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Forest Service

Grand Mesa, Uncompahgre, and Gunnison National Forests

DRAFT Forest Assessments: Terrestrial Ecosystems: Integrity and System Drivers and Stressors

November 2017

Aspens starting to turn below Dunn Peak, Uncompahgre National Forest.

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Chapter 1. Introduction

In this assessment, we address the ecosystem integrity of the major terrestrial ecosystems on the GMUG. 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 GMUG.

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. Assessing ecosystem integrity is required by the Forest Service planning rule. Ecological integrity is the quality or condition of an ecosystem when its dominant ecological characteristics (e.g. composition, structure, function, and connectivity) act to maintain that quality or condition and maximize its ability to withstand or recover from perturbations imposed by natural environmental dynamics or human influence.

Key Issues for Terrestrial Ecosystems on the GMUG

The GMUG needs plan changes to provide better direction for management of ecosystems to achieve a desired outcome based upon best available science. The focus should be on managing to maintain resiliency to provide for ecosystem services and buffer anticipated impacts from climate change. We need to proactively implement management actions that can improve integrity of key ecosystem characteristics and help maintain ecological integrity.

Specifically, we need changes in the forest plan so that it:

- Provides direction for ecosystem management to maintain ecological integrity as a whole, including maintaining the existing diversity of ecosystems on the landscape and a variety of structural stages, including the protection and preservation of old-growth forest where present.
- Provides direction for management in a changing climate while allowing for flexibility to respond to impacts of climate change
- Focuses management actions to mitigate the impacts of known ecosystem stressors on the GMUG, and prevents drivers from becoming stressors.
- Allows and provides direction for ecologically sound uses of prescribed fire and wildfire in the plan area.
- Matches the variability found on the GMUG. Plan components related to snags and downed wood retention and minimum stocking standards need to be reviewed and updated where appropriate.

Some needed changes are ecosystem-specific. For instance, in many cover types, a large percentage of the area is still in mature, dense conditions, susceptible to stand-replacing fires and/or epidemic insect/pathogen outbreaks. Active management that is focused on diversifying the structural stages present and increasing heterogeneity will be important here to increase resiliency to fires, insects, disease, and climate change.

Plan components and management that promotes disturbance and the natural role of fire are needed in many types. In cover types heavily impacted by fire suppression, the revised forest plan should promote continued restoration and/or resiliency treatments.

Some ecosystems, such as the alpine uplands, would benefit from additional monitoring to better understand the current impacts of ecological stressors and prevent further resource damage.

Summary Public Input

The planning team received public input with respect to a variety of topics related to the terrestrial ecosystems of the Forest during the summer of 2017, including emails, electronic and hand-written comments, and conversations at the public open houses, summarized here. Input from the public suggests that there are concerns about recreation-related resource damage, insect and disease activity, and wildfire. Recreation-related comments include concern about off-trail motorized use and its impacts around Pitkin and a suggestion to designate camping sites at Blue Lakes and Ice Lake to reduce resource damage there. While some public input suggests insect and disease issues should be addressed, particularly surrounding Ouray and Lake City, we also received feedback that there is no need for insect or disease related treatment on the Ouray district as sudden aspen decline has stopped and aspen regeneration is occurring. Vegetation treatments that build ecological resiliency and ensure safety near infrastructure, parking lots, campgrounds, and the like may have more support than management done solely for timber production purposes or management that requires road building. The public suggests there is a need for fuels treatment near Tincup and a need for plan direction to address fire concerns around Ouray. They are also concerned about a lack of ability to fight fire in roadless areas due to access issues and lack of ability to manage fire in wilderness through standard techniques. Input from the public also suggests we should continue to address climate change and take advantage of local research regarding climate change.

Use of Best Available Science and Information Gaps

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

- GMUG-specific spatial data – vegetation and structural stage, management activities, fire origin, fire history (FACTS; FSVeg Spatial)
- USFS Stand exam (FSVeg) and forest inventory and analysis (FIA) plot data
- USDA Forest Health Protection Insect and Disease Conditions Report (Gunnison Service Center 2017)
- Climate change-related publications and reports (Vose et al. 2012; Millar et al. 2007; Aplet and McKinley 2017)
- Historic range of variability assessments for the plan area (Kulakowski and Veblen 2006; Romme et al 2009)
- Fire history research (see Appendix C.)
- Current GMUG Forest Plan (written in 1983, amended in 1991)

This assessment is limited by several data gaps. Our spatial vegetation dataset (FSVeg Spatial) has not been updated to reflect the impacts of the recent severe spruce beetle outbreak on the GMUG. A change detection effort is currently underway, with ground-truthing completed in summer of 2017, but this data was not yet available at the time of the assessment. Thus, the assessment is based on pre-outbreak stand data, and we note when current post-outbreak conditions are likely very different than the pre-outbreak data suggests. Other information needs include more robust monitoring of seedling recruitment and regeneration outside of existing monitoring of post-harvest regeneration, an empirical understanding of pre-European settlement fire history, and a field-based inventory of old-growth/late-successional habitats in the plan area.

Chapter 2. Condition and Trends

Terrestrial Ecosystem Identification

Terrestrial ecosystems identified for assessment are based on an initial list of ecosystems included in a 2005 Comprehensive Assessment effort done on the GMUG. Through consultation with GMUG and Region 2 personnel this initial list was refined to a final version with the goal of ensuring that all major ecosystems in the plan area were included, and divisions between ecosystems were made at an appropriate level of precision based on available data and management needs. A final list of 15 terrestrial ecosystems was identified for this assessment (Table 1, Map 1 in Appendix A).

Table 1. Terrestrial ecosystems identified for assessment

	Ecosystem
Forest and Woodlands	Spruce-Fir Forest
	Aspen Forest
	Spruce-Fir-Aspen Forest
	Lodgepole Pine Forest
	Pinyon-Juniper Woodland
	Ponderosa Pine Forest
	Cool-Moist Mixed Conifer Forest
	Warm-Dry Mixed Conifer Forest
	Bristlecone-Limber Pine Forest
Shrublands	Montane Shrubland, Oak-Serviceberry-Mountain Mahogany
	Sagebrush Shrubland
	Desert Alluvial Saltshrub
Grasslands, Alpine, Other	Montane-Subalpine Grasslands
	Alpine Uplands – Grasslands and Forblands
	Rocky Slopes, Screes, Cliffs

Ecosystems are mapped based on the FSVegSpatial dataset within the plan area, and the Southwest Regional GAP analysis data (Prior-Magee et al. 2007) within the larger context area. Details on this process can be found in Appendix A. FSVegSpatial vegetation mapping for the GMUG is generated primarily from aerial photo interpretation, with periodic updates resulting from field verification, management activities and natural disturbances (i.e. wildfires). Vegetation is classified by cover type, which is determined by the dominant cover or species present at the time of classification. There are several known limitations in cover type identification on the GMUG. Ponderosa pine, blue spruce, and Douglas-fir are underrepresented in the Gunnison Basin, partly due to errors in aerial photo interpretation. In addition, habitat structural stage classification for lodgepole pine stands misinterpreted narrow crowns as being smaller-size classes, resulting in an overrepresentation of sapling-pole structural stages and an underrepresentation of mature structural stages.

Scale of Analysis

This assessment utilizes three spatial scales: context, plan, and local. The plan scale is the most intuitive, including the 2.97 million acres of forests, woodlands, and grasslands that comprise the GMUG and are directly affected by Forest Plan components. This scale drives the ecological need for change.

The context scale is larger than the plan scale and is used to put the GMUG's conditions in perspective with the surrounding landscape, including lands outside of Forest Service jurisdiction, and is necessary for determining the opportunities or limitation of the GMUG to contribute to the sustainability of broader ecological systems. Context scale analysis can also identify impacts of the broader landscape on the sustainability of resources within the plan area. The context scale for this assessment encompasses a total area of 20.07 million acres.[1]

The local scale subdivides the plan scale to identify specific priority areas. Our local scale is defined by five "geographic areas", delineated for previous assessments on the GMUG. These units are determined by both geographic differences and management boundaries, and include the Grand Mesa, North Fork Valley, Gunnison Basin, San Juans, and Uncompahgre Plateau. Throughout the assessment, we will refer to geographic areas as needed to highlight important differences in ecosystem types or key ecosystem characteristics. Distribution of ecosystems by geographic area is found in Table 2 and Map 1 (Appendix A). Many ecosystems are not spread evenly throughout the GMUG, but instead are concentrated in one to three out of five geographic areas. For example, lodgepole pine and bristlecone-limber pine forests are located almost exclusively in the Gunnison Basin, which also includes most of the mixed conifer forests. Pinyon-juniper is found predominantly on the Uncompahgre Plateau, which also includes most of the ponderosa pine forests. Given its lower elevation, the Plateau includes very little spruce-fir, unlike the other geographic areas. Almost all of the alpine uplands on the GMUG are found in the Gunnison Basin and San Juans geographic areas.

This assessment primarily focuses on ecosystem conditions at the plan scale (within the GMUG administrative boundaries), but attempts to identify the context-area importance of vegetation managed by the GMUG by comparing the spatial extent of ecosystems found on the plan area to the surrounding context area. At times we use the local scale to identify specific priority areas.

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[1] To determine the context scale we used the National Hierarchical Framework of Ecological Units (ECOMAP; Cleland et al. 2007), a tiered classification system that divides the country into ecoregions, then provinces, then sections, and finally subsections. The context scale in this assessment is delineated by subsections within the four ECOMAP sections that intersect the GMUG. Sections typically cover areas up to about 1,000 square miles. They are described by characteristic geomorphology, geology, climate, soils, and drainage networks. Sections are often inferred by relating geologic maps to potential natural vegetation "series" groupings such as those mapped by Kuchler (1964). Forest management and other anthropogenic activities along with natural disturbance can affect the character and function of sections. The broad geographic setting formed by the four sections intersecting the GMUG requires some approach to eliminate the portions of sections minimally influenced by GMUG management and well beyond the scope of the analysis. To address this we aggregated the 54 subsections with the four sections, and defined our context area as the 30 subsections closest to the GMUG (17 of which intersect forest boundaries), for a total area of 20.07 million acres.

Table 2. Terrestrial ecosystem areal distribution within geographic areas on the GMUG

Ecosystem	Total acres	% of GMUG	Grand Mesa	North Fork Valley	Gunnison Basin	San Juans	Uncompahgre Plateau
Spruce-Fir	534,320	17.0	67,604 (21%)	81,869 (16%)	273,284 (20%)	104,038 (29%)	7,525 (1%)
Aspen	460,345	14.6	65,475 (20%)	130,021 (26%)	118,160 (9%)	39,922 (11%)	106,767 (17%)
Spruce-Fir-Aspen	426,011	13.5	53,640 (17%)	112,420 (22%)	125,698 (9%)	58,759 (16%)	75,496 (12%)
Lodgepole Pine	283,713	9.0	-	-	283,332 (21%)	203 (<1%)	178 (<1%)
Pinyon-Juniper	107,309	3.4	19,315 (6%)	2,680 (<1%)	351 (<1%)	689 (<1%)	84,273 (14%)
Ponderosa Pine	105,003	3.3	-	236 (<1%)	8,974 (<1%)	458 (<1%)	95,336 (15%)
Cool-Moist Mixed Conifer	39,839	1.3	1,682 (<1%)	1,584 (<1%)	33,782 (2%)	1,284 (<1%)	1,507 (<1%)
Warm-Dry Mixed Conifer	19,027	0.6	1,355 (<1%)	610 (<1%)	9,844 (<1%)	1,210 (<1%)	6,008 (1%)
Bristlecone-Limber Pine	8,172	0.3	-	-	8,172 (<1%)	-	-
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	325,209	10.3	60,830 (19%)	83,462 (17%)	11,749 (<1%)	7,297 (2%)	161,871 (26%)
Sagebrush Shrubland	95,988	3.0	2,772 (<1%)	5,996 (1%)	63,779 (5%)	350 (<1%)	23,091 (4%)
Montane-Subalpine Grassland	300,430	9.5	32,757 (10%)	43,028 (9%)	154,919 (11%)	28,449 (8%)	41,277 (7%)
Alpine Uplands – Grasslands and Forblands	121,614	3.9	-	2,592 (<1%)	93,576 (7%)	25,446 (7%)	-
Rocky Slopes, Screes, Cliffs	Unknown						
Other (aquatic, wetland, riparian, bare)*		10					

*Riparian ecosystems are discussed in the aquatic and riparian ecosystem assessment. The desert alluvial saltshrub ecosystem is not listed due to low acreage, but is described in the Ecosystem Descriptions section.

Spatial Niche and Opportunity for Influence

The spatial niche analysis relates the GMUG to its surroundings, in this case, the context area landscape. The contribution of the GMUG to the ecological integrity of a given ecosystem is dependent on the percent of the plan area occupied by the ecosystem, the percent of the context area occupied by the ecosystem, and the relative proportional representation of the ecosystem on-GMUG to off-GMUG. Abundance on the landscape and proportional representation at the plan scale can be combined into a single variable that defines the opportunity for the plan scale to influence context scale conditions: the opportunity for influence (Figure 1). Opportunity for influence increases along the diagonal axis, from upper left to lower right corner, where ecosystems are more common in the plan area than in the context landscape. Higher opportunity for influence means that the sustainability of the system at the context scale is more sensitive to conditions at the plan scale, and management of the GMUG has a unique role in restoring or maintaining integrity when possible. Based on this analysis, the GMUG has an especially high opportunity for influence in 6 ecosystems: lodgepole pine, spruce-fir-aspen, alpine uplands, ponderosa pine, warm-dry mixed conifer, and cool-moist mixed conifer.

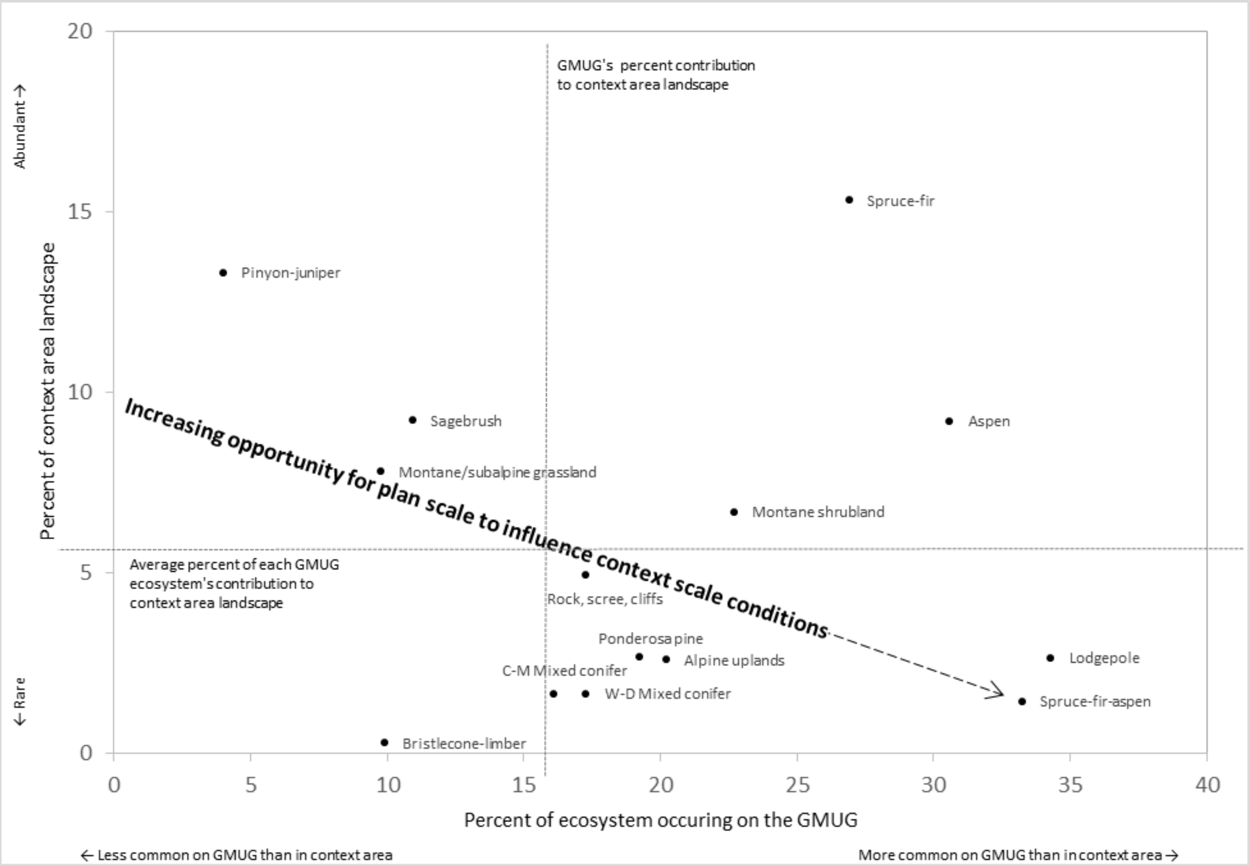

Figure 1. The GMUG's opportunity to influence ecosystem integrity within the context area landscape

Key Ecosystem Characteristics

Key ecosystem characteristics are important specific elements of an ecosystem that sustain the long-term integrity of the ecosystem. They include dominant ecological characteristics of composition, structure, function, and connectivity of ecosystems, and may be stressors and possible effects of stressors. We selected key ecosystem characteristics that a) have available information, b) can be measured or assessed, and c) respond to direct or indirect management, or will inform management in the plan area (per FSH 1909.12-10). We identified six key ecosystem characteristics to assess for terrestrial ecosystems on the GMUG (Table 3). These are discussed in later sections of this document (see hyperlinks in table below); not all characteristics apply to all ecosystems in the assessment.

Table 3. Key ecosystem characteristics for terrestrial ecosystems on the GMUG

Key ecosystem characteristic	Data sources used in assessment
Diversity of cover types	FSVegSpatial, Potential natural vegetation (PNV) spatial data
Diversity of structural stages	FSVegSpatial, Vegetation Dynamics Development Tool (VDDT)
Regeneration and recruitment	Forest Inventory and Analysis (FIA) data, current plan stocking requirements, bioclimate modelling (Rehfeldt et al 2015)
Landscape disturbances	GMUG fire history and fire origin data spatial data, USFS Insect and Disease aerial detection surveys and reports, literature review
Patch size/habitat connectivity	FSVegSpatial with FRAGSTATS analysis
Snags and down woody material	Common stand exams, FIA data, South Central Highlands HRV report (Romme 2009), current plan minimum requirements

Ecosystem Drivers, Stressors, and Management Influences

Ecosystem drivers are factors or processes that affect ecosystem characteristics and contribute to the natural range of variation. Stressors are defined as factors that may directly or indirectly degrade ecosystem composition, structure, or processes in a manner that may impair its ecological integrity (36 CFR 219.19). Many system drivers can be stressors if they are operating in atypical ways, outside of their natural range of variability. Management influences can be drivers or stressors, and typically operate at a more local scale than natural drivers and stressors do. Current management actions on the GMUG are often intended to mitigate impacts of ecosystem stressors, though insufficient or misdirected management can be a stressor in itself, as can legacies of past management. Drivers and stressors of terrestrial ecosystems on the GMUG include succession, wildfire, insects and disease, invasive species, climate, and climate change. Management influences include vegetation management, livestock grazing, roads and trails, recreation use and development, and mineral, oil and gas development. The drivers, stressors, and management influences for each particular ecosystem vary widely.

Drivers and Stressors

Succession is the natural change in the composition, structure, and function of an ecosystem over time during long periods without major disturbances, and is an ecosystem driver. As plants grow and compete for limited resources, the species, size, and amount of plants that compose an ecosystem change. Early successional stages are often dominated by small, short-lived, poorly competitive, non-woody species, such as annual forbs and grasses, which take advantage of the available "biological space" and plentiful soil nutrients and sunlight present after a disturbance. As succession proceeds, soil nutrients are converted into plant biomass, and plant community dominance generally shifts toward larger, longer-lived, woody species that are better competitors for limited soil nutrients and sunlight – shrubs, shade-intolerant tree species, and eventually, shade-tolerant tree species. Disturbances like fire, drought, and grazing can interrupt or reverse succession.

Fire is a natural part of the ecosystems on the GMUG and the context area. Fire regimes describe historical fire conditions that influenced how vegetation communities evolved and were maintained over time. These conditions are generally characterized by fire frequency (the average number of years between fires) and fire severity (the effect fire has on the dominant overstory vegetation).The historical fire regime varies widely across different ecosystems, from a regime of short return intervals and low severity to long return intervals of fires that consume all vegetation (stand-replacing). For example, the spruce-fir forests that are prevalent on the GMUG generally experienced infrequent, stand-replacing fires while the ponderosa pine forests are associated with more frequent, low-severity fire.

Fire generally reverses succession, by establishing an earlier seral state in infrequent fire forest and woodland types. However, within frequent fire types, fire maintains the current seral state. Each terrestrial ecosystem has evolved under a specific fire regime to adapt to a certain characteristic frequency and severity of fire such that ecological integrity is maintained over time. Multiple interacting influences can alter an ecosystem's fire regime. Past management actions including fire suppression and overgrazing (leading to a lack of fine fuels) have resulted in fewer fires in some ecosystem types in the plan area since the late-1800s. This reduced amount of fire then led to a subsequent accumulation of fuels in these ecosystems that has created the potential for larger and more severe fires. Tree mortality from drought or insect and disease outbreaks changes fuel structures and can affect fire behavior. In the future, changing climate is expected to continue to lengthen the fire season and lead to more large fires (Westerling et al. 2006). Characteristic fire is an ecosystem driver, but uncharacteristic fires (those that differ in frequency or severity from an ecosystem's historic fire regime) can be a stressor, and may convert an ecosystem to a different cover type permanently (Savage and Mast 2005; Roccaforte et al. 2012).

For more information, see the Key characteristic: Landscape disturbances section.

Insect and disease outbreaks are major ecological processes that shape the conditions of forests. Most insects and diseases are natural components of the ecosystem and play important ecological roles. Tree mortality and other impacts of insects and disease regulate forest vegetation composition, influence stand density and structure, provide wildlife habitat in dead and dying trees, and contribute nutrients to soils. Insects are also food for birds and other wildlife. At low levels of infestation individual trees are weakened and killed, resulting in small scale changes affecting limited areas. Under certain conditions such as stand maturity, overcrowding, drought, blowdown, and poor site conditions, populations of forest insects and pathogens can increase, resulting in widespread mortality. Without the influence of widespread, natural disturbances in the forest (fire, insects, and disease), the composition and structure of the forest landscape would become less diverse, and therefore less resilient to future disturbance. These change agents are an integral part of forest ecosystem processes. Insects and diseases may function as a driver or a stressor. While forested systems have evolved under certain levels of pathogens that were historically sustainable, an outbreak may have uncharacteristic effects either because of severity levels outside of the historic range of variability, or because of confounding factors that amplify effects.

For more information, see the Key characteristic: Landscape disturbances section.

Climate influences all aspects of vegetation potential and expression. Temperature and precipitation patterns help define dominant species and productivity of vegetation, nutrient availability, and cycling in soils. The natural range of variation in cyclical drought and temperature fluctuations influence characteristic frequency, extent and severity of disturbance from drought, insects and disease, and fire. While climate has varied continually in the past, current ecosystems have evolved under a specific average climate with a defined level of variability. Climate is inherently an ecosystem driver, but becomes a stressor when its mean, variability, or rate of change shifts outside of its contemporary natural range of variability.

Climate change is an ecological stressor. It has direct impacts on ecosystems through changes in precipitation and temperature, in addition to indirect effects from its influence on the frequency, extent, and severity of landscape disturbances such as wildfires and insect outbreaks. Related to this are weather-related stressors such as droughts, floods, and wind events that may be more common with a changing climate (Dale et al. 2001, Walther et al. 2002, IPCC 2014).

As the climate gets warmer and precipitation patterns change, changes in reproductive success, growth rates, competitive environments, and disturbances will likely alter the distribution of forest types and mixtures of species across the landscape (Battaglia 2017). Changes in temperature will change the growth of tree species (Rondeau et al. 2012, Vose et al. 2012, Battaglia 2017), likely with variable effects on different species. Battaglia (2017) suggests that longer growing seasons can potentially be beneficial for tree growth if moisture availability does not decrease. Conversely, earlier snowmelt can lead to increased potential for seedlings to experience frost damage and exposure to drought.

Tree habitat is predicted to 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). Some ecosystems are particularly susceptible to climate change-related impacts. Vulnerability assessments for the surrounding areas suggest that ecosystems adapted to warmer and drier conditions will do better than those adapted to cooler and moister conditions (Battaglia 2017). 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).

Increased tree mortality across the Western U.S. is already being observed due to a combination of high temperatures and drought (Worrall et al. 2008, van Mantgem et al. 2009). Thinning and other management that reduces forest density can help improve tree resistance and resilience to drought and reduce drought-induced mortality (D'Amato et al. 2013, Bottero et al. 2016, Bradford and Bell 2016).

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). Rocca et al. (2014) suggests that fire risk is likely to increase in the short term (next 50 years) across all forest types on the GMUG. The combination of earlier snowmelt and warmer temperatures will allow longer periods for fuels to be available to burn. This will impact species differently, as tree species on the Forest have varying levels of tolerance to fire.

Climate change is a significant factor in this assessment and many other draft assessments, and the topic warranted comprehensive discussion. To streamline the body of this assessment of terrestrial ecosystems, drivers, stressors, we have appended this longer discussion as Appendix G. Climate Change. The appendix identifies three potential future climate scenarios – a hot and dry climate, a warm and wet climate, and an increased variability scenario that fluctuates between hot and dry and warm and wet conditions; potential indicators and changes already observed with those indicators; trends and resources affected; and identifies potential strategic management approaches.

Invasive species are defined by Executive Order 13112 (1999) as those species that are non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. As such, they are an ecological stressor. Not all non-native species are invasive. Invasive plant species generally are species that have been introduced into ecosystems in which they did not evolve, and consequently, tend to have no natural enemies to limit their reproduction and expansion. They also tend to be more vigorous, taller, and more productive than native species (Mitchell 2000). As a result they can out-compete and displace native plant species, often completely taking over a site.

Areas where vegetative cover is disturbed and bare soil becomes exposed are most susceptible to invasions. These lands may be disturbed as a result of human land uses/management (i.e., roads, trails, ditches, agriculture, livestock grazing, timber harvest, prescribed burning, and land clearance) or natural disturbances (i.e., wildfires, wildlife concentration areas). Invasive plant species can be spread or introduced into unoccupied areas by vehicles, humans, and animals along travel routes and waterways. Most invasive plant species require large amounts of sunlight, warm temperatures and relatively long growing seasons (Stohlgren et al 2002). In arid western environments like the Uncompahgre Plateau, riparian and wetland areas are especially susceptible to invasives because of the available water.

Invasive plant infestations are increasing exponentially throughout the western United States, including within the plan area (25,477 acres of inventoried infested area to date on the GMUG), and can have serious ecological impacts. Natural plant community composition can be altered, greatly reducing biodiversity, eliminating habitat and forage for wildlife and livestock, and potentially altering fire regimes. Ecosystem functions such as nutrient cycling and energy flow can be altered. Invasive plants can affect soil characteristics by altering soil chemistry, changing soil moisture levels and evapotranspiration rates, and by lowering water tables (Ehrenfeld 2003).

Approximately half of the 25,000 acres of invasive species currently inventoried on the GMUG are found in the montane-subalpine grasslands and ponderosa pine ecosystems. Invasive plants are also more common in montane shrublands and aspen forest ecosystems within the plan area. In general, vulnerability to non-native plant invasion is low in desert and semi-desert elevations (mostly below the GMUG), then increases to high at medium elevations (up to 8,000 feet), declining to very low at high elevations, which are colder with short growing seasons and are mainly in wilderness areas.

Climate change is expected to increase the impacts of invasive plant species. Many invasive plant species will either increase in abundance, if established, or expand into the lower elevation grassland, shrubland, and open woodland communities, regardless of level of disturbance, as these communities become warmer and drier (Halofsky et al. in press). In addition, the rate and magnitude of infestation will likely increase with greater disturbance levels that are expected to be concomitant with a changing climate (Bradley et al. 2008).

For more information, see the *Invasive Plants* assessment.

Management Influences

Vegetation management includes a variety of management activities, such as timber harvest, broadcast burning, fuels treatments, planting, seeding, and treatment of invasive species. These activities, both past and ongoing, can be used to mitigate ecosystem stressors, but can also be stressors themselves. The impact to the ecosystem of vegetation management varies based on the specific activity, its intensity, and the ecosystem, not just the acreage of the activity, and generally lasts beyond the year of implementation. For example, timber harvesting alters stand structure and function with the level of effect determined by the size, intensity, and type of harvest, pre-existing harvest conditions (past management activities), biotic/abiotic factors (soil type, slope, aspect, and vegetation type), and the distribution of harvesting practices across the landscape.

Vegetation management activities can be designed to improve wildlife habitat, and mitigate the impacts of past management policies (i.e. the legacy of fire suppression). Timber harvest activities can be used to reduce stand density and ladder fuels, and may be used prior to the reintroduction of fire. However, if done improperly, vegetation management can be an ecosystem stressor, and even well-executed vegetation management can have undesirable side effects. For example, heavy equipment used in timber management causes soil compaction and has the potential to disrupt soil hydrologic function, stability, and nutrient cycling, which can affect revegetation on disturbed areas (Swank et al 1989). Design criteria can be used to help avoid or lessen any unwanted side effects associated with vegetation management.

FACTS activities data (1881 – 2016) were analyzed to examine the amount and types of vegetation management that have affected ecosystems. This data suggests that the ecosystems with the most management impacts (in terms of percentage of acres, not intensity) are ponderosa pine, bristlecone-limber pine, lodgepole pine, and warm-dry mixed conifer (Table 4).

Table 4. Ecosystems and their predominant historical vegetation management activities on the GMUG

Ecosystem	Extent of Past Vegetation Management	Historical Vegetation Management Activities
Spruce-Fir Forest	Low	Even-aged management, intermediate treatments, uneven-aged management, planting/seeding
Aspen Forest	Low	Even-aged management, broadcast burning, intermediate treatments, uneven-aged management
Spruce-Fir-Aspen Forest	Low	Even-aged management, intermediate treatments, uneven-aged management
Lodgepole Pine Forest	Medium	Intermediate treatments, uneven-aged management, even-aged management, broadcast burning
Pinyon-Juniper Woodland	Low	Tree encroachment control, broadcast burning, intermediate treatments, fuels activities
Ponderosa Pine Forest	High	Intermediate treatments, planting/seeding, even-aged management, broadcast burning, uneven-aged management, fuels activities
Cool-Moist Mixed Conifer Forest	Low	Uneven-aged management, intermediate treatments, broadcast burning, even-aged management
Warm-Dry Mixed Conifer Forest	Medium	Broadcast burning, intermediate treatments, uneven-aged management, even-aged management, fuels activities, invasive treatments
Bristlecone-Limber Pine Forest	Medium	Uneven-aged management, broadcast burning, intermediate treatments
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	Low	Broadcast burning, intermediate treatments, planting/seeding
Sagebrush Shrubland	Low	Broadcast burning, fuels activities, planting/seeding
Montane-Subalpine Grasslands	Low	Broadcast burning, invasive treatments, planting/seeding, intermediate treatments
Alpine Uplands – Grasslands and Forblands	Very Low	-

*Grazing has not been included here and is further discussed in the Herbivory section below.

*Extent of past vegetation management was determined by the total acreage of activities in each ecosystem as a percentage of the total ecosystem acreage. This is an rough approximation given that spatially overlapping activities are counted more than once, which is also the case when there are multiple entries for one activity (for instance, planting after even-aged management or multiple entries as part of a shelterwood or seed-tree harvest). Low, Medium, and High correspond to 0-33%, 33-67%, and 67-100% of an ecosystem having vegetation management impacts, with Very Low representing less than 1%.

Another indicator of the influence of management is the amount of an ecosystem that is in a designated area. These areas tend to have more restrictions, less active management, and overall more protections that promote ecological integrity, although they are impacted by fire suppression within and adjacent to these areas. These areas include wilderness areas, other congressionally designated areas (such as Roubideau, Tabeguache, Fossil Ridge), Colorado roadless areas, research natural areas, and special interest areas. Alpine uplands have a high level of protection via these designated areas (81%). Most ecosystems have about half of their extent in some type of designated area. Some exceptions include sagebrush, ponderosa pine, and bristlecone-limber pine, which all have less than 20% in these categories (Table 5).

Table 5. Percentage of each ecosystem in designated areas, including wilderness, other congressionally designated areas, Colorado roadless areas, research natural areas, and special interest areas

Ecosystem	Ecosystem Total Acres	Total in Designated Areas	% in Designated Areas
Alpine uplands - grasslands and forblands	121,614	98,590	81.1
Aspen	460,345	206,757	44.9
Bristlecone-limber pine	8,172	1,511	18.5
Cool-moist mixed conifer	39,839	18,362	46.1
Lodgepole pine	283,713	122,941	43.3
Montane shrubland, oak-serviceberry-mountain mahogany	325,209	138,094	42.5
Montane-subalpine grassland	300,430	113,644	37.8
Pinyon-juniper woodland	107,309	57,189	53.3
Ponderosa pine	105,003	15,179	14.5
Rocky slopes, screes, cliffs or bare	166,138	131,646	79.2
Sagebrush	95,988	13,363	13.9
Spruce-fir	534,320	318,350	59.6
Spruce-fir-aspen	426,011	209,126	49.1
Warm-dry mixed conifer	19,027	9,846	51.8

The presence of **roads and trails** is a system stressor. Roads have a large impact on landscape patterns and processes by creating sharp edges in otherwise intact habitats. Some deleterious effects of roads include creating barriers to species mobility, acting as corridors for non-native and edge adapted species, and increasing human access to interior habitats (Baker and Knight 2000). Higher road densities can significantly affect the presence of large mammals such as elk, mountain lions, and black bear and can also alter natural disturbance processes and biotic interactions with communities. Roads also impact natural sediment and hydrologic regimes. They affect hydrologic processes by intercepting rainfall on the road surface and subsurface water moving down the hillslope, by concentrating flow on the road surface or adjacent ditch, and by diverting water from natural flow paths. Roads contribute more sediment to streams than any other land management activity (USDA FS 2000). Ecosystems at low and middle elevations in the plan area are most impacted by roads. Trails are a less significant stressor than roads, but have many of the same impacts, particularly those with motorized use.

Ecosystems with the most area impacted by roads (more than 10%) include sagebrush, montane-subalpine grasslands, and ponderosa pine. The ecosystems with the greatest area impacted by trails include alpine uplands – grasslands and forblands and montane-subalpine grasslands (Table 6).

Table 6. Area impacted by roads and trails by ecosystem

Ecosystem	Total Ecosystem Acres	Total Road Miles in Ecosystem[2]	Total Trail Miles in Ecosystem[3]	% Covered by Roads with Buffer (300 ft)	% Covered by Trails with Buffer (100 ft)
Alpine uplands - grasslands and forblands	121,614	34	154	1.8	3
Aspen	460,345	427	412	6.9	2.1
Bristlecone-limber pine	8,172	6	3	7	1
Cool-moist mixed conifer	39,839	23	22	5.2	1.3
Lodgepole pine	283,713	247	156	6.7	1.3
Montane shrubland, oak-serviceberry-mountain mahogany	325,209	412	303	8.5	2.1
Montane-subalpine grassland	300,430	672	367	12.8	2.7
Pinyon-juniper woodland	107,309	77	58	5.3	1.3
Ponderosa pine	105,003	173	62	12.1	1.4
Rocky slopes, screes, cliffs or bare	166,138	36	53	1.2	0.8
Sagebrush	95,988	291	30	18.4	0.7
Spruce-fir	534,320	363	486	5	2.1
Spruce-fir-aspen	426,011	325	381	5.8	2.2
Warm-dry mixed conifer	19,027	13	7	5.5	1

Herbivory, including **livestock grazing** and **wildlife grazing and browsing**, was an ecosystem driver in the pre-settlement time period, and currently can be an ecosystem driver or a stressor. Before Euro-American settlement, native ungulates grazed and browsed across the GMUG, with their populations kept in check by predators, natural disease cycles, and weather patterns. The Colorado Utes also grazed livestock in the area in unknown quantities (Summit Daily 2016).

Domestic livestock grazing has been a major use in the plan area since Euro-American settlement in 1874, and is one of the multiple uses on the GMUG. Domestic livestock have different impacts on natural communities than native wildlife. They graze in communities historically un-grazed by native herbivores (desert environments) and tend to congregate in

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[2] Roads are existing roads open to the public and open for administrative uses. All road jurisdictions within the GMUG NF boundary are included.

[3] Trails are existing open trails (open during snow-free season) and snow trails that are not coincident with roads or other trails within the GMUG NF boundary.

certain areas, especially riparian systems (Belsky et al. 1999). Cattle grazing on the GMUG was unregulated from the late 1870s to 1905. Efforts to control grazing began once National Forests were established in the plan area in 1905, focusing on adjusting livestock numbers and season of use, though livestock pressure remained high through the 1940s.

Current grazing intensity on the GMUG is much lower than historical levels. The number of permitted cattle, sheep, and horses has decreased over time, as described in the Rangeland assessement. While there is evidence that heavy grazing can degrade arid rangelands (Fleischner 1994; Todd and Hoffman 1999; among others), some native plants are adapted to ungulate grazing (Pieper 1994; Holecheck et al. 2010). Properly managed grazing, with respect to utilization levels, season of use, and numbers and type of animal, minimizes impacts to ecosystem function, can be sustainable over the long term (Pieper 1994; Holecheck et al. 2006; Davies et al. 2011), and can be beneficial to some native plant species and communities adapted to grazing. The amount and timing of precipitation also plays a large role in determining rangeland vegetation conditions. Through adaptive management of the timing, intensity and duration of grazing, effects on vegetation productivity and species composition can be managed (Holechek et al. 2010).

As seen in the Rangeland assessment, rangeland condition, which covers the active and vacant grazing allotments, has improved over time, with increasing amounts in good or excellent condition. Very little area is currently in poor condition. At the ecosystem level, pinyon-juniper has the highest amount in poor condition (3%). Ecosystems with the most area in fair condition include ponderosa pine (49%), pinyon-juniper (42%), montane shrubland (33%), sagebrush (19%), and montane-subalpine grasslands (18%). The remainder of rangelands on the GMUG are either in excellent, good, or unknown condition or are ungrazed/unsuitable for grazing. Wildlife herbivory on the GMUG is generally not an ecosystem stressor, though it has been identified as a problem in aspen regeneration in some small treated areas on the Grand Mesa and Uncompahgre Plateau.

While current grazing practices on the GMUG are ecologically sustainable, the legacy of high historical livestock levels and associated activities does impact the current ecological integrity of some ecosystems on the GMUG. For example, past grazing reduced fine fuels and contributed (along with active fire suppression) to low levels of fire in some ecosystems, particularly ponderosa pine (Belsky and Blumenthal 1997; Holechek et al. 2010). The GMUG also shows impacts of historic range-related activities designed to increase forage capacity, including chaining and reseeding of pinyon-juniper woodlands and disking and reseeding (with non-native crested wheatgrass) of large expanses of sagebrush.

Recreation use is an ecosystem stressor. Increasing levels of recreation on the GMUG, particularly unmanaged and illegal use, exacerbate this stressor. Impacts to terrestrial ecosystems from recreation include trampling of vegetation, soil compaction, erosion, disturbance of wildlife, pollution and littering, nutrient loading, and the introduction of invasive species. On the GMUG, these impacts vary geographically and are dependent on the type and amount of recreational activity. Dispersed camping and road/trail use are some of the most impactful recreation related stressors in the plan area.

Resource damage from dispersed camping has been a recent problem within the San Juans and Gunnison Basin geographic areas on the GMUG. Highly impacted areas occur around Crested Butte and the town of Gothic and the Alta Lakes and Priest Lake areas near Telluride.

Other areas with high dispersed camping impacts include Taylor Park and the Ironton and East/Middle/West Fork of the Cimarron areas near Ouray. Recreation on the Grand Mesa is focused on developed campgrounds and facilities that result in fewer impacts, and impacts of dispersed camping on the Uncompahgre Plateau have been fairly limited thus far.

The Forest began closing part of the Gothic area in 2016 to dispersed camping during the peak summer season and prohibits off-road motorized vehicle travel there. Additional dispersed camping restrictions are also currently being implemented in 12 travel corridors in the Gunnison area. Given the concern over impacts from dispersed recreation in particular, current plan components that direct closure or rehabitation of dispersed recreation sites where unacceptable environmental damage is occurring should be reviewed for adequacy.

Road and trail use are stressors due to the presence of these travel routes, primarily due to erosion and sedimentation as well as continual human presence. Roads and trails facilitate human access, and thus human impacts, to areas of the GMUG that would otherwise be remote. Some trail networks are quite dense and highly used for much of the summer. Climbing Fourteeners (mountains 14,000 feet in elevation and higher) is a very popular activity and is associated with high recreation impacts, particularly in sensitive alpine areas. Alpine ecosystems are especially vulnerable to recreation-related impacts due to the slow growth and recovery of vegetation in those areas. As a result, monitoring of recreation impacts in alpine areas is warranted. Off-highway vehicle use is another stressor that can cause resource damage when users travel off-trail or create new trails.

Recreation use has increased on the GMUG and is predicted to continue to grow due to population growth in the GMUG area. For more information, see the Recreation assessment.

Extraction of mineral resources and **oil and gas development** is an ecosystem stressor, though it does not currently impact large areas on the GMUG. In addition, lease stipulations and reclamation requirements reduce the impacts of these stressors on sensitive ecosystems.

Mining claims on the GMUG cover approximately 26,000 acres. Active and past mining claims overlap a variety of ecosystems. Past mining claims were predominantly in the lodgepole pine, spruce-fir, and rocky slopes, screes, and cliffs ecosystems, as well as alpine uplands, montane-subalpine grasslands, and aspen systems. Active mining claims are predominantly in the spruce-fir, aspen, and spruce-fir-aspen ecosystems, with some in the montane-subalpine grassland, lodgepole pine, and other types.

Coal is currently leased on approximately 15,000 acres, with 1,700 acres pending. Since 2012, two of the three mines are effectively closed, with an overall 60% drop in coal production over the past decade. Coal leases and mining have been mostly in the montane shrubland, aspen, and spruce-fir-aspen ecosystem types. Reclamation activities are required and have generally been successful.

While current levels of mining are low, abandoned mine lands can continue to act as an ecosystem stressor long past their period of active use. Abandoned mine lands may have ongoing issues with soil and water contamination, impacting aquatic and riparian ecosystem health and hindering revegetation efforts (Sheoran et al 2010, Nimick et al. 2004). The renewable and nonrenewable energy resources, mineral resources, and geologic hazards assessment has more information about the GMUG’s abandoned mine lands program.

Currently there are approximately 107,000 acres of the GMUG under lease for oil and gas development. An additional 8,000 acres are pending leasing actions and an additional 146,000 acres have been nominated for lease across the GMUG. Development of oil and gas leases (i.e., exploration and/or production well drilling) has been sporadic on the GMUG since the 1980s. Interest in oil and gas leasing on the GMUG began increasing in 2000 and continued for the following six years. Expressions of interest in leases have declined as oil and gas prices have fallen over the last several years. Oil and gas development activities tend to be in the montane shrubland, aspen, and sagebrush ecosystem types. Leased oil and gas reserves currently do not include the areas of the forest that have sage grouse populations. Any new areas leased would include stipulations to avoid affecting sage grouse populations.

Oil and gas development removes vegetation in order to construct wellpads, and can impact areas within ½ mile of a given wellpad due to construction of associated roads and pipelines, until revegetated. These well pads start at 4-5 acres, and have interim reclamation that reduces their size to 1-2 acres after being drilled. When they are plugged and abandoned, as well as revegetated, the site is considered fully reclaimed. However, even after sites are reclaimed, it may take years or decades for wellpad sites to recover to pre-development vegetation conditions. This can have both local-scale effects on vegetation as well as landscape-scale implications for wildlife due to habitat loss, fragmentation and loss of landscape connectivity (Sawyer et al. 2006, Northrup and Wittemyer 2012, Gilbert and Chalfoun 2011).

As of February 2017, Colorado Oil and Gas Conservation Commission (COGCC) reports active natural gas production is occurring from 11 natural gas wells on the GMUG, all on the Paonia Ranger District. An additional 76 wells on the GMUG are shut-in wells, have been drilled then abandoned, have been plugged and abandoned, or are planned but not yet drilled. Additional wells have been or are currently being analyzed in NEPA documents - these are mostly on existing pads or approved pads that have not yet been constructed.

Terrestrial Ecosystems – Assessment of Ecosystem Integrity

Reference Conditions, Departure, and Trend

Conditions that sustain ecological integrity are known as the ecological reference model. To assess whether an ecosystem has integrity, we first must evaluate and describe reference conditions for each key ecosystem characteristic. When possible in this assessment, we use the natural range of variation (NRV; also commonly referred to as historical range of variation/HRV) as the ecological reference model. NRV is the variation of ecological characteristics and processes over scales of time and space that are appropriate for a given management application (Landres et al. 1999; Keane et al. 2009). In the Western United States, NRV is typically derived from pre-European settlement conditions.

In some situations, there is not enough information to understand the natural range of variation for selected key ecosystem characteristics, and we use an alternative ecological reference model to provide context for the assessment of ecological integrity. Reference conditions are used to provide context for current conditions for the purpose of assessing ecological integrity, but they are not necessarily a management target or desired condition in their own right.

Current conditions for key ecosystem characteristics are compared to the ecological reference model to assess departure, defined as the degree to which the current condition of a key ecosystem characteristic is unlike the reference condition. We also describe likely trends for key characteristics based on existing plan direction and assuming that the influence of climate change and other stressors continues. In some cases, trends may be unstable or undiscernible. While this assessment is focused on reference conditions, it is important to note that the desired conditions used to form future plan components may not be the same as reference conditions discussed here.

Ecosystem Descriptions

Fifteen ecosystems found on the GMUG are described below, and assessed for key ecosystem characteristics, including diversity of cover types, distribution of structural stages, regeneration and recruitment, landscape disturbances, patch size, and snags and down woody material.

Spruce-Fir Forest

The spruce-fir forest ecosystem comprises 534,300 acres on the GMUG (17%). Spruce-fir forests are the highest elevational forests found within the context area, ranging in elevation from approximately 8,200 – 11,000 ft. Engelmann spruce (*Picea engelmanii*) and subalpine fir (*Abies lasiocarpa*) dominate this vegetation type. Other species intermixed in this system include blue spruce (*Picea pungens*), bristlecone pine (*Pinus aristata*), lodgepole pine (*Pinus contorta*) and other higher elevational tree species. In some areas Engelmann spruce may be the only overstory species (Romme et al. 2009).

Stand dynamics within spruce-fir are strongly influenced by the biological characteristics of these two species. Both Engelmann spruce and subalpine fir are easily killed by fire. Subalpine fir is a short-lived species and rarely exceeds a lifespan of 250 years due to heart rot. Spruce has greater longevity, often living over 500 years. Subalpine fir germinates successfully on fire prepared seedbeds and can exist under low light conditions better than Engelmann spruce. In contrast, Engelmann spruce is not an aggressive pioneer species (Bradley et al. 1992). Successional dynamics are also strongly influenced by site characteristics (elevation, topographic position, aspect, slope, soil type, soil moisture). For example, spruce is generally more dominant in very wet or dry environments, and fir in mesic environments (Peet 2000).

Prior to human-caused disturbance, the two most significant broad-scale disturbances 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, root disease, avalanches, blow-down events and fungi shaped the structure and composition of spruce and fir stands (Veblen et al. 1989, Veblen et al. 1991, Lertzman and Krebs 1991, Roovers and Rebertus 1993).

Aspen Forest

Aspen (*Populus tremuloides*) forest occupies 460,300 acres of the GMUG (14.6%). Aspen plays a crucial role in landscape diversity, spatial vegetation patterns, species habitat use and ecosystem processes (e.g. biogeochemical cycling) in an otherwise conifer-dominated landscape (Turner et al. 2003). Aspen is prevalent from 6,500 – 10,800 ft in elevation and is generally found in areas with cool, dry summers, cold winters, and deep, loamy soils with high nutrient availability.

Aspen is an early colonizing, long-lived clonal species that depends on periodic disturbances for regeneration. While aspen do produce seeds, their primary form of propagation is through root sprouts that form extensive clonal colonies (2-7 ac in size; Shepperd 1993). Stable aspen stands are characterized by multilayered aspen stems (uneven aged) with no conifer encroachment. The primary natural disturbance for regeneration is fire, although geomorphic events and wind can also initiate regeneration. In addition to fire, aspen forests are subject to mortality from insects, diseases and drought. Insects include the aspen bark beetle, bronze poplar borer, gypsy moth, and forest tent caterpillar, and diseases are mostly caused by fungi and impact older stands (>80 years old). Sudden aspen decline (SAD) refers to aspen mortality due to the combined effects of drought stress and insect/disease/fungi infestations. High rates of ungulate browsing on clonal shoots may delay aspen regeneration in some areas.

Spruce-Fir-Aspen Forest

The spruce-fir-aspen ecosystem covers 426,000 acres of the GMUG (13.5%). It generally occurs between elevations of 9,000 and 11,000 feet. This ecosystem is dominated by Engelmann spruce, subalpine fir, and quaking aspen. As stands age, aspen stems are slowly reduced and spruce and fir become more dominant. In areas where aspen is dominant soils are often moister, with more organic matter. Major disturbance agents in this system include blowdown, insects, and fire. Current conditions in spruce-fir-aspen on the GMUG are fairly homogeneous in terms of age, size class, and stand density, as a result of large scale fires that burned through these systems in the 1850s and again in 1878 to 1879 (Kulakowski and Veblen 2006, Sudworth 1900). This has resulted in most of this cover type being the same age, size class and stand density. This ecosystem is host to the same insect and pathogen organisms as spruce-fir forests, as well as aspen insects/pathogens.

Lodgepole Pine Forest

The lodgepole pine (*Pinus contorta*) ecosystem covers 283,700 acres of the plan area (9%). Lodgepole pine generally occurs between elevations of 8,000 – 10,800 ft and reaches the southern boundary of its range in the middle of the Gunnison Basin. Lodgepole pine south of this boundary within the context area were planted in small amounts in the early 20th century following severe fires in the late 1800s due to a concern regarding the lack of natural tree regeneration (Romme et al. 2009). Lodgepole pine has a lifespan of ~250 years, which is related to the frequency of stand-replacing fires that occur within this vegetation type (Mehl 1992). The understory of lodgepole pine stands is usually poorly developed with low species diversity due to a dense tree canopy cover and low soil fertility.

Lodgepole pine is seral to Douglas-fir at lower elevations and spruce-fir at higher elevations, though it also exists as a stable cover type. Stable lodgepole ecosystems have evolved with stand replacing crown fires to promote seed establishment from serotinous cones (although open cones also exist). These stands are associated with thin, well-developed soils, cold microclimates, and in areas where shade tolerant species do not exist. Lodgepole pine stands tend to be even-aged and single-storied. Older lodgepole stands have a more grouped, two-storied structure, with gaps caused by dwarf mistletoe (*Arceuthobium americanum*) mortality, endemic levels of bark beetles, tree failures due to stem rot, and windthrow/breakage. The majority of naturally occurring lodgepole on the GMUG regenerated during the late 1800s to early 1900s from drought initiated fire events.

In the 1960s -1980s, lodgepole pine was planted in several areas on the GMUG in response to failures to reforest spruce-fir clearcuts. These areas were outside of lodgepole pine's historic range. These lodgepole stands have generally not fared well, with high levels of mortality and undesirable growth forms (short, forked, bushy) where they have survived.

Pinyon-Juniper

The pinyon-juniper ecosystem occurs on 107,300 acres within the GMUG (3.4%), predominantly on the Uncompahgre Plateau with a smaller extent on the Grand Mesa. This ecosystem is found between elevations of 4,500-8,500 ft, on warm, dry sites on mountain slopes, mesas, plateaus and ridges, particularly those with rocky soil characteristics. At its lower elevational boundary, pinyon-juniper grades into the sagebrush, desert shrub, and desert grassland types, and at its upper boundary it transitions into the ponderosa pine and montane shrubland vegetation types. Pinyon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*) and Rocky Mountain juniper (*Juniperus scopulorum*) dominate this ecosystem. *Juniperus spp.* is dominant at lower elevation/xeric sites and pinyon pine dominates at higher elevation/mesic sites. Understory composition varies by ecosystem subtype and consists of perennial grasses, annual and perennial forbs, and shrubs.

Pinyon and juniper systems in the Western U.S. can be classified as one of three subtypes based on canopy structure, understory composition and historical disturbance regimes: persistent woodlands, wooded shrublands, or savannas (Romme et al. 2008). Persistent woodlands are characterized by dense trees, sparse to moderate shrubs, and few herbs with a fire regime of infrequent, high severity crown fires. Wooded shrublands are characterized by sparse to moderately dense herbs, shrubs, and trees and a moderately frequent mixed-to-high severity fire regime. Savannas are characterized by sparse trees, few shrubs, and dense grass and herbaceous cover with a fire regime of frequent, low-severity surface fires. All three types exist on the GMUG, with the highest abundance of persistent woodland, followed by wooded shrubland, with the savanna type present but rare.

Stand dynamics in the persistent woodland type may be more driven by climatic fluctuations, insects, and disease than fire (Eisenhart 2004, Romme et al. 2008). The Pinyon Ips beetle can cause pinyon trees to die within the same season that they are attacked (Romme et al. 2009). Root disease such as black stain root disease can also significantly alter pinyon stands. Beetle outbreaks are often aligned with drought conditions in these systems. For example, the drought in 2002 enabled the ips beetle to attack large tracts of pinyon pine in the western part of the GMUG in 2003 (USDA FS GMUG 2004). This pinyon pine mortality in the early to mid-2000s eliminated some of the pinyon in lower elevation areas outside of the GMUG boundary, potentially increasing the importance of the remaining pinyon on the GMUG as future seed sources and wildlife habitat for pinyon pine obligate species.

Pinyon-juniper are lower-elevation systems that are highly accessible to people and therefore have seen significant human influences related to grazing, tree removal, fire suppression and development. Heavy, year-round grazing started occurring in the late 1800s throughout pinyon-juniper systems and persisted until the mid-1950s. This contributed to the current tree dominated conditions by removing competing understory species and allowing the woody overstory species to prosper (Manier et al. 2003). Livestock grazing also led to tree removal (chaining) for better livestock forage, and reseeding with non-native crested wheatgrass, which caused significant fragmentation to pinyon and juniper systems (Knight et al. 2000) and unknown ecological consequences.

Ponderosa Pine Forest

The ponderosa pine (*Pinus ponderosa*) vegetation type occupies 105,000 acres within the GMUG (3.3%). Pure ponderosa pine stands are found predominantly from 6,000-9,000 ft of elevation on sandstone substrates. Ponderosa pine is the dominant tree species with occasional Rocky Mountain juniper at lower elevations and Douglas-fir and blue spruce occurring at higher elevations. More mesic ponderosa pine stands may have occasional small aspen clones. Ponderosa pine forest understory in southwestern Colorado is dominated by shrubs with grasses intermixed. Gambel oak (*Quercus gambelii*) is the dominant shrub species along with snowberry (*Symphoricarpos rotundifolius*), Oregon grape (*Mahonia repens*), buckbrush (*Ceanothus fendleri*), gooseberry (*Ribes* spp.), and serviceberry (*Amelanchier utahensis*).

Ponderosa pine forests on the GMUG are predominantly found on the Uncompahgre Plateau. Binkley et al. (2008; as summarized in Romme et al. 2009) reconstructed historical forest structure of ponderosa pine stands on the Uncompahgre Plateau. Average tree density in 1875 was estimated to be 55 trees/acre (range 30-90 trees/acre) and average basal area was estimated at 55 ft^2/acre (range 20-90 ft^2/acre). The stands in 1875 contained a few large trees (some with diameters > 3 feet), relatively numerous trees of medium size (1-2 ft in diameter) and a few smaller trees. Although many ponderosa pine forests are thought to have been maintained in an open structure by fire, there is also evidence that the ponderosa pine forest landscape was heterogeneous, with considerable variability in density and structure (Romme et al. 2009).

In addition to fire, insects and disease play a role in the dynamics of this ecosystem type. Approximately 200 species of insects are known to affect ponderosa pine, with the most important being mountain pine beetle (Romme et al. 2009). A mountain pine beetle (*Dendroctonus ponderosae*) outbreak occurred on the Uncompahgre Plateau in the 1980s. Dwarf mistletoe (*Arceuthobium vaginatum* ssp. *cryptopodum*) and root disease also operate in this ecosystem.

Three main anthropogenic influences are responsible for dramatic alterations in the structure and function of ponderosa pine forest ecosystems since Euro-American settlement: grazing, logging, and fire exclusion (Covington et al. 1997, Romme et al. 2009). These factors have led to ponderosa pine forests that have a relatively uniform and dense stand structure, with most trees small to medium-size and between 70-100 years old (Romme et al. 2009). This structure is associated with a high vulnerability to outbreaks of insects and disease, risk of high-severity wildfire, and concerns about regeneration (Romme et al. 2009).

In addition, climatic oscillations may have also played an important role in ponderosa pine forest dynamics over the past century (Covington and Moore 1994). Shifts in climate towards warm, wet periods have been suggested as the causal mechanism for the pulse of pine recruitment in the early 1800s that corresponded to the longest intervals between fires in numerous areas in the Southwest, pine recruitment in 1919, and recruitment since 1976 due to anomalous warming of the tropical Pacific (Swetnam and Betancourt 1998). The latest recruitment since 1976 followed the worst drought in the Southwest over the past 1000 years during the 1950s. The increased stand density in ponderosa pine over the past ~120 years without a long-term climatic perspective may suggest that anthropogenic changes were the only underlying factor for this change in structure (Swetnam and Betancourt 1998).

Cool-Moist Mixed Conifer Forest

This mixed conifer zone includes the transition zones between the higher elevation spruce-fir ecosystem and the warm-dry mixed conifer type described below. Locally this type is referred to as “cool-moist” mixed conifer, and occupies 39,800 acres on the GMUG (1.3%). This ecosystem is dominated by Douglas-fir, and various combinations of white fir (*Abies concolor*), Colorado blue spruce (*Picea pungens*), Engelmann spruce, subalpine fir, or quaking aspen with ponderosa pine occurring incidentally or absent. The abundance of individual tree species is dependent on local site characteristics (soil, aspect, slope, topographic position) and natural and anthropogenic disturbance history. Elevation typically ranges from about 8,500 to 10,000 feet. Serviceberry, snowberry, elderberry (*Sambucus microbotrys*) bush honeysuckle (*Distegia involucrata*), grasses, and shade loving forbs dominate the understory.

The primary disturbance in cool-moist mixed conifer forests are infrequent, stand-replacing fires, with occasional small, less severe fires. Root disease and insect outbreaks, such as Douglas-fir beetle (*Dendroctonus pseudotsugae*), also play a role in stand dynamics. Because of their mixed composition, these stands are unlikely to initiate insect outbreaks, but they may be affected by outbreaks that initiate in nearby homogenous stands, or by endemic levels of insects.

Warm-Dry Mixed Conifer Forest

The warm-dry mixed conifer type is found between elevations of 7,500-9,000 feet and is dominated by ponderosa pine, Douglas-fir, white fir, and occasionally aspen. This ecosystem occupies 19,000 acres on the GMUG (0.6%), and is found in a transitional zone between ponderosa pine and cool-moist mixed conifer systems. The abundance of individual tree species is dependent on local site characteristics (soil, aspect, slope, topographic position) and natural and anthropogenic disturbance history. Gambel oak, serviceberry, buckbrush, snowberry, mountain lover (*Paxistima myrsinites*), kinnikinnick (*Arctostaphylus uva-ursi*), grasses, and forbs dominate the understory.

Fire regimes in warm-dry mixed conifer systems are characterized by more frequent, less severe fires, with less frequent high-severity fires. Historically, stands typically had relatively open stand structures as a result, though patches of denser forest occurred as well. Where these stands experience high severity fires, there is the possibility for them to be converted to mountain shrublands. Like cool-moist mixed conifer stands, fungal infections and insect outbreaks, including spruce budworm (*Christoneura freemani*), Douglas-fir beetle, fir engraver beetle (*Scolytus ventralis*), and dwarf mistletoes play a role in stand dynamics. Douglas-fir beetle outbreaks are often coincident with drought, and have impacted large areas of the GMUG in recent years.

General patterns of change post-settlement are well documented in stand structure within the warm-dry mixed conifer forest type in the western U.S. (White and Vankat 1993; Mast and Wolf 2004). Specifically, there has been a shift in species composition and abundance to shade tolerant species such as white fir and Douglas-fir at the expense of the shade intolerant but more fire resistant ponderosa pine. This shift in species composition has been attributed to an alteration in the natural fire regime, likely due to a combination of heavy livestock grazing and fire suppression (Wu 1999; Romme et al. 2009).

Bristlecone-Limber Pine Forest

Bristlecone-limber pine forest occupies 8,200 acres of the GMUG (0.3%), with its entire range in the Gunnison Basin geographic area. Most stands of this type on the GMUG are dominated by bristlecone pine (*Pinus aristata*), with only a few occasions of codominant limber pine (*Pinus flexilis*). This ecosystem occurs on dry, rocky ridges and slopes, usually south-facing and between elevations of 8,800 to 12,100 ft. Stands are typically uneven-aged and multi-storied with open, patchy tree canopies. Fire frequency in this ecosystem is highly variable, and insect and disease information for this cover type is minimal. Bristlecone and limber pine are both subject to mountain pine beetle caused mortality, though the small extent of this ecosystem on the GMUG makes it unlikely to initiate an outbreak in the plan area. White pine blister rust is another potential threat to these species, though it is not yet known to be present on the GMUG.

Montane Shrubland, Oak-Serviceberry-Mountain Mahogany

The montane shrubland ecosystem covers 325,200 acres within the GMUG (10.3%). This vegetation type is prominent in the North Fork Valley, along the western slopes of the San Juan Mountains and on the Uncompahgre Plateau, and generally occurs from 6,500 – 9,500 ft in elevation. Some dominant shrubs include Gambel oak, serviceberry (*Amelanchier spp.*), big sagebrush (*Artemisia tridentata*), chokecherry (*Prunus virginiana*), snowberry, mountain mahogany (*Cercocarpus montanus*), and rose (*Rosa* spp). Elk sedge (*Carex geyeri*) predominantly grows under oak while non-native Kentucky bluegrass (*Poa pratensis*) grows in the openings along with bluebunch wheatgrass (*Pseudoroegneria spicata*), Thurber fescue (*Festuca thurberi*), and letterman's needlegrass (*Acnatherum lettermanii*). Vegetation types in this system may occur as sparse to dense shrublands composed of moderate to tall shrubs. Ecosystem structure may be multi-layered, with some short shrubby species occurring in the understory of the dominant overstory species, and can range from dense thickets with little understory to relatively mesic mixed-shrublands with a rich understory of shrubs, grasses and forbs.

Fire is the major disturbance for this ecosystem, with drought, frost, insects, and diseases also playing a role (Kauffman et al. 2016). Natural fires typically result in a system with a mosaic of dense shrub clusters and openings dominated by herbaceous species. Density and cover of Gambel oak and serviceberry often increase after fire, and fire can prevent encroachment of trees into shrubland. In some instances these shrublands may be seral to adjacent ponderosa pine and warm-dry mixed conifer forests (Floyd-Hanna et al. 1996). Fire exclusion in

Gambel oak types often results in increased biomass and decreased landscape diversity (Kauffman et al. 2016).

Sagebrush Shrubland

The sagebrush shrubland ecosystem comprises 96,000 acres within the GMUG (3.0%). Sagebrush is generally found on flat to rolling hills with well-drained clay soils and is characterized by dense shrubs with a significant herbaceous understory of bunch and sod grasses. Sagebrush on the GMUG falls into three different communities. Wyoming big sagebrush (*Artemisia tridentata ssp. wyomingensis*) dominates lower and drier elevations, mountain sagebrush (*Artemisia tridentata ssp. vaseyana*) dominates upper, wetter elevations, and low black sagebrush (*Artemisia nova*) communities can be found interspersed among big sagebrush types, on areas of heavy clay soils. Both Wyoming big and mountain sagebrush reach average heights of 1.6 feet, while black sagebrush has a shorter growth form, averaging 0.6 feet (Johnston et al. 2001).

Historically, 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. Presettlement stand-replacing fire frequency in sagebrush vegetation types is highly debated, and is likely dependent on fuels structure (i.e. open sagebrush vs. sagebrush-woodland ecotone) and sagebrush species (Baker 2006, Wright et al. 1979, Welch and Criddle 2003).

During the past century sagebrush ecosystems on the GMUG have been affected by livestock grazing, spraying to reduce shrub cover and increase grass and forb production, reseeding, fire suppression and most recently prescribed burning. 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 impacts soil through compaction, erosion (Thurow et al. 1988), and nutrient cycling (Semmartin et al. 2004).

Cheatgrass (*Bromus tectorum*) is an invasive species that is currently impacting the sagebrush ecosystem on the GMUG. As discussed in the Invasive Plants assessment, although it may be inventoried on only a small portion of the Forest, cheatgrass is prevalent. On the Uncompahgre Plateau in particular, most areas below 8,000 feet in elevation have cheatgrass. Cheatgrass displaces native vegetation and has been shown to increase fire frequency and severity (Colorado State University Extension 2012). It has become increasingly prevalent in Gunnison County, with managing this weed a priority (Gunnison County 2017).

Desert Alluvial Saltshrub

The desert alluvial saltshrub ecosystem comprises 331 acres within the GMUG, making it very rare on the forest, though it is quite prevalent in lower elevations within the context area. As such, we do not assess it for ecological integrity, but describe it here for completeness. The dominant plants in this vegetation type are salt-tolerant shrubs including shadscale (*Atriplex confertifolia*), fourwing saltbrush (*Atriplex canescens*), saltbrush (*Atriplex gardneri*), rubber rabbitbrush (*Chrysothamnus nauseosus*), and horsebrush (*Tetradymia* spp.). Desert alluvial saltshrub is generally found on marine shales with poorly drained, saline soils (Floyd-Hanna et al. 1996). In areas with extreme concentrations of salt, these shrubs are generally unable to grow and bare ground is abundant or the greasewood vegetation type replaces them. Successional dynamics are limited due to the strict adaptations needed to survive in this harsh environment.

Livestock grazing has had the most impact on this ecosystem since Euro-American settlement, altering the dominant vegetation towards non-palatable species. Because of the typically sparse vegetation cover, fires in this ecosystem were historically rare (West and Young 2000). Recently, fire has become more prevalent in this ecosystem across the Western US due to the establishment of non-native annual grasses, primarily cheatgrass. Areas that have experienced grazing, increases in non-native annuals, and increases in fire frequency are outside their HRV.

The winterfat shrub steppe is also included within this vegetation type and is found within the Upper Gunnison Basin at higher elevations (7,500 - 9,000 ft) than the desert shrub community described above (Johnston 1997). The winterfat shrub steppe is compromised of dwarf shrubs, primarily winterfat (*Krascheninnikovia lanata*), and native grasses. Areas affected by historical grazing have experienced a shift in species composition towards grazing increasers (e.g., snakeweed (*Gutierrezia sarothrae*), and rabbitbrush) and are outside their HRV.

Montane-Subalpine Grassland

The montane-subalpine grassland ecosystem occupies 300,400 acres within the GMUG (9.5%). These grasslands are found interspersed between forested vegetation types at elevations of 7,000-10,500 ft. A variety of factors including topography, geology, soil, climate, and disturbances (fire, mass movement, and snow) are responsible for the presence of meadows in between forested vegetation (Debinski et al. 2000). Soil texture has been identified to be one of the most critical factors explaining the presence of meadows at lower elevation areas, where they are generally found on fine-textured alluvial or colluvial soils while adjacent forested areas are found on coarse-textured, rocky soils (Peet 2000). At higher elevations, soil moisture appears to explain the presence of meadows. Areas with excessive moisture near streams, slope bottoms, or on substrates that keep water at the surface are generally dominated by grasses, sedges, and forbs (Peet 2000). Two dominant mountain grassland types are found on the GMUG: the Arizona fescue (*Festuca arizonica*) type that is associated with ponderosa pine and warm-dry mixed conifer and the Thurber fescue type that is associated with cool-moist mixed conifer and spruce fir. A third type, the non-native Kentucky bluegrass (*Poa pratensis*) type occurs at all elevations on the GMUG (Redders 2003).

Pre-settlement, natural drivers of these grasslands were herbivory by native ungulates and fire. Native ungulates likely moved through these systems as needed with variable extents and severity of grazing. Fires functioned to recycle nutrients, reduce litter, stimulate new plant growth, increase forage, and eliminate woody plant growth. The Utes used fire to increase forage for bison, as well as facilitate travel and improve visibility (Summit Daily 2016). High levels of livestock grazing after Euro-American settlement changed species composition, altered natural disturbance processes (fire) and nutrient cycling, increased erosion (Redders 2003).

Alpine Uplands – Grasslands and Forblands

Alpine uplands cover 121,600 acres within the GMUG (3.9%), and occupy elevations >11,000 ft on high mountain summits, slopes, and ridges (Billings 2000). Climatic variables such as intense cold, wind, solar radiation, and snow dictate the types of vegetation that can exist on these sites. Dwarf shrubs, prostrate herbaceous forbs, bunchgrasses, lichens, and mosses characterize this ecosystem. Topography (aspect, slope, position) plays a strong role in the diversity of alpine vegetation because of its influence on solar radiation, solifluction (downslope soil creep), and snow/water accumulation (Jamieson et al. 1996). It creates a mosaic of different depths of snow accumulation, which influences growing season lengths and moisture abundance (Walker el al. 1993). Some alpine upland subtypes, ranging from little to high snow accumulation, include fellfields (windswept areas), dry meadows (low snow), and moist meadows (base of snowfields) (Bowman et al. 2002).

As with other non-forested ecosystems, reference conditions for alpine systems are not well-known. The majority of alpine areas within the GMUG are currently designated as either wilderness or roadless areas and therefore subject to less contemporary disturbance than other ecosystems. However, many alpine areas on the GMUG were impacted by historic mining activities, particularly in the San Juan Mountains and the Gunnison Basin. Alpine environments are highly susceptible to soil disturbance (compaction, erosion) and are slow to revegetate due to a limited growing season, strong winds, drought, and high evaporation rates. Livestock grazing, mining, and recreation activities can cause soil disturbance in alpine ecosystems that subsequently alters species composition, abundance, biomass, nutrient cycling, and water availability (Redders 2003). In particular, alpine areas on the GMUG that have remnant roads from historic mining development now see high levels of OHV use that causes significant soil impacts.

Rocky Slopes, Screes, Cliffs

This ecosystem of barren and sparsely vegetated landscapes is found from foothill to alpine elevations throughout the GMUG, though we are not able to identify its precise spatial extent or acreage with our existing vegetation data. It occurs on steep cliff faces, in narrow canyons, and on smaller rock outcrops of various igneous, sedimentary, and metamorphic bedrock types, and includes the unstable scree and talus slopes that typically occur below cliff faces as well as alpine scree and rock glaciers. Rock glaciers are talus fields of rock cemented in a subsurface matrix of ice.

This ecosystem is sparsely vegetated, typically having less than 10% plant cover. Species composition consists of plants present in adjacent systems (unless exposed parent material is radically different) and herbaceous species specifically adapted to cliff faces and unstable talus slides. There may be small patches of dense vegetation, but typical structure is characterized by scattered trees and/or shrubs. Characteristic trees include species from the surrounding landscape, such as Douglas-fir, ponderosa pine, limber pine, aspen, white fir, subalpine fir, and pinyon pine and juniper at lower elevations. Shrubs adapted to xeric growing conditions and rocky soils are typically present, e.g. oceanspray (*Holodiscus discolor*), currant (*Ribes spp.*), wild rose, common juniper (*Juniperus communis*), shrubby cinquefoil (*Pentaphylloides floribunda*), three leaf sumac (*Rhus trilobata*), and American wild raspberry (*Rubus idaeus*). Because the elevation range of this ecosystem is so broad, species composition may vary widely from occurrence to occurrence.

Key Characteristic: Diversity of Cover Types

Current and Reference Conditions

Diversity of cover types is a key ecosystem characteristic that contributes to ecological integrity. A heterogeneous landscape with a diversity of species is an important adaptation strategy for both resistance and resilience to the impacts of climate change that can help maintain long-term integrity of ecosystems across the plan area (Lindemayer et al 2006; Thompson et al 2009; Vose et al 2012). Current ecosystem extents across the GMUG were calculated based on FSVeg Spatial data (see Appendix A. for crosswalk), and are compared to reference conditions from a Potential Natural Vegetation (PNV) type classification for the plan area. Environmental factors such as soils, slope, aspect, climate, and elevation determine the plant communities that potentially can grow on a given area. The PNV type for a give location is the vegetation that would become established there if all successional sequences were completed (i.e. disturbance was absent) under present climatic and edaphic conditions. Table 7 compares current ecosystem areas and percent of the plan area to PNV areas and percent of the plan area.

Table 7. Existing and PNV areas and percentage of the GMUG for terrestrial ecosystems

Ecosystem	Total acres	% of GMUG	PNV Total Acres	PNV % of GMUG
Spruce-Fir	534,320	17	544,095	17
Aspen	460,345	15	275,194	9
Spruce-Fir-Aspen	426,011	14	683,126	22
Lodgepole Pine	283,713	9	78,248	2
Pinyon-Juniper	107,309	3	119,809	4
Ponderosa Pine	105,003	3	91,031	3
Cool-Moist Mixed Conifer	39,839	1	91,031	3
Warm-Dry Mixed Conifer	19,027	1	184,968	6
Bristlecone-Limber Pine	8,172	<1	17,403	1
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	325,209	10	268,174	9
Sagebrush Shrubland	95,988	3	140,171	4
Montane-Subalpine Grassland	300,430	10	68,713	2
Alpine Uplands – Grasslands and Forblands	121,614	4	72,571	2
Other (aquatic, wetland, riparian, bare, saltshrub, rocky slopes, screes, and cliffs)		10		16

Departure and Trend

While potential natural vegetation types offer a useful reference condition for existing ecosystem diversity, they should not be used as an exact comparison, as they were developed to show the potential plant communities in the absence of disturbance. In actuality, disturbances operating across the landscape mean that many ecosystems are not at those potential future plant communities. Moreover, limitations in available spatial data may lead to inaccuracies in PNV analyses. For example, montane-subalpine grasslands are likely maintained by a variety of interacting factors (fire, wind, cold-air drainage, climatic variation, soil properties, competition, grazing), which were not all incorporated into the PNV analysis, and may explain why our current landscape conditions are characterized by significantly more grassland area than predicted by the PNV analysis.

While it should not be used as an ecosystem to ecosystem comparison, the PNV data provides a useful reference for overall landscape heterogeneity in ecosystem cover. The PNV reference condition shows a mean percent cover by ecosystem of 6%, with a standard deviation of 6% (Table 8). Our current ecosystem distribution has a mean percent cover of 7%, with a standard deviation of 5.5%, showing no significant departure from reference conditions in terms of ecosystem diversity across the GMUG. Relative to PNV reference conditions, current landscape heterogeneity in ecosystem cover is similar.

Table 8. Overall mean and standard deviation of percent cover of GMUG terrestrial ecosystems for existing and PNV conditions

Mean ecosystem % cover	Standard deviation % cover	PNV mean % cover	PNV standard deviation % cover
7	5.5	6	6

Future trends in diversity of cover types are difficult to anticipate. Climate change may cause the loss of some ecosystems due to differential impacts of drought stress across species. Projected increases in large disturbances (fires, insects, etc.; Vose et al 2012) could lead to greater homogeneity of cover types across the plan area. In order to increase resistance and resilience to climate change, we should strive to maintain existing diversity of ecosystems on the landscape and work to facilitate increases in diversity at both a plan and local scale when possible.

Key Characteristic: Distribution of Structural Stages

Current and Reference Conditions

Vegetation structural stages are defined by size class and canopy closure. Each ecosystem can manifest in a range of potential overstory vegetative conditions, each representing a unique phase in the overall ecology of the system. Distribution of structural stages can be used as an indicator for wildlife habitat, potential disturbance risk, and time since past disturbances. Although age of vegetation is not directly linked to structural stage, relative successional stages are implied by structure. Like diversity of cover types, distribution of structural stages is a key ecosystem characteristic that promotes resistance, resilience, and adaptation to the impacts of climate change and can help maintain ecosystem integrity (Vose et al. 2012, Thompson et al. 2009). Futhermore, landscape heterogeneity is one of the guiding principles of biodiversity conservation (Lindenmayer et al. 2006).

For this assessment, we characterized existing vegetation condition into habitat structural stages developed by USDA Forest Service Region 2 (Table 9). Reference conditions are based on output from a modelling exercise done on the GMUG in 2005. The Vegetation Dynamics Development Tool (VDDT; Beukema et al. 2003) was used to model the expected range in seral conditions that would have existed under historic disturbance regimes for forest, woodland, and shrub ecosystems. VDDT is a stochastic state-and-transition modelling software that can be parameterized based on deterministic transitions (i.e., aging) and probabilistic transitions (i.e., disturbances). Model parameters for disturbance frequency and severity for each ecosystem were developed by a team of resource managers and specialists, and can be found in Appendix B. Results of the VDDT models are not precise predictions, but are useful as a general reference condition. One limitation of these older VDDT models is that they are not spatially explicit, and thus may not accurately represent large-scale disturbances like stand-replacing fires and extensive insect outbreaks. In addition, there is not an exact correspondence between habitat structural stages as defined in our current vegetation data and the seral stages that VDDT models are based on (Table 10), possibly leading to discrepancies in their comparison. Finally, in the VDDT simulations, many “replacement” insect outbreaks were modelled as setting forests back to the “stand initiation” phase, which is likely an unrealistic representation of insect outbreaks in the plan area. Even high severity insect outbreaks typically leave many live saplings and small-diameter trees, in contrast to a high-severity fire that causes complete mortality of a stand.

Table 9. Definitions of habitat structural stages used to characterize ecosystem condition

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

Table 10. Crosswalk from ecological successional stage to VDDT seral stage and FSVegSpatial Habitat Structural Stage

Ecosystem type	Successional Stage	VDDT stage	Habitat structural stages
Forests and woodlands	Early	Stand initiation	1M, 1T, 2S, 2T
	Early-Mid	Stem exclusion	3A, 3B, 3C
	Late-Mid	Understory reinitiation	4A, 4B, 4C
	Late	Shifting Mosaic	
	Fire-maintained open (*Ponderosa only*)	Fire-maintained open (Ponderosa pine only)	1M, 2S
Shrublands	Early	Stand initiation	1M
	Mid	Early shrub dominated	2S, size S/M
	Late	Late shrub dominated	2S, size L

Departure and Trend

Comparison of existing conditions to VDDT model results varied by ecosystem, though a few consistent patterns emerged (Table 11). In all ecosystems, the GMUG has an under-representation of early seral stages on the landscape. This can be partly attributed to data limitations – both imperfect correspondence between habitat structural stages and VDDT seral stages, and difficulty in identifying early seral stages of ecosystems through aerial photography. However, given the relative lack of fire on the GMUG since at least 1970 and likely as far back as the early 1900s, and generally small areas of timber harvest in that same time period, we can reasonably conclude that very little of the GMUG is in an early-seral stand initiation phase. This under-representation of early seral stages is paired with an over-representation of mid-seral stages in almost all ecosystems. While our current data do not reflect the impacts of the spruce beetle outbreak on spruce-fir and spruce-fir-aspen, we expect that post-SB outbreak change detection analysis will show an over-representation of mid-seral stages, under-representation of late seral, and likely a typical representation of early-seral stages, although this will vary geographically across the forest. While the lack of early seral stages in the plan area is at least partly due to management influences, namely the legacy of the past century of fire exclusion, the overabundance of mid-seral stages is predominantly attributable to large, high-severity fires that burned across the GMUG in the late 1800s (Sudworth 1900), rather than historical timber harvest activities, which averaged only slightly more than a thousand acres per year in the late 1800's and early 1900's, as described in the Timber assessment.

Future trends will include the continued aging of stands and associated transitions into later seral stages, and possibly more frequent, extensive, and severe disturbances due to the effects of climate change (Vose et al 2012). In combination, this could cause structural stages in ecosystems across the GMUG to move towards NRV conditions, though in most ecosystems large and severe disturbances will be required to be within NRV for early seral stage proportions. Because of the ongoing spruce-beetle outbreak, spruce-fir and spruce-fir-aspen ecosystems may continue to move closer to NRV for representation of early seral stages, but will likely have lower than NRV percentages in late seral stages.

In order to sustain ecological integrity, our biggest management priority should not be trying to precisely match the modelled NRV conditions for seral stages, but to manage for increased heterogeneity in habitat structural stages across the plan area. Management strategies could include the reintroduction of fire as appropriate, mechanical treatments, and protection and preservation of old-growth forest where it is present on the landscape.

Table 11. VDDT seral stage model results and existing conditions for ecosystems on the GMUG

Ecosystem	Seral Stage	VDDT	Existing condition	Departure
Spruce-Fir*	Early	27-32%	<1%	-
	Early-mid	20-24%	21%	
	Late-mid/Late	43-53%	79%	+
Aspen	Early	8-14%	1%	-
	Early-mid	23-26%	48%	+
	Late-mid/Late	40-67%	51%	
Spruce-Fir-Aspen*	Early	13-19%	<1%	-
	Early-mid	22-29%	24%	
	Late-mid/Late	48-65%	76%	+
Lodgepole Pine	Early	22-39%	1%	-
	Early-mid	36-40%	64%	+
	Late-mid/Late	23-38%	35%	
Pinyon-Juniper	Early	1-3%	0%	-
	Early-mid	5-11%	42%	+
	Late-mid/Late	86-93%	58%	
Pinyon-Juniper with shrub component	Early	28-51%	0%	-
	Early-mid	39-43%	71%	+
	Late-mid/Late	9-29%	29%	
Ponderosa Pine	Early	14-16%	0%	-
	Early-mid	11-14%	21%	+
	Late-mid/Late	9-22%	41%	+
	Fire-maintained open	48-65%	36%	-
Cool-Moist Mixed Conifer	Early	13-24%	0%	-
	Early-mid	20-23%	33%	+
	Late-mid/Late	48-70%	67%	
Warm-Dry Mixed Conifer	Early	14-20%	0%	-
	Early-mid	19-20%	23%	+
	Late-mid/Late	51-76%	77%	+
Bristlecone-Limber Pine	Early	14-20%	0%	-
	Early-mid	19-20%	47%	+
	Late-mid/Late	51-76%	53%	
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	Early	30-70%	7%	-
	Mid	28-34%	49%	+
	Late	0-36%	44%	+
Sagebrush Shrubland	*Not modeled*			
Montane-Subalpine Grassland				
Alpine Uplands – Grasslands and Forblands				
Rocky Slopes, Screes, Cliffs				

*Based on pre-SB-outbreak data; current conditions on the landscape are significantly different

Key Characteristic: Regeneration and Recruitment

Current and Reference Conditions

Regeneration and recruitment of seedlings and saplings is a key ecosystem characteristic that is fundamental to the persistence of existing ecosystems on the landscape. Given that disturbance and plant mortality is a natural and recurring process in all terrestrial ecosystems on the GMUG, regeneration and recruitment within ecosystems is a requirement of their ability to perpetuate on the landscape. Current conditions on the GMUG for regeneration and recruitment are drawn from Forest Inventory and Analysis (FIA) plots sampled between 2002 and 2015 (Table 12), natural regeneration stocking survey data for the Gunnison Basin GA, and planting survival rates for the Forest and are discussed below.

Table 12. Seedlings/acre on FIA plots on the GMUG, sampled during 2002-2015

Ecosystem	# Plots	Seedlings/ac (spp.)	Current plan stocking requirements (trees/ac) - Minimum	Current plan stocking requirements (trees/ac) - Desired
Spruce-Fir	176	593 (Subalpine fir), 343 (Engelmann spruce)	150 - 200	360 - 530
Aspen	138	1,265 (Aspen)	1200	1800
Lodgepole Pine	56	498 (Lodgepole pine)	150 - 245	360 - 430
Pinyon-Juniper	28	120 (Pinyon pine), 3 (Juniper)	NA	
Cool-Moist Mixed Conifer	23	509 (Aspen), 114 (Douglas-fir), 36 (Blue spruce)		
Ponderosa Pine	8	0 (Ponderosa pine)	190 - 205	240 - 310
Bristlecone-Limber Pine	2	38 (Bristlecone pine), 0 (Limber pine)	NA	
Warm-Dry Mixed Conifer	0	No data available		
Spruce-Fir-Aspen	0	No data available		

FIA data

FIA plots sampled between 2002 and 2015 were examined. These plots do not represent a comprehensive assessment of forest regeneration in the plan area, as not all ecosystems on the GMUG are represented, and microplots sampled for seedlings are only 1/300 acre in size. Despite these limitations, the FIA data indicates that regeneration is currently functioning normally on the GMUG, exceeding current plan stocking requirements in all ecosystems but ponderosa pine, which had an inadequate sample size of only 8 plots. GMUG personnel have noted low levels of post-fire regeneration of ponderosa pine in recent years, though it is uncertain whether this is due to inadequate germination conditions associated with normal climate cycles or if it can be attributed to climate change.

Natural Regeneration Stocking Survey Data

Natural regeneration stocking survey data (2001 – 2015) was summarized for the Gunnison Basin geographic area (data provided by Art Haines). On average, 70% of the plots in each cutting unit have adequate regeneration (defined in the data summary as at least 300+ seedlings per acre). Regeneration success does vary by species and temporally due to drought and other factors. In cutting units with spruce regeneration, 74% of the plots had adequate regeneration. Adequate regeneration was a little higher for subalpine fir and aspen, and a little lower for lodgepole pine. Natural regeneration success of Douglas-fir was the lowest, with 56% of the plots inventoried in those cutting units having at least 300 seedlings per acre, but this species also had the smallest sample size of only two cutting units. The current forest plan standards and guidelines indicate the minimum percentage of plots that are stocked should be 75%, with the exception of ponderosa pine, which has a minimum of 70%.

Planting Survival Data

Planting survival rates (2004 – 2016) on the Forest were obtained from the regional silviculturist and were examined. Planting survival rates vary from year to year and by species. In some cases, low survival is attributed to low soil moisture in that year or harsh site conditions. The primary species planted on the GMUG are ponderosa pine and Engelmann spruce, which both appear to have adequate survival rates. First year survival rate of ponderosa pine fluctuated between 57 and 90%, with an average around 75%. Third year survival rate fluctuated between 43 and 93%, with an average around 64%. Engelmann spruce first year survival rate fluctuated between 53 and 100%, with an average of 89%. Third year survival rate of Engelmann spruce has only one year of data recorded, with survival of 100%.

In some recent years, Douglas-fir and lodgepole pine have been planted. The very limited data (from only 1 or 2 years) on these two species suggests rather low survival. Only a small area was planted with Douglas-fir (11 acres in one year, 20 acres in another). First-year survival for Douglas-fir varied between 53 and 67%. Third- year survival was 36%, but this only includes data from a single year. Additional information on why this survival was rather low could not be found. For lodgepole pine, 1st year survival was 63%, but this was based on data from a single year in which the lack of summer moisture reduced the survival rates throughout the region.

Other Information on Regeneration

Because of the large amount of the GMUG in the spruce-fir cover type and the ongoing and extensive spruce beetle outbreak, one concern is whether the areas impacted by spruce beetle have adequate regeneration. Pelz et al. (2016) suggest that three important factors in Engelmann spruce regeneration include local climate (given spruce is quite sensitive to moisture and temperature), local species composition (whether or not subalpine fir or other species such as lodgepole pine or aspen are present), and the slow pace of natural spruce regeneration. This species takes many years after a disturbance to regenerate fully-stocked stands. Seedling recruitment post spruce-beetle outbreak may be more likely where there is no established advanced regeneration (Pelz et al. 2016). New spruce regeneration is not uncommon in pure spruce forests following the ongoing spruce beetle outbreak on the Gunnison Ranger District of the GMUG (A. Haines, personal communication, Pelz et al.

2016). This observation is further confirmed by Prolic et al. (2017), who found sufficient regeneration in higher elevation stands of Engelmann spruce on the Gunnison National Forest, and suggests that partial cutting is a reliable way to secure natural regeneration in these stands. However, their research did not address the lower elevation, hotter, and drier spruce-fir stands that are more likely to experience climate-related regeneration issues.

Departure and Trend

Using current plan stocking requirements as a reference condition, there is no indication that forested ecosystems on the GMUG are currently departed from the reference model in terms of regeneration and recruitment, though we lack data in some systems. It is possible that localized departures from NRV in terms of regeneration or recruitment exist, but it is unlikely that the GMUG is currently outside of NRV at a landscape scale.

However, bioclimate modelling for future spatial distribution of suitable habitat for tree species suggests that the GMUG may trend away from NRV for regeneration and recruitment due to the effects of climate change. Bioclimate models incorporating climatic and topographic predictors for 14 tree species (Rehfeldt et al 2015) were used to identify areas on the GMUG that are projected to be threatened or lost habitat for each respective species by the year 2060. These models are built based on species presence-absence data, historic climate data (1961 – 1990) and topographic variables, and use climate projections for the decade 2055 – 2064 using output from three general circulation models (GCMs) and three scenarios for greenhouse gas emissions to predict areas of threatened or lost suitable habitat by species. Areas of threatened habitat are those that were climatically suitable in the reference period (1961 – 1990), but marginally unsuitable in the future (50% - 70% of nine scenarios predicted unsuitability). Areas of lost habitat are suitable in the reference period but very unsuitable in the future (projections for >70% of nine scenarios predict unsuitability). As these models are based on climate projections, there is significant uncertainty in their predictions. Moreover, predictions of lost suitable habitat by 2060 do not suggest that these areas will hit a climate threshold where immediate large-scale mortality occurs; a more realistic scenario will likely involve gradual declines in tree health and below-average levels of regeneration and recruitment as climate conditions become less and less suitable for existing species.

Comparison with the existing spatial extent of ecosystems suggests that many tree species will have minimal overlap between their current and future suitable habitat (Table 13; Maps 2 and 3 in Appendix A). Furthermore, it is likely that the future ability of a given species to regenerate successfully will be even more limited than its future suitable adult habitat, as the regeneration niche of a plant (requirements for a high chance of success in the replacement of one mature individual by a new mature individual of the next generation) is thought to be more restrictive than the habitat niche (physical and chemical limits tolerated by a mature plant in nature) (Grubb 1977). Results indicate that the ability of tree species to persist within their current spatial extent will be at risk across all forested ecosystems, but particularly so in lodgepole pine, ponderosa pine, and aspen. However, it is important to note that this analysis does not attempt to incorporate emergent suitable habitat, and we expect that some of the ecosystems that are expected to be most at risk within their current spatial extent will have the greatest area of new suitable habitat in projected future climate conditions. We expect that these species will be able to persist on the landscape given opportunities to migrate.

Future monitoring and management should be focused on assessing threats to regeneration and recruitment (climate or otherwise), and could possibly include proactively facilitating movement of plant species into suitable habitat as is necessary and appropriate. How this bioclimate modelling and the framework for facilitation of species movement will be incorporated into the revised forest plan are still very much a topic of discussion on the Forest.

Table 13. Percent area forecasted to be threatened or lost suitable habitat by 2060 (based on emission scenarios RCP4.5, RCP6.0 and RCP8.5) for major species within the current spatial extent of their corresponding ecosystems

[Threatened or lost habitat is based on bioclimate envelope modeling (Rehfeldt et al 2015).]

Ecosystem	Component species, % of habitat threatened or lost* within current ecosystem extent	% Area all component species threatened or lost*	% Area any component species threatened or lost*
Lodgepole pine	Lodgepole pine - 99%	99%	99%
Ponderosa pine	Ponderosa pine - 97%	97%	97%
Aspen	Aspen, 93%	93%	93%
Spruce-fir-aspen	Engelmann spruce - 77%, Subalpine fir - 66%, Aspen - 85%	56%	97%
Spruce-fir	Engelmann spruce - 57%, Subalpine fir - 58%	47%	68%
Warm-dry mixed conifer	Douglas-fir - 85%, Aspen - 71%, Ponderosa pine - 71%	47%	97%
Cool-moist mixed conifer	Douglas-fir - 86%, Aspen - 86%, Blue spruce - 25%	19%	97%
Bristlecone-limber pine	Bristlecone pine - 88%, Limber pine - 25%	18%	95%
Pinyon-juniper woodland	Pinyon pine - 48%, Rocky mountain juniper - 21%, Utah juniper 78%	4%	91%
Montane shrubland, oak-serviceberry-mountain mahogany	Gambel oak - 7%	7%	7%

* Predictions of lost suitable habitat by 2060 do not suggest that these areas will hit a climate threshold where immediate large-scale mortality occurs; a more realistic scenario will likely involve gradual declines in tree health and below- average levels of regeneration and recruitment.

Key Characteristic: Landscape Disturbances

An ecological disturbance is defined as any relatively discrete event in space or time that disrupts ecosystem, community, or population structure, and changes resources, substrate, or the physical environment (White and Pickett 1985). Major disturbances including fire, insects, and disease have historically acted as ecosystem drivers on the GMUG, but all have the potential to become stressors in the event of a change in their characteristic disturbance regimes. A disturbance regime describes a typical pattern of disturbances over space and time, and is characterized by extent, frequency, and severity. One indicator of ecosystem integrity is whether disturbance processes are occurring with the same frequency, severity, and extent as they did historically; i.e., is the disturbance regime within the natural range of variability? This section evaluates historic, current, and potential future patterns of landscape disturbances on the GMUG, with a focus on fire, insects, and disease.

Fire

Current and Reference Conditions

Wildland fire is a component of many of the ecosystems on the GMUG, both as an ecological driver and as a stressor. Some plant species are fire-adapted, with traits such as thick bark (e.g. Douglas-fir) or prolific sprouting after fire (e.g. aspen) that enable them to persist in a frequent-fire environment. Other ecosystems like ponderosa pine are adapted to frequent, low-intensity fires which maintain an open stand structure, which in turn increases resistance to future disturbances.

Fire regimes describe historical fire conditions that influenced how vegetation communities evolved and were maintained over time, and are generally characterized by frequency and severity. Fire frequency is the average number of years between fires, and fire severity is the effect fire has on the dominant overstory vegetation (Schmidt et al 2002). A low severity, or surface fire, burns less than 25% of the overstory vegetation, while a high-severity (stand-replacing) fire, burns more than 75% of the overstory vegetation. Mixed-severity fires have areas of both low and high-severity, resulting in a mosaic, or patchwork of burned and unburned conditions.

Fire regimes generally vary in severity and frequency over a moisture and elevation continuum with lower severity, more frequent fires occurring at lower, drier elevations; and higher severity, less frequent fires occurring at higher elevations. In addition to broad patterns found across elevational and moisture gradients, fire regimes can be generalized according to vegetation type. Dendroecologists reconstruct fire history in forested ecosystems using fire-scarred trees to determine fire years and ring counts from increment cores to determine stand ages. The current state of knowledge on fire regimes for ecosystems on the GMUG is described below and summarized later in Table 16.

In the highest elevation alpine upland ecosystems, fire likely does not play a significant role. This ecosystem is typified by persistent snowpack and patchy fuel distributions and would require a coincidence of severe drought and available ignitions in order to burn.

Below the alpine zone, spruce-fir forests are characterized by late-lying snow-packs and frequent summer precipitation. Due to this moisture, there are typically long intervals between fires, and fires that initiate when fuels are not sufficiently dry are small in extent. Fires in this ecosystem are often driven by regional weather patterns, with large fires only occurring after extended dry periods. When fires do occur in these forest types during drought periods, they are often more severe than fires at lower elevations because of abundant available fuel. The extensive even-aged structures of spruce-fir forests in western Colorado and elsewhere in the southern Rockies indicate these forests are shaped primarily by infrequent (fire return interval of 100 to > 300 years) but lethal stand-replacing fires (Kulakowski and Veblen 2006). The historic fire regime for spruce-fir forests in Colorado’s Front Range was long return interval (>200 years), stand replacing fires, which could cover areas from 1,000 to 10,000 acres (Peet 1981) mixed with infrequent low intensity surface fires that affected much smaller areas. Spruce-fir forests in the San Juan Mountains have a historic fire return interval of 300 years (Romme et al. 2009). Fire return intervals tend to be even longer at higher elevations and in moist depressions and valley bottoms, up to 500 years (Romme et al. 2009). Research in the San Juan Mountains and on the Grand Mesa has shown that there has been a lack of stand replacing fires in spruce-fir forests in those areas since Euro-America settlement and that widespread high-severity fires occurred in the region around 1879 (Romme et al. 2009; Kulakowski and Veblen 2006).

The fire regime in spruce-fir-aspen is similar to that of spruce-fir forests: long return interval stand-replacing fires affecting large areas, mixed with infrequent low-intensity fires affecting small areas. Recent fires have been infrequent, very small, and mostly human-caused in spruce-fir-aspen forests on the GMUG. Current conditions in spruce-fir-aspen in the plan area are the result of large scale fires that burned through these systems in the 1850s and again in 1878 to 1879 (Kulakowski and Veblen 2006, Sudworth 1900). While no comprehensive fire histories have been compiled for this ecosystem, fire management officers (FMOs) and resource specialists on the GMUG estimate a high severity fire return interval of 150 – 300 years.

In aspen forests fire is the primary natural disturbance for regeneration, and stable aspen ecosystems tend to be located at lower elevations in areas adjacent to ponderosa pine stands where the fire regime is frequent, although stable stands also exist at higher elevations (Romme et al. 2001). Fires of moderate intensity produce the highest amount of sprouting that allows stable aspen stands to persist (Parker and Parker 1983). Historically, fires were most likely frequent surface fires that did not burn into the tree canopy. Aspen stands on the GMUG likely have fire return intervals from 75-125 years, though lower elevation aspen associated with Gambel oak or ponderosa pine may have historical fire frequencies of 35-75 years.

The majority of naturally occurring lodgepole on the GMUG regenerated during the late 1800s to early 1900s from drought initiated fire events. Historic fire intervals in lodgepole pine in Colorado’s Front Range were between 200-400 years at higher elevations, though 50-150 year intervals were more characteristic at lower elevations (Peet 1981). There is a paucity of site-specific research regarding lodgepole pine because of its limited natural distribution and abundance in the plan and context areas. Johnston et al. (2001) estimates fire return intervals of 240-300 years in lodgepole pine on the GMUG; FMOs suggest that lodgepole stands <9500 ft elevation have a fire regime of low-to-mixed severity every 35-200 years, and stands >9500 ft elevation have high-severity fires occurring at that same interval.

The role of fire in bristlecone-limber pine forests on the GMUG is unclear. Lower elevation stands (8,000 – 10,000 ft) are thought to have mixed severity fires every 35-200 years, while stands at higher elevations (>10,000 ft) burn much less frequently, and are likely characterized by light surface fires that occasionally scorch the crown of individual trees. No fire scars have been found on high-elevation bristlecone pine in the Gunnison Basin geographic area.

Cool-moist mixed conifer forests are characterized by lethal fires occurring at intervals of 50 – 200 years with occasional small, less severe fires (Fulé et al. 2009, Romme et al. 2009). Cool-moist mixed conifer stands have less frequent fire return intervals, but higher fire severity compared to warm-dry mixed conifer types. When fires do finally burn through these stands after a long period of no fire, the fuel that has built up will lead to a higher intensity fire than what is observed in the dry mixed conifer forests. GMUG specialists think that a low-mixed severity return interval of 35-200 years may be typical for these forests in the plan area.

Fire regimes in warm-dry mixed conifer systems are characterized by more frequent, less severe fires (20 to 50 years) with less frequent high-severity fires (150-200 years) (Johnston et al. 2001). It is likely that many fire events in this forest burned at mixed severity, with low intensity in some areas and higher intensity in others, depending on aspect, fuel buildup, and fine-scale variability in moisture levels. Historically, stands were characterized by relatively open stand structures as a result, though patches of denser stands occurred as well. 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.

Pre-settlement southwestern ponderosa pine forests were regulated by fire. Low intensity surface fires carried by grass and shrubs recurred frequently in southwestern ponderosa pine ecosystems prior to Euro-American settlement and played a major role in regulating the structure, composition, and stability of these ecosystems (Swetnam and Baisan 1996, Fulé et al. 1997). Historic fire intervals were between 10-25 years in ponderosa pine stands on the Uncompahgre Plateau (Brown and Shepperd 2003). These frequent, low-intensity fires, along with shrub and grass competition, prevented dense ponderosa pine regeneration and maintained the open, park-like structure of pre-settlement ponderosa pine stands. Generally, large fire years in ponderosa pine are associated with one to two above-average winter and spring precipitation years followed by a drought year; a sequence which permits fine fuels to accumulate and subsequently dry out. (Swetnam and Baisan 1996).

In pinyon-juniper ecosystems, historic fire return intervals varied but were generally quite long (many centuries). Fire return intervals vary by pinyon-juniper subtypes, with the longest intervals in persistent woodlands, and shorter intervals in pinyon-juniper shrublands, though there is less data on the role of fire in this subtype. Fire history research conducted on the Uncompahgre Plateau found fire return intervals of 200-1000 years in pinyon-juniper woodlands (Eisenhart 2004), while a study in Mesa Verde National Park in SW Colorado determined that the pinyon-juniper fire return interval was 400 years (Floyd et al 2000, 2004). Empirical data on fire return interval in pinyon-juniper stands with a significant shrub component is inadequate (Romme 2009), but fire managers and specialists on the GMUG estimate that this type is characterized by low to mixed severity fire every 35-200 years.

In montane shrublands, fire is the major disturbance and typically burns at a high severity. Floyd et al. (2000) found a fire return interval of 100 years in Mesa Verde NP, though FMOs expect that the pre-settlement return interval on the GMUG was in the 1-35 year range. Fire typically plays an important role in this system, causing die-back of the dominant shrub species in some areas, promoting stump sprouting of the dominant shrubs in other areas, and controlling the invasion of trees into the shrubland system. Density and cover of Gambel oak and serviceberry often increase after fire.

Pre-settlement fire frequency in sagebrush vegetation types is highly debated, and was likely dependent on fuel structure (i.e. open sagebrush vs. a sagebrush-woodland ecotone) and sagebrush species. A study by Wright et al. (1979) suggested that pre-settlement stand replacing fires occurred every 40-60 years, with smaller fires less often. However, Welch and Criddle (2003) have questioned fire frequencies of this interval and state that fires most likely were less frequent than often inferred for sagebrush communities based on sagebrush's longevity, highly flammable bark, low growth form, inability to resprout after fires, poor seed bank, and seeds lacking adaptations to high intensity fires (e.g., thick seed coat). Estimates of fire return intervals for sagebrush systems generalized across the west from multiple studies 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 (Baker 2006).

Subalpine and montane grassland fire regimes are closely tied to adjacent forest types, with more frequent fires at mid elevation ponderosa pine and warm-dry mixed conifer forests and less frequent fires with adjacent cool-moist mixed conifer and spruce/fir forests. There is little evidence for fires occurring in meadows independent of fires in adjacent forested areas (Romme et al. 2009). Livestock grazing since Euro-American settlement has changed fuel types and structure in grasslands, likely altering the fire regime in this ecosystem.

Table 14, Table 15, and Map 4 (Appendix A) summarize contemporary conditions for annual area burned and ignitions by ecosystems and geographic areas on the GMUG. Fire history (area burned) spans 1968-2014, and includes all fires greater than 5 acres. Ignitions data includes 1970-2013 and includes both natural and human-caused ignitions. Over this period, the GMUG had an average of 49 ignitions/year. The majority of these, 65%, were lightning caused, while the remainder were human-caused.

Table 14. Contemporary ignitions and wildfire area burned by ecosystem on the GMUG

Ecosystem	Mean annual ignitions/sq. mile (1970 - 2013)	Total acres burned (1968-2014)	Mean annual acres burned (1968-2014)	Mean annual % burned (1968-2014)
Spruce-Fir	0.007	1,412	38	0.01
Aspen	0.007	1,890	51	0.01
Spruce-Fir-Aspen	0.009	579	16	0.00
Lodgepole Pine	0.009	1,131	31	0.01
Pinyon-Juniper	0.022	4,565	123	0.13
Pinyon-Juniper with shrubs[1]	0.031	374	10.12	0.07
Ponderosa Pine	0.039	9,975	270	0.26
Cool-Moist Mixed Conifer	0.012	144	4	0.01
Warm-Dry Mixed Conifer	0.017	418	11	0.06
Bristlecone-Limber Pine	0.012	0	0	0
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	0.013	14,241	385	0.12
Sagebrush Shrubland	0.009	1,346	36	0.04
Montane-Subalpine Grassland	0.009	8,733	236	0.08
Alpine Uplands – Grasslands and Forblands	0.002	1	<1	<0.01
Other (Rocky Slopes, Screes, Cliffs, Riparian, Wetlands, Bare)	0.007	2,934	79.30	0.02

[1] Here we identify the Pinyon-Juniper with shrubs type as those polygons that have > 30% shrub cover.

Table 15. Wildfire area burned (acres) by ecosystem and geographic area on the GMUG (1968-2014)

Ecosystem	Grand Mesa	North Fork Valley	Gunnison Basin	San Juans	Uncompahgre Plateau
Spruce-Fir	29	234	160	880	109
Aspen	60	2	719	881	227
Spruce-Fir-Aspen	25	25	310	183	36
Lodgepole Pine	0	0	1,131	0	0
Pinyon-Juniper	908	15	0	0	3,642
Pinyon-Juniper with shrubs	57	0	0	0	317
Ponderosa Pine	0	0	466	0	9,510
Cool-Moist Mixed Conifer	0	0	133	0	12
Warm-Dry Mixed Conifer	1	0	350	0	68
Bristlecone-Limber Pine	0	0	0	0	0
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	515	83	10	24	13,609
Sagebrush Shrubland	0	5	312	0	1,030
Montane-Subalpine Grassland	595	476	1,678	23	5,961
Alpine Uplands – Grasslands and Forblands	0	0	0	1	0
Other (Rocky Slopes, Screes, Cliffs, Riparian, Wetlands, Bare)	149	28	222	62	2,472
Mean annual acres burned	63	23	148	56	1,000
Mean annual % burned	0.019	0.005	0.011	0.016	0.163
Mean annual ignitions	5.12	3.97	13.15	4.59	21.94
Mean annual ignitions/sq. mi.	0.010	0.005	0.006	0.008	0.023

Historic fire regimes (return interval, severity, and annual acres burned) were calculated for ecosystems on the GMUG based on a literature review and consultation with experts. When available, fire histories from on or near the GMUG were given preference in the calculation of historic fire intervals. Contemporary conditions were calculated based on spatial fire history data for the GMUG from 1968-2014 for wildfires, and from 1980-2015 for prescribed fire (Table 16). Prescribed fire activities include broadcast burning, jackpot burning, low intensity underburning, and pile burning. Pile burning was included in this analysis because it mimics broadcast burning from a fuels perspective, lowering fuel levels in the entire area from which pile material was gathered.

Table 16. Pre-European settlement fire regimes (left) and contemporary fire conditions (right) for selected ecosystems on the GMUG

[Ecosystems where fire is not a typical disturbance, or fire regimes are not well understood are not included in this table.]

Ecosystem	**Pre-European Settlement Conditions**			**Contemporary Conditions (Wildfire 1968 - 2014; Rx fire 1980 - 2015)**				
	Fire Severity	**Fire Return Interval (FRI; years)**	**Average annual acres burned (based on FRI)**	**Average annual acres burned (wildfire)**	**Average annual acres burned (Rx fire)**	**Average annual acres burned (Wildfire & Rx fire)**	**Percent of historic average annual acres burned (based on FRI)**	**Additional fire needed to be within NRV levels (multiple of current)[1]**
Spruce-Fir	High	200 - 500	1,070 – 2,670	38	324	362	13.6 - 33.8	3.0 - 7.4
Aspen	High	75 - 140	3,290 – 6,140	51	333	384	6.3 - 11.6	8.6 - 16.0
Spruce-Fir-Aspen	High	150 - 300	1,420 – 2,840	16	146	162	5.7 - 11.4	8.8 - 17.5
Lodgepole Pine < 9,500 ft elevation	Mixed	50 - 200	150 – 580	4	162	166	28.6 - 111.1	0.9 - 3.5
Lodgepole Pine > 9,500 ft elevation	High	200 - 400	640 – 1,270	27	214	241	18.9 - 37.0	2.7 - 5.3
Pinyon-Juniper	High	200 - 1000	90 - 460	123	22	145	31.3 - 166.7	0.6 - 3.2
Pinyon-Juniper with shrubs	Low-mixed	35 - 200	70 - 420	10	18	28	6.7 - 40.0	2.5 - 15.0
Ponderosa Pine	Low	10 - 100	1,050 – 10,500	270	274	544	5.2 - 52.6	1.9 - 19.3
Cool-Moist Mixed Conifer	High-mixed	50 - 200	200 - 800	4	66	70	8.8 - 34.5	2.9 - 11.4
Warm-Dry Mixed Conifer	Low-mixed	20 - 50	380 – 950	11	40	51	5.4 - 13.3	7.5 - 18.6
Bristlecone-Limber Pine <10,000 ft elevation	Low-mixed	9 - 55	50 – 320	0	15	15	4.7 - 30.3	3.3 - 21.3
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	High	1 - 100	3,250 – 325,200	385	270	655	0.2 – 20.0	5.0 - 496.5
Sagebrush Shrubland	High	40 - 240	400 – 2,400	36	375	411	17.2 – 100.0	1.0 - 5.8

	% area of selected ecosystems on GMUG burning/year – Wildfire only	**% area of selected ecosystems on GMUG burning/year – Wildfire and Rx fire**
Total of selected ecosystems	0.041	0.134

[1] "Additional fire needed" is the ratio of pre-settlement average annual acres burned calculated from FRIs to contemporary annual acres burned, and represents departure from NRV as a multiplicative factor. For example, aspen forests on the GMUG need at least 8.6, and up to 16 times more fire than they have had in the last 50 years in order to be within their natural range of variability for fire regime.

Departure and Trend

Under wildland fire management and suppression policies of the last century, the fire regime in much of the western US, including the plan area, has been significantly altered, particularly in lower elevation ecosystems. Other activities such as timber management, grazing, invasive species, and rural/urban development also contribute to changes in fuel structures and conditions that are uncharacteristic of the natural fire environment. These anthropogenic effects have resulted in fewer fires affecting fewer acres on the GMUG since the late 1800s, even with the increase in broadcast burning on the Forest since the late 1900s. The subsequent accumulation of live and dead fuels in some ecosystems, along with increased spatial continuity of fuels across the landscape has created the potential for larger and more severe fires. Additionally, a recent high-severity spruce beetle outbreak has created atypical fuel loads in spruce-fir and spruce-fir-aspen forests. It is unclear if this will affect future fire occurrence and severity in impacted areas, as there are studies that both support and contradict this idea (Jorgensen and Jenkins 2010, Page et al. 2014, Bebi et al. 2003, Andrus et al. 2015, Black et al. 2013).

Results of our comparison between historic and contemporary fire return intervals (Table 16) indicate that many ecosystems on the GMUG are outside of NRV for fire regimes, sometimes drastically so. However, these results should be interpreted with care, as our “contemporary conditions” are based on only 34 years of data. In ecosystems like spruce-fir, where historic fire return intervals range from 200-500 years, a 34 year timeframe is too short to accurately represent ecosystem dynamics. In general, the lack of stand-replacing fires within the higher severity, longer-interval fire regimes (i.e. spruce-fir, spruce-fir-aspen, high elevation lodgepole) in the plan area after Euro-American settlement could be interpreted as a result of fire suppression and other anthropogenic effects in the 20th century, or it could be due to a lack of appropriate extreme weather conditions occurring for stand-replacing fires to initiate.

However, results that indicate departures from NRV in our lower-severity, frequent fire ecosystems (i.e. ponderosa pine, pinyon-juniper shrublands, warm-dry mixed-conifer) are much more likely to reflect an actual departure, and are in many cases clearly attributable to anthropogenic influences. Anthropogenic influences include both direct fire suppression and indirect effects from land uses that impact fuel structures, including reduction of fine fuels due to livestock grazing.

In the future, changing climate is expected to continue to lengthen the fire season and favor larger, more frequent fires (Westerling et al. 2006). There is some evidence suggesting that higher temperatures predicted to occur with climate change may lead to increasing trends in fire related tree mortality, independent of fire intensity (van Mantgem et al. 2012). This might mean that fire intensities that did not result in tree mortality in the past, could be expected to result in tree mortality in the future.

Introduction of cheatgrass (*Bromus tectorum*), an invasive annual grass, can serve to increase fire frequency through a positive feedback cycle (Whisenant 1990), and cause ecosystem conversion. As discussed in the Invasive Plants assessment, although it may be inventoried on only a small portion of the Forest, cheatgrass is prevalent. On the Uncompahgre Plateau in particular, most areas below 8,000 feet in elevation have cheatgrass.

Over the past few decades there has been an increase in wildland urban interface (WUI) values (homes, subdivisions, and energy, communication, and recreational infrastructure) adjacent to and on the GMUG. The implications of this trend (which is expected to continue) for fire management include more values to protect from wildfires, more need for fuels treatments adjacent to these values to reduce fire risk, and an expectation from the public that these WUI resources are a priority for protection from wildfire. WUI trends are further discussed in the Infrastructure Assessment and the Land Status and Ownership, Use, and Access Patterns Assessment.

Prescribed fire and wildfire use have been and will continue to be important management tools in sustaining ecological integrity of fire-adapted ecosystems on the GMUG in the future. However, restoring the historic fire regime in all ecosystems may not be a desirable or achievable goal, given altered fuel characteristics, climate change, and operational and budget constraints. Reintroducing historic fire intervals in ecosystems that now have ahistorical fuels structure and novel climatic conditions could result in a decline in some forest types (Diggins et al. 2010). Future fire use decision making will need to consider actions to resist climate change impacts in order to protect high-value resources, actions to create resilience to climate change effects, and actions that may facilitate expected cover type conversions that may accompany climate change (Vose et al. 2012).

Insects and Disease

Current Conditions

Several insects and diseases significantly influence the structure and composition of the forests on the GMUG (Table 17, Table 18, USDA FS GSC 2017). Most insects and pathogens are natural components of the ecosystem and play important ecological roles. Tree mortality and other impacts of insects and diseases regulate forest vegetation composition, influence stand density and structure; provide wildlife habitat in dead and dying trees; and contribute nutrients to soils. Insects are also food for birds and other wildlife.

At low levels of infestation individual trees are weakened and killed, resulting in small scale changes affecting limited areas. When conditions such as stand maturity, overcrowding, drought, blowdown, or poor site conditions act independently or in combination to stress large groups or stands of trees, populations of forest insects and pathogens can increase in these stressed trees, resulting in widespread mortality (“outbreaks”). Trees weakened by one organism are often susceptible to attacks by other organisms as well.

Currently, the insects and diseases having the greatest impact on the GMUG are spruce beetle (*Dendroctonus rufipennis*) and Douglas-fir beetle (*Dendroctonus pseudotsugae*) (Table 17). Other significant insects and diseases include western balsam bark beetle (*Dryocoetes confuses*), western spruce budworm (*Christoneura freemani*), annosus root disease (caused by *Heterobasidion occidentale*), Armillaria root disease (*Armillaria spp.*), lodgepole pine needle casts (*Lophodermella concolor* and *Lophodermella montivaga*), dwarf mistletoes, and Marssonina leaf blight (Map 5, Appendix A).

Table 17. Acres of major damage agents detected in aerial survey on the GMUG

[USDA FS GSC (2017)]

Agent	2015 Acres Affected	2016 Acres Affected	1996-2016 Cumulative Acres Affected
Spruce beetle	100,100	91,000	328,000
Douglas-fir beetle	2,183	3,520	61,400
Mountain pine beetle	600	0	17,120
Western spruce budworm	11,400	16,010	unknown
Subalpine fir mortality	11,700	6,700	
Fir engraver	5,600	2,861	
Lophodermella needle cast	222	2,300	
Aspen diseases, including sudden aspen decline (SAD), aspen discoloration, aspen defoliation, and aspen dieback and mortality.	35,400	3,890	229,000

*Cumulative acres affected for aspen diseases is for 2000 - 2010

The spruce beetle is a bark beetle that infests all species of spruce in North America. On the GMUG, Engelmann spruce is the principal host. The spruce beetle may persist for decades to centuries in spruce stands as a rarely encountered, endemic insect. Under the right conditions, they may have extensive, severe outbreaks over large areas of forest (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 GMUG. In 2016, the Forest had 91,000 acres of active spruce beetle infestation. Cumulative acres affected by spruce beetle (1996-2016) total 328,000 acres, with the majority of that in the Gunnison Basin (USDA FS GSC 2017). On the GMUG, spruce beetle has caused mortality of lodgepole pine in addition to its primary host of Engelmann spruce.

Virtually all major portions of the Gunnison Basin with mature spruce have now been impacted to some degree. Areas currently affected are from Monarch Pass south through the Cochetopa Hills and Los Piños, continuing through the Lake City area, and then westward to the Alpine Plateau and Cimarron Ridge in the San Juans. North of Monarch Pass, the western portion of the Collegiate Range is more recently affected. The beetles are also widespread on the east side of the West Elk Wilderness. Spruce beetle is also currently active on the Grand Mesa, though mortality there is much more dispersed.

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 (Schmid and Frye 1976). However, under epidemic population levels all sizes of Engelmann spruce can be infested and killed. In the current outbreak, saplings less than 5 inches diameter have been killed in areas with high beetle populations.

The Douglas-fir beetle attacks and kills mature Douglas-fir trees with a preference for older and injured trees, especially those that are fire-damaged or scorched. Beetle populations may increase in areas where stress from repeated defoliation by western spruce budworm makes Douglas-fir more vulnerable to bark beetle attack. Douglas-fir beetle is currently at a moderate level on the GMUG. Only 3,500 acres of mortality were mapped in 2016. Of these, the 2,000 new acres were primarily located in the Gunnison Basin. However, Douglas-fir beetle has had significant impacts in the past decade (60,000 acres affected from 1996-2016). Mortality caused by Douglas-fir beetle tends to be dispersed, although there may be concentrated patches of mortality within a generally affected area. Several projects have utilized the anti-aggregation pheromone MCH to reduce Douglas-fir beetle impacts in high-value areas on the GMUG.

The mountain pine beetle, a native insect, attacks and kills pine trees. The predominant host species are lodgepole pine and ponderosa pine, but it will also attack other pine species such as limber pine and bristlecone pine. While mountain pine beetle has gotten a lot of attention in the Rocky Mountain Region, the GMUG has not experienced large outbreaks of mountain pine beetle like other parts of Colorado. Approximately 17,000 acres on the GMUG were affected by mountain pine beetle in the last 20 years.

The western balsam bark beetle has contributed to subalpine fir decline in recent years, acting in tandem with Armillaria root disease. Typically, the beetles attack and kill subalpine fir with root disease. The resulting brood may attack neighboring, uninfected trees. It is also not unusual to find trees killed by root disease that are not attacked by the beetle. The relative contribution of the beetle and the fungus to tree mortality is difficult to determine, and can vary over time and among localities. Subalpine fir mortality has occurred fairly consistently in large areas across the context area for over a decade. However, new acres identified as affected by subalpine fir mortality have declined on the GMUG from 11,700 acres in 2015 to 6,700 acres in 2016, suggesting a slowing trend in fir mortality.

Root diseases impact trees in several ways; they can cause mortality directly through root girdling, and indirectly by increasing susceptibility to secondary agents, such as bark beetles, drought, or windthrow. Root disease fungi co-evolved in equilibrium with their hosts. 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. On the GMUG, both Armillaria and annosus root diseases are common, and cause mortality in Engelmann spruce, subalpine fir, white fir, Douglas-fir, ponderosa pine, lodgepole pine, and pinyon pine. Armillaria is particularly damaging to the true firs.

The western spruce budworm is the most prominent defoliating insect on the GMUG. A native species, it is the most widely distributed and destructive defoliator of coniferous forests in western North America. Its primary hosts are Douglas-fir, subalpine fir, white fir, and Engelmann spruce. Significant impacts can occur in both mixed conifer and spruce-fir forest types. Feeding by this insect can cause growth loss, top-killing, and tree mortality, especially on suppressed trees. The GMUG had 16,100 defoliated acres detected in 2016, compared to 11,400 in 2015. Area of defoliation increased considerably in the Gunnison Basin from 3,200 new acres in 2015 to 9,700 in 2016. A combination of suitable habitat and favorable weather patterns have resulted in the current widespread outbreak in Colorado. Stand conditions contribute greatly to outbreaks. Multistory stands of shade tolerant species favor western spruce budworm survival as larvae disperse from overstory trees. Reduced fire frequency allows shade-tolerant white fir and Douglas-fir to increase in mixed conifer stands, improving habitat for western spruce budworm. Previously, there was a multi-year outbreak of western spruce budworm on the Uncompahgre Plateau in the 1990s and early 2000s.

Needle casts of lodgepole pine were very widespread and conspicuous in the Gunnison Basin in 2016, with 2,300 affected acres observed in aerial surveys. Typically, much more area is infested by *Lophodermella* than is detected from the air. Except in very susceptible populations, damage is often concentrated in lower crowns and small trees where it cannot be seen from the air, and flights may not occur during the time of year when discoloration is most conspicuous. Two *Lophodermella* species commonly cause needle cast in lodgepole pine on the GMUG: *L. concolor* and *L. montivaga*. These diseases are widespread and can usually be found killing foliage in many stands. In some areas they are chronically severe, limiting growth, thinning crowns, and killing trees in the understory. The pathogens infect current-year needles of lodgepole pine, causing discoloration, then needle loss in the second year. The severity of these diseases vary from year to year, probably due to weather during or following bud break in the previous year, when sporulation and infection occur.

Dwarf mistletoes continue to impact significant areas of conifer forest on the GMUG. Dwarf mistletoes are small, leafless parasitic plants that can retard tree growth and eventually cause mortality in the case of a long-term infection. They infect multiple tree species, but on the GMUG lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) has had the greatest impact, with lesser impacts from ponderosa pine dwarf mistletoe (*Arceuthobium vaginatum ssp. cryptopodium*). Dwarf mistletoes are not easily detected in annual aerial surveys; however, roadside surveys performed in 1977-79 found a 52% infestation rate of dwarf mistletoe on lodgepole pine on the GMUG (Johnson et al 1981), and local experts believe that current rates of infestation are the same, if not higher. Looking at the stand exams collected from 2007 – 2016, 20% of the exams had trees with noted mistletoe, and the majority of those were in lodgepole pine stands. Half of the lodgepole pine stand exams included trees with mistletoe. Just under half of the ponderosa pine stand exams included trees with mistletoe as well, but with a much lower average mistletoe rating relative to lodgepole pine.

In 2015, the GMUG experienced an epidemic of Marssonina leaf blight of aspen that may have been unprecedented. Over 35,000 acres were mapped with discoloration and defoliation due to the disease. In 2016, damage dropped to 2,900 acres. This disease tends to vary with spring and summer moisture, but the high populations that developed in 2015 have also carried into 2016. Marssonina leaf blight discolors foliage, then causes defoliation in midsummer. Mortality can occur if trees are heavily infected in several consecutive years.

In addition to these ongoing insect and disease outbreaks, aspen stands are continuing to deteriorate from the impacts of sudden aspen decline (SAD) on 229,000 acres of aspen forest on the GMUG (USDA FS GMUG 2016). Sudden aspen decline is a rapid, landscape-scale deterioration of overstory aspen initiated by drought and warm temperatures. On the GMUG, SAD was initiated by a severe drought in 2002, and increased across the plan area until 2010 (Worrall et al. 2008, 2010). While SAD is no longer spreading on the GMUG, SAD-impacted aspen stands show significantly lower density of live overstory trees and decreased amounts of successful suckering as compared to healthy aspen stands on the GMUG (Worrall et al 2015). Severely impacted stands may convert to another cover type over time if these low levels of regeneration persist.

Departure and Trend

Pre-settlement natural range of variation for insects and disease on the GMUG is difficult to assess. Dendrochronological studies (i.e. Veblen et al 1991b) have used death dates and corresponding “release” dates to reconstruct the frequency of previous bark beetle outbreaks, but reconstructing past severity and extent is more difficult. Pre-settlement conditions for other insects and disease operating at endemic levels or weakening but not killing trees cannot be reconstructed with any certainty. We do know that the insects and diseases currently impacting the GMUG are all native to the plan area, but it is possible that some may be outside of NRV reference conditions in their frequency, extent or severity.

Of the insects and pathogens currently impacting the GMUG, we do not have reason to believe that Douglas-fir beetle, western balsam bark beetle, Armillaria and annosus root diseases, and lodgepole pine needle casts are operating outside of NRV. We suspect that western spruce budworm and lodgepole pine dwarf mistletoe may be outside of NRV, to the extent that fire frequencies in their host systems are outside of NRV. Western spruce budworm survival is favored by multistory stands of shade-tolerant species as larvae disperse from overstory trees. As such, reduced fire frequency in mixed-conifer stands can contribute to levels of spruce budworm activity through its impacts on stand composition and structure. However, results of tree-ring analyses are inconsistent as to whether outbreaks since the early part of the twentieth century have been more extensive and damaging than those in previous decades (Swetnam and Lynch 1989, Ryerson et al. 2003). Dwarf mistletoes are regulated by stand-replacing fire, so fire exclusion has led to increased spread and intensification of the parasite, facilitating conditions that may be outside of NRV.

The current spruce beetle outbreak is likely within NRV in terms of its frequency, may be outside of NRV for extent, and is likely outside of NRV for severity. Specifically, Romme et al. (2009) suggests that while spruce beetle periodically explodes into a severe outbreak, killing trees over areas of thousands of hectares and killing nearly all of the large diameter spruce trees, the small diameter spruce are usually not attacked. Schmid and Frye (1977) discuss an outbreak in the 1870’s that killed mature spruce on the White River National Forest as well as Grand Mesa, in addition to extensive spruce beetle outbreaks in the 1940s that killed more than 50% of the merchantable volume of spruce on the Grand Mesa. The silvics manual (Burns and Honkala 1990) echoes this with discussion of a damaging spruce beetle outbreak in Colorado from 1939 to 1951, where beetles killed nearly 6 billion board feet of standing spruce. However, the current outbreak is thought to be more severe than these historic outbreaks, with mortality of saplings less than 5 inches in diameter. Nonetheless, the lack of evidence of a similar outbreak does not indicate with complete certainty that it is outside of NRV.

It is difficult to anticipate future trends in insect and disease activity with any certainty. However, we expect that climate change will bring warmer winters and more frequent drought to the plan area, both of which can contribute to higher levels of insect and pathogen activity (Vose 2012). In addition to potential increases in frequency, extent, and severity of fire and insect and disease activity, future climate conditions and extreme weather events may increase the role of disturbances that have had relatively minor impacts in the plan area in the past, including blowdown events and floods.

Table 18. Major insects and diseases on the GMUG

Species	Ecosystem	Insects	Diseases
Engelmann spruce	Spruce-Fir; Spruce-Fir-Aspen	Spruce beetle (Dendroctonus rufipennis), Western spruce budworm (Choristoneura freemani)	Armillaria spp.
Subalpine fir	Spruce-Fir; Spruce-Fir-Aspen	Fir engraver beetle (Scolytus ventralis), Western balsam bark beetle (Dryocoetes confusus), Western spruce budworm	Armillaria spp.
Aspen	Aspen; Spruce-Fir-Aspen	Aspen borer (Saperda calcarata), Bronze aspen borer (Agrilus liragus), Western tent caterpillar (Malacosoma californicum), Large aspen tortrix (Choristoneura conflictana)	Black target canker (Ceratocystis fimbriata), Cryptosphaeria canker (Cryptosphaeria populina), Cytospora canker (Cytospora chrysosperma), sooty bark canker (Encoelia pruinosa); Marssonina leaf blight, Shepherd's crook (Venturia macularis), aspen leaf rust (Melampsora medusae), aspen trunk rot (Phellinus tremulae) and white mottled rot (Ganoderma applanatum)
Lodgepole pine	Lodgepole pine	Mountain pine beetle (Dendroctonus ponderosae), Pine engraver beetle (Ips pini)	Lodgepole pine dwarf mistletoe (Arceuthobium americanum), comandra blister rust (Cronartium comandrae), lodgepole pine needle cast (Lophodermella concolor, Lophodermella montivaga)
Pinyon pine	Pinyon-Juniper	Pinyon Ips beetle (Ips confusus)	Black stain root disease (Leptographium wagneri var. wageneri), Armillaria spp., pinyon pine dwarf mistletoe (Arceuthobium divaricatum)
Rocky mountain juniper/Utah juniper	Pinyon-Juniper		Juniper true mistletoe (Phoradendron juniperinum), Gymnosporangium stem rust of juniper (Gymnosporangium spp.)
Ponderosa pine	Ponderosa pine, Warm-Dry Mixed Conifer	Mountain pine beetle, western pine beetle (Dendroctonus brevicomis), pine engraver beetle	Armillaria spp., Annosus (Heterobasidion occidentale), ponderosa pine dwarf mistletoe (Arceuthobium vaginatum ssp. cryptopodium), comandra blister rust, ponderosa pine needlecast (Davisomycella ponderosae)
Douglas-fir	Cool-moist Mixed Conifer; Warm-Dry Mixed Conifer	Douglas-fir beetle (Dendroctonus pseudotsugae), fir engraver beetle, Western spruce budworm	Armillaria spp., Annosus, Douglas-fir dwarf mistletoe (Arceuthobium douglasii)
Blue spruce	Cool-moist Mixed Conifer	Spruce beetle	
Bristlecone pine	Bristlecone-Limber Pine	Mountain pine beetle	White pine blister rust (Cronartium ribicola)
Limber pine	Bristlecone-Limber Pine	Mountain pine beetle	White pine blister rust
Gambel oak	Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	Oak leaf roller (Tortrix spp.), oak looper (Lambdina fiscellaria somniaria)	

Key Characteristic: Patch Size and Habitat Connectivity

Current and Reference Conditions

Landscapes are composed of a mosaic of patches (Urban et al. 1987). A ‘patch’ in the landscape sense is a relatively discrete area of relatively homogeneous environmental conditions, where boundaries are delineated relative to the object of interest. For example, a habitat patch for lynx may not be the same as a habitat patch for elk. Habitat connectivity is the degree to which the landscape facilitates animal movement and other ecological flows, and is determined by patch size and shape and spatial arrangement of patches. Patch size and habitat connectivity are key ecosystem characteristics of crucial importance to wildlife. The ability of individual organisms to move and interact throughout a landscape can aid a species and its survival in general, but is especially crucial in a changing climate. Movement can also help maintain genetic diversity within a species.

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). Conversely, management influences can also lead to uncharacteristic homogeneity of landscapes, due to fire exclusion, selective grazing, and even-aged timber harvesting. Overly homogeneous landscapes can be more susceptible to large disturbances, such as fire and insect and disease outbreaks, have lower adaptive capacity, and lack edge habitat.

Landscape metrics can be characterized by whether or not they measure landscape patterns with explicit reference to a specific ecological process. Structural metrics measure composition and configuration of the patch mosaic without reference to a specific process, while functional metrics measure landscape pattern in a way that is functionally relevant to the organism of interest. In this assessment, we use structural metrics of mean and median patch size, calculated using FRAGSTATS, a spatial pattern analysis program, (McGarigal et al 2012); however, we recommend that if the Revised Forest Plan includes desired conditions regarding patch size and habitat connectivity, they be based on functional metrics for species, or groups of species, of interest.

Our patch size analysis focuses on ecosystems known to be important for wildlife in the plan area, grouping them into general classes based on habitat types. Subalpine forest includes spruce-fir, spruce-fir-aspen, lodgepole pine, and cool-moist mixed conifer types. Montane forest includes warm-dry mixed conifer and ponderosa pine forest. Aspen, pinyon-juniper, sagebrush, and bristlecone-limber pine are all single-ecosystem groups. We calculated mean and median patch size across the entire GMUG, within wilderness and roadless areas for each group, and for late successional forest (identified as habitat structural stages 4B and 4C) within each group (Table 19). This analysis was based on the FSVeg polygons, which were delineated based on aerial photo interpretation. FSVeg is the best available spatial vegetation data for the GMUG, but is not always updated as changes occur.

Table 19. Current mean and median patch sizes for ecosystem groups, late successional (4B/4C) groups, and within wilderness and roadless areas on the GMUG

Ecosystem group	% of Area in Wilderness /Roadless	% of 4B/4C area in Wilderness/Roadless	Mean Patch Size (ac)				Median Patch Size (ac)			
			All	4B/4C	Wilderness /Roadless	4B/4C Wilderness/Roadless	All	4B/4C	Wilderness/ Roadless	4B/4C Wilderness/Roadless
Subalpine forest1	50	51	50	56	49	54	25	27	23	24
Pinyon-juniper	53	56	97	126	98	139	40	45	38	49
Aspen	43	40	42	54	42	52	20	25	21	23
Montane forest	20	19	61	76	38	47	32	37	22	24
Sagebrush	9	-	70	-	32	-	27	-	16	-
Bristlecone-limber	18	13	25	26	39	33	16	17	21	18

[1] Based on pre-SB-outbreak data; current conditions on the landscape are significantly different.

Departure and Trend

We were unable to identify meaningful quantitative reference conditions for patch size of ecosystems on the GMUG. We lack spatially-explicit pre-settlement vegetation data that would allow us to identify historic patch sizes, and management-focused reference conditions would vary greatly depending on the species or process of interest. Current conditions could be departed from the natural range of variation in either direction – either smaller or larger patch sizes – as post-settlement land use and management can both fragment (i.e., road construction, exurban development), and homogenize (i.e., fire exclusion, even-aged timber harvest) the landscape. Lower elevation ecosystems with a smaller percentage of their area in wilderness or roadless areas are likely to be the most departed from reference conditions.

As with departure, future trends in patch size are difficult to discern. The potential for more frequent, severe, and extensive disturbances could lead to larger patch sizes overall, but a dearth of older/late successional forest types. Conversely, population growth and continued exurban development could lead to greater fragmentation and smaller patch sizes, particularly in lower-elevation ecosystems in the wildland-urban interface.

Desired conditions for patch size and habitat connectivity should balance wildlife needs with the need to maintain a heterogeneous and resilient landscape. To best achieve this balance, we recommend that these be formulated based on functional metric analyses for selected species or groups of species. Specific methods of analysis and focal species or groups are still being discussed on the GMUG. Possible focal species include Gunnison sage-grouse, Canada lynx, boreal toad, American pine marten, and raptors.

Key Characteristic: Snags and Down Woody Material

Current and Reference Conditions

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 cycling. At least 84 terrestrial vertebrate species of wildlife rely on snags in Colorado (Hoover and Wills 1984). Snags and down woody material increase stand structural complexity, creating microclimates and microhabitats that support distinct and diverse wildlife assemblages (e.g., beetles and other arthropods: Heyborne et al. 2003, Buddle et al. 2006, Jeffries et al. 2006, Johansson et al. 2007; amphibians: Welsh 1990; birds: Sallabanks et al. 2006; and mammals: Sullivan et al. 2000, 2001, Fisher and Wilkinson 2005, Sullivan et al. 2007). Snags are crucial habitat 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.

We assess snag levels on the GMUG using Forest Inventory and Analysis (FIA) plot data (about 695 plots collected from 2002 – 2015). This data shows a clear trend of increasing snag levels since the spruce beetle outbreak started in the mid-2000s, with recent years showing approximately 25 snags per acre greater than 8” in diameter and around 15 snags per acre greater than 10” diameter (Figure 2).

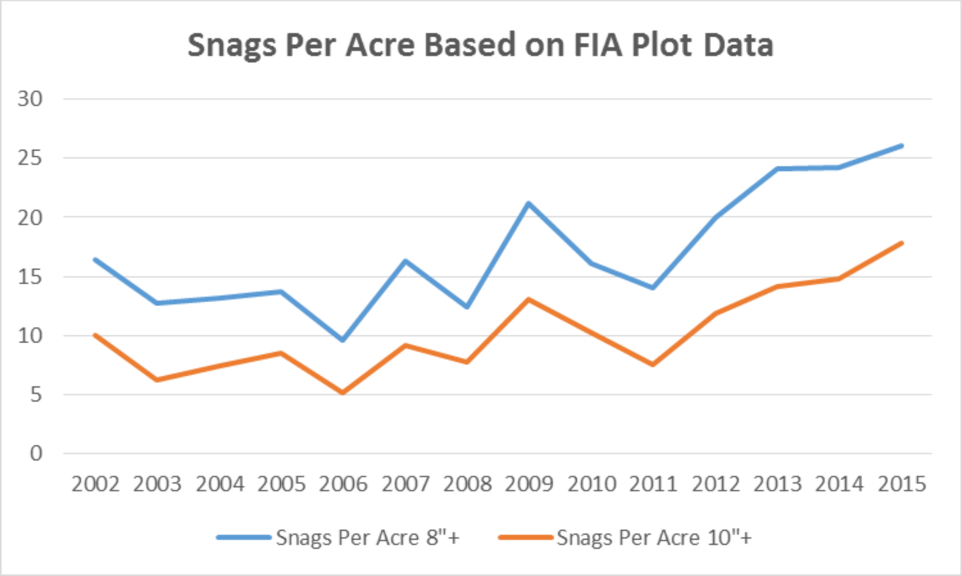

Figure 2. Snags per acre on the GMUG from 2002-2016, based on FIA plot data

Table 20 compares the average snag estimates from more recent FIA data (494 plots, from 2006 to 2015) to the minimum amounts recommended in the current forest plan and the minimum amounts suggested in the South Central Highlands HRV report (Romme et al. 2009). The minimum requirements for retained snags in the current forest plan were taken from table III-9b. In the current forest plan, there is guidance to maintain an average of 2-3 snags (in all stages of development) per acre. There is also forest type-specific direction that requires retained snags to meet a certain size criteria, as seen in the table below, as well as more specific direction on snag retention for particular wildlife species, such as the hairy and Lewis woodpeckers. Overall, snag density on the forest is above the Forest Plan-minimum amounts.

Table 20. Current snag estimates and reference conditions by forest type

Forest Type	Mean snags/ac (FIA) a	Minimum snags/acb	Minimum diameter (in) b	South Central Highlands HRV report
Spruce-Fir	17.3	0.9 – 2.25	10	Sample old growth stand had 14.2 snags/acre with an average dbh of about 17 inches.
Lodgepole Pine	9.3	0.9 – 1.8	8	
Aspen	18.1	1.2-3	8	Cavity-nesting species preferred snags that averaged 50ft tall and 16” dbh (range 5-25”).
Douglas-fir (Cool-moist or warm-dry mixed conifer)	6.7	0.9 – 2.25	10	
Ponderosa Pine	0 (9 exams)	0.9 – 2.25	10	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.
Pinyon-juniper	9.4	-	8	

a – Mean snags/acre are based on snags that are larger than the minimum diameter for that species.

b - Based on Table III-9b in the current Forest Plan.

Down wood estimates were also summarized based on FIA plot data (Table 21). Tons/acre (including down wood pieces 3” and larger) was calculated as well as linear feet/acre (including down wood pieces 10-12” and larger). The FIA data suggests that the forest is generally below the 10-20 tons/acre retention amount, but well above the 50 linear feet/acre retention amount.

Table 21. Current down woody material estimates based on FIA plot data

FIA Forest type	GMUG Ecosystem	Tons per acre	Linear feet per acre (10”+)	Linear feet per acre (12”+)
Aspen	Aspen Forest	4.87	382.9	187.0
Engelmann spruce	Spruce-Fir Forest	7.64	753.3	521.5
Engelmann spruce/subalpine fir	Spruce-Fir Forest	10.54	1,077.2	683.1
Deciduous oak woodland	Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	1.07	28.9	12.4
Lodgepole pine	Lodgepole Pine Forest	5.29	364.8	163.0
Pinyon/juniper woodland	Pinyon-Juniper Woodland	4.62	347.0	302.1
Douglas-fir	Warm-Dry Mixed Conifer Forest and Cool-Moist Mixed Conifer Forest	3.56	310.9	206.9
Ponderosa pine	Ponderosa Pine Forest	3.69	227.6	170.5
All types		5.58	484.5	293.4

Departure and Trend

As a result of the recent spruce beetle outbreak and other disturbance agents, the GMUG currently has a large amount of snags, more than the minimum required by the Forest Plan. In contrast, the available data suggests that downed wood levels are lower than required by the current forest plan. Snag and downed wood retention levels will be discussed and likely updated as part of the plan revision process. Future plan components may incorporate a more flexible approach where retention levels vary based on forest type, the values at risk, site productivity, or other factors.

As snags fall, snag levels may decrease and downed wood amounts may initially increase and then decrease as the material decays. How fast this happens will depend on the forest type and a variety of other factors. In spruce beetle impacted stands, some research suggests that snag fall will be gradual, with many snags still standing at 50 years post-mortality, and some remaining upright until 70 years (Mielke 1950). Other research, and vegetation modelling done on the Rio Grande National Forest suggests snag fall in this type could be much quicker (Delong et al. 2008, USDA FS RGNF 2004). If snag fall happens quickly, it may be followed by a prolonged period of low snag levels that are below the desired amounts in these areas. It is hard to predict longer term trends in quantities of snags and down wood. Disturbances such as large fires and insect outbreaks are predicted to increase in frequency due to climate change (Vose et al. 2012), in which case snags and downed woody material may be maintained into the future. Plan components pertaining to the retention of snags and downed wood should be included in the revised plan, accompanied by a monitoring plan to track whether levels are sufficient for wildlife habitat and maintenance of ecological integrity.

Summary of Assessment of Ecosystem Integrity of Terrestrial Ecosystems

We examined a variety of key ecosystem characteristics for the terrestrial ecosystems of the Grand Mesa, Uncompahgre, and Gunnison National Forests. We assessed the diversity of cover types, the distribution of vegetation structural stages, seedling regeneration, landscape disturbances, habitat connectivity, and snags and woody material. This work suggests the following:

- The GMUG maintains a diversity of ecosystem types that is within NRV, though the distribution of structural stages within these ecosystems is most likely outside of NRV. This atypical distribution of structural stages can be attributed to widespread fires in the late 1800s, followed by over a century of fire suppression. The current distribution of structural stages includes an under-representation of early seral stages, paired with an over-representation of mid-seral stages in most ecosystems.
- Bioclimate models for 14 tree species within the plan area suggest that climatic conditions will not be suitable in the future for many species within a large portion of their current extent.
- Landscape disturbances, including fire and insect and disease, may already be operating outside of their historic range of variability, and may continue to act ahistorically.
- It is unclear whether patch sizes are within NRV, and would be difficult to ascertain even with further research. We advise that if the revised Forest Plan establishes desired conditions for patch size/habitat connectivity, they be formulated based on a functional habitat connectivity analysis for select wildlife species/groups of species on the GMUG.
- Stand exam and FIA plot data suggest an increasing trend in snag levels, with around 15 >10” snags/acre, and 25 >8” snags/acre in recent years, well above required minimums in the current forest plan. The data available to assess down woody material suggests that levels are generally lower than the 10-20 tons/acre retention amount in the current forest plan but well above the 50 linear feet/acre retention amount in the current plan.
- In general, we have less information about key characteristics and ecosystem integrity for non-forested ecosystems, including shrublands, grasslands, and alpine uplands.
- Due to their relative abundance within the plan area combined with relative rarity within the context area, GMUG management has a high opportunity for influence in lodgepole pine, spruce-fir-aspen, alpine uplands, ponderosa pine, warm-dry mixed conifer, and cool-moist mixed conifer ecosystems.

Chapter 3. Current Forest Plan and its Context within the Broader Landscape

Existing Forest Plan Management Direction for Terrestrial Ecosystems

Goals in the current GMUG Forest Plan include:

- Maintain a healthy and vigorous ecosystem resistant to insects, diseases, and other natural and human causes. Provide a range of multiple-use outputs, a few of which are fish and wildlife habitat, wood fiber, and economic benefits to society.
- Prevent and control insect and disease infestations.
- Reintroduce fire as a natural process to enhance resources and meet land and resource objectives.
- Define and inventory old growth for each of the Forest types on the Forest. Develop and implement silvicultural practices to maintain and establish desired old growth values. Implement National Policy on old growth.

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 maintain horizontal and vertical diversity of vegetation, and provide direction on edge-shapes, old growth, and retention of aspen, snags, and coarse woody debris. We have standards and guidelines related to management for habitat needs of wildlife indicator species, and threatened, endangered and sensitive species. Our current plan directs that we use both commercial and noncommercial silvicultural treatments to accomplish wildlife habitat objectives. We have standards and guidelines for silvicultural prescriptions and reforestation stocking rates. We have standards and guidelines related to timing, amount, and regulation of livestock grazing. Current plan standards and guidelines regarding fire management direct us to maintain fuel conditions that permit fire suppression and prescribed fire to maintain habitat needed for selected species or species population levels. The Plan was amended in 2007 to allow fire managers to manage certain lightning caused fires for resource benefits, if prescriptive conditions are met.

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

Forest Plan Consistency with External Plans for Terrestrial Ecosystems

Plans for the broader landscape address many of the same topics at the GMUG’s forest plan. Plans discussed here include those for the White River (2002 plan), San Juan (2013 plan), and Rio Grande National Forests and the 2016 draft plan of the Uncompahgre field office and current (1993) plan of the Gunnison field office of the BLM. The Rio Grande National Forest is in the process of revising their plan – their 1996 plan is used for reference here.

Vegetation Desired Conditions

The San Juan National Forest Plan contains numerous desired conditions, some specific to individual vegetation types. This plan also includes a desired condition (amount) for each vegetation type by structural stage.

Old Forest

The current GMUG plan promotes retention of old-growth. Current standards and guidelines say that “in forested areas of a unit, 5-12% or more will (where biologically feasible) be in an old growth forest classification and most occur in irregular shaped patches.” Plan direction also suggests that these patches of old growth should be no smaller than 30 acres and average

100-200 acres in size each in spruce-fir and mixed conifer vegetation types, with old growth patches in aspen and lodgepole pine areas permitted to be smaller. Areas designated as old growth replacement patches are also discussed.

Plans for the broader landscape also promote the retention of a specified amount of late-successional and/or old forest/old-growth habitat. For instance, the White River National Forest Plan has late-successional retention amounts of 30% for the spruce-fir type and 10% for Douglas-fir and lodgepole pine types. These amounts apply to individual late-successional assessment areas. Old-growth retention amounts are generally 10%. The San Juan National Forest Plan has desired old growth amounts that differ by vegetation type and range from 5 – 35% of each type. The current Rio Grande forest plan does not designate a specific amount of old growth, but does promote the retention of old growth forest.

The draft plan for the Uncompahgre field office of the BLM has an action under all alternatives that supports maintaining or contributing toward the restoration of the structure and composition of old-growth stands. No specific direction pertaining to old forest or old-growth could be found in the plan for the Gunnison field office of the BLM, but the direction for timber management areas says “maintain a variety of all ecosystem timber types and all five forest structural stages that would maintain viable populations of non-game wildlife as identified in the Managing Forest Lands for Wildlife handbook.”

Snags and Downed Wood

The current GMUG plan has direction to retain 2-3 snags per acre, with additional direction to retain 1 – 2 or 3 larger snags (8-10” dbh) per acre. There is also more specific direction on snag retention for particular species, such as the hairy and Lewis woodpeckers. Downed wood is retained at 10-20 tons/acre, which does not vary by forest type, along with 50 linear feet/acre of larger logs (10-12” in diameter).

Plans in the broader landscape also promote the retention of snags and downed wood.

The White River plan requires retention of snags (3 per acre, 8-10” dbh minimum), large snags (1 per acre, 20” dbh minimum) and downed logs (50-150 linear feet per acre, 8-10” minimum diameter). For snags, there is both a retention density (3 per acre) and a recruitment density (3 per acre).

The San Juan plan requires retention of snags and large downed wood. If larger snags aren’t available, smaller snags (at a greater density) are permitted. Snags amounts vary by forest type, with lower snag retention amounts in the lower elevation forest types. Downed wood is retained with a minimum diameter of 15” (with lower values for aspen and some ponderosa pine). The linear feet/acre of downed wood varies by forest type from 30 to 200 linear feet/acre.

The Rio Grande plan has a standard that requires retention of 2 snags per acre (3 per acre for ponderosa pine), with a minimum dbh of 10-14”. Downed log retention varies by forest type from 3-5 tons/acre in aspen to 10-15 tons/acre for spruce-fir. Some of these values may change as part of the Rio Grande’s plan revision process.

No direction on the retention of snags and downed wood was found in the draft plan for the Uncompahgre field office of the BLM. In the BLM Gunnison field office plan, there is plan direction for timber management areas to maintain 2-5 snags for each 3-4 acres of clearcut, with a minimum dbh of 18”. This direction also indicates that live trees meeting the criteria should be girdled if snags tare not currently available in these areas. Direction also includes retention of “two slash piles and five logs 20” and greater DBH per acre for small mammals, black bears, and pine martens.”

Snag and downed wood retention levels in the GMUG plan should be examined and possibly updated with values that may vary based on forest type, the values at risk, site productivity, or other factors. Ten to twenty tons/acre of downed wood is unrealistic and too high for many forest types, especially the drier, lower elevation forest types that experience frequent fire. Downed wood retention can also be described with a variety of metrics (tons/acre, linear feet per acre, logs per acre, etc.) – this should be discussed to ensure the plan is using an appropriate and measureable metric.

Minimum Stocking Standards

The current GMUG plan has complex minimum stocking levels that vary by forest type and site productivity class. Both minimum and desired stocking rates are provided in the plan. These values range from 150 to 1800 trees per acre (see Key characteristic: Regeneration and recruitment section of this document.)

Plans in the broader landscape, such as the Rio Grande, White River, and San Juan plans, generally have minimum stocking standards of 150 trees/acre (300 trees/acre for aspen and sometimes other hardwoods). The White River plan does include a lower level (120 trees/acre) for pinyon-juniper.

No direction on minimum tree stocking standards was found in the draft plan for the Uncompahgre field office of the BLM or the plan for the Gunnison field office of the BLM.

Minimum stocking standards should be reviewed to ensure they are appropriate given contemporary management objectives and the climate and natural fire regime of local forest types. In some of the drier, low elevation forest types, lower minimum stocking rates may be appropriate.

Other

Some plans include more specific direction for particular vegetation types. For example, the White River National Forest Plan has standards specific to the alpine vegetation type that minimize new roads and trails, soil disturbance, structures, and resource damage in this type.

Chapter 4. Potential Need for Plan Changes to Respond to Terrestrial Ecosystem Integrity Issues

General Needs

The current GMUG forest plan provides very little ecosystem-level direction, other than “maintain a healthy and vigorous ecosystem resistant to insects, diseases, and other natural and human causes”. Ecosystem-related standards and guidelines are generally focused on maintaining habitat needs of wildlife indicator species, and threatened, endangered, and sensitive species. The current plan does not include any guidance related to climate change.

Consider plan changes to provide better direction for management of ecosystems to achieve a desired outcome based upon best available science. The focus should be on managing to maintain resiliency to provide for ecosystem services and buffer anticipated impacts from climate change. Rather than focusing all management actions on avoiding negative impacts to ecological integrity (i.e. retention of snags and coarse woody debris), consider *proactively* implementing management actions that can improve integrity of key ecosystem characteristics and help maintain ecological integrity.

Specifically, consider the following changes in the forest plan:

- Consider direction for ecosystem management to maintain ecological integrity as a whole, in *addition* to guidance regarding specific resources (timber, wildlife, rare plants, etc.). This includes maintaining the existing diversity of ecosystems on the landscape and a variety of structural stages, including the protection and preservation of old-growth forest where present.
- Consider direction for management in a changing climate while allowing for flexibility to respond to impacts of climate change (i.e., more frequent and larger disturbance events). Uses an ecological portfolio approach (see Appendix F for explanation) to prioritize areas on the GMUG for observation, restoration, and facilitation strategies.
- Consider focusing management actions to mitigate the impacts of known ecosystem stressors on the GMUG, and prevents drivers from becoming stressors. These actions could include:
    - Use of prescribed fire, managed wildfire, timber harvest, and fuels reduction treatments to increase ecological integrity and resilience to climate change.
    - Anticipating and preventing unwanted ecological impacts from increasing levels of recreational use on the GMUG.
    - Proactively managing invasive species.
    - Monitoring undesirable impacts of livestock grazing.
- Consider allowing and providing direction for ecologically sound uses of prescribed fire and wildfire in the plan area. Although the 2007 amendment made some beneficial changes to the plan, some additional clarification and changes may be needed.
- Consider better defined desired conditions at a scale, or scales, that are relevant to management. Consider providing a spatially-explicit framework to implement management towards desired conditions.
- Consider establishing a monitoring framework that can inform adaptive management through a) monitoring changes of ecosystems at a landscape scale, b) assessing the results and effectiveness of management actions designed to maintain or improve ecosystem resilience and adaptation to climate change.
- Consider direction/monitoring measures to collect additional information to improve our understanding of ecological integrity for GMUG ecosystems, particularly for non-forested ecosystems such as alpine areas, grasslands, and shrublands.
- Consider matching the variability found on the GMUG. For instance, snag and downed wood retention levels should be examined and possibly updated with values that may vary based on forest type, the values at risk, site productivity, or other factors. Metrics

used to evaluate down wood retention should be discussed to ensure the plan is using an appropriate and measurable metric. Minimum stocking standards should be reviewed to ensure they are appropriate given contemporary management objectives and the climate and natural fire regime of local forest types; project-specific determinations by silviculturists may be more ecologically appropriate than Forest-wide standards. See also the Timber assessment.

Ecosystem-Specific Needs

Spruce-Fir and Spruce-Fir-Aspen

The potential need for change in this type varies geographically on the GMUG. In some areas of the forest, a large percentage of this cover type is still in mature, dense stand conditions, susceptible to stand-replacing fires and/or epidemic insect/pathogen outbreaks. Because so much of the area is in relatively uniform conditions, natural disturbances have the potential to impact large areas at one time. Active management that is focused on diversifying the structural stages present will be important here to increase resiliency to fires, insects, disease, and climate change. However, other parts of the GMUG, such as the Gunnison Basin, are undergoing a high-severity spruce beetle outbreak, which will lead to an abundance of young structural stages into the future. After completing salvage treatments and replanting, management of these stands should be more passive.

Aspen

Plan components and management that promotes disturbance and the natural role of fire in this type are potentially needed.

Lodgepole Pine (Predominantly on the Gunnison Basin GA)

Lodgepole pine ecosystems on the GMUG have been impacted by fire suppression and have an under-representation of early seral stages. The revised Forest Plan should consider using fire and vegetation management to increase the presence of early-seral lodgepole stands on the landscape.

Ponderosa Pine and Warm-Dry Mixed Conifer (Predominantly Found on the Uncompahgre Plateau GA)

Anthropogenic influences, particularly fire suppression have led to dramatic alterations in the structure and function of these ecosystems, resulting in dense, uniform stands and changes in species composition.

Consider emphasizing continued management to reduce stand density and create frequent small openings and multiple age classes. These treatments will promote stand conditions conducive to the low-intensity surface fires that are characteristic of this system. Ponderosa pine forests have higher levels of ecosystem stressors, such as invasive plants and roads, and less area in special designations relative to most other ecosystems on the GMUG. The Forest has recognized this and undertaken various restoration projects, including the ongoing Uncompahgre Plateau Collaborative Forest Landscape Restoration Project (CFLRP. Consider promoting continued restoration and/or protection of this ecosystem in the revised Forest Plan.

Cool-Moist Mixed Conifer

The cool moist mixed-conifer ecosystem is likely departed from the natural range of variation as a result of fire suppression, though less so than the warm dry mixed-conifer type given its less frequent fire regime. Consider emphasizing restoration and/or resiliency treatments in this type in the revised Forest Plan.

Pinyon-Juniper

Consider emphasizing management in this type to reduce fuels in the wildland-urban interface and near infrastructure, to create a more resilient landscape where fire can play a more natural role, and to maintain or improve wildlife habitat (winter range) purposes.

Montane Shrubland, Oak-Serviceberry-Mountain Mahogany

Current conditions in Gambel oak and mixed mountain shrub cover types have less structural stage diversity than would have occurred historically. As a result, this cover type is more susceptible to higher intensity fires that may affect larger areas of land than would have occurred in the past (as seen in fires on the Grand Valley and Paonia districts).

Consider emphasizing prescribed fire or mechanical treatments to increase heterogeneity of fuels in these shrublands in the revised Forest Plan.

Sagebrush

Consider emphasizing treatment of cheatgrass where it has invaded or will soon invade sagebrush and consider providing direction for prescribed burning or mechanical treatments to increase the diversity of the herbaceous understory and age and structural classes of sagebrush shrubs. Since much of the sagebrush on the GMUG is designated critical habitat for Gunnison sage grouse, consider direction to maintain or move sagebrush toward desired conditions needed for recovery.

Montane-Subalpine Grasslands

Species composition in grass-forb cover types in some areas on the GMUG have been altered from historic conditions through livestock grazing and introduction of non-native plant species. Management direction is needed to minimize this departure and rehabilitate native plant species composition where it is feasible to do so.

Alpine Uplands – Grasslands and Forblands

Climate change and impacts from increasing levels recreation are the two biggest stressors in this ecosystem; consider incorporating components to minimize these stressors. For example, the current plan has plan components that direct closure or rehabilitation of dispersed recreation sites where unacceptable environmental damage is occurring. These should be reviewed for adequacy, and modified as needed. Monitoring in alpine uplands is needed to better understand the current impacts of ecological stressors and prevent further resource damage to this system.

Rare Ecosystems

Consider promoting maintenance and protection of ecosystems that are particularly rare within the broader landscape in the revised Forest Plan. On the GMUG, this includes cottonwood riparian and fen ecosystems (see Aquatic and Riparian assessment).

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Appendix A. Maps

Poster-size maps located here: https://www.fs.usda.gov/detail/gmug/landmanagement/planning/?cid=FSEPRD563420

Map 1. Ecosystems, geographic areas, and context area for terrestrial ecosystem assessment.

Map 2. Threatened or lost suitable habitat in 2060 (for *all* major component spp. within an ecosystem) based on bioclimate models.

Map 3. Threatened or lost suitable habitat in 2060 (for *any* major component spp. within an ecosystem) based on bioclimate models.

Map 4. Contemporary ignitions, prescribed fires, and wildfires on the GMUG.

Map 5. Major insect and disease activity on the GMUG from 2007 – 2016.

Appendix B. Methods in Spatial Delineation of Terrestrial Ecosystems

Several types of spatial data were used to support the terrestrial ecosystem assessment on the Grand Mesa, Uncompahgre, and Gunnison National Forests (GMUG). This appendix describes the spatial data layers, their sources, and the processing steps used to generate the final data for the assessment. Data sources varied within and outside the GMUG for each spatial layer and are described below.

Within the GMUG, the ecosystem map was based on the FSVegSpatial dataset, using crosswalks from the “Cover Type”, “Local Type”, and “Riparian Polygon” attributes. The ECOMAP Ecoregions spatial data was used to delineate the context area, and ecosystems were identified outside of the GMUG based on the Southwest Regional GAP Analysis Project (SWReGAP) Land Cover Descriptions. Crosswalks to assessed ecosystems for all data sets is found in Table 22 and Table 23.

Table 22. Crosswalk of the terrestrial ecosystems included in the assessment to cover types from the FSVegSpatial layer on the GMUG

Ecosystem Name	FSVegSpatial Cover Type	Additional Criteria
Spruce-Fir	TSF (Spruce/Fir)	
Aspen	TAA (Aspen)	
Spruce-Fir-Aspen	TSF (Spruce/Fir)	*AND* MLF_SPP 1, 2, or 3 = POTR5 (Populus tremuloides)
Lodgepole Pine	TLP (Lodgepole pine)	
Pinyon-Juniper	TPJ (Pinyon/Juniper)	
Ponderosa Pine	TPP (Ponderosa pine)	
Cool-Moist Mixed Conifer	TAA (Aspen), TBS (Blue spruce), TDF (Douglas-fir)	*AND* LOCAL_TYPE = TMC-CM (Mixed Conifer – Cool/Moist)
Warm-Dry Mixed Conifer	TAA (Aspen), TBS (Blue spruce), TDF (Douglas-fir), TPP (Ponderosa pine)	*AND* LOCAL_TYPE = TMC-WD (Mixed Conifer – Warm/Dry)
Bristlecone-Limber Pine	TBC (Bristlecone pine), TLI (Limber pine)	
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	SGO (Gambel oak), SMS (True Mountain-mahogany), TGO (Gambel oak), SSN (Snowberry), SHR (Shrub)	
Sagebrush Shrubland	SSA (Sagebrush)	
Montane-Subalpine Grassland	GAF (Arizona fescue grassland), GFE (Fescue grassland), GPO (Bluegrass scabland)	FOR (Forbs) and GRA (Grasses) that aren't included in another category (e.g. alpine or riparian/wetland)
Alpine Uplands – Grasslands and Forblands	FOR (Forbs), GRA (Grasses)	*AND* LOCAL_TYPE = ALP (Alpine)
Rocky Slopes, Screes, Cliffs	NA	*Unable to identify based on FSVeg cover types*

Table 23. Crosswalk of the terrestrial ecosystems included in the assessment to Land Cover Descriptions from the SWReGAP layer in the context area

Ecosystem Name	SWReGAP Land Cover Description
Spruce-Fir	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland (S028), Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland (S030)
Aspen	Rocky Mountain Aspen Forest and Woodland (S023)
Spruce-Fir-Aspen	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland (S042)
Lodgepole Pine	Rocky Mountain Lodgepole Pine Forest (S031)
Pinyon-Juniper	Colorado Plateau Pinyon-Juniper Woodland (S039), Southern Rocky Mountain Pinyon-Juniper Woodland (S038), S052 Colorado Plateau Pinyon-Juniper Shrubland, S074 Southern Rocky Mountain Juniper Woodland and Savanna
Ponderosa Pine	Southern Rocky Mountain Ponderosa Pine Woodland (S036)
Cool-Moist Mixed Conifer	Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland (S034)
Warm-Dry Mixed Conifer	Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland (S032)
Bristlecone-Limber Pine	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland (S025)
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	Rocky Mountain Gambel Oak-Mixed Montane Shrubland (S046), Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland (S050), Rocky Mountain Lower Montane-Foothill Shrubland (S047)
Sagebrush Shrubland	Colorado Plateau Mixed Low Sagebrush Shrubland (S056), Inter-Mountain Basins Big Sagebrush Shrubland (S054), Wyoming Basins Low Sagebrush Shrubland (S128), Inter-Mountain Basins Montane Sagebrush Steppe (S071)
Montane-Subalpine Grassland	Southern Rocky Mountain Montane-Subalpine Grassland (S085), Rocky Mountain Subalpine Mesic Meadow (S083), Inter-Mountain Basins Semi-Desert Grassland (S090)
Alpine Uplands – Grasslands and Forblands	Rocky Mountain Dry Tundra (S081), Rocky Mountain Alpine Fell-Field (S004)
Rocky Slopes, Screes, Cliffs	Inter-Mountain Basins Cliff and Canyon (S009), Rocky Mountain Alpine Bedrock and Scree (S002), Rocky Mountain Cliff, Canyon and Massive Bedrock (S006), North American Warm Desert Bedrock Cliff and Outcrop (S016), Western Great Plains Cliff and Outcrop (S008)

Appendix C. VDDT Model Parameterization

VDDT model parameters varied by ecosystem type and are described below.

Spruce-Fir (Based on Gunnison Basin Parameters)

Table 24. Successional transition ages for spruce-fir

From Stage	*To Stage*	*Age at Transition*
A	B	70
B	C	180
C	D	350

Table 25. Disturbance probabilities for spruce-fir

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	250	0.0040
B	C	Mosaic Fire	250	0.0040
B	A	Replacement Fire	350	0.0029
B	C	Insects/Pathogens Open	100	0.0100
C	D	Mosaic Fire	175	0.0057
C	A	Replacement Fire	300	0.0033
C	A	Insects/Pathogens Replacement	250	0.0040
C	C	Insects/Pathogens Open	150	0.0067
C	D	Insects/Pathogens Open	60	0.0167
D	A	Replacement Fire	300	0.0033
D	D	Mosaic Fire	175	0.0057
D	A	Insects/Pathogens Replacement	200	0.0050
D	D	Insects/Pathogens Open	40	0.0250

Aspen (Based on Grand Mesa and Uncompahgre Plateau Parameters)

Table 26. Successional transition ages for aspen

From Stage	To Stage	Age	Probability
A	B	10	0.95
A	B	20	1
B	C	80	0.85
B	C	120	1
C	D	160	0.84
C	D	200	1

Table 27. Disturbance probabilities for aspen

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	200	0.0050
B	C	Surface Fire	160	0.0063
B	A	Replacement Fire	200	0.0050
B	C	Pathogen open	40	0.0250
C	A	Replacement Fire	150	0.0067
C	D	Surface Fire	80	0.0125
C	D	Pathogen open	60	0.0167
D	A	Replacement Fire	100	0.0100
D	A	Pathogen open	120	0.0083

Spruce-Fir-Aspen (Based on Gunnison Basin Parameters)

Table 28. Successional transition ages for spruce-fir-aspen

From Stage	To Stage	Age at Transition
A	B	30
B	C	130
C	D	200

Table 29. Disturbance probabilities for spruce-fir-aspen

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	200	0.0050
B	C	Mosaic Fire	200	0.0050
B	A	Replacement Fire	300	0.0033
B	C	Insects/Pathogens Open	100	0.0100
C	D	Mosaic Fire	175	0.0057
C	A	Replacement Fire	300	0.0033
C	A	Insects/Pathogens Replacement	250	0.0040
C	C	Insects/Pathogens Open	150	0.0067
C	D	Insects/Pathogens Open	60	0.0167
D	A	Replacement Fire	250	0.0040
D	D	Mosaic Fire	175*	0.0057
D	A	Insects/Pathogens Replacement	200	0.0050
D	D	Insects/Pathogens Open	40	0.0250

Lodgepole Pine (Based on Gunnison Basin Parameters)

Table 30. Successional transition ages for lodgepole pine

From Stage	To Stage	Age at Transition
A	B	20
B	C	200
C	D	300

Table 31. Disturbance probabilities for lodgepole pine

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	200	0.0050
B	B	Surface Fire	140	0.0071
B	C	Surface Fire	140	0.0071
B	A	Replacement Fire	150	0.0067
B	A	Insects/Pathogen Replacement	200	0.0050
B	C	Insects/Pathogen open	100	0.0100
B	B	Insects/Pathogen open	100	0.0100
C	C	Surface Fire	70	0.143
C	A	Replacement Fire	100	0.0100
C	A	Insects/Pathogen Replacement	150	0.0067
C	C	Insects/Pathogen Open	60	0.0167
C	D	Insects/Pathogen open	50	0.0200
D	A	Insects/Pathogen open	100	0.0100
D	A	Replacement Fire	100	0.0100

Pinyon-Juniper (Based on Uncompahgre Plateau Parameters)

Table 32. Successional transition ages for pinyon-juniper

From Stage	To Stage	Age	Probability
A	B	10	1.0000
B	C	50	0.9
B	C	70	1
C	D	190	0.7627
C	D	200	1

Table 33. Disturbance probabilities for pinyon-juniper

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	30	0.0333
B	A	Replacement Fire	75	0.0133
C	A	Replacement Fire	60	0.0167
C	C	Insects/Pathogens Open	50	0.0200
D	A	Replacement Fire	150	0.0067
D	C	Insects/Pathogens Open	100	0.0100

Pinyon-Juniper with Shrub Component (Based on Uncompahgre Plateau Parameters)

Table 34. Successional transition ages for pinyon-juniper with shrub component

From Stage	To Stage	Age	Probability
A	B	40	1
B	C	100	0.9
B	C	200	1

Table 35. Disturbance probabilities for pinyon-juniper with shrub component

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	80	0.0125
B	A	Replacement Fire	100	0.0100
B	B	Insects/Pathogens Open	50	0.0200
C	A	Replacement Fire	100	0.0100
C	B	Insects/Pathogens Open	100	0.0100

Ponderosa Pine (Based on Uncompahgre Plateau Parameters)

Table 36. Successional transition ages for ponderosa pine

From Stage	To Stage	Age	Probability
A	B	20	0.85
A	B	60	1
B	C	150	0.88
B	C	180	1
C	D	240	0.84
C	D	300	1
E	D	80	
E	D	100	

Table 37. Disturbance probabilities for ponderosa pine

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Surface Fire	50	0.0200
B	C	Surface Fire	35	0.0286
B	A	Replacement Fire	100	0.0100
B	A	Insects/Pathogens Replacement	300	0.0033
B	C	Insects/Pathogens Open	60	0.0167
C	C	Surface Fire	60	0.0167
C	E	Surface Fire	60	0.0167
C	A	Replacement Fire	180	0.0056
C	A	Insects/Pathogens Replacement	120	0.0083
C	C	Insects/Pathogens Open	80	0.0125
C	D	Insects/Pathogens Open	50	0.0200
D	D	Surface Fire	100	0.0100
D	E	Mosaic Fire	40	0.0250
D	A	Replacement Fire	80	0.0125
D	A	Insects/Pathogens Replacement	120	0.0083
D	D	Insects/Pathogens Open	60	0.0167
E	E	Mosaic Fire	30	0.0333
E	A	Replacement Fire	500	0.0020
E	A	Insects/Pathogens Replacement	300	0.0033
E	E	Insects/Pathogens Open	60	0.0167

Cool-Moist Mixed Conifer (Based on Uncompahgre Plateau Parameters)

Table 38. Successional transition ages for cool-moist mixed conifer

From Stage	To Stage	Age	Probability
A	B	30	0.8
A	B	100	1
B	C	140	0.96
B	C	200	1
C	D	240	0.84
C	D	350	1

Table 39. Disturbance probabilities for cool-moist mixed-conifer

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	200	0.0050
B	C	Surface Fire	130	0.0077
B	A	Replacement Fire	180	0.0056
B	C	Insects/Pathogens Open	80	0.0125
C	C	Surface Fire	60	0.0167
C	D	Mosaic Fire	120	0.0083
C	A	Replacement Fire	220	0.0045
C	A	Insects/Pathogens Replacement	300	0.0033
C	C	Insects/Pathogens Open	100	0.0100
C	D	Insects/Pathogens Open	60	0.0167
D	D	Mosaic Fire	60	0.0167
D	A	Replacement Fire	120	0.0083
D	A	Insects/Pathogens Replacement	300	0.0033
D	D	Insects/Pathogens Open	40	0.0250

Warm-Dry Mixed Conifer and Bristlecone-Limber Pine (Based on Uncompahgre Plateau Parameters)

Table 40. Successional transition ages for warm-dry mixed conifer

From Stage	To Stage	Age	Probability
A	B	30	0.85
A	B	60	1
B	C	150	0.88
B	C	200	1
C	D	240	0.84
C	D	400	1
E	D	90	

Table 41. Disturbance probabilities for warm-dry mixed conifer

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	100	0.0100
B	C	Mosaic Fire	75	0.0133
B	A	Replacement Fire	300	0.0033
B	A	Insects/Pathogens Replacement	300	0.0033
B	C	Insects/Pathogens Open	80	0.0125
C	C	Surface Fire	60	0.0167
C	E	Mosaic Fire	100	0.0100
C	A	Replacement Fire	200	0.0050
C	A	Insects/Pathogens Replacement	300	0.0033
C	C	Insects/Pathogens Open	120	0.0083
C	D	Insects/Pathogens Open	100	0.0100
D	E	Mosaic Fire	60	0.0167
D	A	Replacement Fire	100	0.0100
D	A	Insects/Pathogens Replacement	200	0.0050
D	D	Insects/Pathogens Open	100	0.0100
E	E	Mosaic Fire	60	0.0167
E	A	Replacement Fire	300	0.0033
E	A	Insects/Pathogens Replacement	300	0.0033
E	E	Insects/Pathogens Open	60	0.0167

Montane Shrubland, Oak-Serviceberry-Mountain Mahogany (Based on Uncompahgre Plateau Parameters)

Table 42. Successional transition ages for montane shrubland, oak-serviceberry-mountain mahogany

From Stage	To Stage	Age	Probability
A	B	20	0.95
A	B	30	1
B	C	50	0.9
B	C	70	1

Table 43. Disturbance probabilities for montane shrubland, oak-serviceberry-mountain mahogany

From Stage	To Stage	Disturbance	Interval (yrs)	Probability
A	A	Replacement Fire	20	0.0500
B	A	Replacement Fire	40	0.0250
B	B	Surface Fire	20	0.0500
C	C	Surface Fire	20	0.0500
C	A	Replacement Fire	25	0.0400

Appendix D. Historic Fire Interval Sources

Table 44. Historic fire return intervals, sources, and geographic location of the source for ecosystems on the GMUG

Ecosystem	Fire Return Interval (years)	Source	Location
Spruce-Fir	500 at high elevations and valley bottoms	Romme et al 2009	San Juan Mountains, CO
	>200	Peet 1981	Front Range, Colorado
Aspen	140	Romme et al 2009	Western San Juan Mountains, CO
	75 – 125	Expert opinion	GMUG
Spruce-Fir-Aspen	150 - 300	Expert opinion	GMUG
Lodgepole Pine < 9,500 ft elevation	50 – 150	Peet 1981	Front Range, Colorado
Lodgepole Pine > 9,500 ft elevation	200 - 400	Peet 1981	Front Range, Colorado
	300 - 400	Romme 1982	Yellowstone National Park, Wyoming
Pinyon-Juniper	200 - 1000	Eisenhart 2004	Uncompahgre Plateau, Colorado
	400	Floyd et al 2000, 2004	Mesa Verde National Park, Colorado
Pinyon-Juniper with shrubs	35 - 200	Expert opinion	GMUG
Ponderosa Pine	10 – 25	Brown and Shepperd 2003	Uncompahgre Plateau, Colorado
	40 – 100	Expert opinion	GMUG
Cool-Moist Mixed Conifer	50 - 200	Expert opinion	GMUG
	“Closer to spruce-fir than to warm-dry mixed conifer”	Aoki 2010	San Juan National Forest, Colorado
Warm-Dry Mixed Conifer	20 - 50	Romme et al 2009	San Juan National Forest, Colorado
Bristlecone-Limber Pine <10,000 ft elevation	9 - 55	Donnegan et al 2001	Pike National Forest, Colorado
Bristlecone-Limber Pine >10,000 ft elevation	Fire not an important disturbance (no evidence of past fire found)	Baker 1992	GMUG
Montane Shrubland, Oak-Serviceberry-Mountain Mahogany	100	Floyd et al 2000	Mesa Verde National Park, Colorado

Ecosystem	Fire Return Interval (years)	Source	Location
	1 - 35	Expert opinion	GMUG
Sagebrush Shrubland	70 - 240	Baker 2006	Western United States
	40 – 60	Wright et al 1979	
Montane-Subalpine Grassland	Determined by fire regime in adjacent forests	Romme et al. 2009	South Central Highlands, CO
Alpine Uplands – Grasslands and Forblands	Fire not an important disturbance	Expert opinion	GMUG

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Appendix E. Current Plan Direction Related to Terrestrial Ecosystems

Goals

- Manage vegetation in a manner to provide and maintain a healthy and vigorous ecosystem resistant to insects, diseases, and other natural and human causes. This will be done primarily through the commercial timber sale program for tree species located on lands suited for timber production. On other sites and for non-tree species, this will be accomplished through a variety of methods including prescribed fire and livestock grazing. These treatments should, where possible, provide a range of multiple-use outputs a few of which are fish and wildlife habitat, wood fiber, and economic benefits to the society.
- Define and inventory old growth for each of the Forest types on the Forest. Develop and implement silvicultural practices to maintain and establish desired old growth values. Implement National Policy on old growth.
- Increase or improve wildlife habitat diversity. Increase vertical and horizontal diversity.
- Utilize the commercial timber sales program to help decrease the risk of insect and disease infestations both now and in the future.
- Prevent and control insect and disease infestations.
- Conduct all firefighting activities with primary consideration for firefighter and public safety.
- Reintroduce fire as a natural process to enhance resources and meet land and resource objectives.
    - allow fire to function as a more natural process both in Wilderness Areas and non-wilderness areas to help improve forest health and ecosystem function, and enhance wildlife habitat, species diversity, and range and watershed condition.
    - reduce the potential for large catastrophic fires by helping to return the landscape to more historic fuel types and conditions.
    - provide for more consistent policies across agency boundaries, resulting in improved landscape level planning and implementation, as well as allowing for a full range of fire management options at an interagency level.

General Plan Direction and Standards and Guidelines

General plan direction and standard and guidelines related to the terrestrial vegetation is presented below. Plan direction related to aquatic and riparian ecosystems is not included. Specific management area direction is also not included.

Diversity on National Forests and National Grasslands

01 Maintain structural diversity of vegetation on units of land 5,000 to 20,000 acres in size, or fourth-order watersheds that are dominated by forested ecosystems.

a. Old growth forests are valuable as diverse and productive ecosystems and will be protected and managed. Old growth forests are ecosystems distinguished by old trees and related structural attributes. Old growth encompasses later stages of stand development that typically differs from earlier stages in a variety of characteristics which may include size, accumulations of large, dead, woody material, number of canopy layers, species composition, and ecosystem function.

Old growth is typically distinguished from younger stands by several of the following attributes. 1) large trees for species and site; 2) wide variation in tree sizes and spacing; 3) accumulations of large, dead, standing and fallen trees; decadence in the form of broken or deformed tops or bole and root decay; multiple canopy layers; canopy gaps and understory patchiness. The GMUG Forest will develop old growth definitions for each forest type or type groups for use in determining the extent and distribution of old growth forests. The GMUG Forest will conduct old growth inventories and develop and implement silvicultural practices to maintain and establish desired old growth values. In the meantime, project level decisions that might affect old growth will give special consideration to the old growth resource. Old growth values shall be considered in designing the dispersion of old growth. In general, areas to be managed for old growth values are to be evenly distributed, whenever possible, with attention given to minimizing the fragmentation of old growth into small, isolated areas.

Associated standards and guidelines

a. Maintain or establish a minimum of 20 percent of the forested area within a unit to provide vertical diversity.

b. Maintain or establish a minimum of 30 percent of the forested area within a unit to provide horizontal diversity.

c. In forested areas of a unit, 5-12% or more will (where biologically feasible) be in an old growth forest classification and must occur in irregular shaped patches. Designated spruce-fir and mixed conifer old growth patches shall be no smaller than 30 acres in size and should average 100-200 acres in size whenever possible. In aspen and lodgepole pine forest types, designated old growth patches can be smaller than 30 acres and average less than 100-200 acres so that wildlife cover requirement can be met since clearcutting is generally performed in these forest types. All forest vegetation types will be represented in old growth delineations. For every 10,000 acres of forest land capable of providing forest stands meeting old growth criteria, 500-1200 acres of old growth will be evenly distributed throughout the unit. In addition, other stands within the same unit will be designated so that these stands will be managed on extended rotations in order to develop their old growth structure and values so that these stands will serve as old growth replacement stands. 5% or more should be in the grass/forb stages.

d. In the forested units, create or modify created openings so they have a Patton edge-shape index of at least 1.4 and have at least a medium-edge contrast.

e. In the aspen type, 5% should be in the grass/forb and/or seed/sap stages.

02 Retain existing medium- or high-contrast edges within forested diversity units.

03 If medium-contrasted edges are created in units dominated by grassland or shrubland, create openings with Patton edge-shape index of at least 1.4. Manage unmanipulated plan communities to reach late seral stages.

04 In forested diversity units, maintain an average of 200-300 snags (in all stages of development) per 100 acres, well distributed over the diversity unit.

Associated standards and guidelines

a. Snag dependent species must be maintained by providing habitat that will maintain minimum viable populations. Provide as a minimum the following:

- Ponderosa pine, Douglas-fir, and spruce-fir – 90-225 snags per 100 acres 10” dbh or greater (where biologically feasible)
- Aspen – 120 – 300 snags per 100 acres 8” dbh or greater (where biologically feasible)
- Lodgepole pine – 90-180 snags per 100 acres 8” dbh or greater (where biologically feasible)

b. Maintain 10-20 tons of logs and other down woody material per acre for species dependent on this material for their habitat. Retain an average length per acre of down-dead logs (where biologically feasible) of the following minimum diameters:

- Ponderosa pine, Douglas-fir, and spruce-fir – 12 inch diameter, 50 linear feet/acre
- Aspen, Lodgepole pine – 10 inch diameter, 50 linear feet/acre

05 Manage aspen for retention wherever it occurs, unless justified by one of the following:

- Conversion of determinate aspen to conifers, or shrub-or grass/forb seral stages for wildlife, esthetic, recreation, transportation, or watershed purposes.
- Areas of aspen which are larger than are needed for wildlife or esthetic purposes.

06 In predominately aspen stands are managed for regeneration, treat contiguous areas no larger than 40 acres, unless larger areas are needed to protect aspen regeneration or prevent decadence. Treat entire clones.

Dispersed Recreation Management

02 Close or rehabilitate dispersed sites where unacceptable environmental damage is occurring.

Associated standards and guidelines

a. Close sites that cannot be maintained in Frissell Condition Class 1, 2, or 3.

b. Rehabilitate sites that are in Frissell Condition Classes 4 or 5.

Wilderness Area Management

04 Utilize a permit system to manage use levels and patterns during the summer use period based upon the following criteria:

a. When acceptable use levels, as specified in the individual prescriptions, are exceeded during 20 percent of the summer use season, or

b. When acceptable capacities, as specified in the individual prescriptions, in primitive or pristine management areas are exceeded on 10 percent or more of the days during the summer use season.

c. Apply a permit system to an entire wilderness, not just impacted portions of a wilderness.

10 Require users camping overnight with recreational stock to carry cubed, pelleted, or rolled feed and/or certified weed-free hay where grazing is prohibited.

11 Control overnight grazing of recreational stock in alpine and krummholz ecosystems according to use standards in Management Activity 002, Forest Direction.

Associated standards and guidelines

a. Base range condition on the standards in Range Analysis Handbook (FSH 2209.21).

b. Allowable soil disturbance criteria:

- 20% maximum disturbance on ranges with good-excellent soil stability condition on 0-15% slope.
- 15% maximum disturbances on range with fair soil stability conditions on slopes less than 15% and good or better soil stability conditions on slope of 16-25%.
- 10% maximum disturbance on ranges with fair soil stability conditions on slopes 16-25%, and good soil stability conditions on slopes of 26-45%.

13 Implement revegetation only for rehabilitation of areas in less than “fair” range condition based upon their natural potential. Use only native species for revegetation. Implement only where natural vegetation possibilities are poor and only where degradation was due to human activities.

Associated standards and guidelines

a. Base range condition on the standards in Range Analysis Handbook (FSH 2209.21)

16 Close or rehabilitate dispersed sites where unacceptable environmental damage is occurring.

Associated standards and guidelines

a. Close sites that cannot be maintained in Frissell Condition Class 1, 2, or 3.

b. Rehabilitate sites that are in Frissell Condition Classes 4 or 5.

17 Take appropriate suppression action on man-caused wildfires.

18 Maintain fire-dependent ecosystems through Wildland Fire Use, as appropriate. Reclaim areas disturbed as part of fire control activities to meet the visual quality objective of retention and to mitigate against the invasion of non-native species.

Associated standards and guidelines

a. Allow for the full range of fire management responses (full suppression to fire use) under an approved fire management plan.
b. Manage naturally ignited wildland fires in predetermined areas under specified conditions outlined in an approved fire management plan.

20 Control natural insect or disease outbreaks in wilderness only when justified by predicted loss of resource value outside of wilderness. Conduct analysis in accordance with FSM 3440.

Aquatic and Terrestrial Habitat Management

01 Manage for habitat needs of indicator species.

Associated standards and guidelines

a. Deer and Elk – Provide hiding cover within 1000 feet of any known calving areas.
b. Pine Marten (old growth spruce-fir) – Openings created should be less than 300 feet in width. Provide diversity of forest communities.
c. Red Crossbill (mature spruce-fir) – Provide at least 20% of the area in trees bearing cones.
d. Hairy Woodpecker (mature lodgepole pine) – Provide 3-5 snags/acre and meet the adopted VQO for the area. Protect those snags with cavities when they are located within 100 yards of 4-wheel drive access. Leave live broken trees in preference to others in snag selection.
e. Goshawk (mature aspen) – Provide 20% of pole or mature tree stands adjacent to nesting sites with at least 150 square feet of basal area. Provide at least one class 1 log adjacent to nesting sites.
f. Lewis Woodpecker (mature mountain shrub) – Provide 3-5 snags/acre of size class 8 and 9 for cavities, while meeting adopted VWO for the area. Protect snags with cavities within 100 yards of 4-wheel drive roads.
g. Abert Squirrel (mature ponderosa pine) – Leave at least two 12-20” DBH trees per 5 acres for nesting and feeding. Provide a group of smaller trees directly adjacent to nesting and feeding trees for hiding cover. Leave tree size gambel oak in association with ponderosa pine.
h. Sage grouse (late succession sagebrush) – See FSM 2631 management guides.
i. Pinyon Jay (mature pinyon pine juniper) – Leave 3-4 seed bearing trees/acre for feeding and nesting.
j. Bighorn Sheep – use vegetation treatment to restore historic migration patterns and dispersed foraging areas on summer and winter ranges. Restrict activities within one mile of known bighorn sheep lambing grounds from May 1 through June 20 if they would cause unacceptable stress to lambing ewes.

k. Deer, Elk, Black Bear, Goshawk – In areas of historic shortage of dry season water, where there is less than one source per section, create one source per section.

02 Maintain habitat for viable population of all existing vertebrate wildlife species.

Associated standards and guidelines

a. Maintain habitat capability at a level at least 40 percent of potential capability.

b. No activities shall be allowed within one quarter mile of an active Ferruginous hawk, Swainson’s hawk, goshawk, osprey, or prairie falcon next from March 1 to July 31 if they would cause nesting failure or abandonment.

Habitat Improvement and Maintenance

01 Use both commercial and noncommercial silvicultural practice to accomplish wildlife habitat objectives.

Associated standards and guidelines

a. In forested areas, maintain deer or elk cover on 60 percent or more of the perimeter of all natural and created openings, and along at least 60 percent of each arterial and collector road that has high levels of human use during the time deer and elk would be expected to inhabit the area. Cover should be located and measured perpendicular to the road. Gaps between cover along the roads should not exceed one quarter mile. Roads with restricted use could provide for less cover. Maintain cover along 40 percent of each stream and river.

b. In diversity units dominated by forested ecosystems, the objective is to provide for a minimum habitat effectiveness of 40 percent through time. Habitat effectiveness will be determined by evaluating hiding and thermal cover, forage, roads, and human activity on the roads. Cover should be well distributed over the unit. Hiding and thermal cover may be the same in many cases. Minimum size cover areas for mule deer are 2-5 acres and for elk 30-60 acres.

   If an area being evaluated does not meet the accepted definition of fully satisfactory hiding or thermal cover, it still has value as cover but more area may be needed to compensate for the lower quality cover or it may be necessary to control human activity.

   It must be recognized that as plant succession changes, the amount of an area that is either cover or openings is changing. The effectiveness of an area for big game should be evaluated through time. In a Diversity Unit or some sub-part, the amount of area that is actually cover will vary. The intent is to make or keep the area in a condition where deer and elk can effectively use the area by managing the vegetation and human activity.

c. In diversity units dominated by non-forested ecosystems, maintain deer and elk hiding cover as follows:

% of Unit Forested	% of Forested Area in Cover
35-50	at least 50%
20-34	at least 60%
Less than 20	at least 75%

These levels may be exceeded temporarily during periods when stands are being regenerated to meet the cover standard, or to correct tree disease problems, in aspen stands, or where windthrow or wildfire occurred. Maintain hiding cover along at least 75 percent of the edge of arterial and collector roads, and at least 60 percent along streams and rivers, where trees occur.

d. Alter age classes of browse stands in a diversity unit no more than 25 percent within a ten-year period.

e. In addition to providing good habitat, all improvements must also meet the adopted VQO.

02 Improve habitat capability through direct treatments of vegetation, soil, and waters.

03 Maintain edge contrast of at least medium or high between tree stands created by even-aged management.

Associated standards and guidelines

Contrast by Age Class							
Age Class	**Old Growth**	**Mature**	**Poles**	**Shrub-seedling-sapling**	**Grass-forb**	**Shrubland**	**Grassland**
Old Growth	-	Low	Medium	High	High	Medium	High
Mature	Low	-	Medium	Medium	High	Medium	High
Poles	Medium	Medium	-	Medium	High	Medium	High
Shrub-seedling-sapling	High	Medium	Medium	-	Low	Low	Low
Grass-forb	High	High	High	Low	-	Medium	Low
Shrubland	Medium	Medium	Medium	Low	Medium	-	Medium
Grassland	High	High	High	Low	Low	Medium	-

Wildlife and Fisheries Threatened, Endangered, and Sensitive Species

01 Manage for and provide habitat for threatened, endangered, and sensitive species as specified in the Regional Forester’s 1920 (2670) letter dated June 25, 1982.

Associated standards and guidelines

No activities shall be allowed within one mile of an active bald eagle or peregrine falcon nest from February 1 to July 31 if they would cause nesting failure or abandonment.

Manage to provide habitat for the sensitive species, Uncompahgre Fritillary butterfly (Boloria acrocnema), Braya humilis spp and Ventosa (no common name) where they occur.

Range Resource Management

01 Remove livestock for the remainder of the grazing season from allotments managed under a continuous grazing system when further utilization on key areas will exceed allowable use criteria for the season.

02 Manage livestock and wild herbivores forage use by implementing allowable use guides on key areas.

Associated standards and guidelines

Livestock and wild herbivores allowable forage use by grazing system and range type are:

1 Rest Rotation System.

a. use by range type:

-Mainly seed reproduction (Bunchgrass, plains grassland, foothills shrub, and alpine range types):

- 50-60 percent on heavy use pastures
- Up to 45 percent on light use pastures.

-Mainly vegetation reproduction (meadow, sandhill prairie, bluegrass bottoms, and aspen range types):

- Bluegrass - maximum up to 80 percent;
- Others - 55-65 percent on heavy use pastures, 40-50 percent on light use pastures.

-wild herbivores use during spring in rest pastures will not exceed 25%.

b. Allowable soil disturbance or recovery criteria:

Soil and vegetation condition must be restored to at least the pre-treatment condition by the return to the same point in the grazing cycle.

2 Deferred Rotation System.

a. use by range type:

-Mainly seed reproduction:

- 40-50 percent on all pastures.

-Mainly vegetation reproduction:

- 45-55 percent on all pastures.

b. Allowable soil disturbance or recovery criteria:

Soil and vegetation condition must be restored to at least the pre-treatment condition by the return to the same point in the grazing cycle.

3 Rotation System.

a. use by range type:

-Mainly seed reproduction:

- Max of 50 percent on last used pastures.
- Max of 40 percent on last used first used pastures.

-Mainly vegetation reproduction:

- Max of 55 percent on last used pasture.
- Max of 45 percent on first used pasture.

b. Allowable soil disturbance or recovery criteria:

Same as deferred rotation system above.

4 Continuous System (Grazing same time and place every year)

-Mainly seed reproduction:

Use by Condition Class on Key Area				
Season	**Good and Excellent**	**Fair**	**Poor**	**Very Poor**
Full Grazing Season or Spring	31-40%	21-30%	11-20%	0-10%
Summer	36-45%	26-35%	11-25%	0-10%
Fall and/or Winter	46-55%	31-45%	16-30%	0-15%

-Mainly vegetation reproduction:

- Same as primary seed reproduction except increase utilization by 10% on bluegrass.
- Allowable soil disturbance: 20% maximum disturbance on ranges with good-excellent soil stability condition on 0-15% slopes. 15% maximum disturbance on ranges with fair soil stability condition on less than 15% slopes, and on good or better soil stability condition on 16-25% slopes. 10% maximum disturbance on ranges with fair soil stability condition on less than 15% slopes, and on good or better soil stability condition on 26-45% slopes.

5 Alternate Years System

d. use by range type on key areas:

–Mainly seed reproduction

Condition Class on Key Area	Use
Good-Excellent	51-60%
Fair	36-50%
Poor	21-35%
Very Poor	0-20%

-Mainly vegetation production

Condition Class on Key Area	Use
Good-Excellent	56-65%
Fair	41-55%
Poor	31-40%
Very Poor	0-30%

Bluegrass – 80% on good or better condition and same proper use percent for fair and lower as above.

Soil disturbance criteria is same as for continuous grazing.

03 Achieve or maintain satisfactory range conditions on all rangelands.

Associated standards and guidelines

a. Programs and projects to accomplish this should be economically efficient and based on sound ecological principles.

04 Treat noxious farm weeds in the following priority:

a. Leafy spurge, Russian and spotted knapweed, and Canada and musk thistle;

b. Invasion of new plant species classified as noxious farm weeds,

c. Infestation in new areas;

d. Expansion of existing infestations of Canada and musk thistle, and other noxious farm weeds; and

e. Reduce acreage of current infestation.

Silvicultural Prescriptions

01 Apply a variety of silvicultural systems and harvest methods which best meet resource management objectives. Commercial timber sales will be scheduled only on lands suitable for timber production and can occur in all management areas except 8A, 8B, 8C, 10A, and 10C.

Associated standards and guidelines

a. The appropriate harvest methods by forest cover type are:

Forest Cover Types	Appropriate Harvest Methods	
	Even-aged	Uneven-aged
Ponderosa Pine	Shelterwood	Group Selection & Single Tree Selection
Aspen	Clearcut	n/a
Lodgepole Pine	Shelterwood & Clearcut	Group Selection
Engelmann Spruce/Subalpine fir	Shelterwood & Clearcut	Group Selection & Single Tree Selection
Douglas-fir	Shelterwood & Clearcut	Group Selection & Single Tree Selection
Mistletoe Infected Stands	Clearcut	n/a

b. The utilization standards for live and dead material as used in the analysis were as follows. Consult current Forest Service manual and/or hand books for utilization standards to be used for timber sales:

Product	Minimum DBH	Top Diameter	Minimum Length	Percent Net of Gross
Live Trees				
Sawtimber				
Conifer	8	7	8	33.3
Aspen	8	7	8	50
POL	5	4	8-1/3	Variable
Dead Trees				
Sawtimber	8-12	7-10	16	33.3
POL	5	4	Variable	Variable

c. To facilitate the control of soil erosion within acceptable tolerance:

1. Permit conventional logging equipment on slopes of less than 20 percent where soil surveys or site-specific soil data are unavailable.
2. Allow conventional logging equipment on slopes up to 40 percent where soil surveys or site-specific soil data are available to design erosion mitigation needs.
3. Utilize high flotation equipment on slopes up to 60 percent or cable and aerial systems on any slope.

02 Treat as large a percentage of a fourth order watershed in one entry as possible while still complying with the other Standards and Guidelines in order to maximize impacts by reducing the total number of entries in a given watershed over a rotation.

03 Clearcut and/or shelterwood in Engelmann spruce/subalpine fir/Douglas-fir according to the following guidelines:

a. Utilize the shelterwood method on south and west aspects to provide seed and shade protection if windfall risk is below average. It can also be used on other aspects when cold, drought sites are present.

b. Utilize the clearcut method on north and east aspects, or on other aspects if moist site conditions are present and where windfall risk is above average.

c. Openings created by clearcutting should be of a size and shape that provide for the needs of regeneration, are economically efficient and meet other biological management objective found in the Plan.

04 Assure that all even-aged stands scheduled to be harvested during the planning period will generally have reached the culmination of mean annual increment of growth. Rotation age may be longer or shorter depending on site quality, previous management, insects and disease, and management objectives for resources other than timber production. Variations from the Rotation Age table will be documented in the site specific silvicultural prescription.

05 The maximum size of opening created by the application of even-aged silviculture will be 40 acres regardless of forest cover type. Exceptions are:

a. Proposals for larger openings are subject to a 60-day public review and are approved by the Regional Forester

b. Larger openings are the result of natural catastrophic conditions of fire, insect or disease attach, windstorm or

c. The area does not meet the definition of created openings.

06 For management purposes, a cut-over area is considered an opening until such time as:

- Increase water yield drops below 50 percent of the potential increase
- Forage and/or browse production drops below 40 percent of potential production
- Deer and elk hiding cover is re-established so that views do not exceed 200-300’ into the unit. If the unit is adjacent to open roads, view distances may need to be decreased.
- Minimum stocking standards by forest cover type and site productivity are met, and
- The area appears as a young forest rather than a restocked opening, and takes on the appearance of the adjoining characteristic landscape.

Associated standards and guidelines

a. In order to meet the stated Visual Quality objectives of an area, the regenerated stands shall meet or exceed all of the following characteristics before a cut-over area is no longer considered an opening:

Forest Cover Type	Minimum Stocking Level (trees/acre)	Tree Height[1] (% of the adjacent mature stand height or feet)	Crown Closure (percent)	Distribution[2]
Ponderosa Pine	190	25%, 6’	30	70
Lodgepole Pine	150	25%, 6’	30	75
Engelmann Spruce/Subalpine fir	150	25%, 6’	30	75
Douglas-fir	150	25%, 6’	30	75
Aspen	300	25% 6’	30	75

[1] Applies to trees specified as minimum stocking level.

[2] Percent of plots or transects that are stocked.

07 Acceptable management practices:

Management Activity*	Engelmann Spruce, subalpine fir, Douglas-fir	Ponderosa Pine	Lodgepole Pine	Aspen
Tree Improvement	X	X	X	N
Site Preparation	X	X	X	N
Reforestation				
Planting	N	N	N	O
Seeding	N	N	X	O
Natural	X	X	X	X
Regeneration Protection	X	X	X	N
Stocking Control (thinning)				
Precommercial	X	X	X	O
Commercial	N	N	X	O
Salvage	X	X	X	X
Cutting Methods				
Clearcut	X	N	X	X
Shelterwood	X	X	N	O
Selection	X	X	N	O

*Various combinations of these activities provide the acceptable range of management intensity for timber production (36 CFR 219.14(b)).

X = Appropriate practice.

O = Not an appropriate practice.

N = Appropriate, but not a standard practice. May be acceptable where economically justified or necessary to meet management objectives.

08 Provide for wildlife habitat improvement and enhancement of other renewable resources in Sale Area Improvement Plans

09 Make Christmas trees available in areas where other resource objectives can be accomplished through commercial or personal use Christmas tree sales.

10 Utilize firewood material using both commercial and noncommercial methods. Public fuelwood areas can be located on lands not suited for commercial timber production

11 Apply intermediate treatments to maintain growing stock level standards when it is economically efficient to do so.

Reforestation

01 Establish a satisfactory stand on cutover areas; emphasizing natural regeneration within five years after final harvest except:

a. For permanent openings that serve specific management objective
b. When provided for otherwise in specific management prescriptions.

Associated standards and guidelines

a. Minimum Stocking Standards by Productivity and Forest Cover Type:

Forest Cover Type	Site Productivity (Cu.Ft./acre/ year)	Planting Densities[1] (Trees/Acre)	Stocking Rates for Certification		Percent of Plots Stocked		Seedling Height (inches)	
			Min[2]	Desired[3]	Min	Desired	Min	Desired
Spruce Fir	85+	360-680	200	530	75	100	3	18
	50-84	360-540	200	430				
	20-49	300-360	150	360				
Aspen	All	n/a	1200	1800	75	100	12	45
Lodgepole Pine	85+	360-680	245	430	75	100	3	18
	50-84	360-540	200	430				
	20-49	300-360	150	360				
Ponderosa Pine	85+	435-680	205	310	70	100	3	18
	50-84	435-550	205	255				
	20-49	300-360	190	240				

[1] Lower densities are recommended to meet minimum stocking standards. Higher densities are recommended to meet desired stocking standards, with ample stock for selecting genetically superior trees.

[2] Minimum stocking standards are to be used where no precommercial cutting will be done, and only one harvest will be made to regenerate the stand.

[3] Desired stocking standards are to be used where at least one precommercial cut will be done followed by two sawlog harvests before the final cut is done. (Aspen will have only one final cut.)

02 Do not apply final shelterwood removal cut until the desired number (as specified in Minimum Stocking Standards) of well –established seedling/acre are expected to remain following overwood removal.

03 Use trees of the best genetic quality available which are adapted to the planting site when supplemental planting.

04 For management purposes, a final shelterwood removal cut is considered an opening until such time as:

- Increase water yield drops below 50 percent of the potential increase
- Forage and/or browse production drops below 40 percent of potential production
- Minimum stocking standards by forest cover type and site productivity are met,
- The area appears as a young forest rather than a restocked opening, and takes on the appearance of the adjoining characteristic landscape.

Associated standards and guidelines

a. In order to meet the stated Visual Quality objectives of an area, the regenerated stands shall meet or exceed all of the following characteristics before a cut-over area is no longer considered an opening:

Forest Cover Type	Minimum Stocking Level (trees/acre)	Tree Height[1] (% of the adjacent mature stand height or in feet)	Crown Closure (percent)	Distribution[2]
Ponderosa Pine	190	25, 6’	30	70
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Douglas-fir	150	25, 6’	30	75
Aspen	300	25, 6’	30	75

[1] Applies to trees specified as minimum stocking level.

[2] Percent of plots or transects that are stocked.

Timber Stand Improvements

01 Utilize Christmas tree sales for stocking controls where the opportunity exists.

Fire Planning and Suppression

01 Protect life, property, and resource values from wildfire in a cost-efficient manner that maximizes the benefits of shared resources and developing technologies. (FSM 5100)

Associated standard and guidelines

a. Planned budgets and programs are based on an analysis of efficiency and public concern.

b. Fiscal year fire program activities are based on a cost efficient analysis of budget.

c. Wildfire suppression is based on least-cost plus damages with consideration for public concerns.

Wildland Fire Use

01 Take appropriate management action on all wildland fires that qualify for fire use to allow fire to function as a more natural process to benefit resources. Wildland fire use can be used to:

- Improve overall forest health and ecosystem function and enhance wildlife habitat, species diversity, and range and watershed conditions.
- Reduce the potential for large catastrophic fires by helping to return the Forest to more historic fuel types and conditions.

Associated standard and guidelines

a. All ignitions should be managed according to an approved Fire Management Plan that specifies management conditions.

b. The Fire Management Plan will provide direction for fire use, including a general delineation of wildland Fire use areas, fire regime/fire occurrence/historic role of fire for each area, objectives to be achieved by wildland fire, and guidance on monitoring and evaluation.

Escaped Fire Suppression

01 Take appropriate suppression action on all escaped fires considering the following:

a. The values of the resources threatened by the fire (both positive and negative),
b. Management objectives for the threatened area(s),
c. The fuelbeds the fire may burn in,
d. The current and projected weather conditions that will influence fire behavior,
e. Natural barriers and fuel breaks,
f. Social, economic, political, cultural, and environmental concerns,
g. Public safety,
h. Firefighter safety, and
i. Costs of alternative suppression strategies. Use the escaped fire situation analysis to make this determination. (FSM 5130 31).

Fuel Treatment

01 Prescribed fire will be utilized as a vegetative and fuels management technique where it is the most cost-efficient and acceptable alternative to achieve management objectives. (FSM 5190)

Associated standards and guidelines

a. A historical record will be maintained with each prescribed fire plan which documents the biological/physical effects and the fire behavior which produced the effects.
b. Utilize current technologies to achieve an optimum balance between positive and negative effects, and prevent escaped fires.

Insect and Disease Management Suppression

01 Prevent or suppress epidemic insect and disease population that threaten forest tree stands with an integrated pest management (IPM) approach consistent with resource management objectives.

Appendix F. Ecological Portfolio Approach

We anticipate that one of the greatest threats to future ecological integrity on the GMUG will be climate change and its associated amplifications of other ecosystem stressors. As such, strategic direction in a revised Forest Plan, including desired conditions for terrestrial ecosystems, should consider strategies that reduce vulnerability and increase adaptation to climate change, as outlined below (Table 45; Millar et al 2007). It is important to note that these strategies are not mutually exclusive, and many management actions can incorporate multiple strategies at once (Table 46; Butler et al 2012).

Table 45. A framework for management strategies that reduce vulnerability and increase adaptation to climate change

[Modified from Millar et al. (2007).]

Strategy	Description
Promote resistance	Actions that enhance the ability of species, ecosystems, or environments to resist forces of climate change and that maintain values and ecosystem services in their present or desired states and conditions.
Increase resilience	Actions that enhance the capacity of ecosystems to withstand or absorb increasing impacts without irreversible changes in important processes and functionality.
Enable ecosystems to respond	Actions that assist climatically driven transitions to future states by mitigating and minimizing undesired and disruptive outcomes.

Table 46. Examples of climate change adaptation management actions and their corresponding strategies

[From Butler et al. (2012).]

Action	Resistance	Resilience	Response
Sustain fundamental ecological conditions	X	X	X
Reduce the impact of existing ecological stressors	X	X	X
Protect forests from large-scale fire and wind disturbance	X	X	
Maintain or create refugia	X		
Maintain or enhance species and structural diversity	X	X	
Increase ecosystem redundancy across the landscape		X	X
Promote landscape connectivity		X	X
Enhance genetic diversity		X	X
Facilitate community adjustments through species transitions			X
Plan for and respond to disturbance			X

Taking the broad strategies presented by Millar (promote resistance, increase resilience, enable response) and determining how best to apply them to a National Forest landscape is a daunting task. What specific management actions will increase resilience to climate change? What geographic locations and which ecosystems should these actions be implemented in?

We propose consideration of a framework outlined by Aplet and McKinley (2017) for implementation of these types of strategies across the landscape based on a “portfolio approach” that spreads risk across a plurality of management approaches, similar to a financial portfolio. They propose segregating the landscape into a portfolio of zones in which management options appropriate to one of three strategies, observation, restoration, or facilitation (Table 47) may be implemented. This approach prevents homogenization of the landscape, can guard against uncoordinated application of strategies that may result in maladaptation (“actions or inaction that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future”; Noble et al 2014) and spreads the risks associated with management action among classes for low perceived risk (observation) to high perceived risk (facilitation). Consideration of the portfolio approach on the GMUG will need to factor in the amount of the forest that is currently available for active management intervention to achieve desired conditions. In many ecosystems, about 50% of the area is in a special designation, which may exclusively limit the area to a passive, observational management approach. Even areas that aren’t covered by special designations may be untenable for active management due to terrain or access limitations. Funding and capacity for active management actions may be a further limitation in applying this approach.

Table 47. Zones of the portfolio approach to ecological risk management for global change

[Modified from Aplet and McKinley (2017).]

Zone	Response to change	Purpose	Areas of application on the GMUG
Observation	Accept change	To conserve the building blocks of future ecosystems without intervention and therefore without unintended consequences of management. Maintains background rates of change.	Designated wilderness, research natural areas, roadless lands, and other lands most likely to sustain ecological integrity without intervention (e.g., areas of high genetic diversity, limited invasive species, and/or late-seral forest).
Restoration	Resist change	To sustain historically whole ecosystems within their historical range of variability. Provides net slower rates of ecological change.	Lands that were degraded by past management, but can be restored to high integrity ecosystems through management. Ecosystems that are expected to be fairly resilient to future climate, and/or areas of crucial wildlife habitat or other values are well suited to this strategy.
Facilitation	Guide change	To sustain viable populations and other historical legacies in the face of climate change. Populations, soils, and streams, for example, may be manipulated into a condition that is more resilient to climate change, even if the ecosystem diverges from that which dominated historically. Provides net faster rates of change.	Lands that are not in a special designation area, with ecosystems and species that are expected to have high areas of threatened and lost suitable habitat and may require more active facilitation to maintain ecological integrity in future climate conditions.

Appendix G. Climate Change

Introduction

Climate is defined as the average value of weather over a time period, including range and variability, at a defined spatial scale (NOAA 2016, Luce et al. 2012, Furniss et al. 2010). The variables that makeup weather and climate include temperature, precipitation, and extreme disturbance events that are directly tied to ecosystem composition, health, and productivity (Peterson et al. 2011, Vose et al. 2012). Climate change is the change in the long-term statistics of weather (NOAA 2007). These changing conditions, such as changes in precipitation and temperature, are stressors that affect long-term ecological conditions. Existing ecosystems are a result of long-term climate interactions with species as they adapt, migrate, or decline.

Based on decades of research, the Earth’s climate warmed rapidly during the 20th century and this trend is expected to intensify in the future (USDA 2015, Furniss et al. 2010). Evidence supports that the increase in greenhouse gases—carbon dioxide, methane, nitrous oxide, and fluorinated gases—are amplifying natural climate variation resulting in a rapid increase in atmospheric temperature (EPA 2016, Luce et al. 2012, Peterson et al. 2011, Halofsky et al. 2011). These interactions result in complex changes in the heat balance of the Earth, atmospheric flow patterns, and redistributed wind streams that result in changes in precipitation (Halofsky et al. 2011). These changes result in impacts to ecosystem processes including the timing, amount and type of precipitation, invasive species encroachment, shifts in fire regimes and intensity, insect infestations, carbon storage, and species health and resilience (USDA 2016, Peterson et al. 2011).

Summary Public Input

Written comments and conversations at the open houses regarding climate change provided valuable information to help us understand many of the key issues, trends and opportunities that may need to be addressed through plan revision. While this section summarizes these comments, some issues were reiterated by many members of the public, while other concerns were mentioned only by one or a few individuals.

Key Issues, Concerns and Opportunities

Many comments provided local knowledge of conditions that further verified climate change research findings for the region. The comments frequently emphasized the changes in seasonal duration and conditions, with shorter winters and earlier, warmer summers. Conditions and trends commenters attributed to climate change included:

- Changes in conditions that are impacting tourism and use, particularly for Ouray, Crested Butte, Telluride and Monarch ski area
- Changes in precipitation, particularly increased rain on snow events
- Increased outbreaks of spruce beetle and subsequent tree mortality, with the attendant public safety, wildfire, and aesthetic concerns
- Shifts in timing of species arrival and departure, and changes in species observed

- A growing disconnect between blooming times of native species and the arrival of pollinators
- Alterations in native and invasive plant species
- Shifts in seasons impacting the operational dates for outfitter guides and other special use permittees

While many focused on future uncertainty of winter recreation and tourism, and the consequent socioeconomic implications, others also voiced concerns about impacts to other seasonal recreation pursuits, including rafting, fishing, as well as hiking, mountain biking, and other activities that may occur in areas of high tree mortality. Others expressed concerns about effects on water availability, range conditions, wildlife species, invasive species and weeds, and fire frequency and intensity.

Several offered possible actions to reduce or mitigate climate change impacts. Some highlighted the need for adaptive management to accommodate changing conditions and provide for a more resilient landscape, while others voiced concerns that the GMUG would not be able to adapt quickly enough to changing conditions. Some mentioned the need to provide for flexibility in shifting use, timing and locations tied to special use permits, to allow for adaptability to uncertain conditions. A few also expressed the need to continue addressing climate change, particularly as it pertains to the oil and gas leasing process. Many indicated interest in becoming Citizen Scientists for the GMUG, and others offered sources of data, including ozone and air quality, bird, pollinator and plant species monitoring, and research conducted by the Rocky Mountain Biological Lab (RMBL) and the Rocky Mountain Research Station (RMRS).

Potential Indicators

Potential indicators that could be used to measure changes in environmental conditions include temperature; volume, timing, and type of precipitation; stream temperatures and base-flow; and groundwater recharge rates and volume. Potential indicators to measure impacts to species and ecological systems include changes in species distribution, changes in species composition or dominance, habitat connectivity, water temperature/quantity/quality, changes in phenology, and post-disturbance recovery. Some potential indicators to measure socioeconomic impacts, including impacts to activities and uses including (but not limited to) recreation, grazing, timber harvest, and more, are included in Table 49.

Several recent climate-related assessments have been conducted at the statewide scale (Lukas et al. 2014, Gordon and Ojima 2015) for Colorado. In addition, the Grand Mesa, Uncompahgre and Gunnison National Forests (GMUG) have been a key partner in recent investigations into potential impacts at a finer regional scale. Impacts to terrestrial species and ecosystems have been conducted specifically for the Gunnison Basin and the San Juan Mountains (Rondeau et al. 2017). These analyses were informed by data and interpretation within a southwestern Colorado regional context, and thus are also applicable to other planning areas across the GMUG. The GMUG’s watershed vulnerability assessment (Howe et al. 2012) addressed climate change for hydrological processes and aquatic resources. Though all of these assessments were based on a variety of climate models and emissions scenarios, they present generally consistent information on trends and potential future climate-related issues for Colorado. The synthesis provided here (Table 48) is taken primarily from Rondeau et al. (2017), it being the most recent and comprehensive assessment for the GMUG and its surroundings. The geographic planning area for Grand Mesa, Uncompahgre, and Gunnison National Forests is shown in Figure 3.

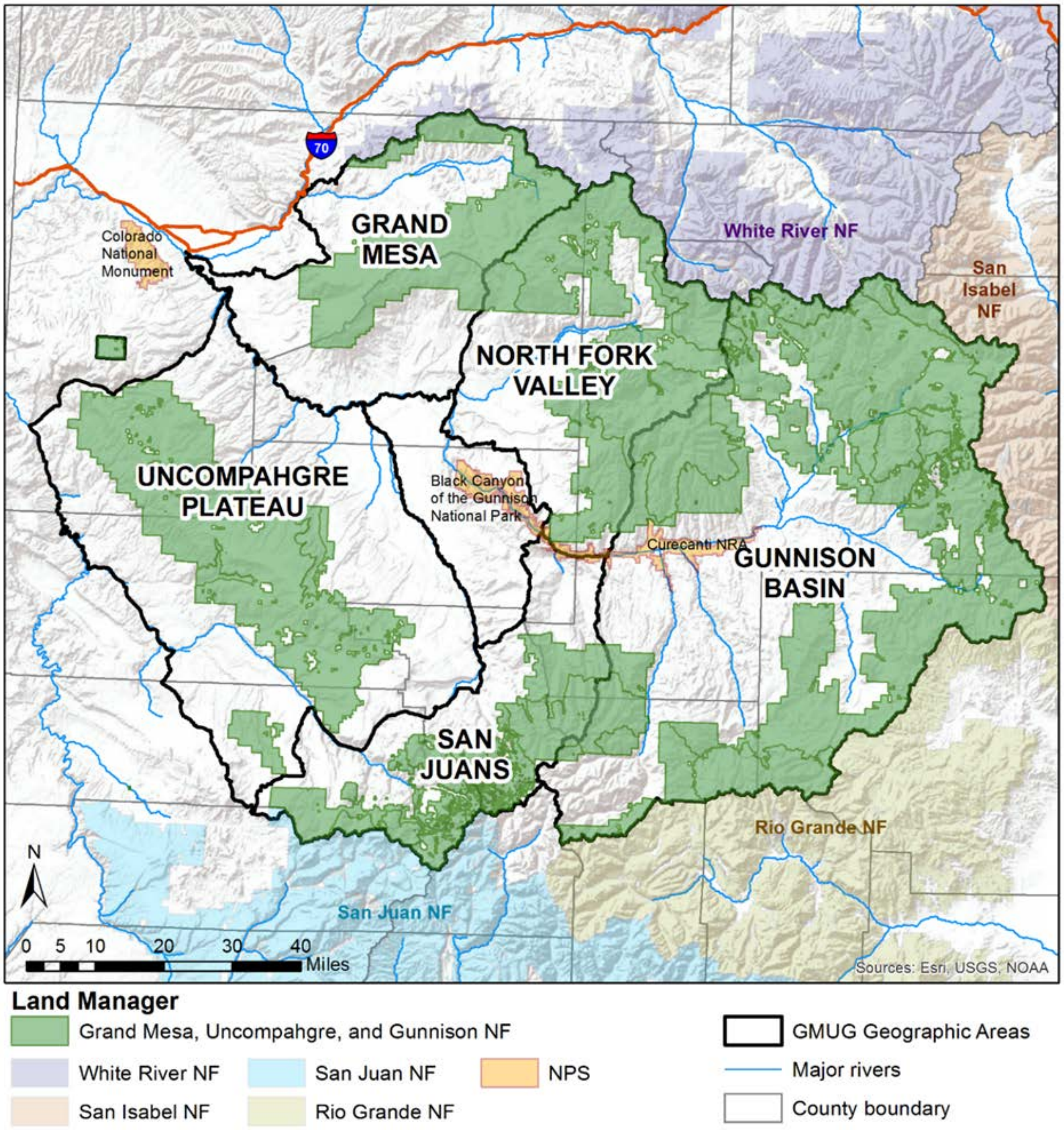


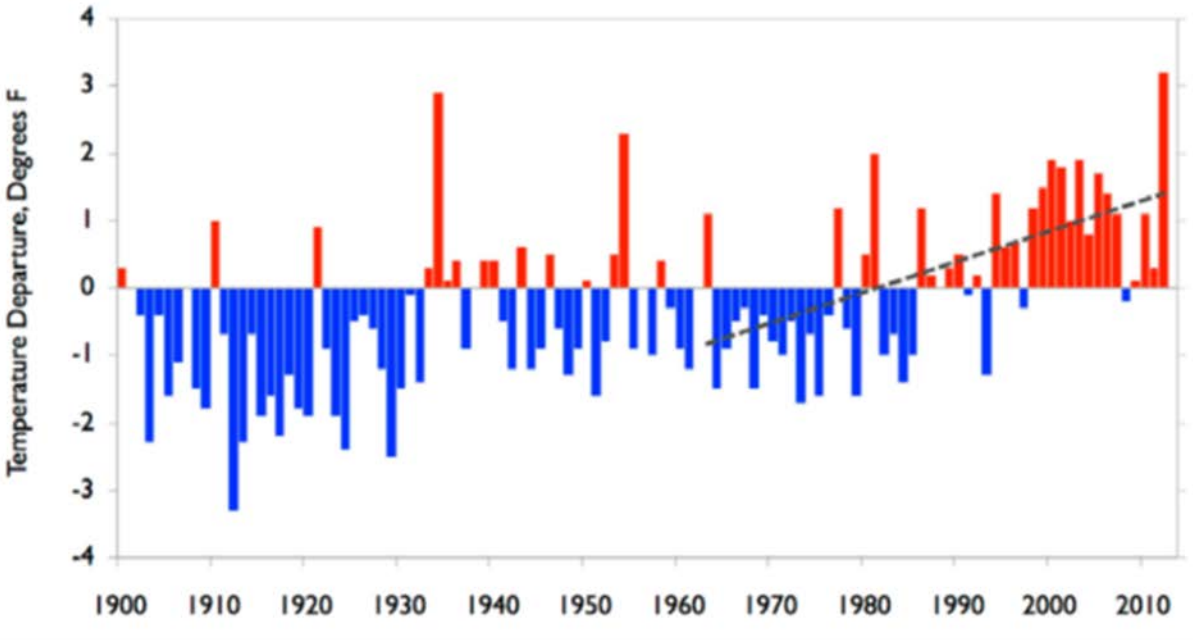
Figure 3. Geographic planning area for Grand Mesa, Uncompahgre, and Gunnison National Forests

Existing Condition of the Indicators

Changes Already Observed

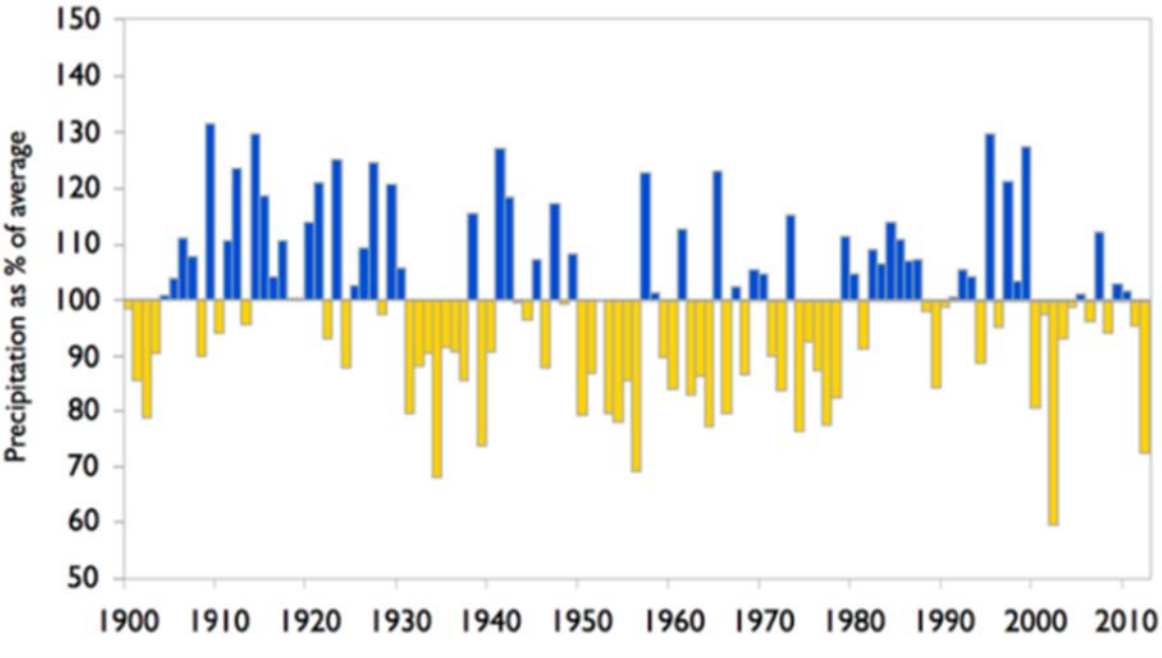
Lukas et al. 2014 summarized changes already observed in Colorado's recent climate. These include:

- A statistically significant increase in mean annual temperature of 2.0 °F over the past 30 years (2.5 °F over 50 years) (Figure 4), with daily minimum temperatures warming more than daily maximum temperatures, and temperature increases in all seasons.
- No detectable long-term trends in mean annual precipitation or snowpack, but below-average snowpack levels in all of the state's river basins since 2000 (Figure 5, Figure 6, and Figure 7).
- Snowmelt and peak runoff shifting earlier by 1-4 weeks over the past 30 years.
- More severe drought conditions over the past 30 years (though there are indications that Colorado has experienced more severe/sustained droughts prior to 1900 than any in the observed record).
- No long-term statewide trends in heavy precipitation events or magnitude of flood events.



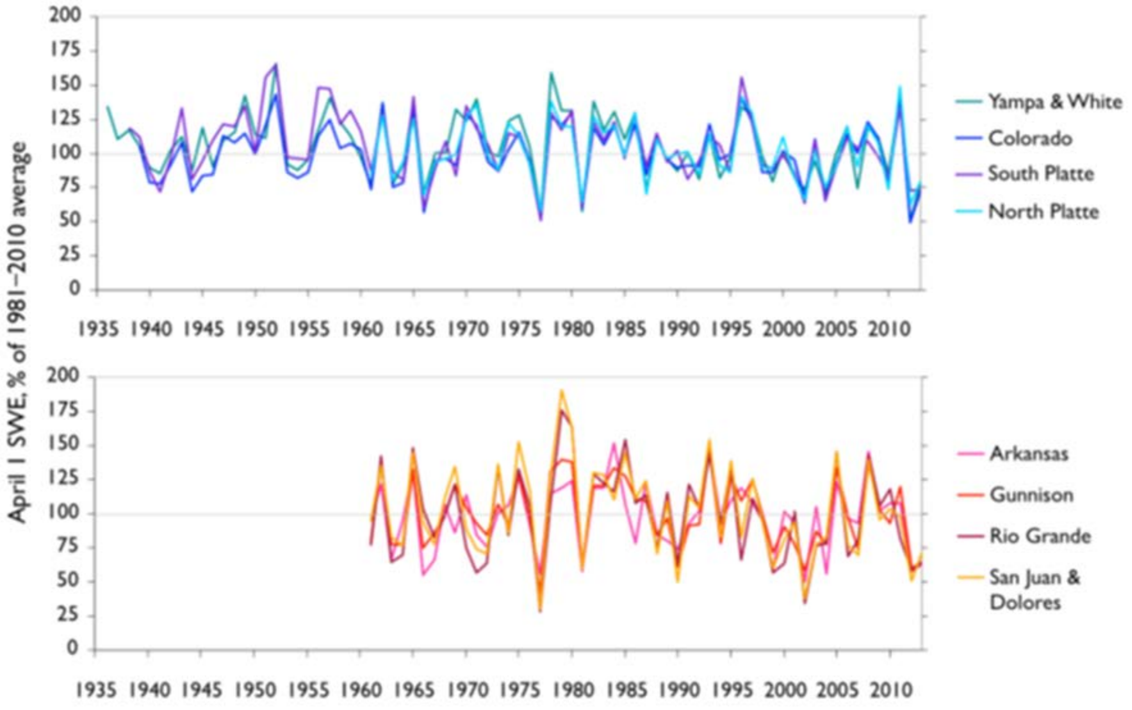
Dashed line shows the 50-year +2.5 ºF trend. Figure from Gordon and Ojima 2015, adapted from Lukas et al. 2014; data source: NOAA NCDC; http://www.ncdc.noaa.gov/cag.

Figure 4. Annual mean temperature for Colorado, shown as departure from the 1971-2000 average



The annual values (blue and yellow bars) are shown as a percentage of the 1971-2000 average. Figure from Gordon and Ojima 2015, adapted from Lukas et al. 2014; data source: NOAA NCDC; http://www.ncdc.noaa.gov/cag.

Figure 5. Annual precipitation for Colorado, 1900–2012



Source: Lukas et al. 2014.

Figure 6. April 1 snowpack for Colorado's major river basins, through 2013

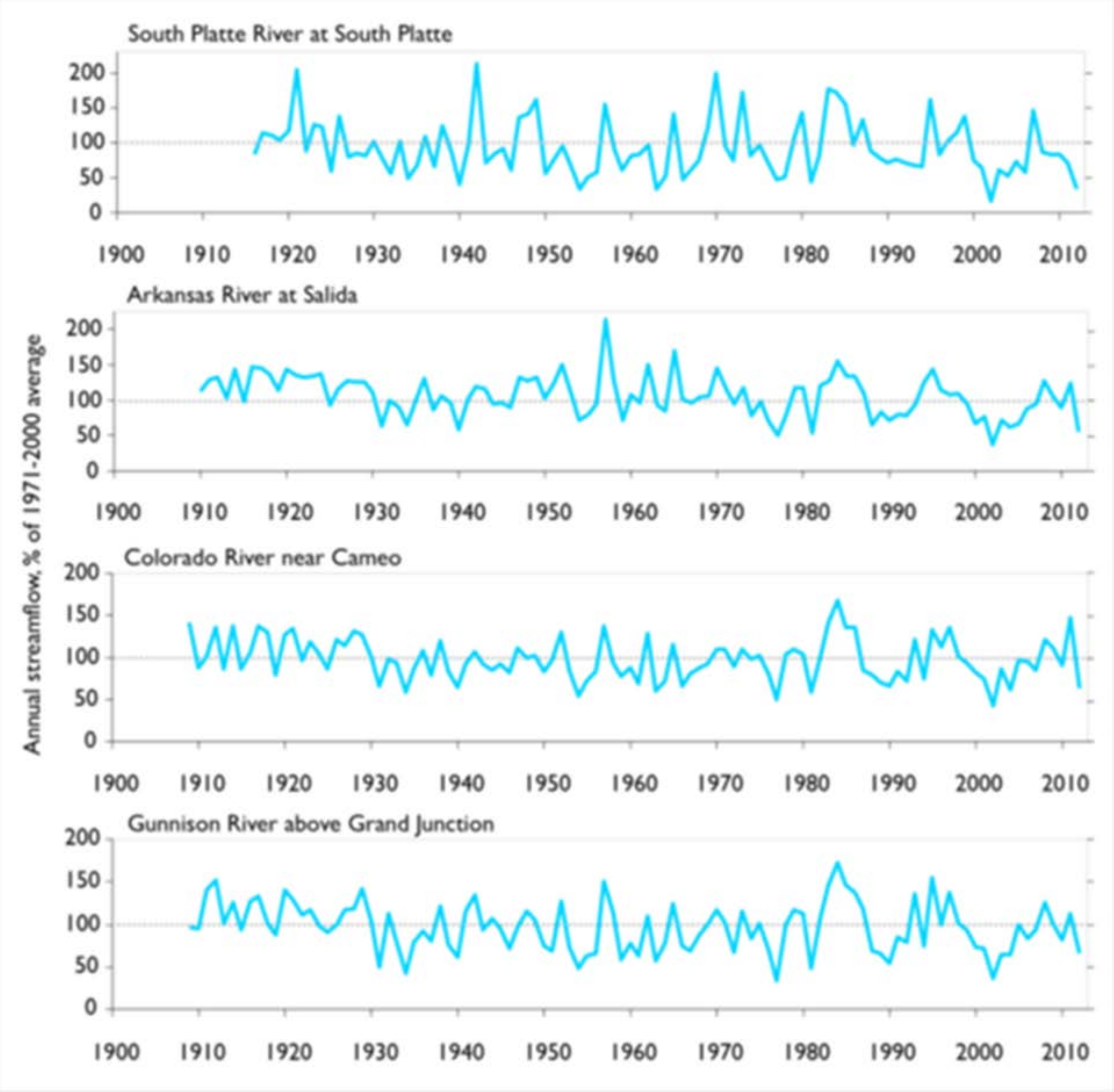
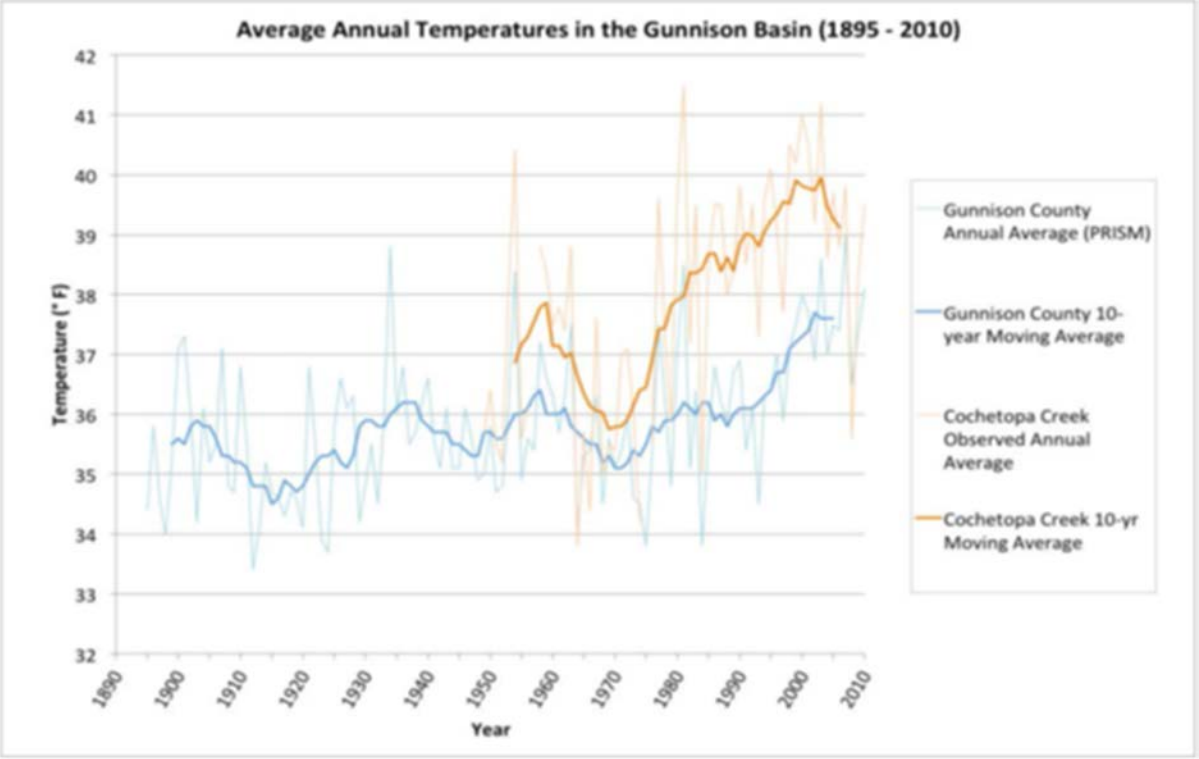


Figure 7. Annual streamflows for four of Colorado's major river basins, through 2012

The Gunnison Basin has experienced an increase in mean annual temperature (Figure 8) similar to the statewide increase, and this is likely to continue.



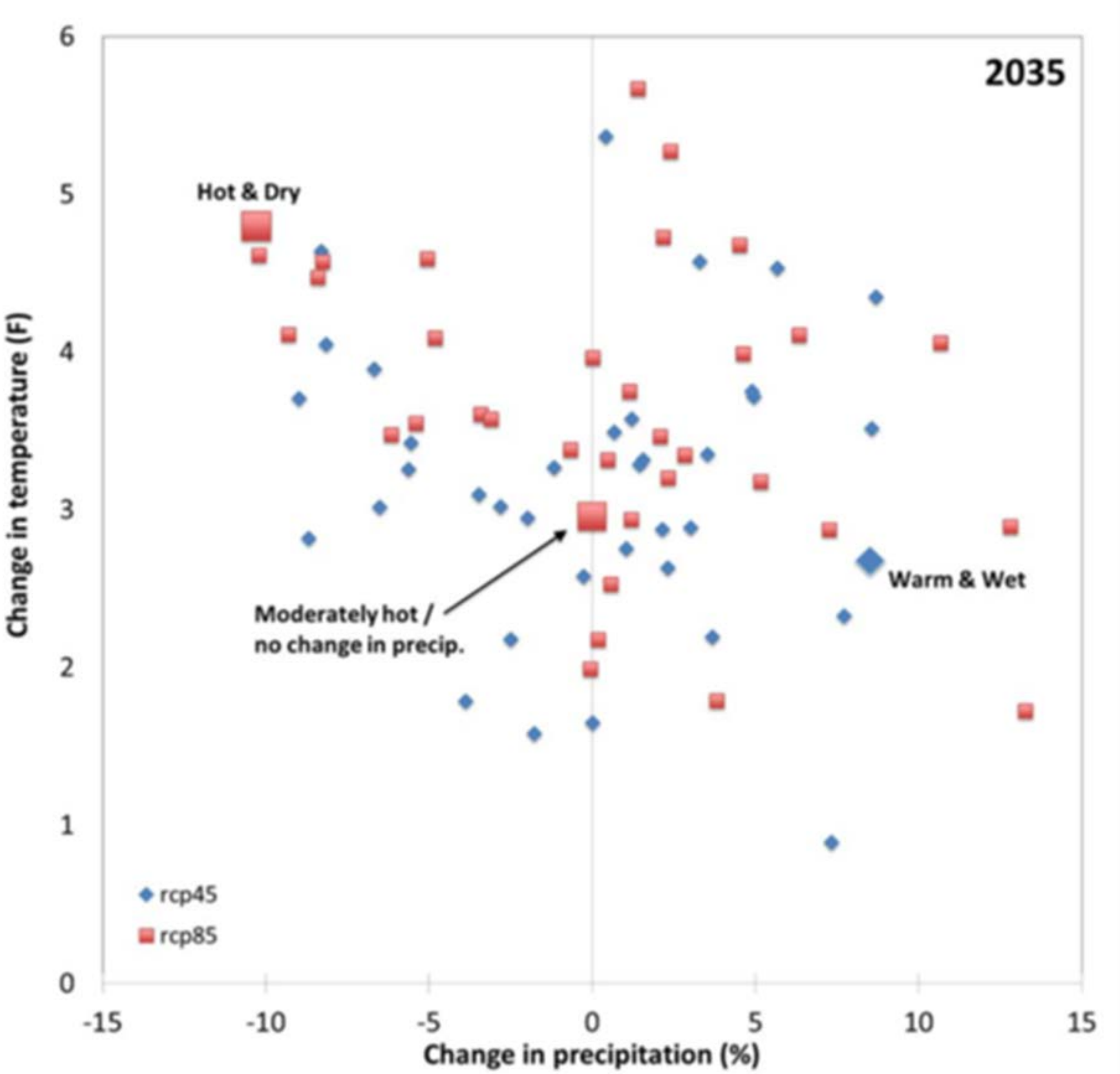
Source: Neely et al. 2011 and Joseph Barsugli (Western Water Assessment), based on data from Colorado Climate Center and Western Regional Climate Center.

Figure 8. The Cochetopa Creek weather station (8,000 feet) and the Gunnison County average show a gradual warming from mid-century to present

Projections for the Future

Information on the potential future climate and related impacts to species and ecosystems in southwestern Colorado has been developed as a result of ongoing collaborative efforts by multiple NGOs, agencies, academics, and private citizens. Though climate models agree that temperatures will increase in Colorado, their projections for precipitation vary widely. To account for this uncertainty, three different but equally plausible future climate scenarios were identified (described below, Figure 9). Except where cited otherwise, the following narrative and graphics have been summarized from Rondeau et al. (2017). This work was largely based on analyses conducted by Imtiaz Rangwala (Western Water Assessment, National Oceanic and Atmospheric Administration), Joe Barsugli (Western Water Assessment), Renée Rondeau (Colorado Natural Heritage Program), and Jim Worrall (U.S. Forest Service) for the Social-Ecological Climate Resilience projects for the Upper Gunnison Basin and the San Juan Mountains region.

Sources of uncertainty include not only errors and inaccuracies in available data, but also limits to our current understanding of species and ecological systems – and especially the fact that we cannot know which climate projections most accurately represent future conditions. Other sources of uncertainty include (but are not limited to) future greenhouse gas emissions, the effects of mountainous terrain on weather and the downscaling of global climate models, response of the North American monsoon, and downscaling methods and choice of hydrologic model(s) (Rangwala 2014). Therefore, the information contained herein should be interpreted as general directions of potential change only. Note that the potential future climate scenarios described below are based on a 2035 timeframe. Reasons for this include the uncertainty relative to how greenhouse gas emission will manifest in out years, and the fact that input from social scientists indicated that 2035 was a timeframe that was both comprehensible to managers and meaningful for their planning horizons.



The Hot & Dry and the Warm & Wet scenarios are labeled; the moderately hot/no change in precipitation is the Increased Variability scenario. Source: Rondeau et al. 2017.

Figure 9. Models used in the three climate scenarios, in relation to the range of climate models along the temperature / precipitation continuum

Future Climate Scenario: Hot and Dry

This scenario (based on the hadgem2-es.1.rcp85 climate model) is characterized by average annual temperatures 5°F higher than those experienced in the late 20th Century (for perspective, Gunnison's climate becomes similar to the current climate of Ridgeway). This, combined with a decrease in annual precipitation of an estimated 10 percent (i.e., comparable to the current precipitation of Del Norte), produces drier conditions year-round and an approximately 45 percent decrease in annual runoff. Lower elevations (below 7,000 feet) are expected to have approximately 30 additional days of summer (temperatures above 77°F), and many nights will not dip below 68°F (20°C). Heat waves are expected to be severe and long lasting. Rain events are likely to be less frequent, but more intense, and summer monsoon rains are expected to decrease (20 percent less than recent historic). Hot and dry conditions would lead to:

- longer growing season (+3 weeks), reduced soil moisture, and increased heat stress
- snowline moving up in elevation (+1200 ft.)
- frequent and extreme spring dust-on-snow events
- earlier snowmelt and peak runoff (+3 weeks, earlier with dust events), and decreased runoff volume (-20%)
- a longer fire season (+1 month), greater fire frequency (12x) and extent (16x) in high elevation forests.

Predicted Effects on Ecological Processes

Droughts

Severe droughts (i.e., comparable to 2002 or 2012) would occur, on average, every five years. Spring snowpack is predicted to decline by 10 percent, and spring temperatures to increase by 4°F, resulting in reduced water availability during the growing season. Species with deep roots (most trees and shrubs) rely on snowpack, which helps deep soils remain moist during the growing season; therefore a reduced snowpack would negatively impact trees and shrubs, especially sagebrush. Summer precipitation is expected to decrease by 20 percent, which would have a large negative impact on shallow-rooted plants (mostly grasses and forbs). In this scenario, snowline would shift up in elevation by approximately 1,200 feet. In addition, increased temperatures and more frequent dust-on-snow events (predicted to occur every year) would shift the average timing of snowmelt a full three weeks earlier. Higher than average peak spring flows followed by lower summer flows would reduce the amount and quality of habitat available for fish, riparian vegetation, migratory birds, and grazing animals, especially during summer. Endangered fish would likely suffer from lower in-stream flow and increased stream temperature. Less precipitation in winter and summer would significantly decrease surface water and shallow ground water. Seeps, springs, and mesic meadows associated with shallow groundwater would decline and species composition would be greatly altered (e.g., shrub invasion into mesic meadows, decline in nearby aspen stands). Droughts would be expected to kill spruce and fir for up to 5 to 11 years after the drought; large trees would continue to die even after the drought ends, due to this lag effect. Fir is more susceptible to drought than spruce, so droughts would likely alter the species composition, with spruce becoming more dominant and fir less dominant.

Insects

Forest insects and diseases are expected to occur at their highest rates in this scenario due to higher temperatures in both winter and summer. Higher temperatures coupled with drought mean trees' ability to withstand insect infestations would be greatly reduced, with a high mortality rate expected. We would expect to experience more acres killed from insects and pathogens than from fires under this scenario. Species that rely on mature spruce-fir forests (i.e. lynx, boreal owl, snowshoe hare, pine marten) could decline due to lack of food and shelter. Aspen trees at lower elevations would be expected to experience die-back associated with increased temperatures and decreased soil moisture. However, aspen stands at upper elevations could increase as coniferous trees decline due to fire and beetle kill.

Fire

In this scenario, the fire season is expected to lengthen by approximately one month, with fire frequency increasing by up to 12 times the 1970-1986 rate. The size of total burned area could increase by 16-20 times due to projected reduction in available moisture across seasons (i.e., in spring a 4°F temperature increase coupled with 9 percent decrease precipitation; in summer a 6° F temperature increase coupled with 20 percent decrease in precipitation; Westerling et al. 2006). The largest burns would be in coniferous forests, including spruce-fir, lodgepole pine, mixed-conifer, and ponderosa pine. Once burned, these areas would likely transform into aspen, shrublands, or grasslands. The growing season is predicted to increase by three weeks, but with less precipitation the understory herbaceous growth (fine fuels) would decrease, which may reduce fire risk in the sagebrush. Fires in the lower elevation sagebrush zone could transform these shrublands into grassland or rabbitbrush/grassland, with "new" grasslands potentially dominated by cheatgrass. Since sagebrush requires at least 7.5 inches of annual precipitation, the degree of water stress expected in this scenario would make it difficult for the low elevation sagebrush to regenerate.

Predicted Effects on Ecosystems

This scenario is expected to have the greatest impact to ecosystems on the GMUG. Existing analysis highlights effects on spruce-fir, pinyon-juniper, aspen and sagebrush ecosystems. Spruce-fir forests would experience a significant loss in climate suitability based on bioclimate models of future conditions. The ability of this forest type to migrate upwards in elevation is likely to be limited as soils at higher elevations are generally not deep enough to support these species. The climate in areas currently occupied by spruce-fir would become suitable for ponderosa pine, aspen, and Douglas fir.

Pinyon-juniper ecosystems may benefit from increases in winter and spring soil moisture recharge that could increase tree survival, but warmer summer temperatures and a decreased monsoon would reduce cone production. Mast years for pinyon pine would occur less frequently and, and seed germination and establishment would be greatly reduced. Warmer temperatures in both winter and summer would benefit pinyon engraver beetles (Ips confusus). Because Ips beetle mortality is greater on older, larger (i.e., cone-producing) pinyon pine trees, resulting loss of pinyon seed would adversely impact pinyon jay populations, and in turn reduce the retention and recovery of pinyon pines. With droughts such as that of 2002 occurring every five years, on average, tree mortality during drought years would increase, with stands below 6,000 feet at greatest risk. Because juniper is more drought tolerant than pinyon pine, these woodlands would be expected to shift toward a predominance of juniper and a loss of pinyon pine. With fire seasons starting earlier and lasting longer, stand-replacing fires are expected to be common, leading to domination by cheatgrass and other invasive species, thus impairing the ability of the woodland to regenerate.

In this climate scenario, hotter and drier sagebrush sites (those below 8,000 feet in elevation) are likely to see significant changes. The effective annual precipitation is expected to drop to approximately 7.5 inches, which is unlikely to support the current sagebrush stands at the driest sites. Stands in the contact zone between Wyoming big sagebrush and mountain big sagebrush may transition into stands of hybrid sagebrush with more Wyoming big sagebrush. Mountain big sagebrush would likely begin migrating upwards in elevation or into nearby upper montane and subalpine mesic meadows as these effectively dry out. The increase in temperature would increase mountain big sagebrush germination and seedling survivorship, especially in higher elevations, so increased shrub density would be likely. Fire frequency would likely increase due to a combination of increased cheatgrass invasion, warmer temperatures, and drier conditions. Because Wyoming big sagebrush is not very resistant or resilient to fires, burned patches would then transition into a grassland with more cheatgrass. However, a rapid post-fire recovery would be expected in mountain big sagebrush at its upper elevation band. Drying in mesic meadows would lead to significant increases in shrub cover as well as fewer forbs, which could reduce Gunnison sage-grouse chick survival. Seeps and springs and other groundwater dependent wetlands would dry up in most years. Low-elevation aspen stands are expected to transition into sagebrush, other montane shrublands, or grasslands due to anticipated frequent and severe droughts in this scenario (2002-level severity occurring every 5th year on average).

Though we lack system-specific analysis, we expect that all other ecosystems on the GMUG will likely be highly impacted under this climate scenario.

Future Climate Scenario: Warm and Wet

Of the scenarios considered, the warm and wet scenario would be the best-case, with the least potential for adverse impact. This scenario (based on the cnrm-cm5.1.rcp45 climate model) is characterized by average annual temperatures at least 2°F higher than the late 20th century (e.g., future temperatures in Gunnison would resemble current temperatures in Cimarron). An increase in annual precipitation of approximately 10 percent is projected, with greater than normal winter snowpack above 10,000 feet, and spring, summer, and fall precipitation increasing at all elevations. However, higher temperatures would offset any gains in moisture due to increased evapotranspiration rates. Summer would lengthen by approximately one week (i.e., ~7 additional days with temperatures above 77°F). This scenario is expected to lead to:

- an extended growing season (+1 week)
- snowline moving up in elevation (+600 ft.)
- occasional extreme spring dust events in dry years (i.e., comparable to current conditions)
- earlier snowmelt and peak runoff (+1 week), but no change in runoff volume
- increased fire frequency (4x) and extent (6x)

Predicted Effects on Ecological Processes

Droughts

Droughts are expected to be less frequent than in the other scenarios. Drought years comparable to 2002 would occur every 15th year on average, so similar to current conditions in terms of frequency. When droughts occur, they would probably be more intense, but fewer occurrences of extended drought would be expected. In this climate scenario, moderate amounts of drying overall are predicted, which may lead to more sagebrush in mesic systems and aspen, an increase in the hybrid sagebrush zone, and aspen dieback and shifting into lower elevation grasslands. Expected drought frequency (15 years, on average) would allow time for some low elevation aspen stands to recover from the intense droughts but many of these aspen islands are expected to degrade due to higher temperatures, with some completely transitioning into mountain shrublands.

Insects

Though outbreaks of insects and diseases are expected to be lower compared to the other scenarios, outbreaks are still expected to increase compared to current conditions, due to increasing intensity of droughts. Recovery from outbreaks may be quicker compared to the other scenarios, and tree mortality would be comparatively lower than other scenarios, but these conditions are still expected to be ongoing issues.

Fire

This scenario poses a lower fire risk than other scenarios, but fire frequency and area burned annually is still predicted to increase by up to four times and six times, respectively, due largely to increased temperatures in spring and summer and longer season. From 1987 to 2003, spring and summer temperatures averaged 1.56° F higher than normal compared to 1970-1986; during that same time period, fire frequency increased four times over the previous average, and total area burned was more than 6.5 times previous levels. High fuel loads related to increased vegetation growth from more precipitation followed by intermittent dry conditions may cause severe fire hazards. Stand-replacing fires in the late successional closed canopy forest are predicted to moderately increase. The increase in precipitation may help offset some fire risk, but annual variation in the rainfall will still exist and severe drought years will still occur. Lightning strikes may increase by up to 40 percent, increasing the chance of fire, especially just prior to the monsoon season.

Predicted Effects on Ecosystems

Overall, this scenario will have the least impact on ecosystems. Spruce-fir will continue to be the dominant forest type on the GMUG. Existing analysis describes potential changes to groundwater-dependent ecosystems, grasslands, sagebrush, and pinyon-juniper ecosystems. Groundwater-dependent wetlands, seeps, and springs may experience little change, or possibly even benefit from increased annual precipitation. Greater snowpack above 10,000 feet would benefit high elevation wetlands, but drought years would adversely impact low elevation wetlands. Though higher soil moisture may reduce or eliminate invasive species in wetlands, conditions in this scenario (year-round moisture, warmer temperatures) would likely lead to greater issues with invasive species overall than the other scenarios. Existing weeds (e.g., leafy spurge, knapweed, yellow toadflax) expanding into lower and montane elevations, and the appearance of new invasive species (e.g., Japanese brome, purple loosestrife), would be expected. Invasive species would degrade rangelands that have, thus far, been relatively weed-free, as well as create increased density of fine fuels for fires, especially at the lower elevations.

Moderate drying is predicted to lead to more sagebrush in mesic systems and aspen forests. Most of the current sagebrush stands would likely be maintained, but in comparatively degraded condition due to increasing cheatgrass and other weeds, and possibly decreasing native grasses and forbs. The zone of hybridization of Wyoming and Mountain Big sagebrush is predicted to increase. Drought frequency should still allow regeneration of sagebrush between droughts, but many stands would have a mix of live and dead shrubs. Ungulate use in winter may increase with increased snowpack in the sagebrush, which would further stress the sagebrush community. Increased winter precipitation, especially in snow deposition areas, could become too wet for sagebrush, thus decreasing habitat value for sage-grouse.

Under this scenario, frequency of droughts is expected to be similar to current conditions, and so should not dramatically affect the ratio of pinyon pine to juniper. Pinyon pine masting and cone production should be supported by sufficient moisture, if other factors (e.g., cool and wet autumns) are favorable. It is possible that this scenario would be favorable for a pinyon pine-juniper expansion, rather than the contraction that would be expected under the other scenarios.

With heat waves occurring once per decade, on average, there could be a shift in the ratio of warm to cool season grasses, with declines in western wheat grass and needle and thread grass, and increases in blue grama and galleta grass. With an upward shift in snowline, current vegetation in the 8,500-9,000 feet elevation band may begin shifting from mixed conifer or aspen to ponderosa pine. Aspen is predicted to dieback and shift, to a moderate degree, into lower elevation grasslands.

Though we lack system-specific analysis, we expect that all other ecosystems on the GMUG will be moderately impacted under this climate scenario, with the most significant impacts to ecosystems in the 8,500 – 9,000 foot elevation band and those affected by invasive species.

Future Climate Scenario: Increased Variability

In this climate scenario (based on the cesm1-bgc.1.rcp85 climate model), average annual temperatures are projected to be 3°F higher than the recent past (e.g., Crested Butte's temperature would be similar to the current temperature of Lake City). No appreciable change in average annual precipitation is predicted, but conditions would be generally drier due to higher temperatures, especially during the growing season. A three percent increase is projected for winter-summer soil moisture recharge, but this is counter-balanced by a predicted three percent decrease in monsoon recharge. Large year to year fluctuations in precipitation are the defining characteristic of this scenario, with rapid swings between very wet years and intense drought years compared to our current climate. Strong El Niño events would be expected every seven years on average (double the current rate); these years could potentially be quite wet. Droughts comparable to 2002 or 2012 would occur on average every decade; these would be more intense than those experienced in the recent past, but generally less than two years long. Winter precipitation would increase, but precipitation in other seasons would decrease.

Summers at lower elevations are expected to have approximately 14 additional days with temperatures above 77°F (25°C), and many nights with lows of 68°F (20°C) or above. Heat wave conditions would be common every few years. During wetter years, increased temperatures would lead to increased vegetation growth, and thus fuel loads for subsequent wildfires. Year to year variation in summer monsoons would increase. There would be greater potential for large spring floods due to abrupt snowmelt from rain on snow events, and/or dust-on-snow events coupled with warmer spring temperatures, especially during El Niño years. However, the largest flooding events would generally be the result of heavy monsoon precipitation. We would expect severe erosion in small streams as water runs over banks and culverts during these floods.

An increased variability pattern fluctuating between hot/dry and warm/wet conditions would be expected to lead to:

- a longer growing season (+2 weeks)
- snowline moving up in elevation (+900 ft.)
- increased extreme spring dust events in dry years
- earlier snowmelt and peak runoff (+2 weeks, earlier with dust events), but decreased runoff volume (-10%)
- very high fire risk during dry years following wet years, greater fire frequency (8x) and extent (11x)

Predicted Effects on Ecological Processes

Droughts

In dry years, intense droughts (i.e., comparable to 2002) are predicted to occur every 10th year on average, and to follow extreme wet years more frequently. This drought frequency is higher than our current baseline, so species composition would be expected to change, but at a slower rate compared to the Hot and Dry scenario. Similar to the Hot and Dry scenario, spruce trees would be expected to increase in dominance compared to fir, though both species would experience high rates of mortality in older trees, while younger trees would be more likely to survive extreme droughts. Island stands of aspen may decline due to the warmer temperatures and reduced soil moisture, but stands in wetter areas and/or on north-facing slopes would probably survive. Groundwater-dependent wetlands, including seeps and springs, are expected to decline somewhat, particularly below 8,500 feet, where spring precipitation will fall as rain rather than snow. Increased evapotranspiration driven by higher temperatures will reduce soil moisture and streamflow, with consequences that would include increases in species that tolerate drier conditions (e.g., sagebrush, shrubby cinquefoil, rabbitbrush) and invasive species (e.g., cheatgrass, knapweed), especially at the lower elevations.

Insects

Insect and pathogen impacts are still expected in this scenario due to warmer temperatures in both winter and summer. Impacts from these stressors would be less under this scenario than under the hot and dry scenario, but greater than under the warm and wet scenario. Bark beetles are expected to expand during drought years, causing extensive conifer mortality, though this is likely to be less severe in this scenario compared to the hot and dry scenario. In general, conifer forests can regenerate more easily following beetle outbreaks than following fires because bark beetles generally do not kill young trees. Large landscape scale disturbances, such as fire and insect outbreaks, will fragment coniferous forests and negatively impact lynx, snowshoe hares, pine martens, and other species that rely on large intact functioning forests, while possibly being a benefit to those species that prosper from a more open forest canopy.

Fire

While the annual fire risk is lower in this scenario compared to the Hot and Dry scenario, when fires do burn, the severity, intensity, and extent could be very high due to the great amplitude between drought and wet years. The wet years build up greater fuels, primarily along the surface and shrub canopy layers; then, when a drought event occurs, the fires are more intense. The fire frequency, at least in the dry years, could be as high as eight times that of the 1970-1986 period, and the size of burn area could increase by 11 times (Westerling et al. 2006). If fire occurs after a beetle outbreak, tree regeneration will be nearly impossible due to a lack of a nearby seed source and nurse plants. The large fires associated with drought years are expected to result in younger forests, more open structure, more early successional species, and more invasive species.

Predicted Effects on Ecosystems

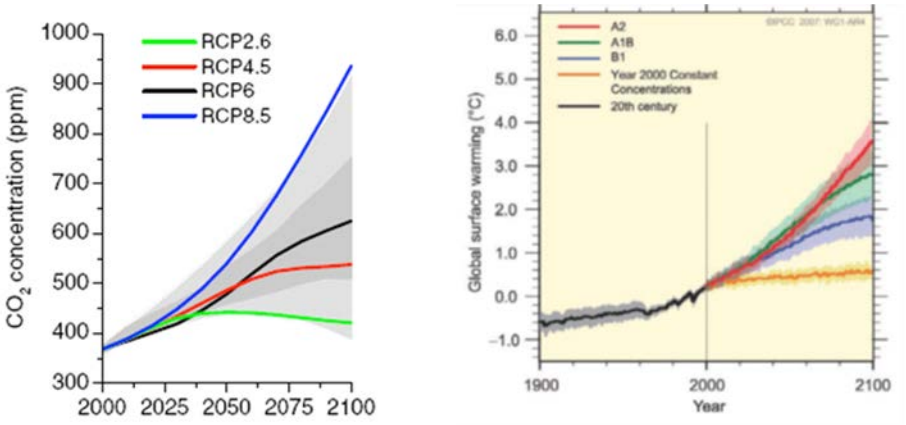
Effects on ecosystems for this scenario are the hardest to predict. Existing analysis highlights expected effects on sagebrush and pinyon-juniper ecosystems. Under this scenario, soil moisture is expected to decrease substantially compared to current conditions, but is likely to remain suitable for sagebrush. However, warmer spring temperatures may reduce spring snowpack, with adverse impacts on Wyoming big sagebrush that would likely include decreased density of sagebrush below 8,500 feet. Drier areas in the lower sagebrush zone are expected to experience a decrease in mesic meadows and less overall biomass, which would adversely impact sage-grouse habitat. Mountain big sagebrush may expand upward in elevation, and drying of nearby mesic meadows may result in increased sagebrush density in existing stands. Juniper establishment in sagebrush would be expected in wet years that follow drought years.

Conditions favorable for pinyon-juniper are expected to move into the zone currently occupied by ponderosa pine. Although pinyon pine could mast during wet years, warmer summer temperatures may inhibit cone formation, and seed germination and establishment could be reduced if episodes of multiple wet years are uncommon. Because juniper is more drought tolerant than pinyon pine, these woodlands would be expected to shift toward a predominance of juniper and a loss of pinyon pine. Loss of pinyon seed sources may adversely impact pinyon jay populations, thus reducing the ability of pinyon pines to remain in their present locations or colonize new areas. Warmer temperatures in both winter and summer would be favorable for Ips beetle outbreaks, with greater tree mortality in drought years. More large-patch fires are predicted, which would also increase tree mortality.

Though we lack system-specific analysis, we expect that all other ecosystems on the GMUG will be impacted by this climate scenario, with the degree of impact determined by their resiliency to intense drought years.

Trends

The trend for temperature is increased warming through the end of this century. Magnitude of warming is dependent, at least in part, on future emissions scenarios. Emissions scenarios are fairly comparable through the middle of the century, but diverge greatly by the end of the century (Figure 10). Trends for precipitation are unknown, but even if precipitation increases, much of the southwestern U.S. is likely to be effectively drier. This is because any potential increase in precipitation will almost certainly fall below the amount needed to offset increases in temperature. According to hydrologic modeling for the Colorado River and other basins (e.g., Nash and Gleick 1991, 1993), as a generalized rule-of-thumb, approximately 5% increase in precipitation would be needed to offset each 1.8°F of warming in order for runoff levels to remain unchanged. With projected mid-century temperatures increasing 4°F or more under the higher emissions scenario (RCP8.5), no areas in Colorado are projected to receive sufficient compensatory precipitation.



(a) (b)

Regardless of emission scenario type (RCP in more recent climate projections v. A-B scenarios used in earlier climate projections), effects on carbon dioxide concentrations and surface warming are comparable. In both cases, projections remain similar through mid-century, but diverge widely by the end of this century. Sources: Figure (a) from Rangwala 2014 based on van Vuuren et al. 2011; Figure (b) from Rieman and Isaak 2010 based on IPCC 2007.

Figure 10. Relationship of emissions scenarios over time

Table 48. Summary of potential future trends in climate-related variables for the GMUG

[Adapted from Rondeau et al. (2017).]

Future Climate Scenarios	Hot/Dry	Warm/Wet	Increased Variability
Summary of potential changes	Sustained and longer duration drought: 2002-like drought occurs every 5 years on avg. Chronic summer-time dry conditions: Summer monsoons are significantly reduced (-20%) Chronic summer time heat waves: Every summer warmer compared to 2002 (5□F above normal)	Water availability does not change but climate is warmer Timing of snowmelt, streamflow, growing season change but more moderate compared to other scenarios Chronic flood risks because of increases in moisture and more heavy precipitation events	No long-term droughts but more frequent and intermittent severe-drought conditions (2002 drought once per decade on avg.) Large year-to-year fluctuations that go from "hot and dry" to "warm and wet" conditions Doubling in the frequency of alternating extreme dry and wet conditions relative to present
Annual temperature increase	5°F	>2°F	2.9°F
Winter temperature increase	4.1°F	3.5°F	3.3°F
Spring temperature increase	3.8°F	2.3°F	2.2°F
Summer temperature increase	6°F At lower elevations: summer days with temperature above 77°F (25°C) increases by ~1 month, and nights with temperature above 68°F = 10 on avg.	2.8°F At lower elevations: summer days with temperature above 77°F (25°C) increases by ~1 week	3.4°F At lower elevations: summer days with temperature above 77°F (25C) increases by ~2 weeks, and nights with temperature above 68°F = 20 on avg.
Fall temperature increase	5.3°F	2.1°F	2.9°F
Annual precipitation	10% decrease	10% increase	No change but large year to year variation
Winter precipitation	19% increase	13% increase	6% increase
Spring precipitation	9% decrease	6% increase	0 change
Summer precipitation	19% decrease	8% increase	3% increase
Fall precipitation	15% decrease	10% increase	9% decrease
Freezing level (i.e., snow-line, elevation above which ice/snow can remain year-round)	Shifts up by ~1200 ft.	Shifts up by ~600 ft.	Shifts up by ~900 ft.
Runoff volume	>20% decrease	Stays the same	10% decrease

Future Climate Scenarios	Hot/Dry	Warm/Wet	Increased Variability
Timing of peak runoff	Earlier by ~3 weeks	Earlier by ~1 week	Earlier by ~2 weeks
Summer monsoon	20% decrease	10% increase	Large year to year fluctuation
Heat waves (i.e., summer like 2002)	Every summer	Every 10 years on avg.	Every 3 years on avg.
Severe drought duration	1-5 years	1 year	1-2 years
Drought comparable to 2002/2012	More frequent (every 5th year on avg.)	No change in frequency (every 15th year on avg.) but moderate increases in intensity; fewer cases of multi-year drought	Every 10th year on avg.
Strong El Niño return frequency	No change	No change	Doubles
Wildfire	Fire season widens by ~1 month; greater fire frequency (~12x) and extent (~16x) in high elevation forest	Increases in fire frequency (~4x) and extent (~6x)	Fire risk during dry years is very high at all elevations b/c of large fuel build up from wet years; on average fire frequency increases ~8x, and area burnt increases ~11x
Dust Storms	Extreme spring dust events like 2009 every other year, causing snowmelt and peak runoff to be ~six weeks earlier	Same as current	Frequency of extreme dust events increases from current but tied to extreme dry years
Growing Season	Increases by ~3 weeks	Increases by ~1 week	Increases by ~2 weeks

Resources Affected

Table 49. Affected resources, potential indicators for monitoring, and direction/magnitude of potential changes

Resource/ Use Affected	Potential Indicators for Monitoring	Highly Vulnerable Resources/Uses (Neely et al. 2011 unless cited otherwise)	Direction and Magnitude of Potential Changes
Vegetation	• Species composition • Change in species distributions (including invasive species) • Post-disturbance regeneration • Presence of groundwater dependent species	• Alpine uplands (xeric and mesic) • Bristlecone-Limber pine forest • Riparian ecosystems • Pinyon-juniper (CNHP 2015) • Lodgepole pine forest • Aspen • Ponderosa pine forest	• Warming temperatures may reduce available moisture, lengthen growing seasons, and increase water demand (Lukas et al. 2014). • Increasing temperature in spring may cause alpine plants to shift timing of flowering and leaf-out earlier, potentially leading to a mid-summer decline (Gordon and Ojima 2015). • Longer/more severe droughts, more frequent/severe fires, more insect outbreaks and spread of non-native plant species, may lead to: o Individual trees and forested landscapes vulnerable to insect and pathogen invasions, o Landscapes vulnerable to changes in connectivity, shifts from carbon sinks to carbon sources, and shifts in vegetation distribution (e.g., forests shifting to grasslands) (Gordon and Ojima 2015).
Wildlife	• Species composition • Change in species distributions (including non-native species)	• Boreal toad • Gunnison Sage-Grouse • White-tailed Ptarmigan • Brown-capped Rosy-finch • Snowshoe hare • Lynx • American pika • Uncompahgre fritillary butterfly • Cutthroat trout • Bluehead sucker (CNHP 2015) • Colorado pikeminnow (CNHP 2015) • Flannelmouth sucker (CNHP 2015)	• Aquatic species could decline due to rising water temperatures, more frequent and severe fires, forest fragmentation and other habitat changes (Gordon and Ojima 2015). • Endangered fish recovery programs vulnerable to potentially reduced average streamflow (Gordon and Ojima 2015).

Resource/ Use Affected	Potential Indicators for Monitoring	Highly Vulnerable Resources/Uses (Neely et al. 2011 unless cited otherwise)	Direction and Magnitude of Potential Changes
		• Razorback sucker (CNHP 2015) • Roundtail chub (CNHP 2015) • Great Basin silverspot • Midget faded rattlesnake	
Aquatic Habitats	• Habitat connectivity • Water temperature • Water quality • Water quantity • Bank stability • Sedimentation • Timing/volume of peak water flows • Watershed function/condition • Species richness and diversity • Distribution of invasive species	• Montane groundwater-dependent wetlands • West Slope rivers (CNHP 2015) • Low elevation lakes (CNHP 2015)	• Warmer stream temperatures could cause spread of non-native species and diseases to higher elevations (Lukas et al. 2014). • Aquatic organisms and ecosystems vulnerable to lower flows and higher water temperatures resulting in greater concentrations of pollutants (Gordon and Ojima 2015).
Rangeland Resources/ Livestock Grazing	• Soil moisture • Regrowth following grazing • Permitted numbers • Season of use • Rangeland Health Evaluation Matrix (R2-2200-RH) – healthy, at risk, or unhealthy? Looking at – o Abiotic Characteristics: A-horizon, pedestalling, rills & gullies, etc. o Rangeland Vegetation Condition: native grasses, forbs & shrubs present in normal amounts, shrub growth form, age class distribution, etc.	• Livestock permittees • Structural range improvements, primarily waters. If not being maintained because of non-use, it could result in fewer water sources available to wildlife. • Native plant ecosystem, pollinators	• Ranchers potentially vulnerable to more frequent losses of forage from increasingly severe droughts (Gordon and Ojima 2015). • Farmers and ranchers potentially vulnerable to facilities losses (structures, ditches, equipment) from extreme weather (Gordon and Ojima 2015). • Cattle could be vulnerable to lower weight gain and other health problems due to higher temperatures (Gordon and Ojima 2015). • Ranchers possibly vulnerable to feed price shocks from increased drought (Gordon and Ojima 2015) • Changes in timing of precipitation may not allow grazed plants to regrow following grazing, which would result in less carbohydrate storage in vegetation and roots, potentially making plants susceptible to winter kill or unable to regrow in the spring if in poor condition following winter dormancy (Trlica 2013). • Droughts resulting in less forage could translate into fewer permitted livestock numbers and/or shorter seasons of use.

Resource/ Use Affected	Potential Indicators for Monitoring	Highly Vulnerable Resources/Uses (Neely et al. 2011 unless cited otherwise)	Direction and Magnitude of Potential Changes
	o Recovery Mechanisms: litter distribution, plant vigor, etc. o Range readiness o Range condition, trend, and changes in plant composition		Conversely, heavy snow years may also result in shorter seasons of use due to later dates when livestock may be allowed on the forests. • Droughts and shifting precipitation patterns could affect the amount and quality of available water for livestock.
Hydrology/ Groundwater	• Water quality • Water quantity • Baseflow • Depth to water table • Soil moisture • Discharge from springs • Groundwater recharge • Subsidence • Water temperature • Volume of peak and low flows • Timing of peak and low flows • Presence of groundwater-dependent species	• Groundwater dependent ecosystems (GDEs) • Shallow and/or unconfined aquifers • Water supplies	• Increased groundwater use can lower baseflows in streams, spring discharge and soil moisture. • Increased groundwater use could lower water tables will affect GDE habitat quality, quantity and species composition. • Increased groundwater use can lead to subsidence and loss of future storage. • Warming temperatures could continue the recent trend towards earlier peak runoff and lower late summer flows (Lukas et al. 2014). • Warmer water temperatures could cause decline in water quality indicators; reduced stream flows could increase concentrations of pollutants (Lukas et al. 2014). • Water suppliers with inadequate storage vulnerable to earlier snowmelt timing and runoff (Gordon and Ojima 2015). • Entities with junior water rights or little storage are potentially vulnerable to future low flows (Gordon and Ojima 2015). • All water suppliers and customers vulnerable to longer/more intense droughts (Gordon and Ojima 2015). • Water suppliers and private homes that rely heavily on groundwater vulnerable to potential reductions in groundwater recharge (Gordon and Ojima 2015). • Infrastructure (older dams/ditches/ canals, reservoirs in areas with high potential for wildfire) potentially vulnerable to extreme events and increased wildfire risk (Gordon and Ojima 2015).

Resource/ Use Affected	Potential Indicators for Monitoring	Highly Vulnerable Resources/Uses (Neely et al. 2011 unless cited otherwise)	Direction and Magnitude of Potential Changes
			• Agricultural producers needing late summer irrigation and some municipal / industrial utilities with junior rights may be vulnerable to earlier snowmelt timing and lower late summer flows (Gordon and Ojima 2015). • Utilities with older treatment technology, lower treatment capacity may be vulnerable to lower flows and higher water temperatures resulting in greater concentrations of pollutants (Gordon and Ojima 2015). • Water treatment facilities in fire-prone areas vulnerable to wildfire could lead to higher chances of erosion (Gordon and Ojima 2015).
	• Soil moisture • Reduction in vegetation leading to increased erosion		
Timber/ Silviculture	• Species composition and mortality • Insect and disease outbreaks • Post-disturbance regeneration		• Longer/more severe droughts, more frequent/severe fires, more insect outbreaks and spread of non-native plant species, may lead to: o individual trees and forested landscapes vulnerable to insect and pathogen invasions, and o landscapes vulnerable to changes in connectivity, shifts from carbon sinks to carbon sources, and shifts in vegetation distribution (e.g., forests shifting to grasslands) (Gordon and Ojima 2015).
Fuels/Fire Management	• Fuel moisture • Fire frequency and severity • Fire management options utilized		• Potential increase in tree mortality could increase fuel loads and risk of wildfire. • Warmer temperatures could increase frequency/severity of wildfire, make trees more vulnerable to insect infestation, and compromise water quality and watershed health (Lukas et al. 2014).
Wilderness/ Special Designations	Trends in: • types of visitors • season of use • types of research		

Resource/ Use Affected	Potential Indicators for Monitoring	Highly Vulnerable Resources/Uses (Neely et al. 2011 unless cited otherwise)	Direction and Magnitude of Potential Changes
Recreation	Trends in: • types of visitors • types of recreation activities • season of use • wildlife response to climate shifts • location of use	• Almost all types of recreation may be vulnerable, from changes in climatic conditions, seasonality, wildfire intensity and frequency, water availability, and aesthetics/viewscape (Gordon and Ojima 2015).	• Rafting and fishing may be vulnerable to earlier/faster runoff, reduced season length (Lukas et al. 2014, Gordon and Ojima 2015). • Changes in reservoir storage could affect recreation on-site and downstream (Lukas et al. 2014). • Declining snowpacks could impact winter mountain recreation and tourism (Lukas et al. 2014). • Wildlife and wildflower viewing may be vulnerable to changing conditions and potential loss of species (marmot, pika) as climate warms (Gordon and Ojima 2015). • Fly fishing potentially vulnerable to degraded cold water trout habitat (rising stream temperatures, declining streamflows) (Gordon and Ojima 2015). • Skiing, rafting could be vulnerable to large swings in temperature and precipitation from year to year, and effect of such swings on perceptions of tourism / recreation in Colorado (Gordon and Ojima 2015). • Summertime recreation and tourism opportunities may be vulnerable to wildfire (closed roads, destroyed trails/campgrounds, reduced air quality), resulting in potential visitors deciding not to travel to Colorado (Gordon and Ojima 2015). • Potential loss in access due to damage to transportation infrastructure from disturbances (i.e., wildfire, floods) (Gordon and Ojima 2015).
Scenery	• Changes in scenic character		• Potentially reduced scenic value from greater drought/insect/wildfire damage (Gordon and Ojima 2015). • Likely shift away from the snow-capped mountain aesthetic that draws many visitors (Gordon and Ojima 2015).
Engineering/Infrastructure	• Types and locations of infrastructure failures	• Roads and trails, especially those that have little or no regular maintenance, are built on steep, unstable slopes, and/or are adjacent to or crossing streams (Furniss and Howe 2016)	• Reservoir operations (flood control, storage) likely vulnerable to changes in snowpack, streamflow timing (Lukas et al. 2014). • Diversion, storage, and conveyance structures may be vulnerable to changes in the timing and magnitude of runoff (Lukas et al. 2014).

Resource/ Use Affected	Potential Indicators for Monitoring	Highly Vulnerable Resources/Uses (Neely et al. 2011 unless cited otherwise)	Direction and Magnitude of Potential Changes
		• Infrastructure (i.e. roads, campgrounds, facilities, etc.) within 300 feet of streams or rivers, or in areas of high fuel loads (increased potential for wildfire) • Dams, reservoirs, and water systems • Culverts and cross-drains	• Potential shift from snow to rain may increase erosive stress to drainage structures (i.e. culverts, cross-drains), thereby increasing the potential for erosion and road failure (Furniss and Howe 2016) • Potential increase in frequency and intensity of wildfires increases value of infrastructure (i.e. roads, trails and water systems) for fire suppression and fuels reduction, and also increases the hazards of infrastructure failure or damage. • Climate change may also effect infrastructure in other ways, including, but not limited to: thermal expansion of bridge joints, increased drought tree mortality near roads, trails and facilities.
Cultural/ Heritage	• Temperature change, precipitation change, soil moisture, soil chemistry, erosion or other indicators that could demonstrate potential effects to the condition of the resources • Condition of cultural resources	• Wooden buildings, structures, standing architecture, organic artifacts, ethnographic resources (culturally important plants/ animals, TCPs), cultural resources near rivers/ streams, drainages, steep slopes, high fire risk areas; essentially all cultural resources are unique and non-renewable	• Accelerated existing threats, rapid decay of organic artifacts, increased deterioration of metal artifacts, destruction of archaeological deposits, loss of scientific data. • Greater wildfire/erosion/flooding risk could damage cultural/historic resources. • Increase/change in recreation patterns/land use patterns could increase erosion and vandalism. • Loss of traditional knowledge due to loss of resources, loss of historic character, alternation/ loss of cultural landscapes/ features. • Loss of resources may equal decrease in cultural tourism. • Potential stressors: higher temperatures, heavier downpour events, increased recreation, increased rec season may equal increased vandalism, changes in land use, increased vulnerability to landslides due to increased rainfall/ fire, changes in vegetation, artifacts threatened by pesticides used on invasive species, deflation/ abrasion/damage from stronger winds, heat stress on culturally important plants, damage from beetle/fire killed tree fall, increased threat from mitigation projects/ emergency clean-up.
Social/ Economic	Trends in: • types of visitors • types of recreation activities	• Industries particularly exposed to climate and extreme weather, especially agriculture, leisure	• Earlier and/or lower runoff could complicate administration of water rights and interstate water compacts, and could

Resource/ Use Affected	Potential Indicators for Monitoring	Highly Vulnerable Resources/Uses (Neely et al. 2011 unless cited otherwise)	Direction and Magnitude of Potential Changes
	• season of use or operation • types and numbers of industries	and hospitality, and mining and extraction (local governments dependent on tax revenue from these industries will also be impacted, particularly those with an already high poverty rate) (Gordon and Ojima 2015). • Recreation businesses in adjacent communities dependent on use seasonality, including, but not limited to rafting, wildflower and wildlife viewing, fishing and hunting, winter uses, etc. (Gordon and Ojima 2015).	affect which rights holders receive water (Lukas et al. 2014). • Groundwater use for agriculture could increase with warmer temperatures; changes in precipitation could affect groundwater recharge rates (Lukas et al. 2014). • Warmer temperatures could place higher demands on hydropower facilities for peaking power in summer (Lukas et al. 2014). • Warmer lake and stream temperatures, and earlier runoff, could affect water use for cooling power plants and in other industries (Lukas et al. 2014). • Changes in conditions impacting recreation and tourism (particularly in winter or in years of increased wildfire risk) may have economic impacts on dependent businesses and tax revenues for state and local governments.
Air Quality	• National Ambient Air Quality Standards • Wilderness Air Quality Related Values • State Regional Haze Plan		• Potential increased frequency/intensity of wildfires would negatively impact air quality. • Potential increased spring dust storms in hot/dry and increased variability scenarios would negatively impact air quality and visibility (regional haze) • Increasing temperature may increase ozone levels resulting in adverse human health impacts and potential impacts to vegetation and wildlife (Union of Concerned Scientists 2011)
Carbon Stocks	• Carbon stocks • Species composition • Post-disturbance regeneration		• Increased frequency/intensity of wildfires/insect/outbreaks would negatively impact carbon stocks, and may change western U.S. forests from a carbon sink to a carbon source (Ryan et al. 2012, USFS 2016) • Increasing drought may cause conversion of aspen stands to shrublands/meadows (less carbon storage capacity), significant carbon release and positive feedback to climate change (Michaelian et al. 2011, Huang and Anderegg 2012, USFS 2016)

Potential Need for Plan Changes to Respond to Climate Change

Management Approaches and Tools

Management in an era of climate change is a complex endeavor that requires maximum flexibility and a strong focus on monitoring and adaptation as we continue to learn. There are so many sources of uncertainty, not only in terms of our limited understanding of ecosystems and species, but also in terms of what the impacts of future climate will actually be. In addition, managers will continue to be faced with non-climate related stressors, as well as competing interests and priorities. Key concepts in today's management lexicon, outlined by Aplet and McKinley (2017) and described further in the main body of the ecosystem assessment, include:

- observing changes without intervention in areas likely to sustain ecological integrity;
- restoring ecosystems to high ecological integrity to slow ecological change; and
- facilitating transformation to new states when necessary.

These concepts apply to both ecosystem management and the social context within which managers work. Though public involvement has long been a hallmark of National Forest management, even more emphasis on education as well as collaborative development of management goals and strategies is now warranted. For the GMUG, a multi-year, multi-partner effort has identified important vulnerabilities and proposed management strategies for high priority resources (Rondeau et al. 2017). These strategies are focused on projected habitat suitability and species distributions in response to predicted climate variables. They include:

- Identify and protect refugia
- Proactive treatment for resilience
- Assist or allow transformation

A suite of methods and tools were used to arrive at these strategies, including spatially explicit distribution modeling, expert collaboration between climate scientists and ecologists, social science investigations (e.g., interviews, focus groups), and decision support frameworks (situation analysis, chain-of-consequences) – all supported by a series of organized and facilitated workshops with multiple partners across public, private, academic, and NGO sectors. The concept of connecting the ecological and social components of management decision-making was embedded within each step of the process. All of these methods and tools are both scalable and readily transferrable to a variety of management issues, including habitats and species, water resources and hydrology, wildfire management, drought preparedness and response, timber management and carbon storage, recreation, cultural resources, and others.

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