'
Else If ((TotalTree)>=70) AND ((SIZE_CLASS)='S')) OR (((SIZE_CLASS)='E')) Then StateClass = 'PJO:E.ssc'
Else If ((TotalTree)>=40) AND ((SIZE_CLASS)='S')) OR (((SIZE_CLASS)='E')) Then StateClass = ' PJO:H.ssm'
Else If ((TotalTree)<40) AND ((SIZE_CLASS)='S')) OR (((SIZE_CLASS)='E')) Then StateClass = 'PJO:B.sso'
Else If ((HAB_STR_ST)='1M')) OR (((HAB_STR_ST)='1T')) Then StateClass = 'PJO:GFB'

Rule set using Gradient Nearest Neighbor (GNN) data (for use outside of the RGNF boundary):

If ((CANCOV)<10)) Then StateClass = 'PJO:GFB'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=25) Then StateClass = 'PJO:G.mvc'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=25) Then StateClass = ' PJO:J.mvm'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=25) Then StateClass = 'PJO:D.mvo'
Else If ((CANCOV)>=70) AND ((QMDA_GE_3)>=13) Then StateClass = 'PJO:F.smc'
Else If ((CANCOV)>=40) AND ((QMDA_GE_3)>=13) Then StateClass = 'PJO:I.smm'
Else If ((CANCOV)<40) AND ((QMDA_GE_3)>=13) Then StateClass = 'PJO:C.smo'
Else If ((CANCOV)>=70) Then StateClass = 'PJO:E.ssc'
Else If ((CANCOV)>=40) Then StateClass = ' PJO:H.ssm'

Else If ((CANCOV)<40) Then StateClass = 'PJO:B.sso'

Region 3 Non-Forest Models: SAG, CPJ, GAM, ISS, MSG

a. SAG Model (Sagebrush Shrubland)

Rule set using FSVeg Data (for use within the RGNF boundary):

IF Tree_Cover >= 25, THEN state class = JP:OOM (late juniper)
ELSE IF Tree_Cover >=10, THEN state class = SPJ:OOO (early juniper)
ELSE IF Shrub_Cover >= 25 AND Grass_Cover < 5, THEN state class = S:SMA (shrub / depleted grass)
ELSE IF Shrub_Cover >= 25, THEN state class = SP:OMA (late reference)
ELSE IF Shrub_Cover >= 10, THEN state class = SP:OOA (mid reference)
ELSE state class = PS:OSA (early reference)

*note: exotic state classes are not included in this crosswalk because FSVeg does not record any polygons with cheatgrass as a dominant species. Therefore some state classes (SPX:MOA, X:MAA, XS:MOA, JX:MSO) will be absent in the initial conditions map. LANDFIRE also recorded few patches of exotic species (UE state class) within the RGNF boundary.

*note: this crosswalk also purposefully omits some state classes (D:MOA, YP:OMA) due to lack of sufficient information; therefore, they will also be absent in the initial conditions map

Rule set using LANDFIRE Data (for use outside of the RGNF boundary):

IF SClass = A, THEN state class = PS:OSA (early reference)
IF SClass = B OR C, THEN state class = SP:OOA (mid reference)
IF SClass = D OR E, THEN state class = SP:OMA (late reference)
IF SClass = UN, THEN state class = SPJ:OOO (early juniper-encroached)
IF SClass = UE, THEN state class = SPX:MOA (early exotic-encroached with remnant native)
ELSE Not Modeled

*note: this crosswalk purposefully omits some state classes (D:MOA, YP:OMA, S:SMA, X:MAA, XS:MOA, JX:MSO, JP:OOM) due to lack of sufficient information; therefore, they will be absent in the initial conditions map

b. GAM Model (Rocky Mountain Gambel Oak - Mixed Montane Shrubland)

Rule set using FSVeg Data (for use within the RGNF boundary):

IF Shrub_Cover + Tree_Cover >= 60, THEN state class = T:SSC (late reference)
ELSE IF Shrub_Cover + Tree_Cover >= 25, THEN state class = TP:SSM (mid-late reference)
ELSE IF Shrub_Cover + Tree_Cover >= 10, THEN state class = TP:OSO (mid reference)
ELSE state class = PM:MOA (early reference)

* note: this crosswalk uses <u>combined</u> tree plus shrub cover to allocate its structural stages

Rule set using LANDFIRE Data (for use outside of the RGNF boundary):

IF SClass = A, THEN state class = PM:MOA (early reference)
IF SClass = B OR C, THEN state class = TP:OSO (mid reference)
IF SClass = D, THEN state class = TP:SSM (mid-late reference)
IF SClass = E, THEN state class = T:SSC (late reference)
IF SClass = UN, THEN state class = T:SSC (late reference)
IF SClass = UE, THEN state class = PM:MOA (early reference)
ELSE Not Modeled

c. ISS Model (Inter-Mountain Basins Greasewood Flat)

Rule set using FSVeg Data (for use within the RGNF boundary):

IF Shrub_Cover >= 25, THEN state class = MP:SOA (late reference)
ELSE IF Shrub_Cover >= 10, THEN state class = MP:OOA (mid reference)
ELSE state class = PM:OSA (early reference)

*note: exotic state classes are not included in this crosswalk because FSVeg does not record any polygons with cheatgrass as a dominant species. Therefore some state classes (X:MSA, XM:OOA) will be absent in the initial conditions map. LANDFIRE also recorded few patches of exotic species (UE state class) within the RGNF boundary.

*note: this crosswalk purposefully omits some state classes (D:OOA) due to lack of sufficient information; therefore, they will also be absent in the initial conditions map

Rule set using LANDFIRE Data (for use outside of the RGNF boundary):

IF SClass = A, THEN state class = PM:OSA	(early reference)
IF SClass = B OR C, THEN state class = MP:OOA	(mid reference)
IF SClass = D OR E, THEN state class =MP:SOA	(late reference)
IF SClass = UN, THEN state class = MP:SOA	(late reference)
IF SClass = UE, THEN state class = XM:OOA	(exotic-encroached with remnant native)

ELSE Not Modeled

*note: this crosswalk purposefully omits some state classes (D:OOA, X:MSA) due to lack of sufficient information; therefore, they will be absent in the initial conditions map

d. MSG Model (Southern Rocky Mountain Montane-Subalpine Grassland)

Rule set using FSVeg Data (for use within the RGNF boundary):

IF DLF_SPECIES CONTAINS POPR, THEN state class = RP:COO	(exotic and ruderal-encroached)
ELSE IF Tree_Cover >= 10, THEN state class = NP:OSO	(conifer-encroached)
ELSE IF Grass_Cover >= 60, THEN state class = P:CAA	(late reference)
ELSE IF Grass_Cover >= 25, THEN state class = P:MAA	(mid reference)
ELSE state class = P:OAA	(early reference)

Rule set using LANDFIRE Data (for use outside of the RGNF boundary):

IF SClass = A, THEN state class = P:OAA	(early reference)
IF SClass = B OR C, THEN state class = P:MAA	(mid reference)
IF SClass = D OR E, THEN state class =P:CAA	(late reference)
IF SClass = UN, THEN state class = NP:OSO	(conifer-encroached)
IF SClass = UE, THEN state class = R:COO	(exotic and ruderal-encroached)

LANDFIRE Models: LF_2811440 and LF_2811590

a. LF_2811440 (Rocky Mountain Alpine Turf)

Rule set (used LANDFIRE data both within and outside of the RGNF boundary):

- If SClass = A or B or UE or SV Then state class = Early1:ALL
- If SClass = C or D or E or UE Then state class = Late1:CLS

b. LF_2811590 (Rocky Mountain Montane Riparian)

Rule set (used LANDFIRE data both within and outside of the RGNF boundary):

- If SClass = A or B or SV or UE Then state class = Early1:ALL
- If SClass = C or D or E or UN Then state class = Late1:ALL

Management Areas

A map of management areas was used to stratify the STSM modeling by planning zone, allowing treatments to take place in appropriate areas on the landscape. The final map containing the management areas modeled on the RGNF is called Pln_Zn_Updated.tif.

Data Sources

The original spatial data (rgnf_management_areas) was provided by the RGNF on 10/16/2014.

Data Processing

The management_areas layer did not include the Baca area as outlined in the LTA layer, so an additional feature was added to management_areas, using the union tool, which represented the area within the LTA

layer but not covered by the management_areas layer (management area description "In_LTA_layer_not_in_mgmt_areas" below). The management_areas layer was converted from multipart to singlepart polygons and converted to a raster with 120m grid cells.

The original management area layer contained 31 separate management areas, including the areas outside the RGNF in the 10km buffer zone (table 16). These 31 management areas were combined into 10 groups for modeling based on discussions with the RGNF. We further combined these 10 groups into three categories of management intensity, ranging from low to high. We examined STSM projections separately for each of these three management intensity categories separately but did not show results separately in our final report, as projections rarely showed substantial differences between management areas.

Table 16. Management areas in the RGNF, grouped into 10 categories that were modeled (Management Area Groups) and further grouped into 3 management intensity categories that were reported in the final report (Management Intensity). Management Area codes and descriptions are from the original data provided by the RGNF for this analysis.

RGNF MA Code	Management Area Description	Management Area Group	Management Intensity
1.11	Wilderness, Pristine	Wilderness	Low intensity
1.11	Inclusion - Research Natural Area in Pristine Wilderness	Wilderness	Low intensity
1.11	Inclusion - National Wild River in Pristine Wilderness	Wilderness	Low intensity
1.11	Inclusion - National Scenic River in Pristine Wilderness	Wilderness	Low intensity
1.12	Wilderness, Primitive	Wilderness	Low intensity
1.12	Inclusion - National Wild River in Primitive Wilderness	Wilderness	Low intensity
1.12	Inclusion - Research Natural Area in Primitive Wilderness	Wilderness	Low intensity
1.12	Inclusion - National Scenic River in Primitive Wilderness	Wilderness	Low intensity
1.13	Wilderness, Semi-Primitive	Wilderness	Low intensity
1.13	Inclusion - Research Natural Area in Semi-Primitive Wilderness	Wilderness	Low intensity
1.13	Inclusion - National Scenic River in Semi-Primitive Wilderness	Wilderness	Low intensity
1.13	Inclusion - National Scenic River in Research Natural Area in Semi-Primitive Wilderness	Wilderness	Low intensity
1.13	Inclusion - National Wild River in Semi-Primitive Wilderness	Wilderness	Low intensity
1.13	Inclusion - National Recreation River in Semi-Primitive Wilderness	Wilderness	Low intensity
1.5	National River System - Wild Rivers Designated and Eligible	Wilderness	Low intensity
3.3	Backcountry	Backcountry	Medium intensity
2.2	Research Natural Areas	Research Natural Areas	Medium intensity
3.1	Special Interest Areas - Emphasis on Use or Interpretation	Special Interest Areas/ National River System	Medium intensity
3.4	National River System - Scenic Rivers Designated and Eligible	Special Interest Areas/ National River System	Medium intensity
4.21	Scenic Byways or Railroads	Dispersed Recreation	High intensity
4.3	Dispersed Recreation	Dispersed Recreation	High intensity
4.4	National River System - Recreation Rivers Designated and Eligible	Dispersed Recreation	High intensity
5.11	General Forest and Rangelands - Forest Vegetation Emphasis	General	High intensity
5.13	Forest Production	General	High intensity
6.6	Grassland Resource Production	General	High intensity

RGNF MA Code	Management Area Description	Management Area Group	Management Intensity
5.41	Deer and Elk Winter Range	Wildlife	High intensity
5.42	Bighorn Sheep Range	Wildlife	High intensity
NA	Outside_RGNF	Outside_RGNF	None
NA	In_LTA_layer_not_in_mgmt_areas	Outside_RGNF	None
NA	Private Land Not Covered by This Plan	Private Land Not Covered by This Plan	None
8.22	Ski-Based Resorts - Existing and Potential	Ski-Based Resorts	None

Appendix B. State-and-Transition Simulation Model Documentation for the Rio Grande National Forest Planning Assessment

This appendix describes the state-and-transition simulation models (STSMs) used for the Rio Grande National Forest (RGNF) planning assessment. An overview of STSMs can be found in the main report.

Model Sources

STSMs used for the assessment were taken from the US Forest Service Region 3 (R3), Integrated Landscape Assessment Project (ILAP; http://oregonstate.edu/inr/ilap), and the LANDFIRE project (www.landfire.gov) (table 17). Each STSM represents one ecosystem (also called a potential vegetation type (PVT), ecological response unit (ERU) or biophysical setting (BPS)). Models are frequently referenced in this document based on the suffix of their model code (e.g. Mixed Conifer-Dry is referenced as MCD).

Table 17. Ecosystems modeled on the RGNF and their corresponding STSM model codes and original model sources. The model code suffix is used to identify models in the following documentation.

Ecosystem	Model Code	Model Source
Inter-Mountain Basins Greasewood Flat (Mixed Salt Desert Scrub)	R3_ISS	ILAP R3 ISS model
Mixed Conifer - Dry	R3_MCD	R3 MCD model
Mixed Conifer - Wet	R3_MCW	R3 MCW model (with half representing high elk browsing removed)
Pinyon-Juniper Woodland	R3_PJO	R3 PJO model
Rocky Mountain Alpine Turf	LF_2811440	LANDFIRE model 2811440
Rocky Mountain Gambel Oak - Mixed Montane Shrubland	R3_GAM	ILAP R3 GAM model
Rocky Mountain Montane Riparian	LF_2811590	LANDFIRE model 2811590
Sagebrush Shrubland	R3_SAG	ILAP R3 SAG model
Southern Rocky Mountain Montane-Subalpine Grassland	R3_MSG	ILAP R3 MSG model
Spruce-Fir Forest Mix	R3_SFM	R3 SFM model (with half representing high elk browsing removed)

Note that we originally included a Colorado Plateau grassland model (ILAP R3 CPJ model), but later combined it with R3_PJO based on feedback from the RGNF.

Model Alterations

We made substantial alterations to the major forested models for the Rio Grande planning assessment, including MCD, MCW, PJO and SFM. Non-forested and riparian models were not modified, except for wildfire probabilities (see below).

Structural Changes

Model structure varied widely among STSMs based on ecological type and model source. Model structure was not altered for most of the models, except for the forested models derived from Region 3

(SFM, MCW, MCD, and PJO). These original models defined canopy cover categories of 0-10%, 10-30% and >30%, which was deemed insufficient for the vegetation dynamics and planning needs on the RGNF. Therefore, we changed the canopy cover threshold between open and mid cover from 30% to 40%, and we added a set of state classes for canopy cover >70% (table 18, figure 8). The only exception was PJO, which did not contain state classes with canopy cover >70%. Original size classes based on diameter at breast height (DBH) from Region 3 were retained (table 18). Note these size class cutoffs are generally similar to Region 2, but that naming is different (e.g., in Region 3, trees of 5-10" DBH are called 'small' but in Region 2, trees of 5-9" DBH are called 'medium'). It is important to keep this difference in naming convention in mind when interpreting the state class output.

Table 18. Tree size and canopy cover classes used in the forested STSMs.

Tree Sizes	Inches
Seedling/sapling	0-5
Small	5-10
Medium	10-20
Large and very large	>20
Canopy Cover	**Percent**
Grass/forb/shrub	0-10%
Open	10-40%
Mid	40-70%
Closed	>70%

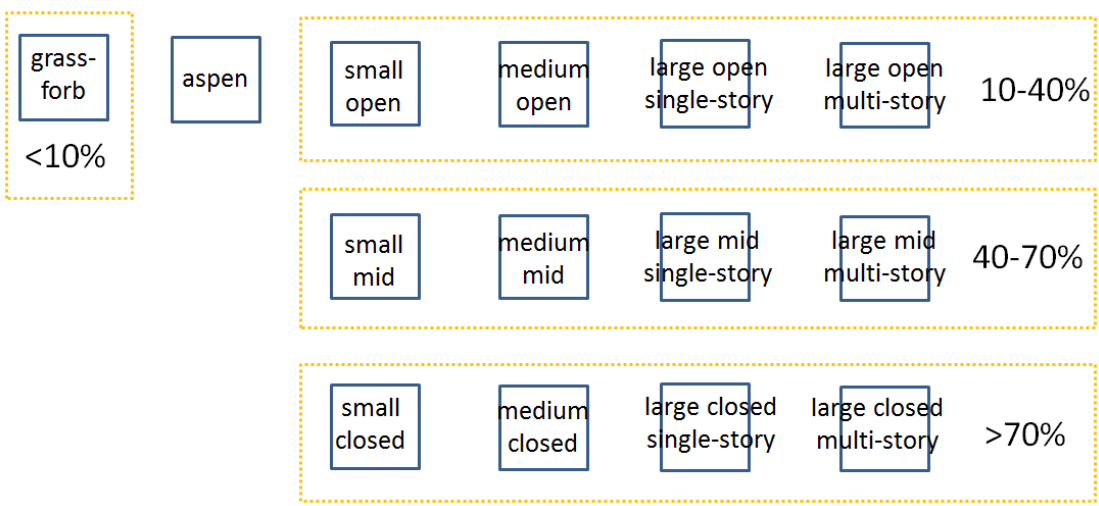

Figure 8. Example of forest STSM containing canopy cover breaks at 10%, 40% and 70% and size breaks between small, medium and large trees (as defined in table 18). Some STSMs distinguish single and multi-story canopy cover and may contain aspen state classes defined based on dominant species instead of structural characteristics.

Growth and Mortality

Growth and mortality rates were taken from Forest Vegetation Simulator (FVS) model runs completed in Region 3. These model runs were processed using the PRESIDE program by the Vegetation Application Group in Region 3, and used Region 3 forest inventory data, binned into size and cover classes as

outlined in table 18. The FVS growth and mortality probabilities reflect growth, mortality, and endemic disease and insect activity (not including outbreaks) and are labeled as transitions starting with the number “2” in the STSMs. Growth transitions causing an increase in size class were modified downward by 20% in the SFM model based on feedback from the RGNF and Region 2.

Wildfire

We developed wildfire probabilities to reflect historic conditions (used for HRV runs) and contemporary conditions (for future modeling under No Management and No Action scenarios) (table 19). Historic fire probabilities were based on literature and expert opinion. Contemporary fire probabilities were based on an analysis of burn perimeters from the Monitoring Trends in Burn Severity (MTBS) records for each ecosystem (see below).

Table 19. Wildfire probabilities, rotations and estimated annual acres burned for historic conditions (left) and contemporary conditions (right). Asterisks indicate systems where invasive species burn at a higher probability, potentially changing the overall probability and rotation. In these systems, fire rotation is dependent on the composition of state classes.

Ecosystem	Historic Conditions			Contemporary Conditions		
	Annual Ac Burned	Annual Probability	Fire Rotation	Annual Ac Burned	Annual Probability	Fire Rotation
Inter-Mountain Basins Greasewood Flat*	0	0.0001	10000	0	0.0002	6600
Mixed Conifer - Dry	1634	0.0100	100	545	0.0033	300
Mixed Conifer - Wet	296	0.0067	150	89	0.0020	500
Pinyon-Juniper Woodland	318	0.0025	400	170	0.0013	750
Rocky Mountain Alpine Turf	547	0.0020	500	37	0.0001	7400
Rocky Mountain Gambel Oak - Mixed Montane Shrubland	26	0.0100	100	2	0.0006	1650
Rocky Mountain Montane Riparian	793	0.0100	100	88	0.0011	900
Sagebrush Shrubland*	33	0.0067	150	2	0.0004	2600
Southern Rocky Mountain Montane-Subalpine Grassland	1734	0.0050	200	267	0.0008	1300
Spruce-Fir Forest Mix	2053	0.0020	500	1579	0.0015	650
Average acres burned per year	7,434			2,777		
Percent of RGNF burning per year	0.4%			0.1%		

For most of the models, we assumed that the overall probability of wildfire in each state class within a model was the same. However, fire severity and effects vary widely among state classes. Therefore, some state classes only contain nonlethal fire without causing any change in state class, some have a mix of severities and effects, and some contain only stand-replacing fire that causes shift to grass/forb/shrub conditions. For example, the probability of fire in grass/forb, open conditions and closed conditions within the MCD model does not vary, but the effects vary from only nonlethal in open state classes to a mixture of nonlethal, mixed-severity and stand-replacing in closed state classes. The fire pathways and mix of severities were based on the original models (Region 3, ILAP, LANDFIRE). Regardless of the number of severities or fire pathways, the overall probability of wildfire remains the same across all state classes within each STSM. The only exception is in systems with potential for exotic grass invasion, where exotic grasses increase the fire probability in certain state classes (see asterisks in table 19).

Fire probabilities for historic conditions were derived from literature, where available, and expert judgment where literature was unavailable (table 19, left column). Historic fire probabilities were available in LANDFIRE models (www.landfire.gov), but we determined that most LANDFIRE models contained a fire probability based on fire return interval, rather than fire rotation. It appeared that converting fire return intervals into an annual fire probability (by calculating its inverse) resulted in projections of too much area burning under historic conditions, and these numbers were not directly comparable to contemporary fire data (see below). Therefore, we did not use the LANDFIRE fire probabilities but instead conducted a literature review to determine fire rotations for each ecosystem in the region (Baker 2006, Buechling & Baker 2004, Floyd et al. 2000, Floyd et al. 2004, Kipfmueller & Baker 2004, Romme et al. 2001, Shinneman & Baker 2009, Sibold et al. 2006, Veblen et al 1994). We then incorporated expert opinion on the RGNF to check and modify literature values as needed, and filled in values where gaps existed.

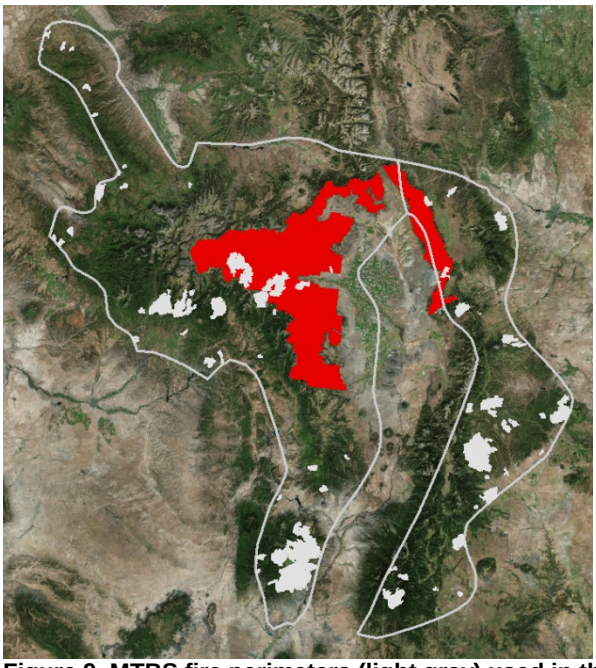

Figure 9. MTBS fire perimeters (light gray) used in the contemporary wildfire analysis on the RGNF. The RGNF is shown in red and the Southern Rocky Mountains ecoregion outlined in white.

Fire probabilities for contemporary conditions were derived from the MTBS dataset (table 19, right column), which provides fire perimeters for fires >1000 acres across the US. We used fire perimeters from 1984-2013 for the southern Rocky Mountains ecoregion (Figure B2). We calculated the area burned by ecosystem using the LANDFIRE biophysical setting vegetation layer, since it is consistent across the region. We converted the MTBS layer to a raster and combined the BPS raster with the MTBS raster using the raster calculator in ArcGIS. This analysis delineated burned and unburned areas in each ecosystem, and we calculated the annual fire probability by ecosystem as: area burned / total area of ecosystem / number of years of record (30). The MTBS dataset only records fires >1000 acres, so we also downloaded the Federal Wildland Fire Occurrence dataset to determine if fire probabilities would change when including smaller fires (<1000 acres), which represent the majority of fire occurrences. Although these fires are most common, they also have the least impact on the landscape. Probabilities differed between the two datasets by only one value in the thousandth decimal place, so we used the values from MTBS analysis only.

We modeled wildfire as a spatial process, allowing fire to spread to adjacent cells if they are susceptible to fire (i.e., vegetated). We specified a patch size distribution based on MTBS data (figure 10).

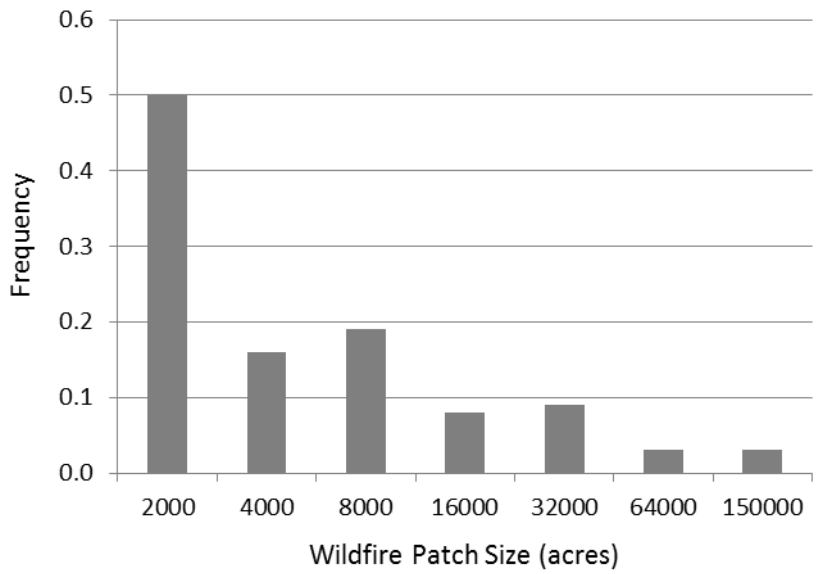

Figure 10. Patch size distribution of wildfires modeled in all ecosystems.

Insects

We added insect outbreak transitions to the STSMs for the Rio Grande modeling assessment (table 20). Background or endemic insect/disease activity is included in the growth and mortality transitions derived from FVS model runs, but larger insect outbreaks were not included in the original Region 3 models. We added these transitions based on a feedback from experts in Region 2 and the Rio Grande. Only insects that tended to produce outbreak cycles were modeled, and species such as the Western balsam bark beetle were not considered because they were assumed to be captured in the growth and succession transitions from FVS.

Table 20. Insect outbreak transition parameters for the forested STSMs, based on expert feedback. Asterisks indicate where insect outbreaks include impacts of western spruce budworm defoliation, predisposing stands to outbreaks.

	Spruce-Fir Forest	Mixed Conifer-Wet	Mixed Conifer-Dry		Pinyon-Juniper Woodland
Parameter	**Spruce beetle**	**Douglas-fir beetle***	**Douglas-fir beetle***	**Mountain pine beetle**	**Pinyon ips**
Interval between outbreaks (yrs)	100-200	35-50	35-50	50-70	35-50
Duration of outbreak (yrs)	10	5	5	5	5
Susceptible stands (state class(es) affected)	large 40-100% single-story and multi-story	large 40-100% multi-story only	large 40-100% multi-story only	large 40-100% single-story and multi-story	medium 10-70%
Effects of outbreak (resulting state class(es))	large 40-70%, medium 10-40%, aspen	medium 10-70%	medium 10-70%	medium 10-70%	small 10-70%

	Spruce-Fir Forest	Mixed Conifer-Wet	Mixed Conifer-Dry		Pinyon-Juniper Woodland
Parameter	**Spruce beetle**	**Douglas-fir beetle***	**Douglas-fir beetle***	**Mountain pine beetle**	**Pinyon ips**
Proportion of susceptible stands transitioning during outbreak	20%	15%	15%	25%	18%

All insect outbreak transitions were called InsectOutbreak for each ecosystem, except for mixed conifer-dry, which had both InsectOutbreak (Douglas-fir beetle) and InsectOutbreak2 (Mountain pine beetle). The species of insect was not specified in the transition name but can be inferred by the ecosystem (e.g. spruce beetle only affects SFM) and the transition name, in the case of the MCD ecosystem. Note that the modeled spruce beetle outbreaks did not include extreme outbreaks such as the one that recently occurred in the RGNF. The Region 2 and the Rio Grande experts who helped develop the insect transition parameters determined that outbreaks of the severity that have recently occurred are too rare to model, and therefore the spruce beetle outbreaks represented in the model represent moderate, but not extreme, severity events.

Insect outbreak transitions were assigned an annual probability of the proportion of susceptible stands transitioning during outbreak / duration of outbreak. Cyclical multipliers were applied so in non-outbreak years a multiplier of zero caused no change and in outbreak years the transition occurred at its assigned probability. Each Monte Carlo simulation had a different sequence of cyclical multipliers with variable timing and interval between outbreaks, within the parameters of table 20.

Insect outbreak transitions were modeled spatially in the SFM, MCW, MCD and PJO models. We used a patch size distribution based on similar species in the Blue Mountains, Oregon, due to lack of information about outbreak patch sizes on the RGNF (figure 11).

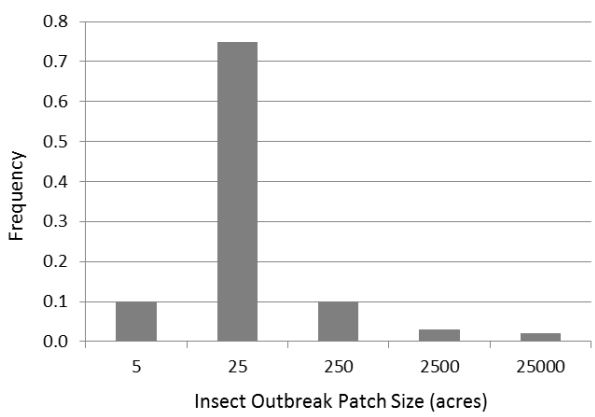

Figure 11. Patch size distribution of insect outbreaks modeled in SFM, MCW, MCD and PJO ecosystems.

Management

Management treatments were modeled as probabilistic transitions in the STSMs and allocated an average annual number of acres under the No Action scenario. We removed the management transitions from the

original Region 3 STSMs for MCW, MCD, PJO and SFM, and developed new transitions based on feedback from experts on the RGNF through a series of meetings.

Management data were compiled for the RGNF from the US Forest Service FACTS database (including a shapefile with spatial data) to determine the type and amount (acres) of treatments to model in the No Action scenario, which represents continuing current management or business-as-usual (table 21). The FACTS database included treatments on the RGNF from 2004-2014. With assistance from RGNF experts, we combined transitions into eight major types, including: broadcast burning, group selection, mastication, planting of trees, salvage harvest, shelterwood, clearcutting, and thinning.

Table 21. Management treatments and codes in the US Forest Service FACTS database for the RGNF and their corresponding treatment types in the STSMs. Where the treatment type is NA, it was determined that the treatment was not a management activity (e.g. wildfire), the treatment could not be modeled using the STSMs (e.g. wildlife habitat improvement) or the treatment perimeter was redundant with another treatment (e.g., piling of fuels), and therefore it was not modeled in the STSMs.

Activity Code	Activity Name	STSM Management Treatment Type
1111	Broadcast Burning - Covers a majority of the unit	Broadcast Burning
4491	Site Preparation for Natural Regeneration - Burning	Broadcast Burning
1113	Underburn - Low Intensity (Majority of Unit)	Broadcast Burning
4152	Group Selection Cut (UA/RH/FH)	Group Selection
4113	Stand Clearcut (EA/RH/FH)	Clearcut-Stand
4117	Stand Clearcut (w/ leave trees) (EA/RH/FH)	Clearcut-Stand
1152	Compacting/Crushing of Fuels	Mastication
1000	Fuels and Fire Activities	Mastication
1150	Rearrangement of Fuels	Mastication
4382	Certification of Natural Regeneration without Site Prep	NA
1130	Burning of Piled Material	NA
1117	Wildfire - Natural Ignition	NA
6080	Wildlife Habitat Seeding and planting	NA
4383	Certification-Planted	NA
1112	Jackpot Burning - Scattered concentrations	NA
1153	Piling of Fuels, Hand or Machine	NA
2320	Range Seeding and Planting	NA
6050	Wildlife Habitat Improvement	NA
4401	Reforestation Need Created by Harvest	NA
4402	Reforestation Need Created by Fire	NA
4403	Reforestation Need created by Insect or Disease Agents	NA
4432	Fill-in or RePlant Trees	Plant Trees
4431	Plant Trees	Plant Trees
4143	Overstory Removal Cut (from advanced regeneration) (EA/RH/FH)	Salvage Harvest
4231	Salvage Cut (intermediate treatment, not regeneration)	Salvage Harvest
4232	Sanitation Cut	Salvage Harvest
4145	Shelterwood Removal Cut (w/ leave trees) (EA/NRH/FH)	Shelterwood
4151	Single-tree Selection Cut (UA/RH/FH)	Shelterwood
4183	Two-aged Seed-tree Seed and Removal Cut (w/res) (2A/RH/FH)	Shelterwood

Activity Code	Activity Name	STSM Management Treatment Type
4193	Two-aged Shelterwood Establishment and Removal Cut (w/ res) (2A/RH/FH)	Shelterwood
4141	Shelterwood Removal Cut (EA/NRH/FH)	Shelterwood
4111	Patch Clearcut (EA/RH/FH)	Clearcut-Patch
4115	Patch Clearcut (w/ leave trees) (EA/RH/FH)	Clearcut-Patch
4521	Precommercial Thin	Thinning
1160	Thinning for Hazardous Fuels Reduction	Thinning
4511	Tree Release and Weed	Thinning

Management information was compiled by treatment type, ecosystem and management area using a spatial overlay to allocate an average annual number of acres treated in each ecosystem and management area (table 22). Only treatments that experts determined were likely to be unique treatment perimeters were included. For instance, entries that indicated a “reforestation need” were unlikely to be actual treatments, and others overlapped with similar treatments. Patch clearcutting was combined with stand clear cutting due to the small number of acres in patch clearcutting (average 9 acres per year). Treatments with annual area <5 acres/year per combination of ecosystem/management area were omitted. No treatments were included in the montane riparian model because the annual acres treated was <20.

Table 22. Management treatments modeled in each ecosystem and management area under the No Action scenario. Ecosystem codes correspond to table 17, management areas are defined in table 16 in appendix A, and treatment groups are listed in table 21.

Ecosystem	Management Area	STSM Management Transition	Acres Per Year
MCD	General	Broadcast Burning	16
MCD	Wildlife	Broadcast Burning	25
MCD	General	Plant Trees	11
MCD	Wildlife	Plant Trees	45
MCD	Dispersed Recreation	Salvage Harvest	12
MCD	Wildlife	Salvage Harvest	49
MCD	General	Salvage Harvest	93
MCD	General	Thinning	66
MCD	Wildlife	Thinning	103
MCD	Dispersed Recreation	Thinning	19
MCD	Special Interest Areas_National River System	Thinning	30
MCW	Wildlife	Broadcast Burning	18
MCW	Special Interest Areas_National River System	Broadcast Burning	19
MCW	Special Interest Areas_National River System	Salvage Harvest	14
MCW	Wildlife	Salvage Harvest	40
MCW	Backcountry	Thinning	8
MCW	Dispersed Recreation	Thinning	21
MCW	Wildlife	Thinning	39
MCW	General	Thinning	123
MSG	Special Interest Areas_National River System	Broadcast Burning	16

Ecosystem	Management Area	STSM Management Transition	Acres Per Year
MSG	General	Broadcast Burning	93
MSG	Wildlife	Broadcast Burning	362
PJO	General	Broadcast Burning	5
PJO	Special Interest Areas_National River System	Broadcast Burning	13
PJO	Wildlife	Broadcast Burning	192
PJO	General	Mastication	48
PJO	Wildlife	Mastication	108
PJO	Dispersed Recreation	Thinning	7
PJO	Wildlife	Thinning	16
PJO	General	Thinning	23
PJO	Special Interest Areas_National River System	Thinning	31
SFM	Special Interest Areas_National River System	Broadcast Burning	8
SFM	General	Broadcast Burning	16
SFM	Wildlife	Broadcast Burning	77
SFM	General	Clearcut-Stand	47
SFM	General	Group Selection	101
SFM	General	Plant Trees	105
SFM	Backcountry	Salvage Harvest	12
SFM	Special Interest Areas_National River System	Salvage Harvest	41
SFM	Wildlife	Salvage Harvest	110
SFM	General	Salvage Harvest	679
SFM	General	Shelterwood	81

Management transitions were modeled spatially with a patch size distribution derived from the activities in the FACTS database (figure 12).

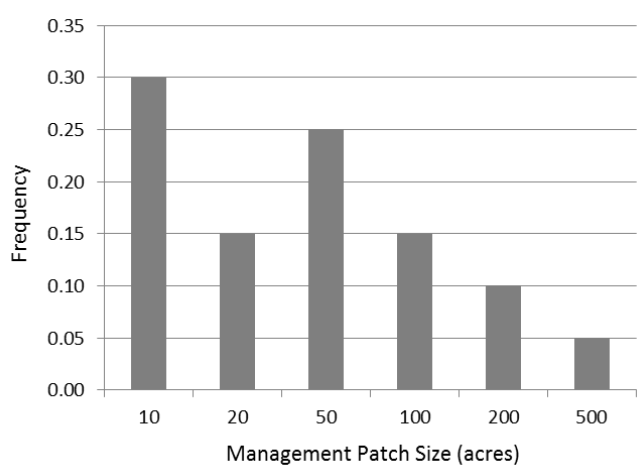

Figure 12. Patch size distribution of management transitions modeled in the RGNF under the No Action scenario.

Habitat Structural Stages

Each state class in the STSMs was assigned a habitat structural stage (HSS) for display in the report (table 23). State classes consisted of a cover type, representing the dominant vegetation species or groups, and a structural stage, representing structural characteristics such as size and canopy cover.

Table 23. State classes by ecosystem in the STSMs, their descriptions (including cover type and structural stage), and their HSS. State class IDs correspond to maps produced by ST-Sim and HSS are used to display results in the main report.

ID	Ecosystem	Name	Cover Type	Cover Type Description	Structural Stage	Structural Stage Description	HSS
5	LF_2811440	Early1:ALL	Early1	Early-Develop1	ALL	AllStructures	1M
10	LF_2811440	Late1:CLS	Late1	Late-Develop1	CLS	Closed	1M
5	LF_2811590	Early1:ALL	Early1	Early-Develop1	ALL	AllStructures	4B
34	LF_2811590	Mid1:CLS	Mid1	Mid-Develop1	CLS	Closed	4C
49	R3_GAM	PM:MOA	PM	PerennialGrass/MidShrub	MOA	Gr-Mid_Sh-Open_Tr-Absent	2S
67	R3_GAM	T:SSC	T	TallShrub	SSC	Gr-Sparse_Sh-Sparse_Tr-Closed	2S
68	R3_GAM	TP:OSO	TP	TallShrub/PerennialGrass	OSO	Gr-Open_Sh-Sparse_Tr-Open	2S
69	R3_GAM	TP:SSM	TP	TallShrub/PerennialGrass	SSM	Gr-Sparse_Sh-Sparse_Tr-Mid	2S
3	R3_ISS	D:OOA	D	SeededGrass	OOA	Gr-Open_Sh-Open_Tr-Absent	2S
35	R3_ISS	MP:OOA	MP	MidShrub/PerennialGrass	OOA	Gr-Open_Sh-Open_Tr-Absent	2S
36	R3_ISS	MP:SOA	MP	MidShrub/PerennialGrass	SOA	Gr-Sparse_Sh-Open_Tr-Absent	2S
51	R3_ISS	PM:OSA	PM	PerennialGrass/MidShrub	OSA	Gr-Open_Sh-Sparse_Tr-Absent	2S
71	R3_ISS	X:MSA	X	Exotics	MSA	Gr-Mid_Sh-Sparse_Tr-Absent	2S
73	R3_ISS	XM:OOA	XM	Exotics/MidShrub	OOA	Gr-Open_Sh-Open_Tr-Absent	2S
12	R3_MCD	MCD:A.GFB	MCD	Mixed Conifer-Dry	A.GFB	Grass-Forb-Brush	1T/2T
13	R3_MCD	MCD:B.sso	MCD	Mixed Conifer-Dry	B.sso	B.Seedling/Sapling_Open	3A
14	R3_MCD	MCD:C.smo	MCD	Mixed Conifer-Dry	C.smo	C.Small_Open	3A
15	R3_MCD	MCD:D.mos	MCD	Mixed Conifer-Dry	D.mos	D.Medium_Open_Single	4A
16	R3_MCD	MCD:E.vos	MCD	Mixed Conifer-Dry	E.vos	E.VLarge_Open_Single	4A
17	R3_MCD	MCD:F.ssc	MCD	Mixed Conifer-Dry	F.ssc	F.Seedling/Sapling_Closed	3C
18	R3_MCD	MCD:G.smc	MCD	Mixed Conifer-Dry	G.smc	G.Small_Closed	3C
19	R3_MCD	MCD:H.mcs	MCD	Mixed Conifer-Dry	H.mcs	H.Medium_Closed_Single	4C

ID	Ecosystem	Name	Cover Type	Cover Type Description	Structural Stage	Structural Stage Description	HSS
20	R3_MCD	MCD:I.vcs	MCD	Mixed Conifer-Dry	I.vcs	I.VLarge_Closed_Single	4C
21	R3_MCD	MCD:J.mom	MCD	Mixed Conifer-Dry	J.mom	J.Medium_Open_Multi	4A
22	R3_MCD	MCD:K.vom	MCD	Mixed Conifer-Dry	K.vom	K.VLarge_Open_Multi	4A
23	R3_MCD	MCD:L.mcm	MCD	Mixed Conifer-Dry	L.mcm	L.Medium_Closed_Multi	4C
24	R3_MCD	MCD:M.vcm	MCD	Mixed Conifer-Dry	M.vcm	M.VLarge_Closed_Multi	4C
25	R3_MCD	MCD:N.unc	MCD	Mixed Conifer-Dry	N.unc	N.Grass_Forb_Brush/Shrub Unchar	1T/2T
160	R3_MCD	MCD:O.ssm	MCD	Mixed Conifer-Dry	O.ssm	O.Seedling/Sapling_Mid	3B
161	R3_MCD	MCD:P.smm	MCD	Mixed Conifer-Dry	P.smm	P. Small_Mid	3B
162	R3_MCD	MCD:Q.mms	MCD	Mixed Conifer-Dry	Q.mms	Q.Medium_Mid_Single	4B
163	R3_MCD	MCD:R.vms	MCD	Mixed Conifer-Dry	R.vms	R.VLarge_Mid_Single	4B
164	R3_MCD	MCD:S.mmm	MCD	Mixed Conifer-Dry	S.mmm	S.Medium_Mid_Multi	4B
165	R3_MCD	MCD:T.vmm	MCD	Mixed Conifer-Dry	T.vmm	T.VLarge_Mid_Multi	4B
159	R3_MCW	Aspen:Aspen	Aspen	Aspen	Aspen	Aspen	Aspen
4	R3_MCW	Early A:GFB	Early A	Early State with no elk	GFB	Grass-Forb-Brush	1T/2T
26	R3_MCW	MC-I:G.so	MC-I	Mixed Conifer-Wet Shade Intolerant	G.so	G.Seed/Sap/Small_Open	3A
27	R3_MCW	MC-I:H.mos	MC-I	Mixed Conifer-Wet Shade Intolerant	H.mos	H.Medium_Open_Single	4A
28	R3_MCW	MC-M:I.vos	MC-M	Mixed Conifer-Wet Mixed Tolerant	I.vos	I.VLarge_Open_Single	4A
29	R3_MCW	MC-M:J.vom	MC-M	Mixed Conifer-Wet Mixed Tolerant	J.vom	J.VLarge_Open_Multi	4A
30	R3_MCW	MC-T:C.sc	MC-T	Mixed Conifer-Wet Shade Tolerant	C.sc	C.Seed/Sap/Small_Closed	3C
31	R3_MCW	MC-T:D.mcs	MC-T	Mixed Conifer-Wet Shade Tolerant	D.mcs	D.Medium_Closed_Single	4C
32	R3_MCW	MC-T:E.vcs	MC-T	Mixed Conifer-Wet Shade Tolerant	E.vcs	E.VLarge_Closed_Single	4C
33	R3_MCW	MC-T:F.vcm	MC-T	Mixed Conifer-Wet Shade Tolerant	F.vcm	F.VLarge_Closed_Multi	4C
166	R3_MCW	MC-T:K.sm	MC-T	Mixed Conifer-Wet Shade Tolerant	K.sm	K.Seed/Sap/Small_Mid	3B
167	R3_MCW	MC-T:L.mms	MC-T	Mixed Conifer-Wet Shade Tolerant	L.mms	L.Medium_Mid_Single	4B
168	R3_MCW	MC-T:M.vms	MC-T	Mixed Conifer-Wet Shade Tolerant	M.vms	M.Vlarge_Mid_Single	4B
169	R3_MCW	MC-T:N.vmm	MC-T	Mixed Conifer-Wet Shade Tolerant	N.vmm	N.Vlarge_Mid_Multi	4B
37	R3_MSG	NP:OSO	NP	Conifer/PerennialGrass	OSO	Gr-Open_Sh-Sparse_Tr-Open	1M
38	R3_MSG	P:CAA	P	PerennialGrass	CAA	Gr-Closed_Sh-Absent_Tr-Absent	1M
39	R3_MSG	P:MAA	P	PerennialGrass	MAA	Gr-Mid_Sh-Absent_Tr-Absent	1M

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40	R3_MSG	P:OAA	P	PerennialGrass	OAA	Gr-Open_Sh-Absent_Tr-Absent	1M
53	R3_MSG	RP:COO	RP	RuderalGrass/PerennialGrass	COO	Gr-Closed_Sh-Open_Tr-Open	1M
42	R3_PJO	PJO:B.sso	PJO	Pinyon-Juniper	B.sso	B.Seedling/Sapling_Open	3A
43	R3_PJO	PJO:C.smo	PJO	Pinyon-Juniper	C.smo	C.Small_Open	3A
44	R3_PJO	PJO:D.mvo	PJO	Pinyon-Juniper	D.mvo	D.Medium to Very Large_Open	4A
48	R3_PJO	PJO:GFB	PJO	Pinyon-Juniper	GFB	Grass-Forb-Brush	1T/2T
170	R3_PJO	PJO:H.ssm	PJO	Pinyon-Juniper	H.ssm	H.Seed/Sap_Mid	3B
171	R3_PJO	PJO:I.smm	PJO	Pinyon-Juniper	I.smm	I.Small_Mid	3B
172	R3_PJO	PJO:J.mvm	PJO	Pinyon-Juniper	J.mvm	J.Medium to Very Large_Mid	4B
2	R3_SAG	D:MOA	D	SeededGrass	MOA	Gr-Mid_Sh-Open_Tr-Absent	2S
6	R3_SAG	JP:OOM	JP	Juniper/PerennialGrass	OOM	Gr-Open_Sh-Open_Tr-Mid	2S
8	R3_SAG	JX:MSO	JX	Juniper/Exotics	MSO	Gr-Mid_Sh-Sparse_Tr-Open	2S
52	R3_SAG	PS:OSA	PS	PerennialGrass/Sagebrush	OSA	Gr-Open_Sh-Sparse_Tr-Absent	2S
54	R3_SAG	S:SMA	S	Sagebrush	SMA	Gr-Sparse_Sh-Mid_Tr-Absent	2S
63	R3_SAG	SP:OMA	SP	Sagebrush/PerennialGrass	OMA	Gr-Open_Sh-Mid_Tr-Absent	2S
64	R3_SAG	SP:OOA	SP	Sagebrush/PerennialGrass	OOA	Gr-Open_Sh-Open_Tr-Absent	2S
65	R3_SAG	SPJ:OOO	SPJ	Sagebrush/PerenGrass/Juniper	OOO	Gr-Open_Sh-Open_Tr-Open	2S
66	R3_SAG	SPX:MOA	SPX	Sagebrush/PerennialGrass/Exotics	MOA	Gr-Mid_Sh-Open_Tr-Absent	2S
70	R3_SAG	X:MAA	X	Exotics	MAA	Gr-Mid_Sh-Absent_Tr-Absent	2S
74	R3_SAG	XS:MOA	XS	Exotics/Sagebrush	MOA	Gr-Mid_Sh-Open_Tr-Absent	2S
75	R3_SAG	YP:OMA	YP	EarlySeralShrub/PerennialGrass	OMA	Gr-Open_Sh-Mid_Tr-Absent	2S
159	R3_SFM	Aspen:Aspen	Aspen	Aspen	Aspen	Aspen	Aspen
4	R3_SFM	Early A:GFB	Early A	Early State with no elk	GFB	Grass-Forb-Brush	1T/2T
55	R3_SFM	SFM-I:G.so	SFM-I	Spruce-Fir Mix-Shade Intolerant	G.so	G.Seed/Sap/Small_Open	3A
56	R3_SFM	SFM-I:H.mos	SFM-I	Spruce-Fir Mix-Shade Intolerant	H.mos	H.Medium_Open_Single	4A
57	R3_SFM	SFM-M:I.vos	SFM-M	Spruce-Fir Mix Mixed Shade Tolerant	I.vos	I.VLarge_Open_Single	4A
58	R3_SFM	SFM-M:J.vom	SFM-M	Spruce-Fir Mix Mixed Shade Tolerant	J.vom	J.VLarge_Open_Multi	4A
59	R3_SFM	SFM-T:C.sc	SFM-T	Spruce-Fir Mix Shade Tolerant	C.sc	C.Seed/Sap/Small_Closed	3C
60	R3_SFM	SFM-T:D.mcs	SFM-T	Spruce-Fir Mix Shade Tolerant	D.mcs	D.Medium_Closed_Single	4C

ID	Ecosystem	Name	Cover Type	Cover Type Description	Structural Stage	Structural Stage Description	HSS
61	R3_SFM	SFM-T:E.vcs	SFM-T	Spruce-Fir Mix Shade Tolerant	E.vcs	E.VLarge_Closed_Single	4C
62	R3_SFM	SFM-T:F.vcm	SFM-T	Spruce-Fir Mix Shade Tolerant	F.vcm	F.VLarge_Closed_Multi	4C
173	R3_SFM	SFM-T:K.sm	SFM-T	Spruce-Fir Mix Shade Tolerant	K.sm	K.Seed/Sap/Small_Mid	3B
174	R3_SFM	SFM-T:L.mms	SFM-T	Spruce-Fir Mix Shade Tolerant	L.mms	L.Medium_Mid_Single	4B
175	R3_SFM	SFM-T:M.vms	SFM-T	Spruce-Fir Mix Shade Tolerant	M.vms	M.Vlarge_Mid_Single	4B
176	R3_SFM	SFM-T:N.vmm	SFM-T	Spruce-Fir Mix Shade Tolerant	N.vmm	N.Vlarge_Mid_Multi	4B

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